Realizing Trust Dynamics and Governance for Humanizing Driverless Technology

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Doctor of Philosophy (Ph.D.)

By

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Abstract

Driverless Technology (DT) in the shape of Autonomous Vehicles (AVs) will emerge as a powerful catalyst transforming the future cascade of mobility, infrastructure, and social wellbeing. Due to the proliferation of AVs, NZ is likely to seek a panacea against challenges of ageing, congestion and road trauma. Public trust is quintessential in harnessing these technologies. Trust is a key mediator in users' acceptance and promoting human-machine interaction (HMI). Present day research lacked examining this phenomenon and is mainly focused on optimistic technological orientations of AVs. User acceptance theories and models were originated to address the requirements of Information Technology and most of these were neither qualitatively nor quantitatively tested in real driving situations for autonomous and semi-autonomous vehicles. Trust in HMI is mainly considered as a by-product of interpersonal human trust without considering the institutional perspectives. This warrants investigations into the user acceptance needs to unfold trust dynamics, the applicability of existing theories, and linkages of interpersonal and institutional trust for driverless systems.

The study examined the trust impacting technology and governance factors in real-world autonomous driving environments. The study explored how dynamic trust evolves through experience and interaction with a system and technology from initially learned trust. In a mixed methods Multiphase Design research settings comprising four studies, the study developed an AD Trust Acceptance Model, HMI AD Event Relationship Identification Framework (HMI-ADERIF), and an integrated trust and governance model for adoption in NZ. The recommended AD trust Model has provided a way for the researchers to fundamentally re-assess and augment the various trust models and theories present in the literature today. HMI-ADERIF provides a guide for manufacturers to make it easier to understand the chain of events and how the relationship with trust affecting factors occurs during a single or continuous AD scenario. The study has also developed a unique system dynamics (SD) model to accrue perceived societal and technological benefits. The research provides profound insights into the likely AVs diffusion timelines and a roadmap for the next 100 years till 2121.

Study – 1 is based on a qualitative AV user study in live traffic conditions with BMW X5 xDrive40i SUV. Study – 1 is embedded in the main quantitative Study – 2 (SEM) in a concurrent embedded correlational design setting in Phase - 1. Study – 1 observed the users' interpersonal and institutional trust towards finalizing key autonomous driving (AD) corroborating factors. Study – 2 deployed an exploratory survey and tested seven hypotheses using Structural Equation Modelling (SEM) and Confirmatory Factor Analysis (CFA) with IBM SPSS and AMOS version 26. Study – 2 validated the integrated trust and governance model, and confirmed the role of 'trust' as a mediator between interpersonal and institutional trust.

Study – 3 employed the convergent parallel design with Study - 4 concurrently in Phase-2, and developed a quantitative SD model for NZ using System Dynamics (SD) modelling technique. Study – 3 provided policy insights for articulating transport investment decisions for shaping up driverless eco-system. Study – 4 used 13 experts' interviews for useful interpretations, realization of research outcomes and validation of trust and governance framework.

Table of Contents

List of Figures

List of Tables

List of Appendices

Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

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List of Publications

Conference Proceedings

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Ethics Approval

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Glossary

Adaptive Cruise Control	ACC
Adoption	AD
Advance Driver Assistance Systems	ADAS
Agent Based Simulation	ABM
Anthropomorphism	AnT
Artificial Intelligence	AI
Association of British Insurers	ABI
Auckland University of Technology Ethics Committee	AUTEC
Augmented Reality	AR
Australian and New Zealand Driverless Initiative	ADVI
Australian Road Research Board	ARRB
Automated Driving System	ADS
Automatic Steering	AS
Automation Acceptance Model	AAM
Autonomous Driving	AD
Autonomous Emergency Break	AEB
Autonomous Vehicles	AVs
Average Variance Extracted	AVE
Blind Spot Monitoring	BSM
Case Study Research	CSR
Centre for the Protection of National Infrastructure UK	CPNI
Cognitive Works Analysis	CWA
Comparative-fit-index	CFI
Composite Reliability	CR
Confirmatory Factor Analysis	CFA
Connected and Autonomous Vehicle	CAV
Cooperative Intelligent Support System	C-ITS
Cyber Physical Systems	CPS
Deep Learning	DL
Defense Advanced Research Projects Agency	DARPA
Department for Transport UK	DfT
Department of Transport US	USDOT
Design Science Research	DSR
Distributed Situational Awareness	DSA
Driver Support Feature	DSF
Driving Automation System	DAS
Dynamic Driving Task	DDT
Dynamic Synthesis Methodology	DSM
Electroencephalography	EEG

Exploratory Factor Analysis	EFA
Federal Motor Vehicle Safety Standards	FMVSS
Flight Management System	FMS
Forward Collision Warning	FSW
Full Autonomous Driving	FAD
General Data Protection Regulation	GDPR
Global Navigation System	GNSS
Global Positioning Systems	GPS
Goal Directed Task Analysis	GDTA
High Definition	HD
Highly Automated Vehicle	HAV
Human Computer Interaction	HCI
Human Factor Engineering	HFE
Human Machine Interaction	HMI
Human-Autonomy System Oversight Model	HASO
Increment fit index	IFI
Industry 4.0 revolution	4IR
Inertial Measurement Unit	IMU
Inertial Navigation System	INS
Internet of Things	IoT
Internet of Vehicles	IoV
Lane Control Assistance	KCA
Lane Departure Warning	LDW
Lane Keeping Assistance	LKA
Legal Readiness	LR
Level of Automation	LoA
Light Detection and Ranging	LIDAR
Local Dynamic Map	LDM
Machine Learning	ML
Mental Model	MM
Ministry of Transport	MOT
Mobile ad-hoc Networks	MANETs
Mobility-as-a-Service	MaaS
National Institute for Standards and Technology	NHTSA
National Transport Commission Australia	NTC
New Zealand	NZ
New Zealand Transport Authority	NZTA
Normed fit index	NFI
Northland Transport Technology Testbed NZ	N3T
Object/Event Detection and Response	OEDR
On-Board Units	OBUs

Operation Design Domain	ODD
Out Of Loop	OOTL
Parking Assistance	PA
Perceived Ease of Use	PEOU
Perceived Usefulness	PU
Privacy	PRI
Reinforcement Learning	RL
Road – Side Units	RSUs
Root Mean Square Error of Approximation	RMSEA
Safety	SAF
Security	SEC
Shared Autonomous Vehicle	SAV
Simultaneous Localization and Mapping	SLAM
Situation Awareness	SA
Society of Automotive Engineers	SAE
Socio – Technical System Theory	STS
Standardized Root Mean Square Residual	SRMSR
Structural Equation Modelling	SEM
System Dynamics	SD
System Purpose, Process and Performs	PPP
Technology Adoption Model	TAM
Technology Specific Innovation System	TSIS
Theory of Planned Behaviour	TPB
Theory of Reasoned Action	TRA
Training	TR
Trust	TRS
Tucker-Lewis coefficient Index	TLCI
Unified Theory of Acceptance and Use of Technology	UTAUT
Variance Inflation Factor	VIF
Vehicle – to – Infrastructure	V2I
Vehicle – to – Vehicle	V2V
Vehicle to Everything	V2X
Vehicle to Pedestrians	V2P
Vehicular ad-hoc networks	VANETs
Virtual, Augmented and Mixed Reality	VAMR
Web of Trust	WoT

Chapter 1 - Introduction

1.1 Overview

Chapter 1 delineates the research context in the AVs, leading to the scoping and the significance of this study. It explores the innovative driverless technology amid current global and national settings. It emphasizes the role of holistic trust dynamics and co-evolution of autonomous technology and regulations for the successful adoption of autonomous vehicles (AVs) in NZ. It outlines the research gaps, the problem statement, the research aim, objectives, questions, scope, and limitations. It provides a brief synopsis of the research methods followed by the research contribution and finally, a summary of the subsequent chapters is provided.

1.2 The Context

Autonomous Vehicles (AVs) promise advantages for both society and individuals, such as increased road safety, reduced emissions, improved traffic flow and mobility of underserved and elderly disabled people (Fisher et al., 2020, p. 2; Wintersberger, 2020, p. 1). However, in this paradox of automation, where human errors can be significantly reduced, other unintended consequences may slow down their adoption. It includes the incorrect understanding of users' needs and trust in the system (Dirsehan & Can, 2020; Ekman, 2020a). The emergence of new types of human errors resulting in crashes (Khattak et al., 2020), and inappropriate and delayed policy interventions (Mordue et al., 2020).

Approximately 1.35 M people die annually due to traffic accidents causing enormous financial loss to the countries, amounting to 3% of their gross domestic product (WHO, 2020). The road crashes will cost around $2 trillion to the world economy between 2015 -2030 (Shammut, 2020). NZ has witnessed a dramatic annual population change of +96,400, leading to an estimated 5.03 M resident population (S. NZ, 2020) and a rise of 120,000 people in the last three years only in Auckland. A similar rise in vehicles is creating enormous congestions across the transport networks, causing extra 360,000 daily trips. Consequently, motorway speeds have declined from 64km/h to 55km/h between 2014 and 2016 due to an increase in road accidents (Orsman, 2017). In NZ, crashes are expected around 400 annually (MOT, 2020). Moreover, the Greenhouse Gas

(GHG) emissions from road transport have increased by 85% (Hasan et al., 2019). The deployment of AVs in the US alone to improve safety could result in cost savings from $355-$488 billion and reduce congestion by around $447 billion by 2050. It will result in new job opportunities for new industries, manufacturers, software sectors and AVs start-ups (Clements & Kockelman, 2017). This phenomenon signals perceived time savings, ease of parking, fewer accidents, increased robotic developments, lower vehicle emissions, better fuel economy, and other societal benefits (Dirsehan & Can, 2020). The COVID -19 pandemic and ever evolving user and environmental demands for transportation could exacerbate the development and deployment of AVs around the globe (Thakur, 2020).

Since AVs need to interact not just with passengers but with pedestrians, fellow drivers, and other road users. Their acceptability depends on the people's trust in the entire driverless ecosystem. Trust is considered a lynchpin in determining the willingness of people to rely on automation in uncertain situations (Hoff & Bashir, 2015). It calls for investigations into key influencing factors in autonomous driving (AD) for establishing faith in driverless ecosystem and designing human machine interaction (HMI) guidelines. Their successful proliferation in society requires an introspective analysis of users' trust in the entire system in general and during a dynamic driving task (DDT) in particular using human factor (HF) research (Tang et al., 2020) based on real time user studies. In an earlier survey of knowing the public readiness for AVs among five countries, namely China, India, Japan, US, UK and Australia, the top most concern among NZ people is about 'Trust in technology (85.3%)' (Starkey & Charlton, 2020).

The COVID – 19 pandemic conditions are likely to accelerate the development of trust for AVs in the long term to improve safety, deliver supplies, advancement in infrastructure and day to day commerce (Boll, 2020). Critical technology adoption theories include the technology adoption model (TAM) (Davis, 1989) and the unified theory of acceptance and use of technology (UTAUT) (Venkatesh et al., 2003), which enumerate various factors, including trust (Kaur & Rampersad, 2018). However, none of the technology adoption models was formulated to address driverless technologies. The burgeoning rise of AVs epitomizes an era of transformation to new business models while at the same time it eclipses regulatory oversight. Several studies noted the gap between technology and the regulatory regime that guides its implementation

(Bonnefon et al., 2016; D. J. Fagnant & K. Kockelman, 2015; Lee & Hess, 2020). Policy makers and industry stakeholders have failed to fill the regulatory vacuum due to the fear of accountability arising from various levels of autonomy in case of any untoward situation (Shladover & Nowakowski, 2019). AVs' absence of an appropriate governance regime may ultimately compromise their proliferation and hinder market share profits, reputation, and future electability (Winkle, 2016). The regulation transition from traditional to autonomous vehicles needs to be correspondingly incremental, requiring continuous reforms to accommodate changes in technology and infrastructure (Crayton & Meier, 2017). Earlier research has identified several policy challenges for testing the vehicles and the widespread use of AVs, including safety, (cyber) security, privacy, cost, liability, sustainability, infrastructure necessity, and licensing (D. J. Fagnant & K. Kockelman, 2015; Taeihagh & Lim, 2019). NZ regulatory framework is adequate for vehicles with automated features such as lane keeping, automated emergency breaking, collision mitigation, but it requires improvements in terms of vehicles at higher level of automation (level 3 and above) (FleetPartners, 2020).

The core challenge is to bridge the gap between AV technology and general public acceptance to adopt smarter solutions towards safer transportation (Alawadhi et al., 2020). Human factors issues during interaction with AVs and formation of calibrated trust based framework is essential for better realization and acceptance of this technology (Sun et al., 2020; Tang et al., 2020). To achieve the desired result, there is a pressing need to identify the public expectations and trust needs, AVs implementation challenges, and critical success factors influencing the adoption of AVs in NZ. Within this context, scoping of this research study is done, primarily to arrive at a holistic trust-based framework addressing technology and governance challenges simultaneously for AVs implementation in NZ.

1.3 Problem Statement

Driverless technology is at the forefront of the current Industry 4.0 revolution (4IR), serving as a perfect lynchpin in connecting the digital and real world as an essential part of a cyber physical system (CPS) in smart cities (Mouftah et al., 2020; Pieroni et al., 2018; Sell et al., 2019; Um, 2019). This disruptive yet beneficial technology will assist in shaping the future shared mobility paradigms, transport infrastructure, and urban landscape. It will ensure road safety with the optimum flow, less congestion, improved environmental outcomes, efficiency, and productivity (D. J. Fagnant & K. Kockelman, 2015; Yan et al., 2020). The global market in self-driving cars is estimated to reach $7.03 billion by 2021 and $21billion by 2035 (Du et al., 2021). The recent COVID – 19 crisis catalyzed the proliferation of AVs in emergency and uncertain situations for driverless transportation, contactless delivery, and increased safety within the folds of the autonomous Mobility-as-a-Service (MaaS) value chain (Boll, 2020; MSCI, 2020). On the other hand, criticism towards AV deployment is geared towards job cuts, urban sprawl, reduced automobile ownership, and other technical, financial, and social challenges (D'Oca et al., 2018).

NZ is set to gain long lasting benefits in the testing and deployment of AVs. The NZ environment is presently marred with significant challenges. Including the growing and aging population, traffic congestions, accidental deaths, rise in immigration, ill equipped transport and road infrastructure, and lagging government legal strategies (Fitt, Frame, et al., 2018; Geoscience, 2020; KPMG, 2020; MOT, 2020; S. NZ, 2020). Public acceptance is essential for the widespread adoption of AVs in NZ and elsewhere (Yuen, Wong, et al., 2020). Generally, if societal and behavioural intentions align with technical innovations, it will lead to users' acceptance (Kraetsch et al., 2021).

In human-centred transport research, the theoretical concept of trust is considered critical in successful technical design features and acceptance of AVs. Trust realization in the adoption of AVs demands observing how the conditions and factors affecting trust change as the technologies become more intelligent based on experimental user and ethnographic studies (Raats et al., 2020; Zhang et al., 2020). Two facets that materially affect the trust dynamics include the extent of human interaction with the automation technology tasks within the domain of human machine collaboration, so called internal environment (Craig Morrisona, 2020). Secondly how the external "world view" environment set in by governance and legal readiness structure as seen by user and technology alike affects trust. Hoff and Bashir (2015) stressed the need to investigate trust impacting factors in real world environments, explore situational and dispositional factors. They argue about the significance of multidimensional construct to study how dynamic trust evolves through experience and interaction with a system and technology from initially learned trust. Present day research is mostly focussed on the optimistic technological orientation of AVs as a commercially viable and safe technological enterprise. Existing literature lacks a broader view on the impacts (both positive and negatives) of AVs on social, behavioural (Cavoli et al., 2017; Cohen & Hopkins, 2019) and legal arrangements, and public acceptability accessibility (Fitt, Curl, et al., 2018).

These developments call for investigations into new methodologies in identifying users' acceptance requirements. These complexities warrant exploring key AD factors affecting trust, addressing HMI and governance challenges in live traffic conditions outside simulated or controlled environments. It further asks for examining how and why dynamic calibrated trust develops in specific events and conditions. There is a pressing demand for interdisciplinary research to establish trust's theoretical and methodological foundations in AVs. Moreover, there is a need to study the applicability of various trust and automation theories and identify the significance of interpersonal and institutional trust. These are noteworthy research voids in recent literature. This study will try to determine the significant perspectives of driverless technologies within the AVs context and find key AD factors affecting the trust while investigating the challenges in adopting AVs locally and internationally. And in doing so, determine a conceptual trust based framework comprising HMI and governance determinants for AVs deployment in NZ. The research study will further explore this integrated trust model's theoretical output to visualize a futuristic roadmap for AVs' adoption and arrive at appropriate policy planning and guidance strategy for their successful deployment in NZ.

1.4 Research Aim, Objectives and Questions

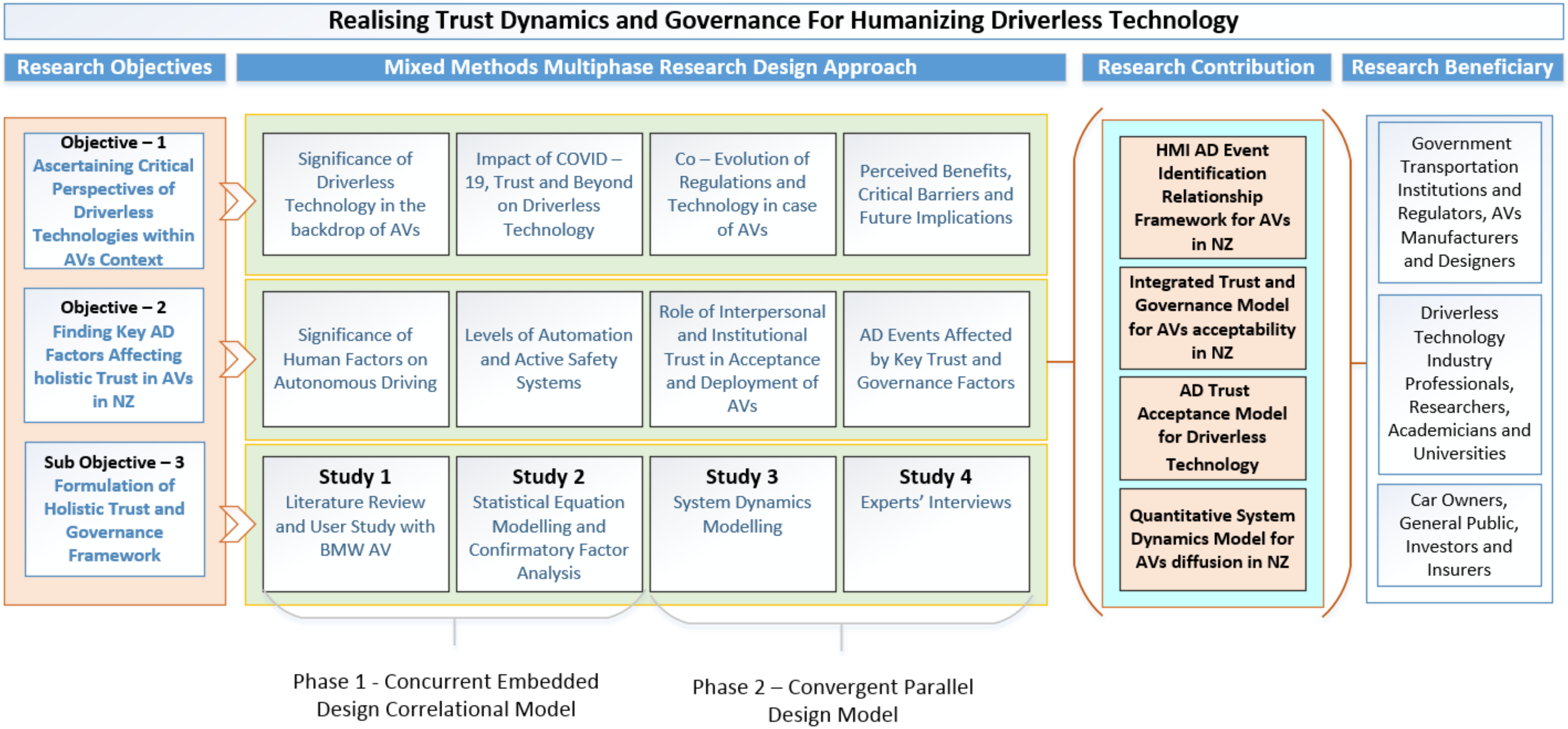
The research aim is to develop a holistic trust and governance framework for optimum acceptability and adoption of Autonomous Vehicles (AVs) in New Zealand. To achieve the aim, the research has three key objectives and ten research questions (see Table 1.1). The graphical layout of the research study goals in the light of stated objectives is shown in Figure 1.1 below.

Table 1.1
Research Aim, Objectives and Questions

Research Aim	Objectives	Research Questions
To develop a holistic trust and governance framework for optimum acceptability and adoption of Autonomous Vehicles (AVs) in NZ.	**1.** To examine the critical perspectives of driverless technologies in the backdrop of the deployment of AVs.	**RQ 1.** What is the significance and futuristic role of driverless technologies internationally and locally within AVs' context? **RQ 2**. How COVID -19, like pandemic crisis, can affect autonomous driving (AD) technologies? **RQ 3.** How can the co-evolution of regulations and technology influence the implementation of AVs in NZ and elsewhere? **RQ 4.** What are the perceived benefits and critical barriers for the deployment of AVs globally and in NZ?
	2. To analyse the role of key AD factors affecting trust based on significant HMI and governance determinants for the implementation of AVs in NZ.	**RQ 5.** What is the significance of human factors (HFs) for autonomous driving (AD)? **RQ 6.** How do trust and user acceptance contribute to humanizing and adopting autonomous driving (AD) technologies? **RQ 7.** What are the key AD factors affecting interpersonal and institutional trust during human-machine interaction (HMI) for AVs deployment in NZ? **RQ 8** What HMI AD events are affected by key trust affecting factors during human – AV interaction?
	3. To develop and assess an integrated trust and governance framework for the successful adoption of AVs in NZ.	**RQ 9.** How to articulate a relationship between key corroborating trust affecting factors for developing an integrated trust and governance framework for the adoption of AVs in NZ? **RQ 10.** How to visualize a futuristic roadmap for AVs' adoption and planning appropriate policy and guidance strategy for their successful deployment in NZ? **RQ 11.** Develop an integrated trust and governance framework and examine its feasibility and validation for AVs deployment in NZ.

Figure 1.1

Research Study Objectives, Process, Contribution and Beneficiary



1.5 Research Contribution

This research establishes the theoretical underpinnings of trust in AVs. It uses experimental testing of AV in live traffic conditions employing BMW AV level 2, Statistical Equation Modelling (SEM), and System Dynamics (SD) Modelling techniques. It identifies key trust affecting AD factors in NZ and determines a trust based framework for AVs in NZ. This holistic framework captures the general public aspirations and addresses the future challenges for the successful implementation of AVs in NZ.

Moreover, it provides valuable insights, guidelines, and deployment pathways for designers, practitioners and regulators when developing HMI Systems for AD vehicles. Numerous earlier studies on the subject (Basu & Singhal, 2016; Brinkley et al., 2019; Häuslschmid et al., 2017b; Kaur & Rampersad, 2018; Lee & See, 2004; Rahman et al., 2018) are based on conceptual models developed by Mayor, Hoff and Lee (Hoff & Bashir, 2015; Lee & Moray, 1992; Mayer et al., 1995). These and other models such as TAM, UTAT (Adell, 2010; Davis, 1989; Osswald et al., 2012; Park & Kim, 2014; Rödel et al., 2014; Venkatesh et al., 2003) fall short of addressing the driverless or semi driverless system in automation and users' acceptance requirements holistically. Earlier research is generally based on simulation or user studies in controlled environments. These studies did not explore the linkages between interpersonal and institutional trust perspectives and the applicability of automation acceptance theories in the driverless technology domain. This study has attempted to follow a practical approach of creating a calibrated trust framework for the AD system within an HMI design process. The research study outcomes are in line with the NZ Technology Action Plan, NZ Ministry of Transport AVs Work Programme and Regulation 2025 Project, and NZTA policy on testing AVs in NZ (MOT, 2021; NZTA, 2021)

The main research contributions include; (1) AD Trust Acceptance Model for Driverless Technology (DT), (2) HMI AD Event Identification Relationship Framework (HMI – ADEIRF) giving insights regarding dynamic trust development process to HMI designer and other stakeholders, (3) Integrated trust and governance model for optimum acceptability of AVs in NZ, (4) A quantitative system dynamics model for observing the futuristic diffusion timelines and deployment roadmap for AVs in NZ, and (5) Provision of a comprehensive checklist for NZ managers. The detailed contribution of this study is deliberated in Chapter 5.

1.6 Research Methods

This mixed methods Multiphase Design research is based on Concurrent Embedded Design Correlational Model and the Convergent Parallel Design in two phases adopting the Pragmatic Paradigm and Design Science Research (DSR) approach. Phase – 1 comprised Study – 1 (AV User Study) and Study – 2 (SEM). Phase – 2 comprised Study -3 (SD Modelling) and Study – 4 (Experts' interviews). DSR is divided into three stages of pre-development, development and post development stage. DSR's goal is to develop scientifically grounded solutions to solve a real world problem, thus establishing a link between theory and practice (Rocha et al., 2012). The fundamental DSR requirements accepted by all schools of thought is to validate the artefact development using existing theories and guidelines (Österle et al., 2011). In a socio-technical context, the artefact is influenced by the environment in which it operates. Various authors suggested steps for conducting DSR (Holmström et al., 2009; Lukka, 2003; March & Smith, 1995; Vaishnavi & Kuechler, 2004; Vaishnavi & Kuechler, 2015).

A core research criterion as conceived by DSR is to set a framework based upon the connection between relevance (context of design) and rigor (the business/environment) and the scientific knowledge base built by previous research (Cash & Piirainen, 2015; Drechsler & Hevner, 2016; Hevner, 2007). In addition, DSR identifies " the virtues of hard, generalizable data" (Krivokapic-Skoko & O'neill, 2011) and supplements the strengths and weaknesses of qualitative and quantitative data (Amaratunga et al., 2002; Johnson & Onwuegbuzie, 2004).

The design commences with the awareness of the problem occurring due to innovation in the shape of AVs, i.e**.,** lack of trust as a significant determinant for the adoption of AVs technology in NZ**.** After awareness of the problem in stage – 1 (pre development stage) of the process, during stage – 2 (developmental stage), various issues, including people aspirations and key challenges in the adoption of AVs, are explored. First, an AV user study in live traffic conditions is carried out in collaboration with BMW NZ Group using Autonomous Level 2 BMW X3 M40i SUV Vehicle to finalize trust affecting AD factors in HMI and governance domains. SEM follows it to investigate and validate the framework relationships. In the post-development stage, the data accrued from the literature review, user study, and SEM Modelling process is used to develop an SD Model as a justification of framework (see Table 1.2). Then framework utility check is carried out through experts' interviews.

Table 1.2

Research Study Methodology

Purpose	Research Approach	Research objectives and Questions	Data Collection Techniques
The Pre- Development Stage			
To develop a problem statement, research aim, objectives and significance of the study	Literature Review	Obj -1 and 2 RQ 1, 2, 3, 4, 5, 6,7	Content Analysis
Research Approach	Design Science Research		
The Developmental Stage			
Designing and Development HMI Trust & Governance Conceptual Framework	Mixed Methods	Obj - 2, RQ 8 Obj- 3, RQ 9	User Study Survey, SEM
The Post – Development Stage			
Justification of Framework	Mixed Methods	Obj-3, RQ 10,11	System Dynamics Modelling
Framework Utility Check			Experts Interviews

In an embedded design, the quantitative and qualitative studies (study 1-2) seek solutions regarding two different research questions within a study concurrently i.e. RQ8 and RQ9. The research obtained qualitative data (used as a subservient role) to develop predicting relations in a larger SEM quantitative study. In phase-2, the Convergent Parallel Design is pursued where design seeks to "obtain different but complementary data on the same topics. The integrated results are triangulated during interpretation. The study – 3 incorporates quantitative System Dynamics (SD) modelling technique, and study – 4 uses semi structured experts' interviews capturing follow up data from study – 1 and study – 2. The data and results from study – 3 and study – 4 are collected simultaneously and merged in the research implications. In the end, these interviews and convergence of data assisted in inclusive research analysis and interpretations. The study – 4 examines the feasibility of integrated trust and governance framework and after validation provide recommendation for adoption.

The studies seek to interrogate practical and pluralistic approaches that allow a combination of methods to articulate the actual behaviour of participants, the beliefs and consequences that follow from their behaviour allowing methodological pluralism. It assisted in utilizing the logic of inquiry through deduction (testing of hypothesis and theories developed during the process), achieving complementary strengths. Details of the research methodology are discussed in Chapter 3.

1.7 Research Limitations

This research study was affected by non – availability of AV manufacturers and technology experts in NZ. Moreover, there is less technical and legal know-how among the general public, industrial stakeholders, and policy makers. This could be due to a small market economy and no wider implementation and usage of these vehicles in NZ. Therefore, the researcher has to gather the most qualitative data from overseas experts and academicians in autonomous technology, robotics, AI, and human factor engineering from the UK, Germany, Sweden, and Australia. Moreover, the present pandemic crisis of COVID – 19, physical contact restrictions, and lock down affected the production and supply of AVs, hampering the user study investigations at critical junctures. Therefore, it was not possible to use AV level 3 vehicle as it is still not available in the market. Level 2 vehicle with most of the functions of Level 3 vehicle given by BMW NZ Group was employed during user study. Additionally, due to the current maturity of marketing and manufacturing forces in NZ and abroad, only broader functions and key factors were observed, tested and presented. Detailed limitations of this research study and future directions are noted in Chapter 5.

1.8 Thesis Organisation

This thesis encompasses seven chapters. The first two chapters describe the literature review through updated content analysis according to the research aim and objectives. The third chapter delineates the research methodology utilized. The fourth chapter presents findings, and the Fifth chapter provides discussion and highlights research implications. The brief synopsis of the chapters is as follows:

Chapter 1. It introduces the research context outlining the significance of driverless technology in AVs. It highlights the background, followed by a problem statement indicating the research gaps and potential benefits of this study. Later, the research aim, objectives, contribution, methods, limitation, and thesis organisation is described.

Chapter 2. It examines critical perspectives of driverless technology within AVs context, co-evolution of regulations and technology, and the impact of the present COVID – 19 pandemic on AVs proliferation. It discusses AVs' historical background, infrastructure requirements, and control systems. It provides insights into human factor engineering, automated driving controls, how automation works, and the driver's situation concerning its environment. It also identifies the potential opportunities and critical barriers for AVs implementation and observes public opinion and expectations at home and abroad. The chapter observes the key influencing factors for AD and looks at the role of the driver's mental model, situational awareness, feedback, and training in the resumption of control. Additionally, the research identifies the significance of cyber security, privacy, liability, safety, technology and infrastructure issues. At the end, it provides a summary of the critical AD barriers for adoption of AVs.

Chapter 3. The Chapter describes the significance of trust and user acceptance in driverless technology and highlights various trust taxonomies, theories, models, and frameworks present in the literature. It also delineates the role of interpersonal and institutional trust to formulate a holistic trust and governance framework for AD in NZ. In the end, it provides key research findings, conclusions and implications arising from the literature review of Chapters 1 and 2, and identifies seven hypotheses within the context of literature.

Chapter 4. This chapter highlights the research methodology. It delineates the research tools and techniques utilized. It provides the philosophical and theoretical perspectives within the Pragmatic Paradigm philosophically and DSR approach theoretically. It describes the detailed process of harnessing mixed research methodologies utilizing Multiphase Design comprising Concurrent Embedded Correlational Model in Phase 1 and Convergent Parallel Design Model in Phase 2. Moreover, the chapter provides justification, data collection, and analysis techniques for four research studies to formulate a holistic Trust and Governance Framework for successfully deploying AVs in NZ.

Chapter 5. It presents the results of Study 1 to 4 to support and validate the research aims and objectives. It highlights Study – 1 findings based on the user study carried out with BMW AV level2/3 vehicle on Auckland roads in real time conditions. This complementary user study assisted in confirming the significance of critical influencing factors within the context of literature in different usage phases and classifying them into two groups. The chapter identifies three phases, eight events and nine trust influencing factors and formulate the HMI AD Event Identification Relationship Framework (HMI-ADERIF). Then it finalizes the key trust affecting AD factors in HMI and governance categories. Next, through extensive analysis of 305 respondents from an online quantitative survey research on Qualtrics platform and user study, it ascertains 15 barriers/concerns in the human factors domain and 17 AV adoption preferences. After incorporating the finalized results of Study 1 and 2, it presents the result of SEM and CFA using IBM SPSS/Amos version 26 to validate the integrated trust model and the linkages of interpersonal and institutional trust. It also identifies another integrated model for validating the role of 'trust' as a mediator between legal readiness and adoption. It is followed by the result and findings of Study – 3 for projection into AVs diffusion timelines in NZ till 2121. Finally, it interprets and validates the studies through thematic analysis of experts' interviews.

Chapter 6. This chapter synthesizes the findings from Study – 1 to Study – 4, and deliberates on the research case in the backdrop of the research aims and objectives within the context of literature. It is followed by a detailed synopsis of research insights and the uniqueness of research, and comparison with earlier researches in the field. At the end, it provides summary of the findings to realize the research aim and objectives.

Chapter 7. The Chapter concludes the research and delineates its distinct contribution to the immediate discipline and wide body of knowledge covering a broad range of disciplines. It provides final comments on the significance, innovativeness and contributions of four studies. The Chapter presents significant implications for private and public sectors in NZ besides articulating concrete measures for restructuring the policy and pragmatic decision making in the country for successful deployment of AVs.

Chapter 2 - Critical Perspectives of Driverless Technology within Autonomous Vehicles Context

2.1 Prelude

This chapter provides a detailed account of AVs, including historical background, infrastructure requirements, and control systems. It highlights the critical perspectives of driverless technology within AVs context, co-evolution of regulations and technology, and the impact of the present COVID – 19 pandemic on AVs proliferation. It describes the significance of Human Factors (HFs) on autonomous driving (AD) and the diver's environment to their mental model, situation awareness, training, and role of anthropomorphism. Then it looks comprehensively at AVs perceived benefits and critical challenges to realize key autonomous driving (AD) factors for successful adoption of AVs.

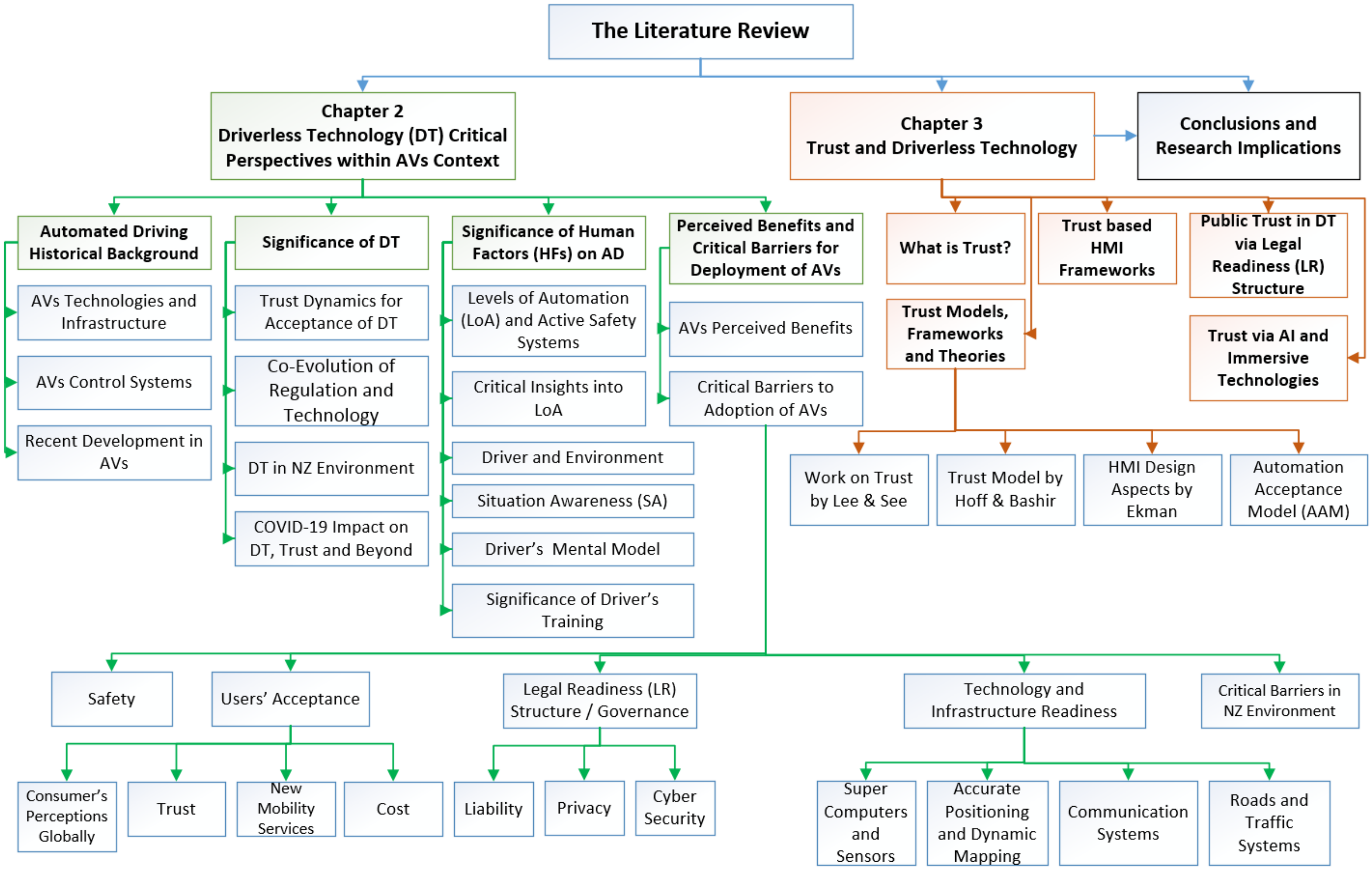
2.2 Introduction

Future mobility concept within the ambit of smart cities agenda is characterized by the rise of sustainable vehicular technologies and intelligent transport services (ITS) using big data-based networks and cloud services (Lanamäki, 2021; Yigitcanlar Tan et al., 2019). Undoubtedly, AVs are one of the most advanced innovations in automated technology, which utilizes numerous ITS tools (Faisal et al., 2019). These are considered capable of making decisions without human interference while facing uncertainty.

To understand and evaluate the phenomenon of the acceptability of AVs, it is imperative to comprehend the dynamics of driverless technologies and the role of human factors (HFs) involved in autonomous driving (AD). This requires insights into the emergence, working mechanism, recent developments, and the futuristic impact of AVs technologies. Moreover, it needs to identify key enablers and barriers that restrain the adoption of AVs in the technological and governance/legal readiness domain. This will help define the key AD factors to formulate a holistic trust and governance framework towards the smooth transition and adoption of AVs. Figure 2.1 illustrates the details of the literature review of this study divided into chapter 2 and chapter 3.

Figure 2.1

The Literature Review



2.3 Automated Driving - Historical background

To pursue the dream of autonomy, the vehicle design was first practically sketched by Leonardo Da Vinci in the shape of a self-propelled carriage in 1478 for Renaissance Festival (Fuller, n.d). Vehicle automation was initially conceived in 1918 (Pendleton et al., 2017), and General Motors first introduced the concept of AV at the 1939 World's Fair (Shladover, 2018). Automated Vehicle (AVs) can be defined as:

> "…vehicles that include an automated driving system (ADS) that is capable of monitoring the driving environment and controlling the dynamic driving task (steering, acceleration, and braking) with limited or no human input" (NTC, 2018, p. 1).

In the 1950s, General Motors, in collaboration with Radio Corporation of America Sarnoff Laboratory, carried out initial research & development (Shladover, 2018). In the ensuing decades, from 1964 to 2007, several other R&D projects were initiated. A series of prototypes were developed in the US, Japan, and Europe (Forrest & Konca, 2007), including automated bus and truck platoons and smart vehicle systems. An automated trip under the European PROMETHEUS project in the 1980s was carried out on public roads from Bavaria to Denmark (Billington, 2018). At the same juncture, the U.S. Defence Department developed the first automated ground vehicles (AGVs) to support ground forces which are still in progress.

During the 1990s, the US Department of Transport (USDOT), in collaboration with the National Automated Highway System Consortium, commenced $90M Automated Highway System (AHS) program culminating in successful Demo'97 comprising automated driving in cars, trucks, and buses on Interstate 15 in San Diego witnessed by thousands of people. It created a paradigm shift in public consciousness (Fisher et al., 2020). At the same time, Japan carried out Demo 2000 in Tsukuba, showing AV capabilities through Advance Cruise – Assist Highway Research Association and emphasized the role of infrastructure supported systems. In the late 1990s, the European Commission kick-started tests of platooning automated heavy trucks on public roads under the European CHAUFFEUR project (Shladover, 2012). The surge in these efforts occurred through the Defense Advanced Research Projects Agency's (DARPA) Grand Challenges Program in the US in 2004 and 2007. AVs traversed the desert terrain and urban roads, and the top three finishers were Carnegie Mellon University/General

Motors, Stanford University, and Virginia Tech, respectively. These vehicles handled various challenging situations, including traffic circles, four-way stops, parking lots, and road obstacles manoeuvring among human-driven vehicles (Pendleton et al., 2017; Shladover, 2018). These efforts catalyzed Google's self-driving driving car program in 2010, and by 2017 Google's AV feet, WAYMO, finished three million miles driving within four US states. Volvo introduced its first AV in 2017, and today, Audi, BMW, Mercedes – Benz, Nissan, and numerous other companies have already ventured into this market (Faisal et al., 2019). A list of important project details regarding AVs is given in Table 2.1 below.

Table 2.1

History of AVs: Important Milestones

Year	Event	Information
1977	The first self-driving vehicle built by Tsukuba Mechanical engineering lab	It runs at 20 miles per hour and tracked white street markers up to 50 meters.
1980	Project of Ernst Dickmanns at Bundeswehr Universität München	Vision-guided Mercedes-Benz robot van travelled at 60 miles per hour on streets without traffic.
1987-1995	PROMETHEUS Project (European Commission)	The car drove in traffic with speeds exceeding 110 miles per hour on German Autoban.
1995	CMU Navlab "No Hands Across America Project"	The car traversed 3000 miles autonomously. Human input was needed for throttle and brakes.
1997	Automated Highway System Demo'97	More than 20 full AVs operated on a highway in San Diego, California.
2000-2002	CARSENSE(European Commission)	Slow speed driving with complicated situations of traffic jams using a wide range of sensors including stereo camera vision, lasers and radars.
2000	Advance Cruise – Assist Highway Research Association Demo 2000 (Japan)	Thirty-eight cars, buses and trucks used driver information and control assist systems employing magnetic sensors on the road.
2000-2003	CHAMELEON (Europe)	The system used a sensor for obstacle detection and crash prediction.
2001	DARPA (The Defense Advanced Research Projects Agency) Demo III	Unmanned ground vehicles traversed rugged off-road terrain, avoiding obstacles
2001-2004	CarTALK 2000 (Europe)	Funded project to control inter-vehicle distance, collision and lane departure avoidance, reducing accidents by 30%
2001-2004	ARCOS (Research Action for Secure Driving) (France)	Focussed on new driving assistance system based on inter-vehicle communication
2001-2005	INVENT (Intelligent traffic and user-oriented technology) (Germany)	The prototypes were tested in Magdeburg City to improve traffic flow and safety.
2004-2008	PREVENT (Europe)	This system warned drivers in hazardous situations and tested safety applications.
2005	DARPA (The Defense Advanced Research Projects Agency) Grand Challenge II	AVs race in a desert environment with no traffic. Stanford Uni team won the race.
2007	DARPA Grand Challenge I	AVs race in Urban environment conducting military supply mission.

Note: The list of major AVs tests and trials from *Autonomous Cars and Society* by Forrest. A and Konca.M, 2007. Department of Social Science and Policy Studies Worcester Polytechnic Institute Worcester, MA 01609.

2.3.1 AVs technologies and infrastructure

AVs perceived superiority to the human driver is a function of high-level computing supplemented by vehicle–to–vehicle (V2V) and vehicle–to–infrastructure (V2I) communication enabling AVs to learn faster (Taeihagh & Lim, 2019). AVs can be defined as "vehicles in which at least some aspects of a safety-critical control function (e.g., steering, throttling, or braking) occur without direct driver input."(Cunningham & Regan, 2015; NHSTA, 2020). AVs operate on a three-phase design known as "sense – plan – act", employing a combination of radar, Lidar, and mono or stereo camera systems (Bagloee et al., 2016). AVs carries out a variety of functions, including localization, path planning, control, and management. Whereas, Connected Autonomous Vehicle is an "AV that communicates with other infrastructure to gather information"(Faisal et al., 2019).

AVs uses a combination of sensors, machine learning systems, actuators, ultrasonic and inertial measurement unit, and complex algorithms to process software and carry out travel without human involvement (Singh & Saini, 2021). "*The sensors collect real-time data of the environment comprising geographical coordinates, speed and direction of AV, its acceleration and intervening obstacles*" (Urooj et al., 2018). The key feature of the AV is the advanced driving system (ADS). The SAE (2021) standard J3016 defined it as:

> "The hardware and software that are collectively capable of performing the entire [dynamic driving task] on a sustained basis, regardless of whether it is limited to a specific operational design domain; this term is used specifically to describe a level 3, 4, or 5 driving automation system" (p. 3).

The end goal of ADS is to drive the vehicle to its destination safely, efficiently, and legally (Fisher et al., 2020). ADSs will form the core of the Driverless Technology ecosystem comprising AVs, monitoring centres, and road infrastructure. The car navigation system is equipped with a global positioning system (GPS) to collect location information. The location system employs an inertial navigation system (INS) to find the relative location of AV (Farrell & Barth, 1999). HD map is an electronic map that stores traffic and road facilities (Zhao et al., 2018). Path planning is done by map matching.

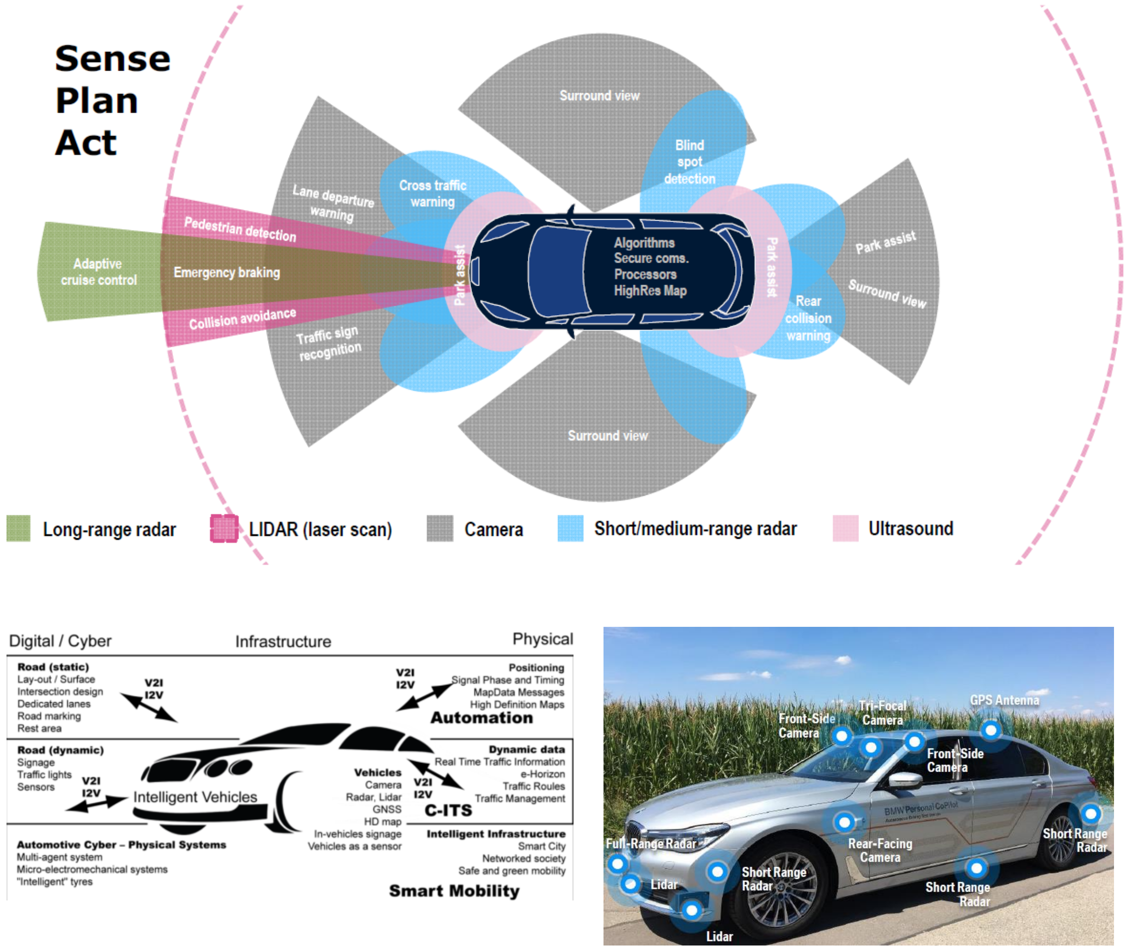
To perceive the environment, AV uses laser, visual, and radar perception. In laser perception, cloud data of target point, shape, or location is generated using the concept of reflection time and signal strength. Light Detection and Ranging (LIDAR) is employed for collision avoidance and emergency braking by emitting multiple laser pulses per second. After colliding with the surrounding objects, the reflected pulses create a 3 – dimensional representation by calculations based on the speed of the light and distance covered by the pulse. Radar perception relates to measuring distance by calculating the time taken by the transmitted wave to return. Information acquisition is an essential requirement for localization and perception. Vehicular ad-hoc networks (VANETs) apply the principles of mobile ad-hoc networks (MANETs) to the vehicle domain in the case of connected cars (Sheikh et al., 2020). Advanced Driver Assistance Systems (ADAS) control trajectories override driving commands to avoid a collision. Actuation technologies, i.e., throttle, computer control steering, braking, and transmission, are mature enough. However, embedded control software development, inter-vehicular communication, and real-time cloud computing support are real technical challenges (Babak et al., 2017; Tokody et al., 2018).

Additionally, some challenges need to be addressed to achieve a full automation scenario. It includes vehicle – to – X connectivity (V2X) comprising vehicle–to–vehicle (V2V) and vehicle–to–infrastructure (V2I), Decision control algorithms, digital infrastructure (road automation). These comprise static and dynamic physical world representations, human factors, sensor perception in poor weather and unfavourable lighting conditions, HD Mapping, simultaneous localization and mapping (SLAM), and roadworthiness testing (Smith & Svensson, 2015; Van Brummelen et al., 2018). AV control systems include lateral control and longitudinal controls. Lateral controls relate to steering for path planning. Longitudinal controls assist in speed control and regulate a vehicle’s cruise velocity (Babak et al., 2017). Lateral control keeps the vehicle in the chosen lane and comprises Lane Departure Warning Systems (LDWS), Lane Keeping Assist System (LKA), and parallel parking assistance.

Longitudinal control assists in forward and reverse directions and include rear parking assistance, adaptive cruise control (ACC), which controls the vehicle's speed relative to the vehicle in front, and pre-crash brake assistance (Forrest & Konca, 2007). Figure 2.2 highlights various AV Technologies.

Figure 2.2

AV Technologies



Note: Technologies allow AVs to sense, plan and act in response to the dynamic driving environment. From *Autonomous Cars and Society* by Forrest. A and Konca.M, 2007, Department of Social Science and Policy Studies. Copyright 2007 Worcester Polytechnic Institute Worcester, MA 01609 and *Safety and security through the design of autonomous intelligent vehicle systems and intelligent infrastructure in the smart city* (p.384-396) by Tokody, D., Albini, A., Ady, L., Rajnai, Z., & Pongrracz, F, 2018, Interdisciplinary Description of Complex Systems: INDECS, 16(3-A).

2.3.2 Recent Developments in AVs

Recent developments are exacerbated in the backdrop of the COVID – 19 pandemic (McBride, 2021). Applications and services based on VANET technology comprise prior warnings about accidents, fog, and black ice, notifications about crashes and construction on roads, over-speed, and traffic signals (Singh & Saini, 2021). Leading car manufactures such as Ford, BMW, Kia, Hyundai, Honda, Toyota, Mercedes – Benz, General Motors, Nissan, Volvo, and Volkswagen incorporated emergency breaking, smart parking, semi-automatic pilot driving, and accident warning (NHSTA, 2020).

Partnerships between car manufacturers and technology companies like BMW – Daimler Mercedes in Europe, Ford - AI Argo in the US, and others have enabled further advancement in AVs (Faggella, 2020; McBride, 2021; Van Brummelen et al., 2018). Amazon experimented with autonomous package delivery and invested jointly with Google and tesla for AV robot Amazon scout. It is forecasted that AVs are likely to constitute around 50% of vehicle sales, 40% of all vehicles travel and 30% of vehicles by 2040. Figure 2.3 depicts a brief synopsis of competition between various car giants.

Figure 2.3

AV Competitors

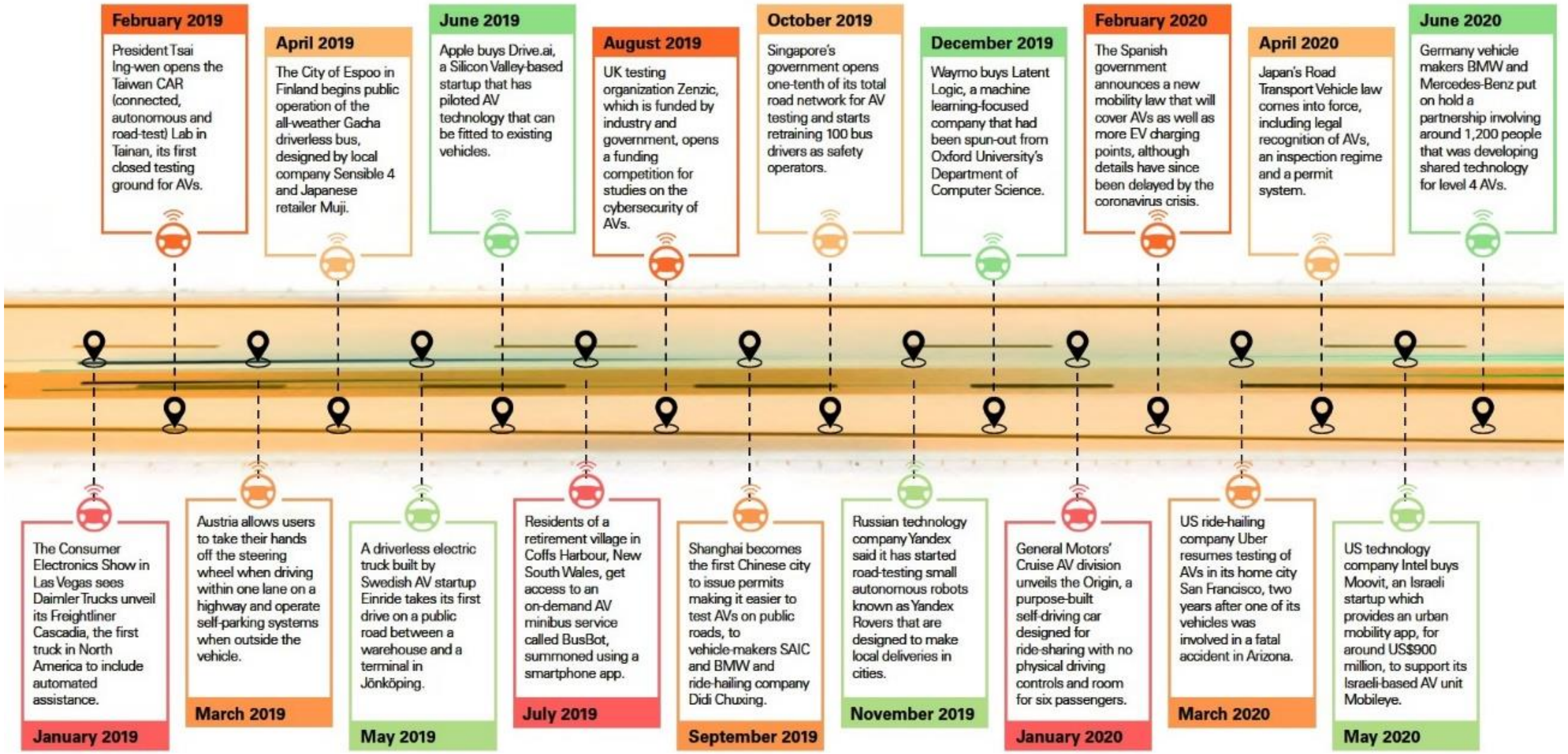
	BMW	Mercedes-Benz	Nissan	Google	General Motors
VEHICLE	5 Series (modified)	S 500 Intelligent Drive Research Vehicle	Leaf EV (modified)	Prius and Lexus (modified)	Cadillac SRX (modified)
KEY TECHNOLOGIES	Video camera tracks lane markings and reads road signs Radar sensors detect objects ahead Side laser acanners Ultrasonic sensors Differential GPS Very accurate map	Stereo camera sees objects ahead in 3-D Additional cameras read road signs and detect traffic lights Short- and long-range radar Infrared camera Ultrasonic sensors	Front and side radar Camera Front, rear, and side laser scanners Four wide-angle cameras show the driver the car's surroundings	LIDAR on the roof detects objects around the car in 3-D Camera helps detect objects Front and side radar Intertial measuring unit tracks position Wheel encoder tracks movement Very accurate map	Several laser sensors Radar Differential GPS Cameras Very accurate map

Note: Many car makers are manufacturing prototype AVs capable of driving in certain situations. From Autonomous Vehicles: challenges, opportunities, for transport policies (p.284-303) by Baglooe. S.A., Majid, T., Asadi, M., and Oliver, T. 2016. Copy right Journal of Modern Transportation.

Self-driving Software Company Aptiv collaborated with Lyft and did 100,000 plus rides in Boston, Las Vega, Pitts burg, Shanghai, and Singapore. Audi unveiled an autonomous A8 vehicle along with its merger with Argo AI. Didi Chuxing is testing Robo taxis. General Motors (GM) has teamed up with Honda and Lyft for cruise automation. Huawei partnered with BYD to produce low-cost LIDAR products and Russian autonomous giant Yandex for affordable driver assistance technology. Tesla partnered with Baidu in January 2020 to use its mapping data (Insights, 2020) . A bird's eye view of the recent developments in AVs is depicted in Figure 2.4.

Figure 2.4

AVs Developments – Recent Milestones



Note: KPMG (2020). *2020 Autonomous Vehicles Readiness Index* from https://home.kpmg/uk/en/home/insights/2020/07/2020-autonomous-vehicles-readiness-index.htm

2.4 Significance of Driverless Technology

Driverless technology comprising automation, electrification, and sharing is likely to alter the urban landscape and future mobility (Agriesti et al., 2020, p. 45). It is a collection of automation control technology, artificial intelligence, visual processing, and pattern recognition. Presently, novice unmanned driving technology is gradually gearing towards fully autonomous driving (FAD) functionality by improving accurate algorithms, advanced cloud platforms, deep learning capabilities and autonomous decision-making capabilities (Liang, 2020). According to the US Department of National Highway Traffic Safety Administration (NHTSA), 94% of severe traffic accidents happen because of human errors (NHSTA, 2020). AVs promise to eliminate human errors in traffic using sensors, cameras, light detection, and global positioning systems (GPS) technologies. AVs employ various safety-critical control functions such as steering, throttle, or braking without direct driver input (Dirsehan & Can, 2020).

AVs use Artificial Intelligence (AI), Deep Learning, and real-time HD mapping to ensure safety during driving (Jones, 2017). AVs are likely to revolutionize future mobility paradigms, improve safety and environmental impacts (Litman, 2020; S. Wang et al., 2020), and open new travel options for the elderly, disabled, and underage persons (IRGC, 2016). These technologies will shift a considerable share of the mobility market value away from products towards "mobility-as-a-service" (MaaS). AVs will converge transportation, automotive, software, hardware, and data services (Pizzuto et al., 2020). Nonetheless, the real disruption from autonomous driving (AD) will come in road transport, enabling efficient sharing of vehicles and the use of micro-mobility modes as a last-mile connection. Self-driving cars will reach 4.8 million units in 2035, and their value may reach $ 200 billion-1900 billion in 2025 (Agriesti et al., 2020). Although AVs caused occasional fatal accidents, either on drivers or pedestrians (NTSB, 2019a, 2019b), they prevented serious pedestrian injuries (BBC, 2016).

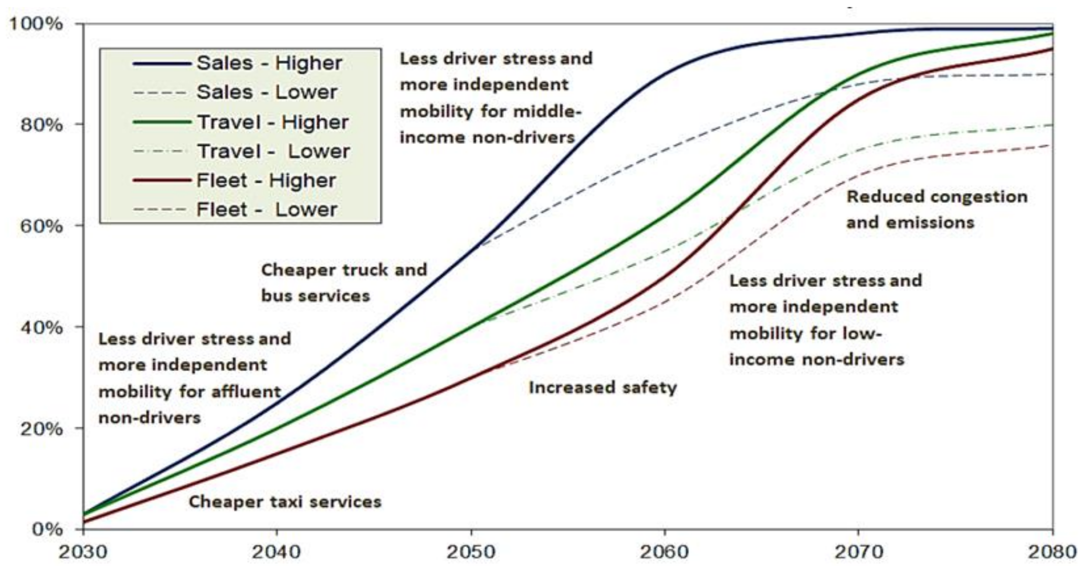
Generally, the public is inclined towards AVs (Rödel et al., 2014). However, these attitudes might vary depending upon the user experience and offering of the automation levels (Kyriakidis et al., 2015). AVs' decision-making capabilities are likely to gather detailed situation awareness in the future, capable of anticipating and reacting to complex situations better than humans (Hussain & Zeadally, 2018; Karnouskos, 2020).

It is believed that environmental perception technology, driver assistance systems, and automotive safety electronics are key driverless technologies. These technologies foster safety, energy conservation, market demand, high-level perception, advanced road facilities, and related legal provisions (Liang, 2020). The automotive future is perceived to be electrified, autonomous, shared, connected and yearly updated"(Kuhnert et al., 2018). Connected and Autonomous Vehicles (CAVs) are considered a subset of Cyber Physical Systems (CPSs) comprising digital software platforms, physical infrastructure, and human components in highway transportation (Liu et al., 2020).

Environmentally, AVs are likely to reduce energy consumption (Wadud et al., 2016), and avoid environmental degradation (Bagloee et al., 2016). As well as optimize fuel usage (Mamouei et al., 2018), lower emissions and air pollutions (Bauer et al., 2018), and noise nuisance (Nikitas et al., 2017). But reduced congestion will only take place with dedicated lanes to allow platooning, as shown in Figure 2.5 below.

Figure 2.5

AVs sales, Fleet Travel and Benefit Projections

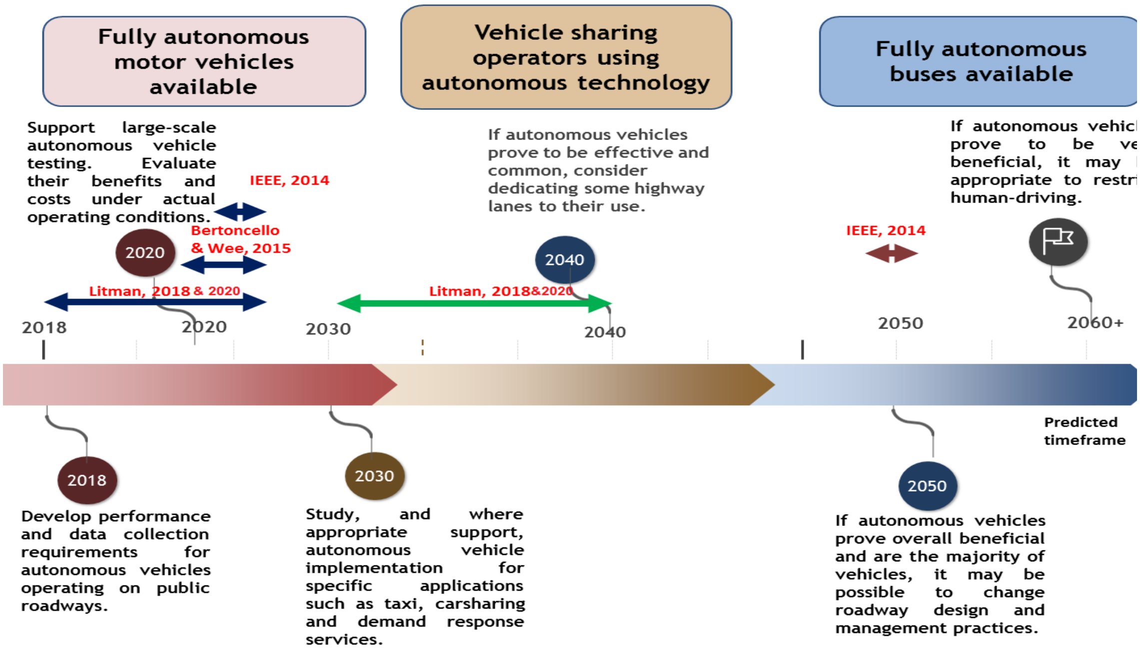


Note: This figure graph shows AVs sales, fleet travel and benefit projection from 2030 to 2060 and onwards. *From Autonomous vehicle implementation predictions: Implications for transport planning* by Litman, T. Copyright 2020. Victoria Transport Policy Institute Australia.

Earlier research indicated that AVs would be commercially available from 2030 to the 2040s. However, these will be costly and likely to become affordable by the 2050s (Litman, 2020). Moreover, it is predicted that half of the new vehicles and half of the vehicle fleet will be autonomous by 2045 and 2060, respectively (Litman, 2020). Figure 2.6 below highlights the AVs technology proliferation timeline.

Figure 2.6

AV Technology Planning and Impact Project Timeline



2.4.1 Trust Dynamics for Acceptance of Driverless Technology

According to social science research, public attitudes towards a new technology are affected by culture (Williams, 2003), psychological (Frewer et al., 1998), and cognitive factors (Au & Enderwick, 2000). The role of human trust in automated systems is to envisage and optimize operators' intervention behaviour based on their trust or the properties of automation that determine their trust (Muir & Moray, 1996). It may form a yardstick in measuring the success of the implementation of AVs, especially when faced with an asymmetric information dilemma (Raats et al., 2020). Trust is a widely researched phenomenon (Hoff & Bashir, 2015; Muir & Moray, 1996; Schaefer et al., 2016). Muir's three dimensional model in human-automation theory bases its foundation on interpersonal trust (Barber, 1983; Muir & Moray, 1996; Rempel et al., 1985). It is controlled by three distinct factors, namely predictability, dependability, and faith. Predictability refers to perceived consistency in the behaviour of the machine.

Dependability is the stability of a machine based on the accumulation of behavioural evidence, and faith relates to expectations that the machine performs beyond the current situation. Lee and See (2004) proposed four dimensions of trust: foundation, performance, process, and purpose. The foundation means national and social order in which trust thrives. The performance relates to what automation does in the past and present operations. The process describes how automation operates within the programmed algorithm, and its purpose relates to the designer's goal for which automation was developed (Chancey et al., 2017; Lee & Moray, 1992). Recent research suggests that naïve users initially build trust in the perceived performance of automation systems. And later develop it further based on more interactions with the technologies (Yamani et al., 2020).

Moreover, it has also been identified that trust development depends on risk perception. And, increased perceived risk raises automation trust, especially in the backdrop of performance (Sato et al., 2020). Risk can be defined as "the extent to which there is uncertainty about whether potentially significant and/or disappointing outcomes of decisions will be realized" (Sitkin & Pablo, 1992). A key challenge to the adoption of AVs is the public trust (Kyriakidis et al., 2019; Kyriakidis et al., 2015). Trust in technology is a cognitive attitude that changes over time (Lee & See, 2004) and is an intermediate behaviour variable (Comte, 2000). The foundation of trust refers to the social order that allows trust to arise, whereas performance, process, and purpose are purely related to technical domains of automation (Lee & See, 2004).

2.4.2 Co-Evolution of Regulation and Technology

A visible tendency for policy to lag behind new technological innovations is seen in several industries (Justo-Hanani & Dayan, 2015; Mordue et al., 2020; Saxena et al., 2017). The policymakers need to understand the rapidly evolving technologies and anticipate the associated risks to foster a regulatory policy to balance and advance the innovation (OECD, 2011). There is always a rift between industrial and regulatory guidelines. "Technology symbolizes markets, enterprises, and growth, while regulation represents government, bureaucracy, and limits to growth" (Wiener, 2004, p. 483). The regulatory oversight happens due to a number of reasons. These include insufficient knowledge (Goldbach, 2015) and taking a long time to develop and implement complex politically sensitive policy (Trump, 2017). Another reason is asymmetric resource availability between regulators and other stakeholders like manufacturers, engineers, the general public (Abbot, 2012). As AVs enter the roadways, these will be sharing the roads with human drivers for the near future. Regulations on AD systems need to balance two competing demands in addition to satisfying the public risk threshold. It includes protecting public safety from undue risk caused by immature AD systems leading to crashes and encouraging testing and innovation in this technology to produce safer vehicles in the future (Shladover & Nowakowski, 2019). The difference between the testing and deployment regulations is that the system's safety is considered independent of the driver's input, and the system must carry out self-diagnostic. The system must ensure safety even if the driver falls asleep.

Moreover, AVs must operate under the given (ODD) operation design domain conditions (limited by road type, geography, speed, weather, or lightning) by the manufacturer (NTSB, 2019). The recent deployment of vehicles at various autonomy levels resulting in occasional death, injuries, or crossing red lights illustrates the need to keep the regulatory process in tandem with the development of technology (NTSB, 2019). In Europe, The General Data Protection Regulation (GDPR) has laid down Europe's firm stance on new data privacy and security laws and levy harsh fines for violators (GDPR, 2020). Safety is paramount for public trust and acceptance (Lee & Hess, 2020). The transition of AVs from testing to widespread use will cause privacy issues to be more pronounced. One of the research identified that;

> "The vehicle industry has expressed concerns about the privacy limitations and the risks of cyber-attacks in these cooperative systems, particularly for the safety-critical applications involving collision warning and collision avoidance"(Petit & Shladover, 2015, p. 546).

Communication with other vehicles is vital for safety. However, it can give rise to privacy issues, including the travel time, the activity of the user, and location (Lee & Hess, 2020). Safety is related to the vehicle itself and communication with the environment, including internet connectivity, data, and reporting (UNECE, 2018). Liability is a closely linked issue as it becomes necessary once safety is compromised during a collision. Global manufacturers use two sets of vehicle safety standards, including U.S. Federal Motor Vehicle Safety Standards (FMVSS) and the United Nations Economic Commission for Europe and the E.U.(Commission, 2019a).

Certification of standards differs between “type approval” countries, including the EU area and Australia (Canis & Lattanzio, 2014; Commission, 2019b) administering the certification, and self-certification countries where the manufacturers conduct the tests. Shladover and Nowakowski (2019) noted that safety has two dimensions. The first one deals with the functional safety of internal faults, and the other relates to driving behaviour competency to deal with external hazards in the driving environment. The provision of detailed data reporting for test vehicles is another facet of safety for collecting information on potential safety risks. With higher levels of automation in AVs, product liability insurance for manufacturers or comprehensive insurance for fleet owners may become more important than insurance for drivers or vehicle owners (Fabian et al., 2018).

US has 420 AV company headquarters, and its vehicle makers are continuing developmental work on AVs (KPMG, 2020). In January 2020, General Motors launched ‘Origin’ a ride-share self-driving car, and in 2019 Apple bought ‘Drive.ai.’ Uber resumed AV testing in San Francisco in March 2020. Ford invested US$1 billion in American AV start-up ‘Argo AI’, and German vehicle maker Volkswagen invested an additional US$2.6 billion (KPMG, 2020). The federal government lays down the “national safety standards” in the US, and states issue licences and regulate driver behaviour (Halsey, 2018). National Institute for Standards and Technology (NHTSA) delineated a Vehicle Performance Guidance for selling, manufacturing, designing, supplying, testing, operating, and deploying AVs (NHSTA, 2020). California pursues functional safety plans for testing AVs besides self-certifying the safety requirements (DMV, 2020). The Chinese government made testing AVs on public roads easier with human supervisors in test vehicles (Shepherd, 2019, 2020). Chinese government adopts a light control-oriented strategy to address safety risks and seeks to create a “friendly policy environment” for accelerating the development of AVs (Taeihagh & Lim, 2019). The City of Shanghai has already issued permits to Chinese vehicle maker SAIC and ride-hailing company Didi Chuxing. BMW of Germany and AV start-up ‘AutoX’ announced to launch 100 Robo-taxis in the city (Shepherd, 2019, 2020).

In the UK, the Department for Transport (DfT) published an AV test code of practice that manufacturers pursue throughout the life of AVs. It permits testing on public roads without any approval. UK Bill HC 143 has clarified the liability of insurance and AV owners if an accident occurs. UK's Dft, in collaboration with the Centre for the Protection of National Infrastructure (CPNI), created guidelines asking manufacturers to follow the Privacy Architecture framework outlined by ISO 29101, demonstrating a light control-oriented strategy. UK has also launched 'Future of Transport Urban Strategy Regulatory Review' (CCAV, 2020; Dft, 2015, 2017a, 2017b). According to McCall et al. (2019), the Association of British Insurers (ABI) proposed several requirements for sensible regulation of vehicle automation from an insurer's perspective. It includes precise labelling AV capabilities or vehicles' geo-fencing to suitable environments and standardized access to telemetry data. It asks for self-certification for automation performance instead of pre-market approval to bring the products to market and de-incentivize manufacturers to work around regulations. The document also suggests a possible shift of the compulsory insurance requirement from driver to vehicle in the long term. UK Government and Industry invested US$250 million establishing six test facilities for AVs as "TestBed UK" by Zenzic in the south-east and central England (KPMG, 2020). UK has also launched its review of exploring the regulatory framework for AVs besides having consultations regarding flexible bus services and micro-mobility vehicles such as electric scooters and MaaS (KPMG, 2020).

Australia is one of the four countries, including Singapore, Finland, and the Netherland, with the highest score for its AV regulations (KPMG, 2020). Transport for New South Wales (NSW) has been testing autonomous buses since 2017. Motoring organization 'Royal Automobile Club' (RAC) is offering rides in its driverless electric 'intellibus' on public roads of Busselton in Western Australia since 2019. Vehicle maker EasyMile and Coffs Harbour City Council commenced an on-demand service called 'BusBot' to a retirement village in 2019. It has also used AVs for mining and fully remotely controlled iron ore pits trucks (KPMG, 2020). In Australia National Transport Commission (NTC) published non-mandatory guidelines for safe AV testing and has developed four regulatory options to regulate safety (NTC, 2020). The Australian state Victoria stresses safety management plans in the permit with high penalties of violations. Europe emphasizes stricter controls, and testing is typically "confined to predefined areas" (KPMG, 2020; Tech, 2020). Sweden enhanced its scope on AVs tests on public roads. Driverless electric truck built by Swedish AV start-up 'Einride' has allowed human supervisors to leave their hands off steering wheels (KPMG, 2020; Tech, 2020).

Singapore's 2020 budget laid US$4.3 million to support AV testbeds and is at the top in policy and legislation. Volvo launched a 12-meter AV electric bus in Singapore's Nanyang Technological University (KPMG, 2020). German vehicle manufacture BMW is involved in tests in China and testing sites in the Czech Republic and Hungary. Daimler is spending US$570 million on AV trucking and started testing a fully autonomous Freightliner Cascadia on public roads in Virginia, US. Operators are trialling autonomous buses in Berlin, Hamburg, Leipzig, and Deutsche Bahn national railway company (KPMG, 2020). The German federal strategy allows driving level 4 AVs since 2017. Germany only requires VDA (Verband der Automobilindustrie) for AV level 3 (Automobilindustrie, 2015). VDA level 3 regularizes automated features used to drive the vehicle under limited conditions.

Regarding data and reporting, Victoria demands real-time monitoring and recording of performance and location and compliance with permit requirements during the test (appropriate training, driver and vehicle safety assessment) (Victoria, 2018). Germany and California require a black box that is placed inside the vehicle and records all CAVs tests. California also requires a disengagement report. California and Victoria hold the test company liable for any untoward incident or failure in case of liability issues. Victoria holds the legal entity liable for any damage which is responsible for testing. The human safety driver, vehicle owner, or both can be held accountable in Germany. Similarly, Dutch Safety Board (2019) stressed the need for user-centred design to improve the AV design to prevent the human misuse of the system, such as tracking of driver eye movements so that they should not sleep. Singapore and Germany have the highest safety controls, and Germany has the best liability regulation.

The research noted best safety practices around the world (Lee & Hess, 2020). First, the presence of a human safety driver during on-road testing and a separate license with additional provisions for remote monitors. Second, the safety driver and remote monitor should be capable enough to deactivate the system at any time. Third, a training program for the safety drivers and remote monitors, and a comprehensive safety management plan as developed by Australia. Fourth, substantial fines and penalties for non-compliance with safety rules. Fifth is the submission of disengagement reports in California, whose format should be standardized across all manufacturers. Sixth, testing permit accompanied with substantial insurance. Seventh, the requirement to record the trials in real-time and the availability of black boxes in AVs for safety investigations.

2.4.3 Driverless Technology in NZ Enabling Environment

NZ's low population density, inconsistent safety infrastructure, road markings, limited private capital, and government funding are significant barriers to AVs' more comprehensive development and deployment (KPMG, 2020). However, NZ has a well-known history as a popular testbed of emerging technologies due to its unique geographic isolation, tech-savvy people, population density, and similarities to American and European markets (Fookes, 2016). NZ supports the testing of AVs due to no explicit legislative requirement of the driver in the vehicle. It has a wide range of climatic and road conditions, availability of winter testing facilities, world-class universities, and the appeal of the NZ lifestyle (NZTA, 2021). AVs can lead to a step-change in road trauma reduction (Philp, 2020). There is likely a greater demand for electric AVs for transporting feed and supplies, mowing, and spraying (Petterson, 2020).

However, it has potential in autonomous aviation, maritime areas, and the use of drones. It has already hosted tests of the Cora self–flying air taxi developed by Wisk, a US joint venture of Boeing and Kitty Hawk (Wisk, 2020). In the maritime environment, crewless vessels such as the 'Sea Explorer' glider surveying submarine is in operation, and automated straddle carriers are unloading ships and loading trucks on the ports of Auckland. The NZ and Australian governments are carrying out joint trials of a South Positioning Augmentation Network to become operational in 2023 (Geoscience, 2020). NZ transport technology Company 'HMI technologies' has run AV shuttle trials in Christchurch, Melbourne, and Sydney in the commercial domain. It has also run its first 5G network-connected vehicle test in Auckland (Harry, 2019; HMI, 2018). The Australia and NZ Driverless Vehicle Initiative (ADVI), led by the Australian Road Research Board (ARRB), is trying to accelerate the deployment of AVs in Australia and NZ. Northland Transport Technology Testbed (N3T) is a trialling system that combines real-time weather data, sensors in the road, and Advanced Driver Assistance Systems (ADAS) in trucks to sense the risk of rolling and decrease speed to stop the accident. It has the potential to be transformed into autonomous platooning (FleetPartners, 2020).

The NZ Transport Authority (NZTA) exempts vehicles entering the country that does not comply with existing compliance standards under Section 166 of the NZ Land Transport Act 1998 (MOT, 2021). Moreover, the NZ Ministry of Environment looks after the climate impact policy (CIPA) relating to greenhouse emissions. It has a role to play in the AVs domain (MOT, 2021). Another advantage to AVs is the Accident Compensation Corporation (ACC) which prevents injury liability, and manufacturers are only liable to product liability (NZ, 2020a). Therefore, the present legislative arrangement fully supports the testing of AVs in NZ. NZ enabling environment has two likely AVs deployment pathways in the foreseeable future. The first is to create fleets of AVs in contained urban spaces. Second, the number of vehicles with autonomous features incrementally on NZ roads (MOT, 2021). NZ currently focuses on an amicable AV deployment regulatory regime comprising safety, liability, cyber security, and social and economic issues. New Zealand Transport Authority (NZTA) and Ministry of Transport have released reports relating to AVs, including 'Intelligent Transport Systems Technology Action Plan 2014-18', 'Regulation 2025: Emerging Insights', 'Overview of Autonomous Vehicle Program' and, the Government Policy Statement on LAND TRANSPORT 2021/22-2030/31. NZ authorities are revisiting critical pieces of transport legislation, such as the Land Transport Act 1998 and the Civil Aviation Act 1990 (Fookes, 2016; NZ, 2020c, 2020d; NZTA, 2014, 2021). NZ is a signatory of the 1949 Convention of Road Traffic Art. 8(1), "every vehicle… shall have a driver" (UN, 1949), which is in contrast to the NZ legislation regime that does not require a driver. The NZ householders' survey identified that people are cautious of technologies that 'contradict autonomy and vehicle ownership.' However, younger generations are comfortable with automation (Wolken et al., 2018).

This research noted that planners in NZ are struggling to imagine the consequence of driverless technology disruption. The challenge for transport planning professionals is to articulate a coherent and cohesive framework (Gleeson et al., 2018) and the public policy engagement to garner people's trust in this technology. The law changes are needed for liability clarification in offences involving AVs, including speeding and illegal parking (Cameron, 2018). NZ needs to adopt US Federal Government Policy to encourage manufacturers to produce safety assessments of their AVs under NZ conditions. Besides specific amendment is required in Land Transport Act to create a new liability regime (Cameron, 2018).

2.4.4 COVID – 19 Impact on Driverless Technology, Trust and Beyond

The COVID-19 is not an essential component of this research study, however, a need is felt to draw parallels in order to realize a prudent outcomes of the study. Countries around the globe responded to the COVID -19 with lockdowns and cutting edge technology solutions with AVs and smart cities. The COVID -19 pandemic and ever evolving user and environmental demands for transportation could exacerbate the development and deployment of AVs around the globe (Thakur, 2020). Intelligent Transport Systems and COVID-19 safety guidelines set sights on taking out human presence out of the eco - system. Both pursue similar themes of keeping fewer humans in transportation infrastructure and vehicles, reduce people working to operate freight transportation supply lines, lower accidental deaths and illnesses, avoidance of mass movements of people in crowded public buses, rails and subways (Wiseman, 2020a, 2020b). New York City's subway system is considered to be main disseminators of COVID -19 (Harris, 2020). It has already been pointed that China's self-driving car project accelerated during pandemic (Shepherd, 2020). Driverless technology is believed to have an expanded role in addressing the movement of people and goods amidst pandemic requirements and its fallout would further see the crowded public transit relieved by on – demand, autonomous minibuses to promote social distancing and AVs meeting shipping demands for contactless delivery (Threlfall, 2020). Future urban landscape is likely to witness the advance of emerging transportation technologies like SkyTran for private compact carriages and platoons of private autonomous cars with very few people (Wiseman, 2017, 2020a). AVs has proved to be blessings in fight against pandemic in number of ways including transporting medical supplies and health care professionals, disinfecting, cleaning hospitals and public spaces and serving as night time security robots and creating alerts against non-wearing of masks or large gatherings. In China, Apollo and Neolix uses AVs to disinfect road on Shanghai Zhangjiang AI Island. Apollo in collaboration with iDriver Plus provided AVs to 16 hospitals.

Similarly Baidu released 104 AVs in 17 cities of China for anti-epidemic jobs and Baidu Apollo robo taxi is proving free rides to passengers across 130 sq kms of aread since April, 2020. Baidu Apploa has also pioneered to build Vehicle to Everything (V2X) pilot zones in Chongqing's Youngchuan district and Anhui province to test level 4 AVs. For the deployment of smart cities and intelligent Transportation System, Baidu Apollo released the Ace Transportation Engine to integrate AI with infrastructure, equipment, services and industry governance (Baidu, 2020). In America, AVs, sidewalk robots and shuttles from various companies such as General Motors Co's, Toyota-backed Pony.ai, Nuro, TuSimple, Navya etc are delivering groceries, meals and medical supplies (Jane Lanhee Lee, 2020). Since the onset of COVID – 19 pandemic, 62% of the US people perceive that self-driving vehicles are the way of future and their enthusiasm is continuously growing (Vigliarolo, 2020). On one hand pandemic resulted in decline of transit ridership due to working from home, job cuts, slowed consumer purchasing of new vehicles and halting of AVs production by Argo AI, Waymo, Aurora, Ford, Volkswagen, and BMW resulting into short term disruption of AVs deployment. On the other, this disruption created unlimited opportunities in longer term, where AVs can be used for responding in times of emergencies and uncertainties, rise in appeal of personal car ownership, potential advantages in logistic, deliveries, and food service industry (Boll, 2020; Sridhar, 2020). It has forced OEMs to propel AV technology to the next level and transit from production to R&D. COVID – 19 is likely to have a lasting impact on future mobility solutions. In short to med term, regulatory uncertainty will increase thus mostly focussing on (1) sustainability and increase in EVs, (2) relaxation on private mobility and emission targets to assist OEMS, (3) and loosening of regulatory mandates to recover ailing automotive market. Similarly, investment in micro-mobility and shared mobility might drop along with suspension of AVs testing. However, in long term, it is believed that AVs, mirco-mobility solutions and other technologies that support physical distancing could be the winner (Mickinsey, 2020).

The COVID – 19 pandemic conditions are likely to influence the public trust towards driverless technologies. Lee and Moray (1992) Model envisages that with an increased interaction with an automated system, the user is more likely to develop performance based trust as well as purpose based trust. Muir's three dimensional in human automation theory bases its foundation on interpersonal trust (Barber, 1983; Muir & Moray, 1996; Rempel et al., 1985) controlled by three distinct factors: predictability which refers to perceived consistency in behaviour of machine, dependability which refers to stability of machine based on accumulation of behavioural evidence, and faith refers to expectations that the machine performs beyond the current situation. Later, Lee and See (2004) proposed four dimensions of trust namely foundation which means national and social order in which trust thrives, performance relates to what automation does in past and present operation, process which describes how automation operates within programmed algorithm and purpose which relates to the designer's goal for which automation was developed (Chancey et al., 2017; Lee & Moray, 1992). Recent research suggests that naïve users initially develops trust on the perceived performance of automation system and later develop it further based on other dimensions with more interactions with the technologies (Yamani et al., 2020). Moreover, it has also been identified that trust development depends on risk perception and increased perceived risk raises automation trust, especially in the backdrop of performance (Sato et al., 2020). Risk can be defined as "the extent to which there is uncertainty about whether potentially significant and/or disappointing outcomes of decisions will be realized" (Sitkin & Pablo, 1992). These model mirrors the present pandemic situation where general public is interacting and adopting new technology but have little knowledge about capabilities of the technology. Theories of human automation suggest that as pandemic recedes and/or is more controlled relative to uncertainties in the environment, the users who initially have faith in the AV technology will continue to trust if they gather enough behavioural evidence to maintain appropriate level of trust with sufficient dependability and predictability (Yamani et al., 2020) such as daily use of AVs being witnessed today to fight pandemic as highlighted in above paras. COVID – 19 is likely to accelerate the development of trust and deployment of AVs amid smart cities in the long term to improve safety, deliver supplies and advance new infrastructure besides increasing day to day commerce (Boll, 2020). The manufacturers of the driverless technologies need to focus on communicating system information correctly to retain users who may be "forced" to use unfamiliar technologies during the COVID-19 pandemic (Yamani et al., 2020).

2.5 Significance of Human Factors (HFs) on Automated Driving (AD)

The transformation towards entire automated fleets is likely to take decades. The human will remain in the loop during this transition journey and therefore form a critical part of the system. With any new technological innovation, a disconnect happens between academic research and industrial development (Kyriakidis et al., 2019). Related manufacturers, fleet operators, researchers, regulatory agencies, policy makers, insurance industries, and the users compete for overlapping interests in the system. These stakeholders form a link between the driver's behaviour, the behaviour of the system, and the realization of overarching benefits (Fisher et al., 2020) to society. The HFs knowledge is central to addressing the competing interests and challenges before, during, and after the deployment of AVs on public roads (Kyriakidis et al., 2019). Proctor and Van Zandt (2017) defined HFs as "…. …*the study of those variables that influence the efficiency with which the human performer can interact with the inanimate components of a system to accomplish the system goals*" (p. 9). World Health Organization (2009) described HFs that "…*examines the relationship between human beings and the systems with which they interact by focusing on improving efficiency, creativity, productivity, and job satisfaction, on minimizing errors*"(p. 100). HFs defined by the industry as:

"…the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and other methods to design and optimize human wellbeing and overall system performance" (Proctor & Van Zandt, 2017, p. 9)

To understand the HFs involved in automated systems, there is a need to understand the system and its goal, human and associated safety risks during human-machine interaction (HMI) (Fisher et al., 2020). Researchers need to look into trust in automation and its linkages with safety, user interfaces, warning and control systems, handover control procedures, situation awareness, drivers mental model, training, vulnerable road users, and special people needs (Fisher et al., 2020). HFs research scientists warned against going for automation straightaway without looking into the synergy between humans and automation (Fitts, 1951; Hancock, 2014). Bainbridge (1983b) explained the 'ironies of automation' and pointed out that 'the more advanced a control system is, the more crucial role of the human operator.' Humans tend to be poor supervisors, and there is a need to investigate how humans may misuse, disuse, and abuse automation technology (Parasuraman & Riley, 1997). A human operator will remain in the loop up to level 4, and its role is still not established, and HFs knowledge is often difficult to track down (Fisher et al., 2020; Kyriakidis et al., 2019).

Several researchers concluded that HFs challenges about HMI are yet to be resolved. These include the impact of automation on driver's mental model, workload and, situation awareness (Brookhuis et al., 2009; De Winter et al., 2014; Saffarian et al., 2012; Whitmore & Reed, 2015; Young et al., 2007). Also the level of acceptance (Brookhuis et al., 2009), reliance and trust on automated systems (Chancey et al., 2017; Coelingh, 2013; Dzindolet et al., 2003; Lee & See, 2004), and potential changes in behaviour (Gouy et al., 2014). Additionally, the necessary human skills needed during manual driving (Vlakveld, 2015), the role of humans in emergency situations when automation fails (Levitan et al., 1998). As well as the clarification of supervisory control between human operators and automated systems (Banks & Stanton, 2016; Lu et al., 2016; Marinik et al., 2014). Researchers highlighted the estimation of minimum time needed for the operator to resume manual control when asked by an automated system (Christian et al., 2016; Merat et al., 2014; Zeeb et al., 2015). Few other studies explored the interaction between AVs and other vehicles and road users (Madigan et al., 2016; Martens & van den Beukel, 2013; Merat & Lee, 2012). The study of the HFs relates to all stakeholders.

Manufacturers need to know about user interfaces that do not increase driver's stress overload drivers, are designed for a diverse range of impairments, and bring operators back in the loop ASAP at higher levels of automation (Fisher et al., 2020). Driving tutors need to find out new ways of training AV drivers. Insurance companies need to identify the feature that can lower claims. Regulatory agencies must know the driver licensing needs for AVs and guidelines for AV OEMs. And middle and low-income countries need to make decisions on affordable and lifesaving user interfaces (Fisher et al., 2020). One of the renowned HF scientist's excerpts is:

> "HFs research is needed; First, outline the acceptance criteria of human drivers regarding the AD functionalities. Second, how to define the individual capabilities of human drivers (e.g., situation awareness and reaction times). Third, to provide design solutions for AVs user interfaces. Finally, to explore the interaction between AVs and other road users" Dr. Klaus Bengler interview excerpt from Kyriakidis et al. (2019).

Another HF scientist outlined additional research topics as under:

> "An additional research is required: (1) to define how human drivers should be informed in case of a system failure, (2) depending on the type of failure, what the human driver is able and allowed to do, (3) to optimise the safe interaction of the new technology with human drivers, and (4) to ensure public acceptance and trust in AVs" Dr. Karel Brookhuis interview excerpt (Kyriakidis et al., 2019)

2.5.1 Levels of Automation and Active Safety Systems

In line with the categorized vehicle-centric taxonomy, the automation levels at which vehicle operates depends on three critical factors. First, it relates to either one, both, or neither lateral (automatic steering) and longitudinal (ACC) features. Second, the role of the driver (should monitor or need not monitor the roadway), and third, the time available to the driver to resume control (immediate to never) (Fisher et al., 2020; SAE, 2021). Earlier, a 4-level of vehicle automation taxonomy was formulated by the National Highway Traffic Safety Administration (NHTSA) in 2013 (Wadud et al., 2016), and 5-level automation was developed by the Society of Automotive Engineers International (SAE) in 2014 and 2016 (Coppola & Morisio, 2016; Faisal et al., 2019). In 2016, NHTSA adopted SAE's taxonomy and automation levels (NHSTA, 2020).

The Operational Design Domain (ODD) concept is significant to an automated driving system (ADS; SAE Levels 3 or higher). It describes the "operating conditions under which a given driving automation system is designed to function; including, but not limited to, environmental, geographical, and time of day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics" (SAE, 2021). According to SAE J3016 (SAE, 2021), an ADS is "The hardware and software that are collectively capable of performing the entire Dynamic Driving Tasks (DDT) on a sustained basis, regardless of whether it is limited to a specific ODD." ADS relate to level 3-5, and the Driving Automation System (DAS) refers to any level that performs part or all of the dynamic driving task on a sustained basis. The DDT consists of "all of the real-time operational or tactical functions required to operate a vehicle, excluding the strategic functions such as trip scheduling and selection of destinations and waypoints" (Wintersberger, 2020).

At the lower levels (Levels 1 -2), Driver Support Features (DSFs) carries out the portion of driving jobs, controlling longitudinal or lateral control (Level 1) or both (Level 2), with the human having to monitor or intervene as required. It includes Lane centring and Adaptive Cruise Control (ACC). In Level 3, the ADS does the entire driving tasks within the defined ODD, whereas human input is required to take over the control when requested by the system. In Levels 4 and 5, the ADS carries out full vehicle control. For Level 4, it is conditional and relates to a particular ODD, whereas for level 5, it is unconditional and human input is not required. However, achieving this level is not likely in the near foreseeable future (Fisher et al., 2020). Ideally, in a highway system, an ADS can “see” several seconds ahead of time, which may be in the order of 300m (Waymo, 2017). These automation levels identify the various degrees of human versus machine controls and do not address implementation aspects. A specific vehicle can operate at different levels of automation depending on enabling environment and the task. A robust ADS design is quintessential against system failure resulting from any software or hardware failure. However, since it is difficult to arrive at a 100 percent fail safe system yet. Hence fallback position is required. At lower levels (0-3), it is the human driver, whereas at higher levels 4 and 5, the system itself is the fallback and must detect the problem “Safe Stop” Minimal Risk Condition (MRC) (NHSTA, 2020). It applies to the situations when ADS leaves its ODD and requires either pulling out of the traffic stream and parking at a safe place or stopping in the lane with flashers on. Table 2.2 lays down the operational functions of the automated driving system (ADS) and the role of humans at each level of vehicle automation.

Table 2.2

SAE Levels

Categories	Level of Automation	Names/ definitions	Role of Human Driver		Role of ADS	Fall back of DDT
			Manual control	Active Monitoring	Operational functions	
Driver Support Functions (DSF)	0	No AS No ACC	Both steering / accelerating 	Yes		N/A
	1 (Driver Assistance)	AS/LCA or ACC but not both	Steering or accelerating but not both 	Yes (most functions are controlled by the driver)	Lateral and Longitudinal control	Yes, Limited Warning
	2 (Partial automation)	Both AS/LCA or ACC engaged, PA	Hands off 	Yes (at least one driver assistance system is automated)	Lateral and Longitudinal control	Yes, Limited Warning
Automated Driving System (ADS) Features	3 (Conditional Automation)	AS and ACC	Eyes off 	No (driver can shift safety-critical functions to vehicle)	Lateral and Longitudinal control, Localisation, Perception, Planning, Management	Yes, several seconds of warning
	4 (High Automation)	AS and ACC	Attention off 	No (fully autonomous, but not in every driving scenario)	Lateral and Longitudinal control, Localisation, Perception, Planning, Management	Yes, minutes of warning
	5 (Full Automation)	AS and ACC	Passenger 	No (fully autonomous, vehicle's performance is equal to a human driver in every driving scenario)	Lateral and Longitudinal control, Localisation, Perception, Planning, Management	No

Note: AS: automatic steering; ACC: adaptive cruise control; LCA: Lane Control Assistant; PA: Parking Assistant. Taxonomy of road vehicle automation derived from SAE. 2018.

2.5.2 Critical Insights into Level of Automation (LoA)

LoA significantly impacts driver situation awareness (SA) and level of engagement and provides increased safety and reduced human error. At the same time, it has substantial human factor challenges associated with driver's negative adaptation due to misunderstanding, misuse, and overreliance on system or distraction from the driving tasks (Blanco et al., 2015; Lee et al., 2021; Rau et al., 2014). Moreover, automation might negatively impact the driver's ability to perceive critical factors or system failures due to passive monitoring, decreased information processing abilities, workload level, and willingness to engage in non-driving tasks.

Though the SAE taxonomy of LoA is relatively well defined, however, more deliberations are needed in the context of driver's situation awareness (environmental monitoring), handover situations, and legal liability in case of a crash from level 2 to level 4 (McCall et al., 2016b; Wintersberger, 2020). Situational Awareness (SA) is a "perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future" (M. R. Endsley, 1995; Endsley, 2016). Underlying research paradigms need to be explored and matured during the emergency instances where the driver is likely to be legally liable for possessing adequate SA. Still, he may not be fully aware and respond appropriately to being involved in other tasks. At level 3 and above, the system is responsible for environmental monitoring in autonomous mode; however, there is confusion in being situationally aware between levels 3 and 4. At level 3, the drivers need to resume control after a certain amount of undefined time. However, they don't need to monitor or intervene while being receptive to various alerts actively. At level 4, standard and fallback performance do not require necessary involvement of humans and are limited to specific ODDs. At level 5, ODD is unrestricted. At higher levels, the most critical point is the control transition stage once control is handed back to the driver from ADS, handback or takeover situations.

Resultantly, the legal responsibility in case of an accident would fall on the driver or the system. Few experts believe that to counter this ambiguity, especially at level 3, the responsibility needs to change concerning the handover timeline. This requires a further breakdown of taxonomy levels by explicitly looking at the taxonomic categorization for a split of liability between the vehicle driver and the autonomous system (McCall et al., 2019). Earlier researchers identified many factors to improve driver's SA and related taxonomies. These include focussing on driver skills for safe transitions, design of vehicle interfaces, taxonomy based on handover situations, and assigning liability for an incident during handover and impact on SAE levels (Flemisch et al., 2012; McCall et al., 2016a; McCall et al., 2019; Nilsson et al., 2014; Parasuraman et al., 2000). Parasuraman et al. (2000, 2008) elaborated on ten levels of computer automation. They identified that automation needs to be categorized by the different phases of the control loop where automation supports the operator and the degree of human intervention. They observed acquisition, analysis, decision, and action automation, highlighting various examples from the aviation sector. Researchers further highlighted that

> "mental workload, situational awareness, complacency (over trust), and skill degradation" are critical human factor challenges when the human operator is ever expected under abnormal conditions to take over control and "the burden of proof should then be on the designer" (Parasuraman et al., 2000, pp. 289,292).

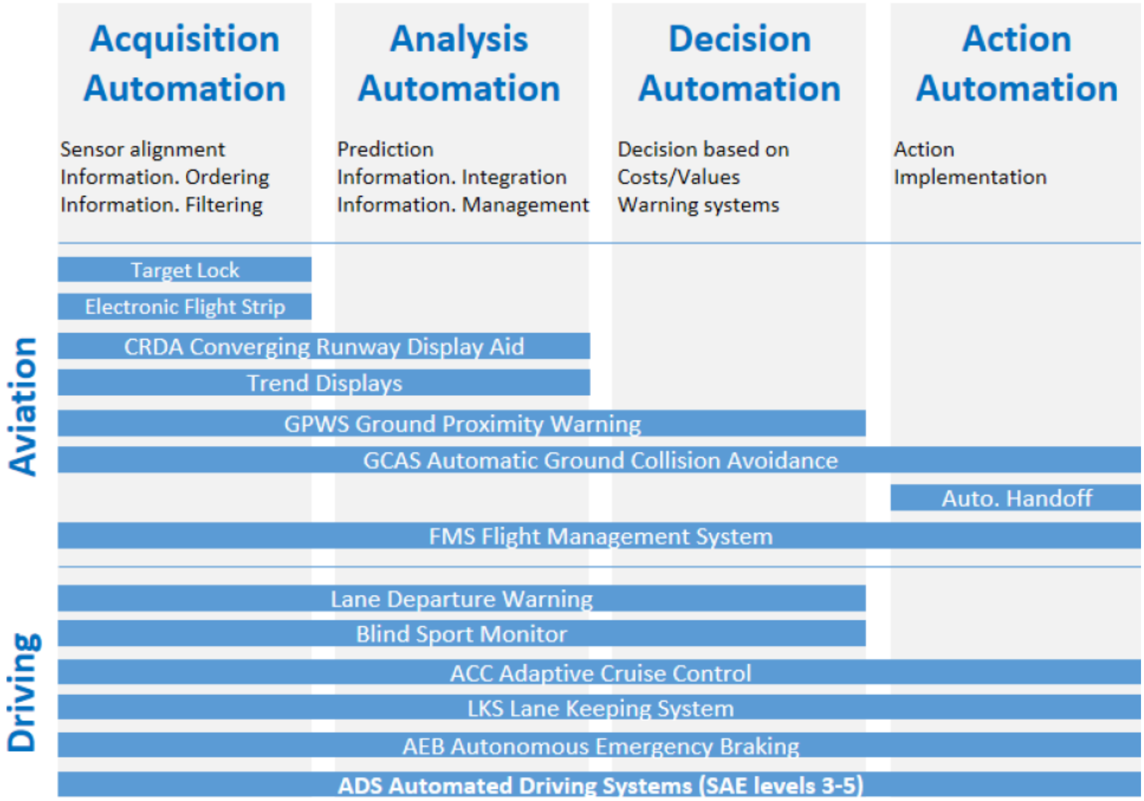
Generally, cases liabilities may not be assigned to OEM unless there is a fault in the autonomous system. Consequently, this liability trend makes owning AV rather unattractive. It is evident that with the increasing levels of autonomy, the issues of liabilities become blurred. Therefore, there is a need to link responsibility more closely to autonomy levels and explore alternative insurance models, including the no-fault approach (McCall et al., 2019).

2.5.3 Driver and Environment

Research points toward looking at parallels between the driver and its environment and the aviation industry for valuable insights and analysis. The flight management system (FMS) in aviation is based on multiple controls sub-systems at the strategic, tactical, and operational levels. It automates the overall flight path providing input to the autopilot (Wintersberger, 2020). Pilots perform "automation monitoring" using instrument flight rules (IFR) in contrast to "environment monitoring" by drivers using a driving automation system. However, there is more significant variability in driver and vehicle environment (Young et al., 2007). Driving automation systems automate all phases (i.e., action automation) without informing the driver how and why certain decisions are implemented. Whereas the aviation system automates specific phases like decision automation and demand agreement for error trapping. The driving automation operates across all phases based on agreements between operators and systems (flight controllers and pilots). In driving, it suits well when drivers have insufficient reaction time (such as for autonomous emergency break AEB), but otherwise pose greater challenges in high-risk environments (Parasuraman et al., 2000; Wintersberger, 2020). Figure 2.7 provides a comparison of different phases in aviation and driving.

Figure 2.7

Different Types of Automation in Different Phases of Processing Loop – Aviation vs Driving



Note: Different types of automation in the different phases of the processing loop adopted from *a model for types and levels of human interaction with automation* by Parasuraman, R., Sheridan, T. B., & Wickens, C. D. 30(3), p 286-297. 2000. Copyright IEEE Transactions on systems, man, and cybernetics-Part A: Systems and Humans.

The driving environment has shorter time frames and is more complex than aviation as split-second decisions are needed. Roads are narrower and flooded with other road users nearby. There is usually ample space in the air to conduct manoeuvres (Feldhütter et al., 2016). Pilots undergo extensive training and licensing process besides knowing fundamental principles of the system, while drivers are not necessarily domain experts and lack system experience (Trösterer et al., 2017).

2.5.4 Situation Awareness

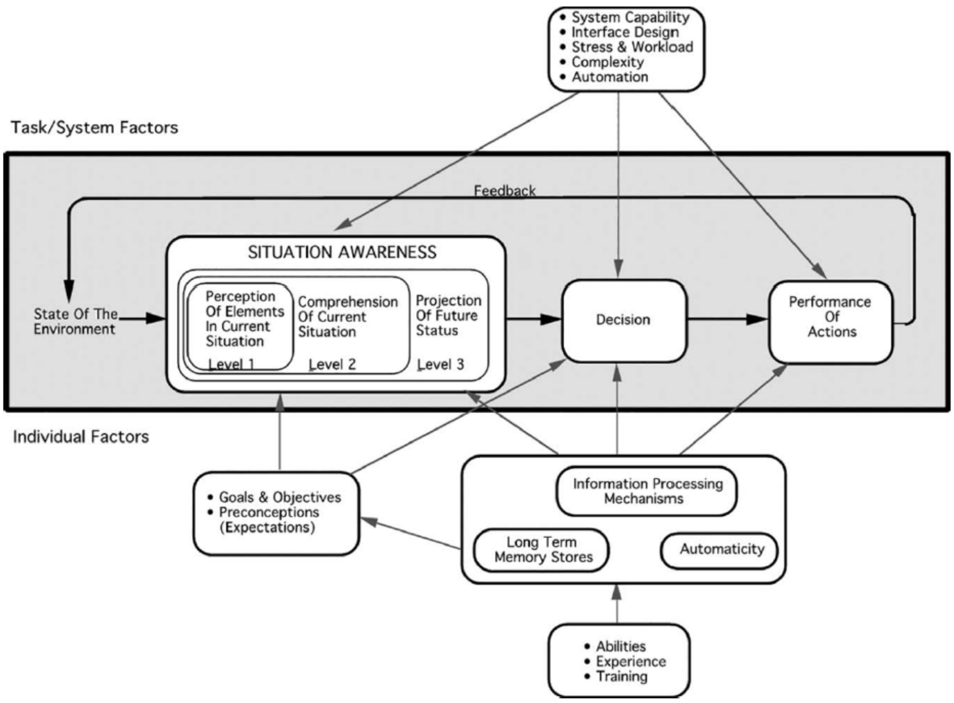
Situation awareness (SA) serves as a lynchpin in assimilating complex drivers and vehicles' complex environments in terms of complicated traffic, bad lightning and visibility, sudden movement of people, and other road users in front. Therefore, it is quintessential to understand and timely respond to events (McCall et al., 2019). Lack of SA is a cause of most of the driving errors (Gugerty, 1997). M. R. Endsley (1995) demonstrated that out of loop (OOTL) problem occurs due to the loss of SA when overseeing automation. Low SA happens due to three primary mechanisms. First, the changes in the information presented are due to interface related failures and a low level of transparency. Second, the lack of monitoring and vigilance, and overtrust exacerbated by complacency and over-reliance on automation. And third, the operator lower-level engagement when acting as a passive monitor of automation (Endsley, 2017). These primary mechanisms create a fundamental '*automation conundrum,'* a barrier to autonomy in critical safety functions. Lack of SA and over-reliance contributed to the May 2016 Tesla crash when AV did not correctly identify the truck (NTSB, 2016).

In earlier researchers, Matthews et al. (2001) identified different aspects of SA. These comprise Spatial Awareness: location relative to the environment, e.g., lateral position on the road; Identity awareness: knowledge of salient items; Temporal Awareness: how the situation is likely to change over time; Goal Awareness: how completing a goal becomes possible or not possible and, System Awareness: awareness of the current system status.

Endsley (1988) laid down different levels of SA, including perception, comprehension, and projection. The perception (Level 1 SA) relates to the driver's ability to receive input from internal and external environments. The comprehension (Level 2 SA) means how the operator realizes the current information from the surroundings and the projection (Level 3 SA), which is the near future estimation of change in the current situation. The reasons for over 40% of driver-related crashes occur due to poor perception related to inadequate surveillance, inattention, and internal and external distractions. In contrast, misjudgement of gap or others' speed and false assumption of others' actions accounts for 3.2% and 4.5% due to lack of comprehension and projection (Fisher et al., 2020). A significant factor in SA application is a clear demarcation of Level 1, 2, and 3 SA requirements through a goal-directed task analysis (GDTA). GDTA describes the goals for a given operational role in the domain (e.g., driver, pedestrian, and mechanic). The critical decisions associated with each goal and the SA requirements needed to make each decision (Fisher et al., 2020; Kokar & Endsley, 2012). Endsley's (1995) cognitive model of SA can be used to know the factors impacting driver SA in the dynamic road environment (see Figure 2.8 below). SA helps the drivers to find out the intentions and the correct information about the system rather than training users on what to do in specific scenarios (Parasuraman et al., 2008). The system must provide the right information by giving correct feedback at the right time using contextual information and system information besides helping the driver integrate, assimilate, and know the future implications of the current context.

Figure 2.8

Model of SA in dynamic decision–making



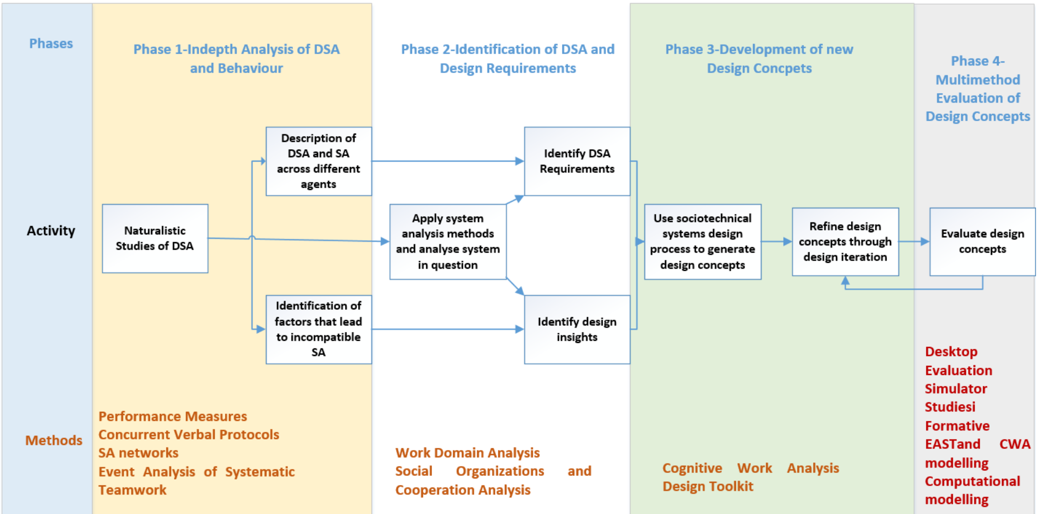
Note: SA Cognitive Model from *Situation awareness and cognitive modelling* by Endsley, M. R. 27(3), p 91-96. 1995. Copyright IEEE Intelligent Systems. Key cognitive processes including driver attention, working memory, and goal-directed and data-driven approaches in complex driving environments are given at the bottom of the figure.

2.5.5 Distributed Situational Awareness

A holistic understanding of AV systems calls for going beyond the SA needs of human road users towards the SA needs of AVs. AVs need to share SA with human agents as well as non – human agents such as AVs, infrastructure, and overall transportation system. Stanton et al. (2006, p. 1291) defined the DSA model as “activated knowledge for a specific task within a system and the use of appropriate knowledge held by individuals and captured by devices that relates to the state of the environment and changes as the situation develops” (Figure 2.9).

Figure 2.9

A framework for DSA based design



Note: A framework for DSA based design from Distributed situation awareness in road transport: theory, measurement, and application to intersection design by Salmon, P. M., Read, G. J. M., Walker, G. H., Lenné, M. G., & Stanton, N. A. 2018. Copyright Routledge.

A failure to consider DSA needs through the design life cycle will lead to an unsafe and congested road transport system. Earlier studies either focussed on driving simulators or paid attention to isolated events of automation failure or handover control while testing the safety risks of automation. These studies neglected key areas in HMI, such as the interaction of AVs with vulnerable road users and with other AVs designed by different manufacturers with differing algorithms (Fisher et al., 2020). In a recent Uber – Volvo collision, the SA needs of the AV and the driver and other road users require further deliberations where AV should provide an adequate alert to the driver regarding pedestrian detection (Stanton et al., 2019). Salmon et al. (2016) recently developed a complex control structure model in Queensland, Australia, which describes all the agents involved in road transportation up to government and agencies. Similarly, other authors observed the use of Cognitive Works Analysis (CWA) (Vicente, 1999) to find out essential design requirements, the Socio-Technical System (STS) theory (Read et al., 2017), and STS Design Toolkit to formulate new designs.

2.5.6 Driver's Mental Model

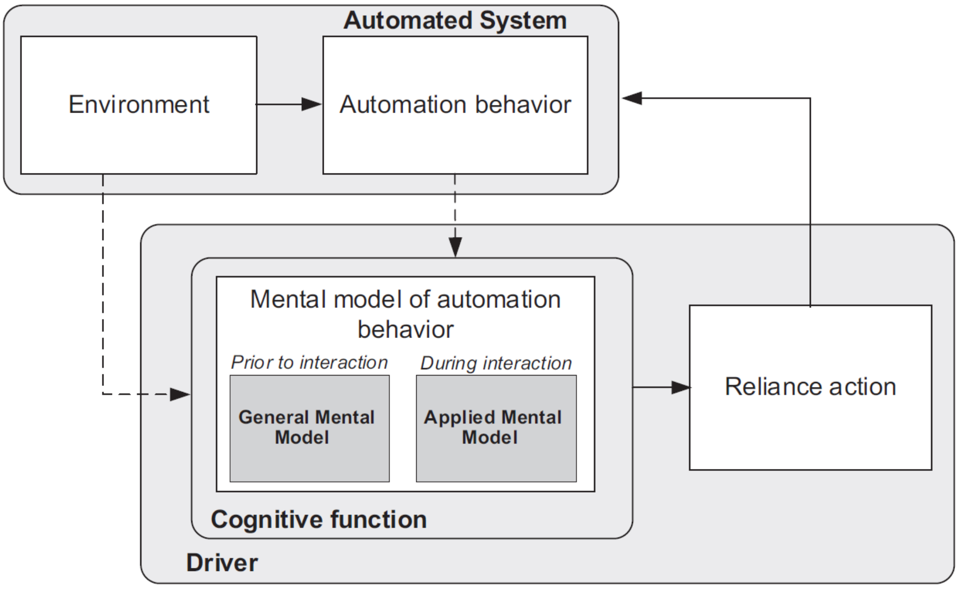
System behaviour is predicted by the accuracy and completeness of the operator's mental model, which shapes up from various driving experiences and the effectiveness of the system interfaces. Toffler (1970) stated that "every person carries within his head a mental model of the world – a subjective representation of external reality." This notion of the mental model was first believed by Craik, who observed that "a brain could translate an external process into a model of the world, which is a small-scale model of external reality and its possible actions within the head"(Craik, 1943). Later Norman highlighted that "people form internal mental models of themselves and the things with which they interact with the environment, with others, and with the artefacts of technology that can provide predictive and explanatory power for understanding the interaction"(Norman, 1983).

It has been argued that a mental model is an operator's knowledge about the system, its purpose, form, function, and structure (Johnson-Laird, 2013; Rouse & Morris, 1986). Research on mental models can be divided into two branches; the first focuses on internal mental processes and cognitive phenomena within psychology based on comprehension, reasoning, and deduction. And the other supports interactions between people and the external world, i.e., HMI, which stepped out from psychology and applied mental models (Xie et al., 2017). Norman (1988) stressed the need to bridge the gap between designers' and users' mental while using technological products. Decrease in situational awareness results in mode confusion (Cunningham & Regan, 2015). Mode confusion is described as a 'mismatch between the actual operations of AV and as perceived by driver's mental model' (Ekman et al., 2018). Generally, research in this domain mainly focuses on the role of mental models in using computers and appliances (Shih & Alessi, 1993) and learning and training (Revell & Stanton, 2014; Tollman & Benson, 2000). As mental models reside in the head, these cannot be detected directly as they pose challenges of incompleteness, vague boundaries, instability over time, and superstitions (Norman, 1988). Therefore, they need to be inferred indirectly. Within HCI, the researchers use techniques of verbalization through interviews, think aloud and laddering, rating, drawing sketches, and card sorting for figuring out individual and shared mental models (Payne, 2007; Rieh et al., 2010; Rowe & Cooke, 1995; Zhang, 2012). Presently, drivers get help from vehicle automation. However, they still need to monitor automated systems and traffic environments to carry out object/event detection and response (OEDR), act as fallback agents, and fulfil all non-automated functions (Lee, 2018; SAE, 2021). To share safe driving goals in sync with automation, drivers need to supervise automation in any dynamic, uncertain situation through information integration, analysis, system expertise, continuous attention, and analytical decision-making using manual skills (Bhana, 2010; Casner et al., 2014). Accurate, well developed mental models are quintessential for successful HMI; otherwise, they lead to misunderstandings and inappropriate use (Fisher et al., 2020) and negatively affect trust and acceptance (Lee & See, 2004).

Mental models are associated with two types of knowledge. Declaratory knowledge based on acquired education is referred to as General Mental Model. And the procedural knowledge gained by the practice is known as Applied Mental Model (Rumelhart & Norman, 1981; Shiffrin & Schneider, 1977). The general mental model is the initial mental model of the driver before using an automated system constructed through a variety of measures such as owner’s manual, word of mouth, marketing, and perceptions (Cotter et al., 2008; Fisher et al., 2020). A correct general model is essential for constructing the applied mental model to assist the driver successfully in vehicle automation use behaviour in the short and long term and reliance decisions (Seppelt & Lee, 2007). A calibrated trust depends on correct information supplied to the driver on the system purpose, process, and performance (PPP) (Lee & See, 2004). To measure and quantify user mental model, Beggiato and Krems (2013) developed a 32 item questionnaire on ACC functionality in specific PPP situations. Seppelt (2009) made a 16 item questionnaire to determine users' knowledge of the designer’s intended use. Recently updated research on these mental models suggests that training drivers understand in situ vehicle limitations and capabilities during dynamic HMI phenomena, provide routine training, and assist in adapting intelligent tutoring systems (Fisher et al., 2020; Seppelt & Lee, 2019). Figure 2.10 illustrates the driver conceptual mental model.

Figure 2.10

Conceptual model of a driver's mental model on automation reliance.

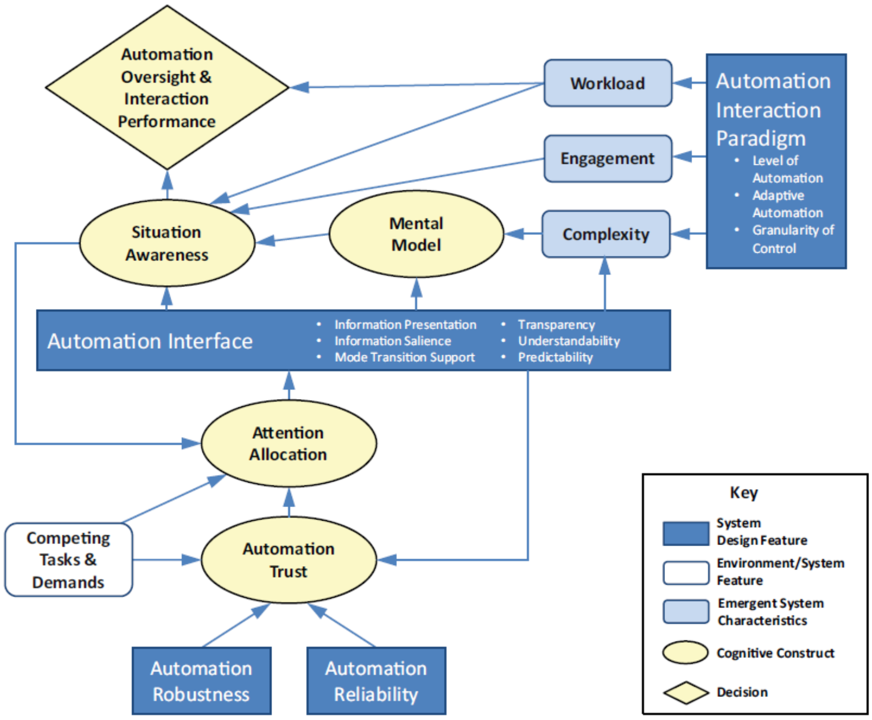


Note: Conceptual model of the influence of a driver's mental model on automation reliance from *Handbook of human factors for automated, connected, and intelligent vehicles* by Fisher, D. L., Horrey, W. J., Lee, J. D., & Regan, M. A. 2020. Copyright CRC Press

Endsley (2017) described the relationship between factors contributing to the 'automation conundrum' in the shape of a model of human-autonomy system oversight (HASO). The operator must have sufficient SA, time, and resources to assess the critical situation and intervene accordingly. The increase in automation reliability (ability to function accurately) and robustness (ability to perform under various possible conditions) decreases driver attention allocation. The model displays that with improved automation performance, reliability and robustness, there will be an increase in driver's trust and the likelihood of ignoring automation performance. An effective interface design significantly improves SA of automation and levels in automation (Endsley, 2016). On the other hand, automation can negatively influence SA by increasing system complexity and inaccurate mental models due to various features, tasks and, driver workload. The model (Figure 2.11 below) presents the fundamental system design features that influence the driver cognitive process, such as SA, Mental Model, and workload involved in successful collaboration with automated systems.

Figure 2.11

Human – Autonomy System Oversight (HASO) Model



Note: The HASO Model presents the fundamental automation design features that influence the human cognitive abilities interacting with successful oversight and intervention. From Here to autonomy: lessons learned from human-automation research by Endsley, M. R. 59(1), p 5-27. 2017. Copyright Human factors Journal.

2.5.7 Significance of Driver's Training

Training is defined as the "systematic acquisition of knowledge, skills, and attitudes that together lead to improved performance in a specific environment"(Grossman & Salas, 2011). Nowadays, there is a proliferation of Advanced Driver Assistance Systems (ADAS) in new vehicles. However, drivers often misunderstand their capabilities and limitation (Larsson, 2012; McDonald et al., 2018; McDonald et al., 2017; Rudin-Brown & Parker, 2004). Designers of AV systems want to convey the conceptual image of their product to the users, which, if not portrayed correctly, leads to wrong interpretation (Norman, 2013). The users' mental model often differs significantly from the designer's intentions due to varying reasons, leading to users' errors. Hence the perceived benefits of these technologies cannot be realized (Jonassen, 1995; Parasuraman & Riley, 1997). Mental models can be formed and structured carefully through training so that drivers are fully cognizant of their roles and responsibilities while operating AVs (Wickens et al., 2015).

It has also been observed that drivers generally do not read or rarely translate the owner's manual accurately. On the other end of the spectrum, manufactures may also try to avoid potential legal claims by requiring consumers to undergo extensive training regarding hazards and limitations of the system. Training must be designed to improve safety, create an appropriate level of trust, and increase user acceptance of the benefits of technology (Fisher et al., 2020). Practical evaluation of driver support features like an autonomous emergency brake (AEB), blind-spot monitoring (BSM), forward collision warning (FCW), lane departure warning (LDW), and lane-keeping assistance (LKA) coupled with feedback is critical to the success of drivers' training.

The construct of trust, defined as "the attitude that an agent will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability" (Lee & See, 2004), s complicated and multi-faceted. Drivers' inappropriate trust and knowledge in vehicle automation, its limitations and operation design domain (ODD) and over trust (automation bias) due to complacency leads to misuse of disuse of the AV systems (Fisher et al., 2020; Mosier et al., 1998). The training documents should cover topics of AV system's intent, ODD, system capabilities and limitations, HMI, engagement/disengagement methods, risk of misuse, emergency fallback scenarios, and operational boundary responsibilities. These topics must scaffold with hands on experience program for users to ensure that they are fully aware of the system (AAMVA, 2018; US DOT, 2016). A study observed that complete understanding of adaptive cruise control (ACC) function took a different length of time (Pereira et al., 2015). In another study survey, 130 ACC users indicated that drivers need special attention to situations they usually do not pay attention to during conventional driving (Larsson, 2012). Abraham et al. (2017) highlighted various methods for learning vehicle technologies, including trial and error, vehicle owner's manual, demonstration, web-based content, embedded training, and feedback (Fisher et al., 2020).

2.5.8 Anthropomorphism

Anthropomorphism has been regarded as a design feature to increase trust in highly automated vehicles (HAVs) (Hoff & Bashir, 2015; Waytz et al., 2014). The word is a combination of Greek words "Anthropos" for man, and "morphe" for form and is defined by Duffy (2003, p. 180) as:

> "...the tendency to attribute human characteristics to inanimate objects, animals and others to help us rationalise their actions. It is attributing cognitive or emotional states to something based on observation to rationalise an entity's behaviour in a given social environment".

This definition is supported by Zhang et al. (2008) in the HMI perspective as "...physical characteristics, like human shape and size, as well as perceivable behaviours and mannerisms". Waytz et al. (2014) observed that anthropomorphic features employed in vehicle–driver communication such as name, gender, and voice increase trust in a vehicle to perform reliably. Other studies also reported increased trust to control conditions using a humanoid robot as co-drivers (Kraus et al., 2016; Lee, Kim, et al., 2015). However, most studies to investigate this phenomenon are simulator based (Häuslschmid et al., 2017a). Epley et al. (2007) three-factor theory explains why humans perceive non-human agents as human-like? It is due to elicited knowledge, effectance motivation, and sociality motivation.

The basic assumption is that humans tend to interact with technology similarly as they interact with humans (Fong et al., 2003). DiSalvo and Gemperle (2003) highlighted four reasons for using anthropomorphism in the HMI design process, namely; (1) keep things the same, (2) explain the unknown, (3) reflect product attributes, (4) and project human values. For example, the BMW Vision Next 100 uses a small sculpture to depict the intelligence of the system " The Companion" at the centre of the dashboard (Aremyr & Jönsson, 2017). Lee, Gu, et al. (2015) investigated four conditions representing varying levels of anthropomorphism. They concluded that agents with a high level of anthropomorphism and a low level of automation are likely to generate more feelings of trust and perceived safety, leading to more feelings of trust in positive users' perceptions of the system. The Summary of the key AD barriers in the HFs domain (as discussed above) is given in Table 2.3, and their linkages with users' acceptance are illustrated in Figure 2.12 below.

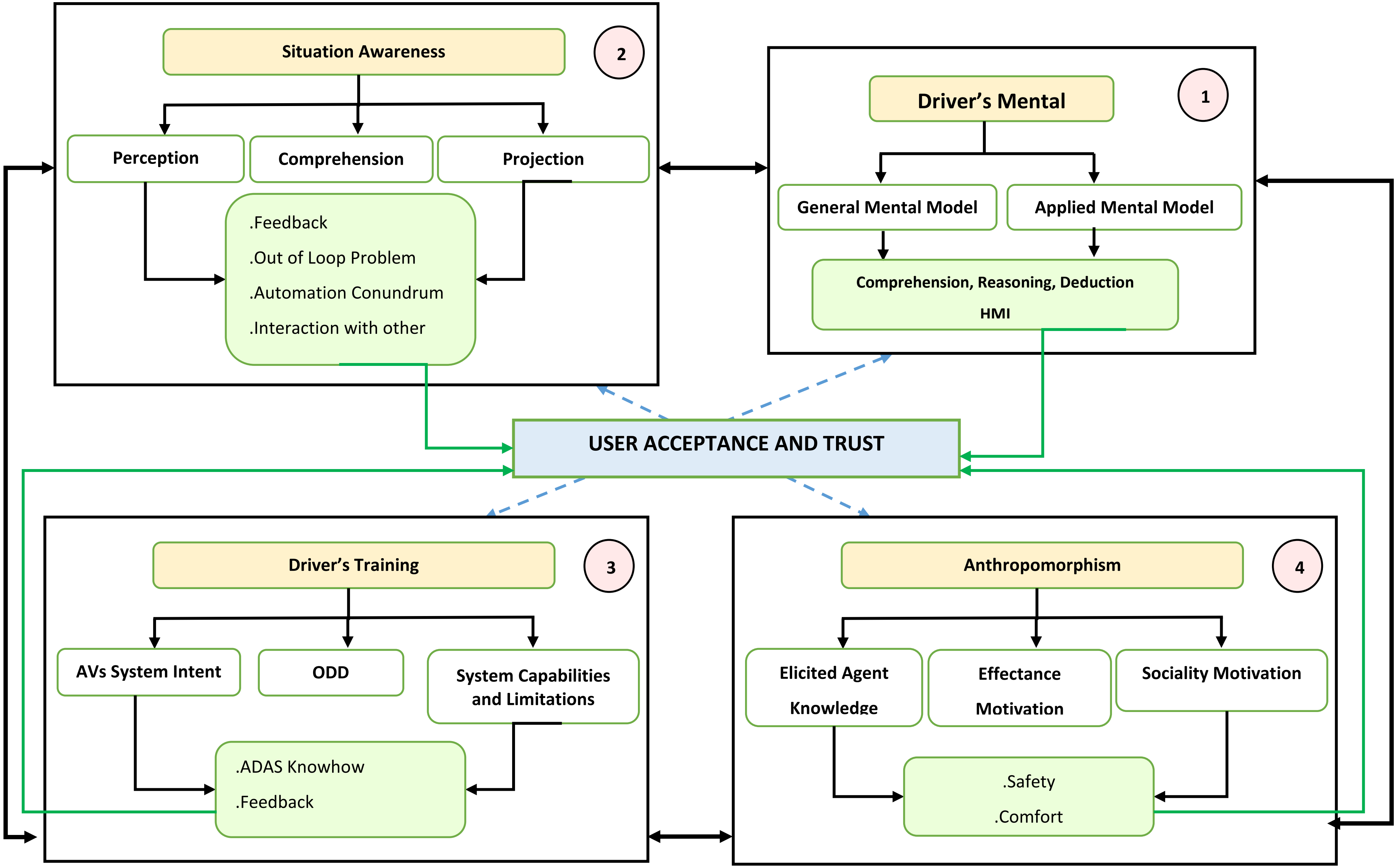
Table 2.3

Key Enablers & Barriers AD – Human Factors (HFs) Domain (Internal Determinants)

Barriers/Enablers	Description	Likely Impacts	Intervention Aspects	Key studies	References	Survey Constructs References
Situation Awareness / Vehicle Feedback (SA) Human Ability based	The SA is the 'perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future.	Feedback, Out of loop problem (OOTL), Automation conundrum, Interaction with other road users and vehicles Trust and User Acceptance	Perception, Comprehension, Projection	Endsley SA Cognitive Model, Stanton DSA Model, Salmon Complex Control Model, Vicente Cognitive Works Analysis	M. R. Endsley (1995) Stanton et al. (2006) Salmon et al. (2018) Vicente (1999) Fisher et al. (2020) Ekman (2020b); Endsley (1988) Rest Refer para 2.5.3	Filip et al. (2016)
Driver Mental Model (MM)	To rightly use the system, the user mind needs to figure out the system functions and competencies for assimilation.	Comprehension, Reasoning and Deduction HMI, Trust and User Acceptance, SA	General Mental Model, Applied Mental Model	Role of MM in computers, Role of MM in training, Norman, Craik and Seppelt studies, Endsley HASO Model	Craik (1943) Toffler (1970) Norman (1983) Endsley (2017) Fisher et al. (2020) Seppelt and Victor (2020),Rest Refer para 2.5.4	
Driver Training (TR) Human Expertise Ability based	To improve the user's knowledge, system training is conducted before and after the first usage.	ADAS knowhow, Driver MM, Safety, Trust, SA and feedback, User Acceptance	AVs System intent ODD, System capabilities and Limitations	US DOT, Pereira and other studies referred above in para 2.5.5	US DOT (2016) Pereira et al. (2015) Abraham et al. (2017) Fisher et al. (2020) Larsson (2012) Rest Refer para 2.5.5	Adopted from driving behaviour questionnaire DBQ and driving skill inventory DSI Hancock et al. (2020); Reason et al. (1990) Lajunen and Summala (1995),Spolander (1983)
Anthropomorphism (AnT) Robot Attribute-based	A system that acts more like a human in terms of voice, gender and name.	Safety, Comfort, Trust, User Acceptance	Elicited Agent Knowledge, Effectance Motivation, Sociality Motivation	Epley three-factor theory, Kraus, Lee, Kim, DiSalvo and other studies referred above in para 2.5.6	Duffy (2003), Hoff and Bashir (2015) Epley et al. (2007) Aremyr et al. (2018) Waytz et al. (2014)	Adopted from Aremyr and Jönsson (2017), Bartneck et al. (2009) With relation to Trust Helldin et al. (2013)

Figure 2.12

Autonomous Driving Adoption – (Internal Determinants)



2.6 Perceived Benefits and Critical Barriers

The integration of the Cyber Physical Systems (CPS) with the Fourth Industrial Revolution (FIR) relates to the application of Autonomous Driving (AD) and Connected Autonomous and Intelligent Vehicles (CAIVs), giving rise to the new mobility concepts (Bezai et al., 2021; Pieroni et al., 2018). These innovations will radically change the transportation infrastructure and profoundly impact future planning, realizing numerous potential benefits. Since AVs will form a core component of the future transportation system, there is a requirement to identify the essential influencing factors for the successful adoption of AVs (Alawadhi et al., 2020). These significant factors are shaped by the AVs implementation enablers comprising perceived benefits and critical barriers in their smooth proliferation. Moreover, these enablers mainly stem from end-users psycho-social behaviours and how AVs' adoption will be influenced by public opinion (Yuen, Wong, et al., 2020) and government actions (Bezai et al., 2021).

2.6.1 AVs Perceived Benefits

AVs will increase safety and comfort, reduce congestion, fuel consumption, pollution, and facilitate mobility accessibility to disable, underage and older people (Hing, 2019; Litman, 2020). Moreover, self-driving is likely to decrease the number of accidents and crashes (D. J. Fagnant & K. Kockelman, 2015). Several scholars discussed the potential benefits of adopting AVs, summarized in Table 2.4 below.

Table 2.4

Perceived AVs' Benefits found in Literature

Anticipated Benefits	Studies References
Economic and Social	Bechtsis et al. (2018); Litman (2020), Bichiou and Rakha (2019)
Increased Safety and road capacity, reduced congestion, parking cost and energy consumptions, shared mobility	Bezai et al. (2020); Bezai et al. (2021), Litman (2020),Singh and Saini (2021), Bagloee et al. (2016); D. J. Fagnant and K. Kockelman (2015); Hing (2019); Joiner (2018); Lohmann (2015)
Control of Traffic Flow, Efficient Road Transport, Increase Tourism Innovative freight delivery Entertainment, attractiveness Increase in Travel speed, offer mobility who are unable to drive	Alfonso et al. (2018); Cohen and Hopkins (2019); B. Liu et al. (2019) Alessandrini et al. (2015) Panagiotopoulos and Dimitrakopoulos (2018) Alessandrini et al. (2015); Kröger et al. (2019)

AVs are the harbinger of a substantial transition to societies and cities since internet emergence (Bezai et al., 2021). Adopting AVs is likely to reduce or eliminate these crash errors while outperforming human operators in perception, execution, and decision making (J. Wang et al., 2020). Earlier studies identified that there would be a one-third reduction in crashes if all vehicles employ adaptive headlights, land departure, and forward-collision warnings, and blind-spot assistance (Bagloee et al., 2016; Jermakian, 2011). AVs are likely to serve as private and commercial vehicles (Faisal et al., 2019). Private AVs can offer flexibility in use, whereas commercial AVs could be operated as a bus, shuttle, tram, taxi, and freight services or as a shared AV due to the advantage of multitasking and relatively inexpensive (Fagnant & Kockelman, 2014; Krueger et al., 2016; Milakis et al., 2017).

AVs proffer environmental benefits to encourage fuel and energy efficiency and the organization of traffic flow (Lohmann, 2015). Nowadays, the limited and costly land supplies in the city centres of most large cities, such as Auckland, have raised significant challenges for the environment and economics. Petrillo et al. (2018) stressed the need to improve road capacity and traffic congestion mitigation. AVs are considered as a potential solution (Fox-Penner et al., 2018). Meyer et al. (2017) demonstrated that AVs are expected to offer a higher comfort of travelling at lower prices and, at the same time, increase road capacity. In their results, increases in road capacity result from shorter reaction times of AVs compared to humans. Ye and Yamamoto (2019) also supported this point. They analysed optimal solutions to accommodate AVs in terms of managed lanes and attempts to formulate the road capacity of the mixed traffic. Kröger et al. (2019) evaluated the impact of the potential changes of road capacity due to automation in sensitivity analyses. In their results, AVs would be able to take advantage of eco-driving principles throughout a journey, reducing fuel consumption by 20% and reducing GHG emissions of GHGs to a similar extent (Igliński & Babiak, 2017).

Levin and Rey (2017) highlighted that when vehicles know their reservation in advance, they can adjust their speed to reach the intersection at the appropriate time. This speed adjustment reduces fuel consumption and avoids start-up loss times. D. J. Fagnant and K. M. Kockelman (2015) indicated that motorway delays would be decreased by 60% and fuel consumption by 25%. This would result in 8%-23% (Tsugawa & Kato, 2010) and an 8%-16% reduction in a Japanese and a European case separately (Igliński & Babiak, 2017). The result was also confirmed by Ross and Guhathakurta (2017), where an 8.9% reduction was estimated in fuel consumption.

Moreover, other strategies such as Variable Speed Limit (VSL), which reduced fuel consumption by 16%, help reduce fuel consumption by preventing excessive stops at signalized intersections. This benefit was also found to be consistent with Marchau et al. (2019). Besides, a cooperative vehicle intersection control (CVIC) algorithm presented a 44% reduction in fuel consumption (Chang & Edara, 2018). In the light of the above studies, it is suggested that the adoption of AVs are expected to improve road capacity while reducing fuel consumption and emissions. In another online survey of 1533 participants from the US, UK, and Australia, it was found that people perceive AVs would bring better fuel economy (72%), fewer accidents (70.4%), and decrease the severity of crashes(71.7%) (Schoettle & Sivak, 2014a). Furthermore, Cunningham et al. (2019) found out from 6133 survey respondents of Australia and NZ that people believe AVs will enhance mobility for people with driving impairments (76.7%). Still, they did not fully endorse the benefits of improved safety and better fuel economy. Analytical findings from 16 articles observed AVs potentials in the realization of benefits in (1) safety, (2) reliability, (3) flexibility, (4) comfort, (5) contribution to traffic optimization, (6) integrated transport use, (7) sustainability, and (8) cost savings (Starkey & Charlton, 2020).

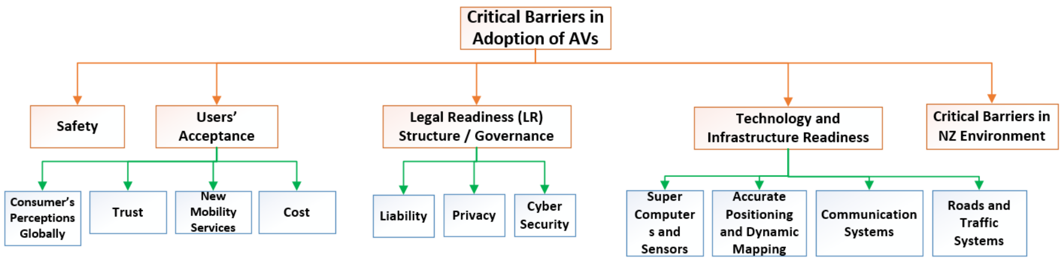
Chen et al. (2020) recently measured public acceptance of driverless busses in China and found that people are more concerned about safety performance, riding time, cost, and personal safety. Schoettle and Sivak (2014a) found that almost 88% of participants are somewhat worried about riding in AV due to safety consequences of equipment or system failure (96.2%), legal liability of drivers (92.8%), and confusion due to unexpected situations (94.7%). Kyriakidis et al. (2015) observed that participants are concerned regarding software hacking and misuse, legal responsibility, safety, and data privacy. Some studies also indicate that males are less concerned about AVs than women, are confidents of AVs benefits, and are comfortable with various driving functions (Cunningham et al., 2019; Payre et al., 2014; Schoettle & Sivak, 2014a). Moreover, it is found that younger individuals are more open towards AVs (Becker & Axhausen, 2017). In a more recent interview of 30 riders during an automated shuttle bus ride in Berlin, Nordhoff et al. (2019) found that they have unrealistically high expectations.

2.6.2 Barriers to AVs Adoption

The inevitable AVs technology will affect humanity's social well-being and shape future cities and transportation infrastructure. The widespread adoption of this technology is affected by how people perceive and accept AVs. It needs to examine the prospective users' perception linkages with the critical challenges in the backdrop of legal readiness/governance structure. Numerous studies have investigated these barriers earlier (Becker & Axhausen, 2017; Bezai et al., 2021; Chen et al., 2020; D. J. Fagnant & K. Kockelman, 2015; Johansson, 2019; Nastjuk et al., 2020; Schoettle & Sivak, 2014b; Yuen, Wong, et al., 2020). However, this research study will investigate these critical barriers distinctly into (1) safety, (2) user acceptance, (3) governance/legal readiness, and infrastructure categories to find out key AD factors and to realize the research aim and objectives (Figure 2.13).

Figure 2.13

Critical Barriers in Adoption of AVs



2.6.2.1 Safety

Over 40% of fatal accidents occur due to alcohol use, driver distraction, drug use, and fatigue (D. J. Fagnant & K. Kockelman, 2015). Driver error is the main reason for over 90% of all crashes attributed to human factors such as inattention, speeding, aggressive driving, inexperience, and slow reaction time (NHSTA, 2020; Taeihagh & Lim, 2019). The crash cost carries a ripple effect leading to medical expenses, legal and court costs, workplace and productivity loss, emergency service costs, insurances, property damages, and congestion burden (Bagloee et al., 2016).

Analysis of several recent articles points towards four major safety barrier domains: pedestrians (road users), technology, share-ability, and infrastructure. (Bezai et al., 2021). In the UK, 26% of road deaths were related to pedestrians, and about 66 injuries and five fatalities occur every day (Kilbey et al., 2013; Perch, 2014). A US study revealed that an 80 % reduction in pedestrian fatalities could be avoided by having AVs equipped with pedestrian sensors (Combs et al., 2019). Safety demands foolproof traffic management strategies comprising good wireless connectivity based on big data, AI, IoT, and cloud computing in the infrastructure domain due to complexity in urban areas (Villagra et al., 2018). Automated Road Transport System (ARTS) recommended a CityMobil 2 project (Alessandrini, 2018), and Volvo suggested a magnetic road project (Perch, 2014). Panagiotis Lytrivis et al. (2018) identified gradual up-gradation of infrastructure based on 30 years planning horizon focussing on the section of roadways besides ensuring appropriate training of experts, deploying, operating, and maintaining the infrastructure (Jadaan et al., 2017). There are some concerns about insurance and safety regulations (Aguiléra, 2018; Bezai et al., 2020).

ICT application will play a decisive role where road safety is compromised by visibility, communication, and road conditions (Alfonso et al., 2018). It is suggested that hybrid communication based on On-Board Units (OBUs) and Road–Side Units (RSUs) and standardization is the key to realize the benefits. However, the development of common standards and interoperability remain the key concern (Skeete, 2018). On the other hand, introducing AVs might give rise to new safety issues. It is likely that vehicle users might not fasten seat belts, adopt unsafe time headways (contagion effect) (Gouy et al., 2014) and pedestrians become less cautious. Besides, with the increase in complexity of AV technology, there is likely to be an increase in technical errors compromising vehicle safety (Collingwood, 2017; Litman, 2021). State of California Department of Motor Vehicles reported that the majority of AVs related accidents are caused by other parties such as vehicles, bicycles, and drunk pedestrians sharing the road with AVs (DMV, 2019). Moreover, cyber-attacks would be a great threat to traffic eco-system safety where message falsification, radio jamming would seriously jeopardize AVs operations (Amoozadeh et al., 2015). It might also increase energy expenditure up to 300% during platooning while influencing the motion of AVs (Gerdes et al., 2013).

Before full commercialization, the AV cars must drive 291 million miles without any crash to ensure 75% equivalence to a human operator based upon reliability yardstick (Howard, 2020; Singh & Saini, 2021). An independent safety test, ‘Mcity ABC’ is suggested by the University of Michigan’s autonomous car testing facility to analyse these aspects. It is testing safety performance of AVs regarding accelerated evaluation (lane change, car following, and left turns), behaviour competence (in rigorous scenarios), and corner cases (e.g., cyclists taking left turn in busy traffic, the zig-zag motion of joggers on the street) (Peng, 2019).

2.6.2.2 Users' Acceptance

People's mindsets and attitudes serve as the key to adopting new technology and affect the realization of perceived benefits (Liljamo et al., 2018; Yuen, Wong, et al., 2020). Public opinion guides the manufacturer to future development pathways (Kyriakidis et al., 2015). AV technology is a giant leap from traditional vehicle technologies, influencing public opinion due to various users' concerns. These include safety, lack of control (situational awareness), steep learning curve (training), cyber security, trust, and non-readiness of legal and liability rules (Yuen, Wong, et al., 2020). It has been revealed that people from Australia (61.9%), the US (56.3%), and UK (52.2%) bear a positive view of AV technology (Schoettle & Sivak, 2014a). However, the public in the US, compared to the UK, found more concerned about the legal responsibility of drivers and owners, data privacy, and interactions with non-AVs. UK public is more worried about the system and vehicle security and interaction between AVs and pedestrians/cyclists. While investigating differences in public opinion of China, India, Japan, US, UK and Australia from 1722 respondents, it was found that Chinese respondents overwhelmingly believe in AVs benefits (87.2%). The Indians were 3.3 times more concerned than Chinese and Japanese respondents were found least concerned regarding issues of safety, system failure and liability (Schoettle & Sivak, 2014b). Bansal et al. (2016) found that people were unwilling to ride AVs for short distances (42.5%) and long distances (40%). The unwillingness is mainly due to the users' distrust in automation (Joiner, 2018; Winter et al., 2018).

The three main behavioural theories (Table 2.5 below) identify factors influencing public acceptance and specify their interrelationships (Yuen, Wong, et al., 2020). Hekkert et al. (2007) Technology Specific Innovation System (TSIS) described the processes based on significant 'functions of innovation system'. The Innovation diffusion theory is based on relative advantage, compatibility, complexity, trialability, and observability of a new product (Wang et al., 2018). With the development of a product and its manufacturing process over time, the cost decreases and its design become more standardized (Abernathy, 1978). The technology S-curve framework depicts the technological innovation cycles. It highlights that due to increase in consumption choices, the utility of the product increases (Innovation, 2006). The Perceived value theory is derived from a new product's economic, functional, hedonic, and social benefits (Cunningham et al., 2019; Yuen et al., 2018). And, the trust theory that highlights ‘a psychological state of the public comprises the intention to accept vulnerability in a situation involving risk, based on positive expectations of AVs (Castelfranchi & Falcone, 2010). The formation of trust can be increased through driving expertise (training), integrity, and benevolence. Trust theory addresses key public concerns through public trust in the AVs’ ability to perform their tasks safely and reliably (Lee & Kolodge, 2020). The exact determinants of users’ acceptance for AVs are still not conclusive (Nordhoff et al., 2016).

Table 2.5

A review of behavioural theories and factors influencing public acceptance of AVs

Theory’s Characteristics	Innovation diffusion theory	Perceived value theory	Trust theory
Paradigm Basic assumption	Innovation acceptance Its characteristics support the speed of diffusion and acceptance of an innovation	Consumer utility A rational user will select or accept an artefact that offers the best value amongst market choices	Social psychology The acceptance of innovation can be increased by developing trust
Representative constructs	Relative advantage, compatibility, complexity, trialability and observability	Perceived value	Trust
References	Rogers (2003)	Kotler and Armstrong (2010)	Castelfranchi and Falcone (2010); Dzindolet et al. (2003); Lee and See (2004)

Note: Table Adopted from *The determinants of public acceptance of autonomous vehicles: An innovation diffusion perspective* by Yuen, K. F., Wong, Y. D., Ma, F., & Wang, X. 2020.Copyright Journal of Cleaner Production, 121904.

2.6.2.2.1 Consumer Perceptions

Human psychobiology related to AD is constrained, and the real intention behind realizing acceptance is still not conclusive (Meinlschmidt et al., 2019; Nordhoff et al., 2016). Since people cannot imagine the AVs' adoption, they are more concerned about safety and reliability (Bansal & Kockelman, 2017). The onus of responsibility in case of accident or any damage to AV will impact commercialization and the use of AVs (De

Bruyne & Werbrouck, 2018). Moreover, increasing the sense of security in AVs (Boutueil, 2018), media campaigns (Anania et al., 2018), and the use of libraries (Joiner, 2018) will have a positive effect on acceptance and awareness about legislation and insurance. Khan (2017) highlighted few factors that can influence users' acceptance; (1) self-perceived knowledge of technology, (2) general view of technology, (3) safety and trust, (4) comfort with technology, (5) pleasure with driving, (6) social influences, (7) gender preferences, (8) and age. Schoettle and Sivak (2016), in a survey of 618 respondents, found that most people (59.1%) want to get notification of taking control of partially self–driving vehicles through vibration, voice, and visual signals.

2.6.2.2.2 Trust

One of the significant challenges in the successful adoption of AVs is trust (Adnan et al., 2018; Wintersberger, 2020). User's perceptions require transition to trust a new traffic regime (Choi & Ji, 2015). People need to be educated, trained, and allowed to use and interact with AVs. The top reason for the lack of adoption will be the lack of trust in technology (Alawadhi et al., 2020). The trust will be discussed in greater length in Chapter 3.

2.6.2.2.3 Users' Perceptions towards New Mobility Services

Ferrero et al. (2018) noted that the widespread use of car-sharing services is changing people's perceptions from car ownership to a service on demand. Provision of new mobility services decreases the value of time, affecting mode choices and riders' behaviour and significantly impacting users' acceptance (Kolarova et al., 2018). An analysis of US households survey data found a sharp decrease in car ownership and a quick shift to vehicle sharing and driverless taxis (Schoettle & Sivak, 2015) due to lower VKT and the use of new demands from low-income people. Driverless taxis are likely to obviate the associated annual fixed, maintenance, and parking costs of car sharing (D. J. Fagnant & K. Kockelman, 2015; Martin & Shaheen, 2011). Therefore, AV technologies are likely to be conducive to driverless cabs or similar car-sharing models, excluding the cost of cab driver's time and talent (Bagloee et al., 2016). Privacy will be a significant barrier, as information gathered through V2X communication can be misused (Yuen, Wong, et al., 2020). Therefore, AVs' acceptance will depend on users' willingness to share their data from the vehicle, which consequently requires compliance with the data protection legal framework. Besides, data protection algorithms need to be embedded within AV systems.

2.6.2.2.4 Cost

Cost can potentially slow down AVs' adoption due to costly sensors technologies and AVs' longer life spans (Bezai et al., 2021; Liljamo et al., 2018; Zhong et al., 2018). AVs' cost and operational expenses are still uncertain (Alawadhi et al., 2020; D. J. Fagnant & K. Kockelman, 2015). It has been argued that total AV software and hardware cost is likely to be around £3000 by 2025 and would decrease to half by2035 (Sachin Babbar, 2017). Puylaert et al. (2018) observed that direct and indirect costs include energy costs, travel time, trip length, congestion, safety, reliability, and insurance costs. The estimated increase in the price of installing remote sensing and top view cameras amounts to more than USD 5000 (Litman, 2021). The cost of travelling per mile on AV is estimated at around USD 0.42 to USD 0.49 (Hörl et al., 2016), and an average user is likely to pay an additional USD 5551 and USD 14,589 for Level 4 and 5 AVs (Bansal et al., 2016).

However, it is claimed that AVs' social acceptance and reliability would decrease the cost of usage (Bansal et al., 2016) besides increasing shared mobility and on-demand access (Webb et al., 2019). Wadud (2017) used the total cost of ownership while comparing AVs and conventional vehicles (CVs). The study found out that commercial application of AVs will remain the most dominant success. Overall, it is believed that users' experience would be the key to integrating the physical world with the digital one. Therefore, their real-time performance on actual roads will decide their social acceptance (Geng, 2017; Straub & Schaefer, 2019).

2.6.2.3 Legal Readiness Structure/Governance

Legal advancement is the key to the successful adoption of AVs (Alawadhi et al., 2020). There is a proliferation of AV technologies with every passing day (Bichiou & Rakha, 2019). Numerous studies highlight the role of national policies for successful deployment of AVs (Automobilindustrie, 2015; Bezai et al., 2021; Canis & Lattanzio, 2014; CCAV, 2020; DMV, 2020; GDPR, 2020; KPMG, 2020; Lee & Hess, 2020; Mordue et al., 2020; Shladover & Nowakowski, 2019; Singh & Saini, 2021; UNECE, 2018). Moreover, the legal framework ensures safety, encourages AVs large scale testing and ensue technological advancements (De Bruyne & Werbrouck, 2018). Legal readiness structure is a prime challenge for AVs deployment due to liability, insurances, and explaining who bears the individual or shared responsibility in case of a crash (Schellekens, 2015). Chen et al. (2017) studied the use of three different lane policies for diverse combinations of conventional vehicles (CVs) and AVs. They concluded that one lane should be dedicated to AVs and platooning and the other one for CVs permits smooth AVs transition. In another study, policy regarding dedicated zones for AVs use for mixed driving modes and various phases of penetration was investigated. The results depicted a decrease in travel time (Conceição et al., 2017). Straub and Schaefer (2019) suggested a series of questions that can help in guiding future policy towards AVs. Faisal et al. (2019) suggested future policy directions for the formulation of AVs policies. These include avoiding conflict between federal and state government laws, negotiations between stakeholders such as governments, industries, and experts on liability and privacy, and technology standardisation. The study stressed the need for prioritizing vehicles on road and pricing to manage vehicle kilometres travelled (VKT). The legal readiness for AVs deployment will be later discussed in detail in succeeding paras.

2.6.2.3.1 Liability

In traditional car crashes, the driver is primarily liable as they retain control of the vehicle (Collingwood, 2017). Hence third parties involved in the design of AV safety systems remain vulnerable to lawsuits involving AV product liability during an AV crash (Automotive, 2019). The complication arises relating to the driver engagement with varying levels of AVs, mainly level 2 to 4, where the question arises should the drivers be expected to take over in certain situations? And is he expected to know that? What about criminal liability if a driver of AV is found intoxicated at the "wheel" in case of a crash, even though he is not driving AV? Who should be responsible for personal injury and property damage resulting from the AV crash? (Hing, 2019).

In a survey study, 72% of people out of 302 participants were found uncomfortable with the liability of AVs in case of an accident (Bloom et al., 2017). Evas et al. (2018) reported that European Parliament is asked to deliberate on "limitation to liability" (risk management approach or strict liability) and "Obligatory insurance scheme and guarantee fund." It is predicted that insurance law would involve multiple parties contributing to the insurance. It is likely to include the extent to which car owners would need third–party liability insurance and carmakers need product liability coverage. The

UK is the only country that has enacted the Automated and Electric Vehicles Act 2018, clarifying liability for insurers in accidents caused by AVs (Taeihagh & Lim, 2019).

2.6.2.3.2 Privacy

AVs optimize data obtained from sensors, high definition maps, and other V2V and V2I communication (Taeihagh & Lim, 2019; West, 2016). AVs relay information about vehicle exact geographical location and movement (Glancy, 2012) for AV operations and locate AV users. This information might be used to harass AV users, steal users' identity and predict users' actions. In addition, it would seriously jeopardize the AVs operations through illegal access of interconnected AVs' wireless network to conduct remote surveillance, undermining individual autonomy through psychological manipulation (Schoonmaker, 2016). With the increased adoption of AVs and interconnected transport systems, a balance needs to be struck between public safety and privacy protection. Adequate privacy assurances will be critical for successfully adopting AVs and underpinning public trust (Andrew Hii, 2020). In a recent study by NTC Australia, it has been suggested that the location data and data from health sensors that monitor driver alertness and facial recognition will be classified as personal information under Privacy Act 1988 (NTC, 2019). The US and South Korean governments enacted new data privacy legislation, including the 'SPY CAR' act in the US, giving NHTSA authority to protect access of driving data on all vehicles manufactured for sale in the US.

Similarly, the EU has already amended the EU General Data Protection Regulation (EU GDPR Directive of 95/46/EC of 1995) to process data for all EU residents, strengthening consent conditions. In addition, it has increased fines up to 4% of companies' global revenue and protected citizens 'right to explanation' allowing them to review certain algorithmic decisions (GDPR, 2020). China and Japan have taken legislative action to control all personal data privacy and cyber security risks (KPMG, 2020; Taeihagh & Lim, 2019). The UK's DfT, in coordination with the Centre for the Protection of National Infrastructure (CPNI), created guidelines for privacy and cybersecurity, suggesting manufacturers follow the Privacy Architecture framework outlined by ISO 29101 (Dft, 2017a). Germany's current data protection laws are strict towards personal data connected to AVs (Taeihagh & Lim, 2019).

2.6.2.3.3 Cyber Security

Policymakers, auto manufacturers, and future AV users portray concerns about electronic security (D. J. Fagnant & K. Kockelman, 2015). Current cyber-attacks mostly happen as an act of espionage rather than sabotage. Within the context of AVs, cyber-attacks are considered more detrimental than just getting information due to the complexity of the degree of connectivity and advanced level of technology (Kennedy, 2016). Several cyber-attack applications include software hacking, physical attack on hardware, keeping users locked inside the vehicle due to remote less entry, wrong reading of user interfaces, and slowing down of vehicle (Linkov et al., 2019). Technology manufacturers unknowingly develop systems that are prone to such attacks (Sheehan et al., 2019).

The risk of cybercrime is a significant concern for governments, policymakers, and insurers around the world. Since AV technologies are still evolving, there is less empirical evidence on cyber-attacks (Alawadhi et al., 2020). While hacking Chrysler Jeep through its internet connection and controlling its engine and brakes, Miller and Valasek observed that these malicious attacks on AVs are a potential possibility (Schellekens, 2016). Feeding fake messages, sensor manipulation, bright light on cameras, and radar interference to blind AVs regarding obstacles and spoofing of the global navigation system (GNSS) are significant threats (Bagloee et al., 2016; Page & Krayem, 2017; West, 2016). It requires continuous updating of system software to detect these malfunctions and to change existing security architectures (NHSTA, 2020). In the US, OEMs are suggested to design systems on international standards such as NHTSA, SAE, and the Alliance of Automobile Manufacturers.

A new electronic system research department to analyze and monitor cyber vulnerabilities and the ‘SPY Car Act’ has been introduced to enforce cyber security and privacy laws (SCA, 2017). This law presents specifications for information security during the move and in transit, separates critical and non-critical systems in every vehicle, and required instantaneous disclosure of any attempt to hack driving data. EU is also following suit to control cyber security risks by introducing a comprehensive cyber security strategy in 2013 (EU, 2016). Like the EU’s GDPR, China has introduced cyber security laws to protect personal information and critical infrastructure information. It describes the responsibilities of network operators, certifications of security technologies, and enforced penalties for violations. Singapore strengthened its strategy against computer-related offences through Computer Misuse and Cybersecurity Act amendment in 2017 (Qi et al., 2018). The UK Government implemented two cyber security strategies (2016 – 2021) and the creation of the National Cybersecurity Centre (NCSC) in 2016 (Cabinet Office, 2017). Germany has set up five working groups to analyze these threats, and Australia is also working on similar lines (Taeihagh & Lim, 2019).

2.6.2.4 Technology and Infrastructure Readiness

Information and Communication Technologies (ICT) embedded in the suitable infrastructure allows users to exploit innovative technologies (Aguiléra, 2018). It is believed that technology and infrastructure readiness will serve as a key enabler in the adoption of AVs. These will assist in creating the right traffic conditions within the folds of safety and security regulations for the proliferation of driverless technologies (Bezai et al., 2021).

2.6.2.4.1 Super Computers and Sensors

AVs are likely to deal with an enormous amount of data processed every second regarding road and climatic conditions, communications, and obstacles. It requires new system architecture based on centralized computer systems, sensors, and significant development in algorithms (Aria et al., 2016; Bezai et al., 2021; Bichiou & Rakha, 2019). AVs depend on the collection and fusion of data from various sensors, including LIDAR, radars, and cameras, to assist in computer vision, decision making, and intrusion detection systems against cybersecurity risks and ensuring reliability (Armingol et al., 2018; Loukas et al., 2019; Wadud, 2017). These technologies assist AVs in performing various tasks, including automatic braking, lane-keeping, and adaptive cruise controls. Additionally, AVs need navigation tools based on GPS for their accurate localisation. Presently, these sensors are vulnerable to environmental conditions, and GPS technology also suffers from signal blockage, requiring more research in advanced onboard and off-board localization and fusion systems (Alawadhi et al., 2020; Van Brummelen et al., 2018; Zheng et al., 2019). AVs related software and hardware need ample time for testing various scenarios, trials, and legal approval before deployment (Kalra & Paddock, 2016; Mullins et al., 2018). In this backdrop, google AVs testing has covered 2 million miles on actual streets and is still in progress (Guanetti et al., 2018).

Selecting real-world scenarios during these tests is very significant (Marletto, 2019). Moreover, highly customized simulation tools for simulation studies are necessary (Tsolakis et al., 2019).

2.6.2.4.2 Accurate Positioning and Dynamic Mapping

AV needs to localize itself to the surrounding environment and vehicles to navigate autonomously. Static information can be created from simultaneous localization and mapping (SLAM) or high-definition mapping (HD) from the geographical database from lane borders, road signs, and speed limits (Héry et al., 2021). Dynamic information can be collected from the local dynamic map (LDM) (an overlay) regarding the pose, longitudinal speed, or yaw rates of the vehicles using perception from overhead sensors (Rosa et al., 2015). An LDM is a cyber-physical representation of the physical driving environment. This information can be used for path planning or control.

Though deep learning techniques have sought tremendous improvements, perception information is still limited to physical view and range of sensors (Cognetti et al., 2014). Recent research presented a decentralized cooperative localization method based on the exchange of LDMs (Héry et al., 2021). Another study observed Channel – SLAM method to enable multi-paths to improve single-vehicle positioning using a cooperative mapping approach (Chu et al., 2021). Recently, 5 G's new radio development brought vehicular positioning and tracking opportunities (Win et al., 2018). Global Positioning System (GPS) and Inertial Measurement Unit (IMU) with LiDAR and Global Navigation Satellite Systems (GNSS) can produce high–resolution ground maps (3D) for precise localization (Konrad et al., 2018; Levinson et al., 2011). However, due to inaccuracies and accumulated errors, more research needs to improve AV’s navigation (Bezai et al., 2021).

2.6.2.4.3 Communication Systems

With the emergence of the Internet of Vehicles (IoV) and Internet of Things (IoT), AVs establish communication through integration of Vehicular Ad-hoc Networks (VANETs), On-Board Units (OBUs), and Road-Side Units (RSUs) (Atzori et al., 2018). VANETS are employed to establish communication between vehicles and different nodes V2X. V2X comprises Vehicle to Vehicle (V2V), Vehicle to Infrastructure (V2I), and Vehicle to Pedestrians (V2P) (Alfonso et al., 2018; Aria et al., 2016). The c ost, privacy and security issues are critical barriers in this domain (Arena & Pau, 2019; Saini et al., 2018). Data transmission within the network is another challenge due to complex changes in the urban driving environment and high mobility (Bezai et al., 2021; Gao et al., 2020).

2.6.2.4.4 Roads and Traffic Signs

Road and Traffic signs need to be upgraded to prepare infrastructure for AV deployment (Alawadhi et al., 2020). AVs require intelligent transport infrastructure to recognize the driving environment easily. AVs use a digital version of traffic lights, yield signs, street signs, speed limit signs, stop or change direction, yield to other vehicles approaching an intersection, and other related physical infrastructure (Latham & Nattrass, 2019; Sparrow & Howard, 2017; Zohdy & Rakha, 2016). Similarly, AVs will require charging infrastructures such as the location of charging stations, the impact of charging time on fleet size, trip demands, and the waiting times (Chen et al., 2016). Duarte and Ratti (2018) highlighted the role of visibility and consistency of road signage. The study stressed the need to lower the variability in parameters to increase AVs adoption, such as speed, following speeds, and road width. AVs also rely on road markings to keep themselves in the centre of the lane, and these markings are subject to wear and tear on sealed roads. In NZ, AV deployment requires significant development of infrastructure (Leslie & Jenson, 2017).

2.6.2.5 Public Perceptions and Critical Barriers in NZ Environment

Earlier studies revealed that most of the people (>90%) in NZ knew about self–driving cars, electric cars, hybrid cars and believed in perceived benefit in reducing accidents, improved fuel economy decreased traffic congestion, and reduction in emissions (Starkey & Charlton, 2020). The respondents wanted to use CAVs to do other things during the travel and desired AVs journey on motorways, especially once they are tired or over drunk. However, very few respondents wanted to use AVs for the transportation of their children. Only 23% had practically used ADAS, and a quarter of 20% of the sample reported that they would never use AV. The significant barriers highlighted by the survey respondents were (1) trust, (2) safety, (3) lack of control, and (4) higher cost. In addition, few reported that they would like to enjoy driving themselves in a classic car.

A recently shared mobility survey in 2020 found out that 80% of respondents knew about app-based ride-hailing services, 76% ridesharing services, and 64% car sharing (Starkey & Charlton, 2020). Barriers to use these services were car ownership, lack of availability, safety, cost, inconvenience, loss of freedom, and not sure how to use these services. The same study did 12 focus group discussions across NZ and found that transport sharing is feasible to use a private car.

Another study under Australian and New Zealand Driverless Initiative (ADVI) comprising 5,102 Australian and 1,049 NZ based on a 90 item survey on Qualtrics platform found that respondents are willing to pay more for an AV than the exact vehicle without automation (Cunningham et al., 2019). However, both countries' public views differ regarding awareness of technology, perceived benefits, associated concerns, and willingness to pay (Cunningham et al., 2019). The respondents were found least concerned about data privacy (67%) and riding in a car with no driver (67%) and highly believe in benefits like the mobility of people with driving impediments (73%) and reduce insurance premium (50.6%). A research study survey by the University of Otago on self–driving, hybrid, electric cars, and bikes observed that safety is considered to be the most critical barrier and enabler in self–driving cars, and the cost is cited as the primary concern in electric cars (Lucy & Ben, 2018). A moderate correlation behaviour was found between perceived attractiveness and knowledge of self–driving cars, whereas Aucklanders reported more knowledge regarding AVs and perceived them safer than other regions.

Lack of legislation towards full AVs creates a vacuum due to legal uncertainty in NZ, thus slowing AVs' deployment at early stages. This may also result in an increase in the cost of AVs and detrimental to users’ confidence in accepting the technology (Evas et al., 2018; Funkhouser, 2013; Geistfeld, 2017). NZ has 3rd highest market share of electric cars with no AV Company, research, investment, or patent. NZ innovation capability is likely to be boosted by a trial of satellite-based augmentation system technology in collaboration with Australia to improve the accuracy of GPS (KPMG, 2018). However, it has to strengthen its legal readiness structure, 5G coverage, and road infrastructure. In present shape, the NZ Accident compensation scheme (ACC) is a no-fault scheme, where an injured person may claim compensation paid out of petrol taxes and motor vehicle licence fees but cannot bring a civil action. This means they will be having no recourse against AV manufacturers (Cameron, 2018; Hing, 2019). Manufacturers do not contribute to motor vehicle funds under ACC since they do not suffer financial impact due to personal injuries associated with their products (NZ, 2020b). Liability for property damages caused by conventional vehicles (CVs) is covered under the tort of negligence, the Consumer Guarantees Act 1993 (CGA), statutory land transport rules, and the Fair Trading Act 1986. The current framework puts the onus of liability for property damage in case of general negligence on quality parameters, which augurs well for CVs and semi-autonomous vehicles, but this is unsuitable for full AVs. So current framework only relates to manufacturer liability if a human driver is in control (Hing, 2019).

In the privacy domain, the NZ government has recently enacted The Privacy Act 2020, replacing The Privacy Act 1993 that described 12 information privacy principles. In the recently promulgated Act, the role of the Privacy Commissioner has been enhanced, and early intervention and risk management by agencies, including AV manufactures, has been advocated (MOJ, 2020). In NZ, privacy torts alongside the Privacy Act provide another avenue of relief but are not entirely suitable for AVs. However, torts may provide relief in hacking and malicious disclosure but need to be broadened in case of information collected by AVs and then given to advertisers (Geistfeld, 2017). NZ is recommended to follow the privacy aspects similar to the 'US SELF Drive Act' (Green, 2020), where manufacturers would be required to develop a privacy plan before AVs deployment and proactively pursue the 'privacy by design' concept (Cavoukian, 2009). The NZ government should also enforce the need for consent in the processing of personal data. AV manufacturers must bear liability for personal injuries caused by their products.

Additionally, the scheme for property damage on the lines of the ACC needs to be formulated and funded by AV manufacturers, users, and the government. The Privacy Act 2020 is quite comprehensive for AVs deployment (Hing, 2019). In NZ, all cybercrime offences involving computers are defined in Crimes Act 1961, sections 249 to 252, and the Harmful Digital Communication Act 2015 (Jain, 2020; NZ Govt, 2020; Police, 2020). NZ Cyber strategy comprises Cyber Resilience and Cyber Capability addressing Cybercrime and International Cooperation. NZ ranks 14th on Human Development Index (HDI) (UNDP, 2020), and it lost around \$6.5 million due to cybercrimes (TVNZ, 2019). For Q2 2020, NZ lost \$1.7 million more than the last quarter (Jain, 2020). 1/3rd of NZ people have faced a cybercrime in the previous 12 months, and it takes around 28 days for NZ police to resolve a cybercrime case (State, 2018). A study reported that 1 out of every six adults in NZ is subjected to some form of identity theft (Williams, 2020). The research found that NZ is quite proactive when dealing with cybercrime with the help of an organization like Netsafe (Jain, 2020). However, the cybersecurity risks and terrorism are likely to have a dampening effect on motivation towards vehicle automation (Fitt, Frame, et al., 2018). Within the context of ethics, NZ also needs to develop a platform for public engagement and regulations to find out the appropriate course of action for AVs (Leslie & Jenson, 2017). Towards this end, 'The Moral Machine Experiment' by MIT (Massachusetts Institute of Technology) gathered around 40 million respondent decisions from 233 countries regarding correct choices in various scenarios (Alex, 2018).

2.7 Summary of the Critical Barriers in Adoption of AVs

The literature review identified key AD Barriers for the successful adoption of AVs mainly in two domains in the context of users' acceptance and trust. The first domain relates to the HMI challenges in the HFs domain, which relates to the users' cognitive abilities and how they interact with AV. These are named internal determinants comprising the user's mental model, SA, training, and anthropomorphism. The second domain pertains to HMI challenges in the backdrop of legal readiness/governance structure that are quintessential for users' trust and acceptance of AVs. These are named external determinants, including safety, legal readiness mechanism comprising privacy, cybersecurity, and liability, and infrastructure summarized in Table 2.6. Users' acceptance linkages with external drivers are graphically depicted in **Figure 2.14**. Since infrastructure readiness belongs to the overall safety of the driverless ecosystem, hence **Figure 2.15** highlights the summary of the key internal and external AD determinants and their linkages with users' trust and acceptance. These identified key AD enablers and barriers include mental model, SA, training, anthropomorphism (HFs domain), and safety, privacy, and security/cybersecurity (Legal Readiness domain) for successful adoption of AVs in NZ.

Table 2.6

Key AD Enabler & Barriers – Legal Readiness / Governance Domain (External Determinants)

Barriers/Enablers	Aspects of Intervention	Outcomes / End State	References	Survey Constructs
Safety (SAF)	Road Users Shareability	Legal Readiness Framework (Synergy with Security and Privacy) Maturity of Technology Users' Trust, Users' Acceptance / Adoption	(Amoozadeh et al., 2015; Bezai et al., 2021; Binfet-Kull & Heitmann, 1998a; Board, 2019; Collingwood, 2017; Commission, 2019a; D. J. Fagnant & K. Kockelman, 2015; Flemisch et al., 2012; Gerdes et al., 2013; Gugerty, 1997; Hess, 2020; Howard, 2020; Huntington, 2018; Koopman, 2018; Litman, 2020, 2021; Milakis et al., 2017; NHSTA, 2020; Peng, 2019; Singh & Saini, 2021; Skeete, 2018; Straub & Schaefer, 2019; Taeihagh & Lim, 2019; J. Wang et al., 2020; Ward, 2011)	Adopted from Venkatesh et al. (2003) and Kaur and Rampersad (2018)
Users Acceptance	Consumers Perception Trust New Mobility Services Cost	Users Adoption Trust and Legal Readiness (Governance) Framework Users Trust Car Sharing Services	(Anania et al., 2018; Bansal & Kockelman, 2017; Becker & Axhausen, 2017; Bezai et al., 2021; Boutueil, 2018; Castelfranchi & Falcone, 2010; Cunningham & Regan, 2020; De Bruyne & Werbrouck, 2018; Du et al., 2021; Ferrero et al., 2018; Geng, 2017; Hilgarter & Granig, 2020; Hörl et al., 2016; Khan, 2017; Kolarova et al., 2018; Kotler & Armstrong, 2010; Kraetsch et al., 2021; Kyriakidis et al., 2015; Lee & Kolodge, 2020; Liljamo et al., 2018; Lucy & Ben, 2018; Martin & Shaheen, 2011; Meinlschmidt et al., 2019; Nordhoff et al., 2019; Nordhoff et al., 2016; Puylaert et al., 2018; Rogers, 2003; Sachin Babbar, 2017; Schoettle & Sivak, 2014b; Schoettle & Sivak, 2015, 2016; Starkey & Charlton, 2020; Wadud, 2017; Wang et al., 2018; Webb et al., 2019; Winter et al., 2018; Yuen et al., 2018)	Adoption scenarios from Schoettle and Sivak (2014a) and Kaur and Rampersad (2018)
Governance Structure (Legal Readiness)	Liability Privacy Security/Cybersecurity Ethics	User Studies and Trials Social Interaction Privacy, Security synergy with Safety Users Trust & Adoption Trust & Legal Readiness	(Alawadhi et al., 2020; Alex, 2018; Andrew Hii, 2020; Bezai et al., 2021; Cabinet Office, 2017; Chu et al., 2021; Cunneen et al., 2020; EU, 2016; Evas, 2018; Fried, 2012; Geistfeld, 2017; Gogoll & Müller, 2017; Goodall, 2016; Green, 2020; Héry et al., 2021; Jain, 2020; Johnson, 2017; Kaur & Rampersad, 2018; Leslie & Jenson, 2017; Linkov et al., 2019; MOJ, 2020; Mordue et al., 2020; NTC, 2019; NZ, 2020b; NZ Govt, 2020; Police, 2020; SCA, 2017; Sheehan et al., 2019; State, 2018; TVNZ, 2019; UNDP, 2020; Williams, 2020)	

Technology and Infrastructure Readiness	Super Computers and Sensors Accurate Positioning and Dynamic Mapping Road and Traffic Signs	Security protocol Cloud Computing Testing & Simulations Intrusion Detection	(Alawadhi et al., 2020; Arena & Pau, 2019; Aria et al., 2016; Bezai et al., 2021; Chen et al., 2016; Chu et al., 2021; Du et al., 2021; Duarte & Ratti, 2018; Gao et al., 2020; Héry et al., 2021; Latham & Nattrass, 2019; Saini et al., 2018; Sparrow & Howard, 2017; Zohdy & Rakha, 2016)

Figure 2.14

Autonomous Driving Adoption – (External Determinants)

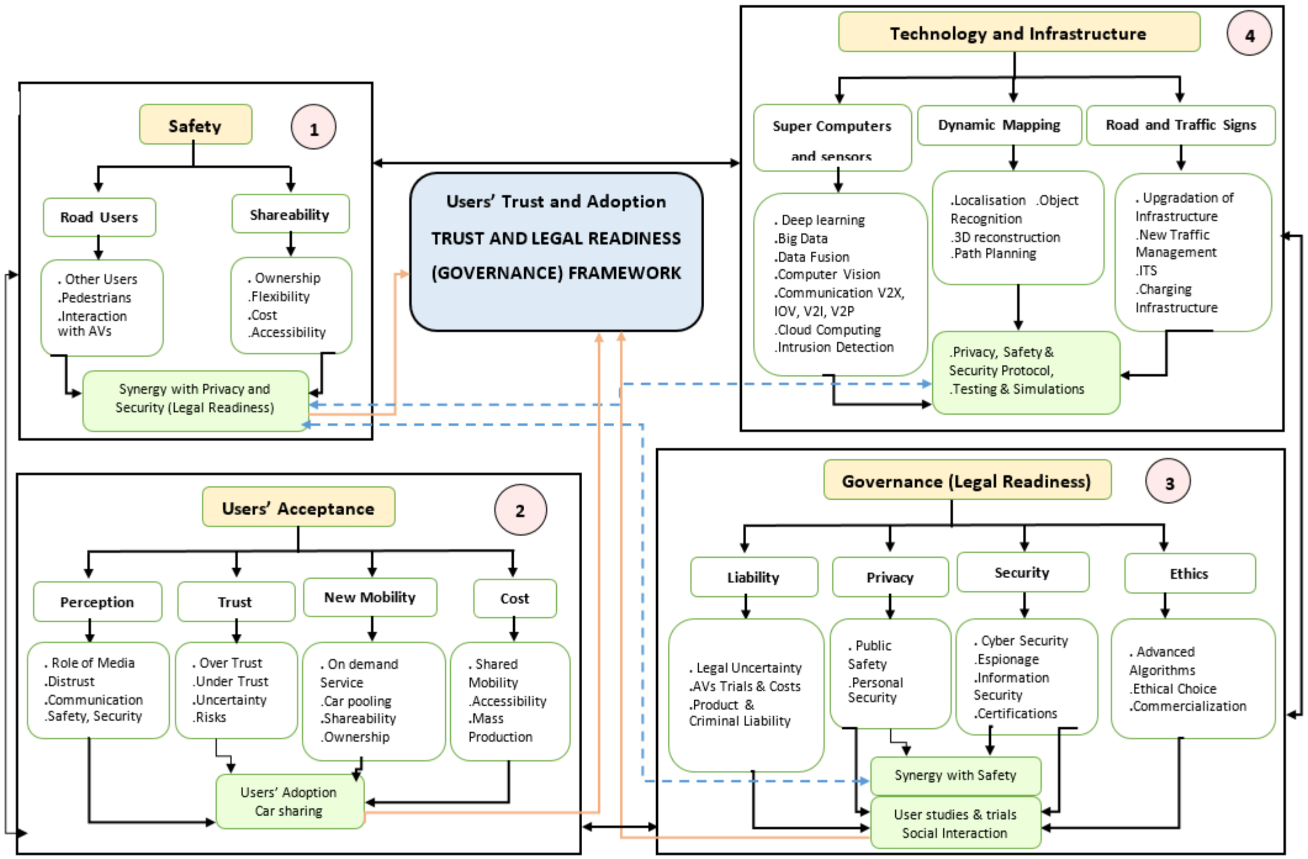
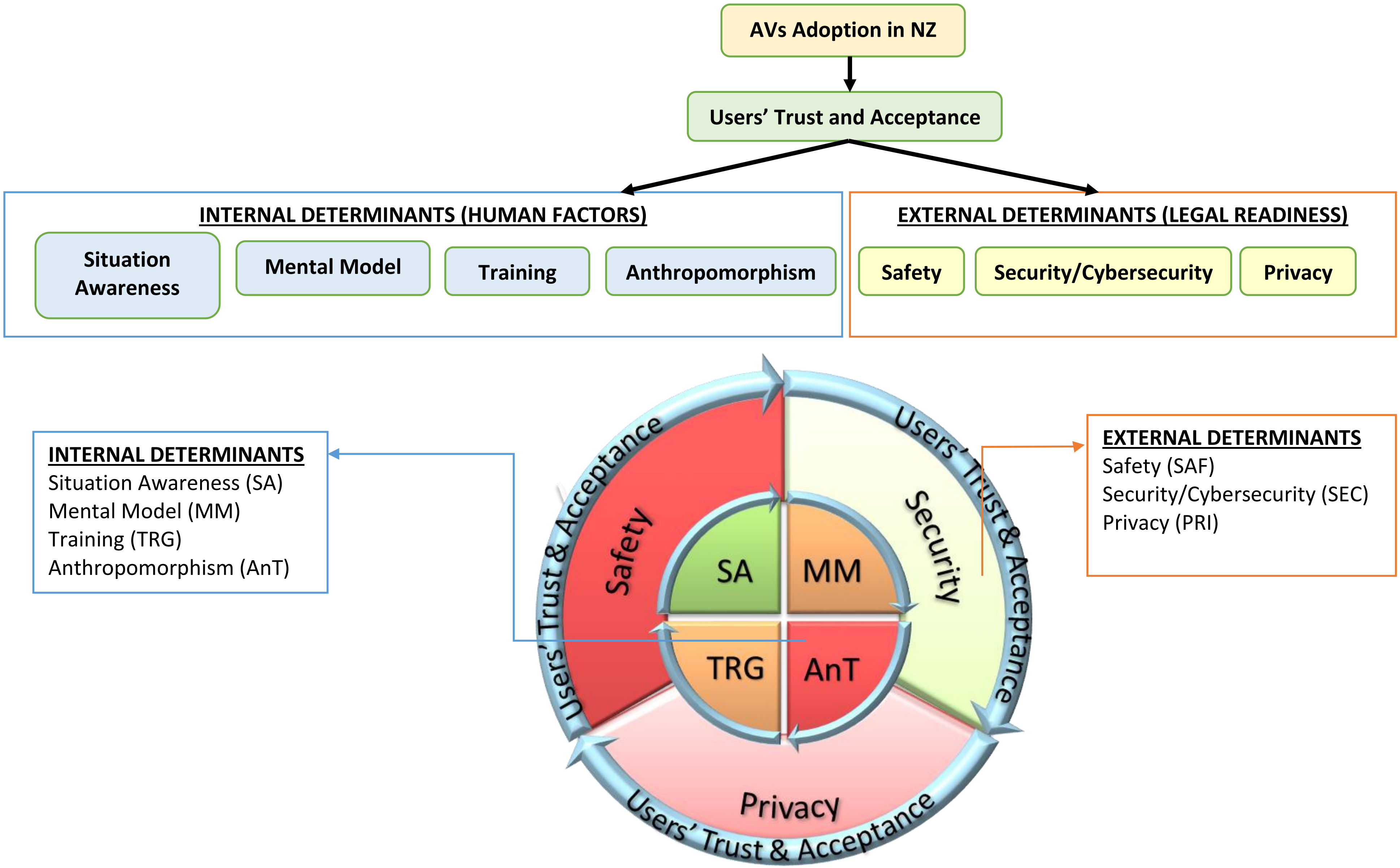


Figure 2.15

Autonomous Driving Adoption in New Zealand – (Internal and External Drivers)



2.8 The Chapter Summary

This Chapter is Part - 1 of the literature review. It has analytically synthesized the predominant concepts, working principles, and user's acceptance challenges in autonomous driving (AD) relating to AVs. The Chapter highlighted the role of human factors (HFs) and co-evolution of regulations and technology within the context of users' trust for successful adoption of AVs in NZ. It has identified the key AD influencing factors in HFs and Legal readiness/governance domains for the smooth proliferation of driverless technologies, and realization of the perceived societal benefits. The Chapter has also briefly explored the trust dynamics and the user acceptance linkages with these identified domains. The next Chapter would examine the significance of the 'trust' for acceptance of AVs in greater detail.

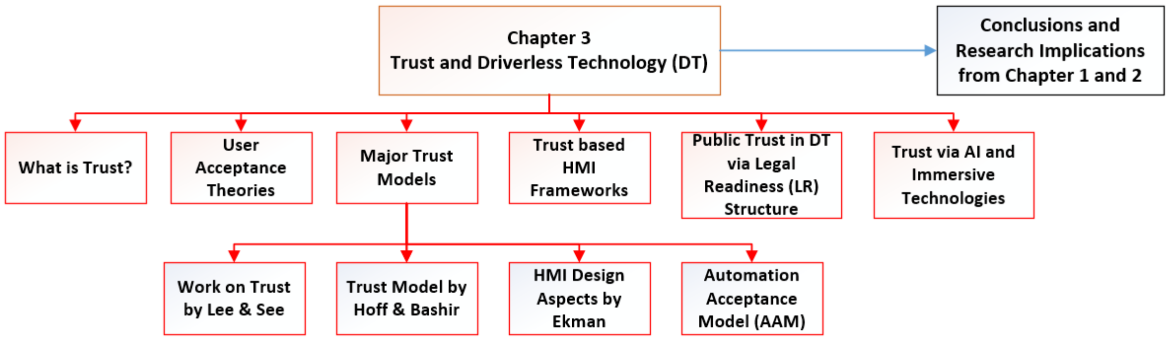
Chapter 3 - Trust Dynamics in Driverless Technology within Autonomous Vehicles Context

3.1 Prelude

This Chapter describes the significance of trust and user acceptance in driverless technology and highlights various trust taxonomies, theories, models, and frameworks present in the literature. It also delineates the role of interpersonal and institutional trust to formulate a holistic trust and governance framework for AD in NZ. In the end, the Chapter provides key research conclusions and implications arising from the literature review of Chapters 1 and 2 (see Figure 3.1).

Figure 3.1

The Literature Review – Chapter 3



3.2 Trust and Driverless Technology

Users' Trust in driverless technology is quintessential to realize the benefits of AVs (Ekman, 2020a). Trust is a precondition for using automated systems (Muir & Moray, 1996; Parasuraman & Riley, 1997). Furthermore, it is essential for user acceptance (Ghazizadeh et al., 2012) and a good user experience (Waytz et al., 2014). The Research on Trust in automation surfaced in the early 1980s when it was found that pilots are not fully exploiting the perceived safety benefits due to the increased use of automated systems (Wickens & Kessel, 1979). These automation induced challenges were classified as "*ironies of automation*" by Bainbridge, who posited that "*the more advanced a control system is, the more crucial may be the contribution of the human operator*" (Bainbridge, 1983a). With the proliferation of driverless technology, drivers face new responsibilities relating to the monitoring system (SAE level 2 and below) for error detection and taking back manual control (SAE levels 2 and 3) in an emergency.

The second challenge is exacerbated by the driver's loss of manual skill due to the automation's continuous task performance (Wintersberger, 2020). The outcome of user–automation interaction can only be safe if users' trust is appropriate to the performance of the automation (Lee & See, 2004). An over trust in an automated system can lead to misuse and crashes (Parasuraman & Riley, 1997). And under trust may lead to disuse of the system by the user. Knowledge and experience of the automation system are necessary to achieve an appropriate level of trust (Edelmann et al., 2019). Understanding AVs limitations and constraints are therefore essential for the users. Muir (1987) stated that "*no matter how sophisticated or intelligent the system may be, the operator must neither underestimate nor overestimate the system capabilities*."

Recent research studies in AVs are mainly focused on the use of driving simulators. However, simulation studies do not allow holistic capturing of the intricacies of perceived risks, uncertainties, and interdependencies for valid measurement of users' trust (Mayer et al., 1995; Rempel et al., 1985). Realistic user studies are essential to identify the theoretical and practical design space and related variables to garner an appropriate level of users' trust (Ekman, 2020a). Trust has complementary trajectories towards the mental model and SA, where it guides driver attention and behaviour for an effective response towards the system (Fisher et al., 2020; Kokar & Endsley, 2012; Lee, 2006). Furthermore, trust mediates micro and macro interactions regarding people's reliability and acceptability towards new forms of transport (Fisher et al., 2020). To formulate a holistic trust and governance conceptual framework for AVs, this study will examine the various trust theories, acceptance of support systems, and AD factors affecting trust. These findings will assist in chalking out an overall frame of reference where vehicle automation and users reside in an interconnected network. The study will then examine this web of trust (WoT) and explore its mediation linkages at the micro-level with human-machine interaction constructs and an overall government regulatory structure at a macro level.

3.2.1 What is Trust?

Trust is a multidimensional and multifaceted construct that perpetuates from seconds to decades and can be approached from many different angles (Lee & See, 2004; Muir, 1987). Common among all trust theories is the concept that trust is an attitude held by a trustor[1] (either human or a machine). It ensures the relationship between the trustor (the actor who trusts something) and the trustee[2] (the actor to be trusted). Therefore, trust can be defined as "*the attitude that an agent will help achieve an individual's goals in a situation characterised by uncertainty and vulnerability*"(Lee & See, 2004). Hence, there is a need for an incentive to collaborate between both actors, i.e., trustor and trustee. However, collaboration might fail due to the risks and uncertainties in the relationship (Mayer et al., 1995; McKnight & Chervany, 2000). Initially, a collaborative relationship stems out of trustor beliefs regarding impressions and information about the trustee. Then through affective evaluation of information, beliefs are transformed into attitude and intention to rely on the trustee. Resultantly it transits into the behaviour specifically known as reliance (Lee & See, 2004). This relationship activates in the presence of a risk of something going wrong (Ekman, 2020a).

Rempel et al. (1985) interpersonal trust model elaborates three non-mutually exclusive cognitive and emotional abstracts of trust: predictability, dependability, and faith. Predictability denotes the trustor ability to predict the trustee's behaviour based on past behaviours. Dependability describes trustee relationship as a whole, i.e., "*as relationships progress there is an inevitable shift in focus away from assessments involving specific behaviours, to an evaluation of the qualities and characteristics attributed to the partner*." Finally, faith thrives once a relationship encounters novel situations that cannot be anticipated due to prior experiences. Muir presented the two-dimensional framework of trust combining these stages, taking the lead from sociology as proposed by Barber (1983) and highlighted the phenomenon of *distrust, mistrust,* and *calibration* (Muir, 1987). It is similar to Parasuraman and Riley's work on use, misuse (overreliance: to use once not required or failing to monitor effectively), disuse, and abuse (inappropriate use of automation applications by manager and designers) (Parasuraman & Riley, 1997). Operators must adjust or calibrate trust according to the

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[1] A person who forms trust in an agent.
[2] An agent such as a human or a machine which form collaborative relationship in trust.

capabilities of automation. Various other aspects have been explored regarding the trust formation process by different authors. These include the trustee's competence, benevolence, integrity, and predictability. The competence is the influence of trustee to achieve trustor's goals and benevolence is the trustor's expectation that the trustee is motivated in favour of the trustor. Whereas integrity is the trustee's expectation that the trustor keeps the promise and tells the truth (Mayer et al., 1995), and predictability is the consistency of the trustee's action so that the trustor foresee future actions(McKnight & Chervany, 2000). Hence, to sustain collaboration between two actors working towards a common end state, the trustee must hold confidence in the eyes of the trustor.

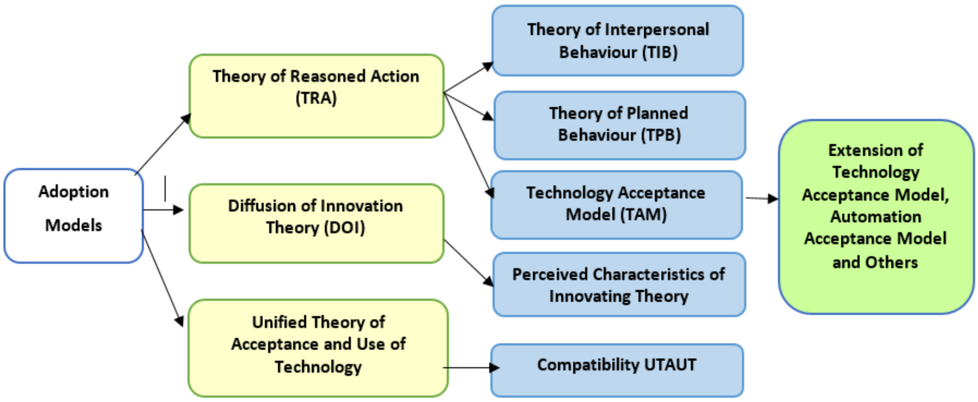
Performance, purpose, and process are three key sources of information that convey information about the automated system's goal-oriented characteristics. Information of performance relates to an automated system's capability, predictability, and reliability, similar to capability and competence elements in interpersonal trust. This information is acquired from automated systems' current and historical operation and elaborates its capability to realize user goals. User trust, therefore, resides in the performance of the automated system (Hoff & Bashir, 2015). Information on purpose relates to the designer's intended use of the system. It is similar to benevolence in interpersonal trust (Lee & See, 2004). Information regarding the process relates to the attributes of the automated system. In a nutshell, trust can be formed "*from a direct observation of system behaviour (performance), an understanding of the underlying mechanisms (process), or from the intended use of the system (purpose)*"(Lee & See, 2004).

3.2.2 User acceptance Theories

Acceptance is a multifaceted concept and has been defined in many ways with overlapping characteristics (Rahman et al., 2018). Generally, measuring acceptance with behavioural intention is more pragmatic and explored by numerous researchers. Adell (2009) defined acceptance as "*the degree to which an individual corporates the system in his/her driving, or if the system is not available, intends to use it*" (p.31). Davis (1993) stated that "*user acceptance is a user's intention to actually use a given system, determined by his/her overall attitude towards using [it].*" The user acceptance theories focussing on behavioural intention using technology (Wibowo, 2019) include Technology Acceptance Model (TAM) (Ajzen, 1991; Davis, 1985, 1989; Davis et al., 1989), Theory of Planned Behaviour (TPB), Unified Theory of Acceptance and Use of Technology (UTAT) (Venkatesh et al., 2003) and Automation Acceptance Model (AAM) (Ghazizadeh et al., 2012). The TAM was built on the theory of reasoned action (TRA) by Fishbein and Ajzen (1975). It was initially proposed to explain the acceptance of information technology by the users. Various adoption theories are shown in **Figure 3.2**.

Figure 3.2

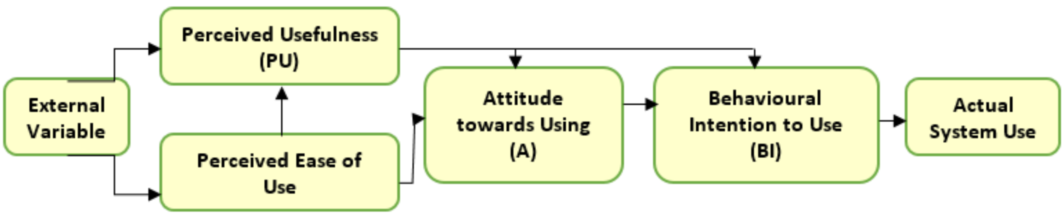
Adoption Models – User Acceptance



In TAM, perceived ease of use (PEOU) and perceived usefulness (PU) are two main predictors of attitude, and this attitude forecasts behaviour intention to use and the actual use of the system (Davis, 1989). PU refers to the degree to which a user believes in technology performance, and PEOU refers to the perceived effort of the user while using an automated system (**Figure 3.3**). The TAM bears a close resemblance to Neilsen's usefulness explanation, where utility denotes PU and usability refers to PEOU (Nielsen, 2012).

Figure 3.3

Technology Acceptance Model

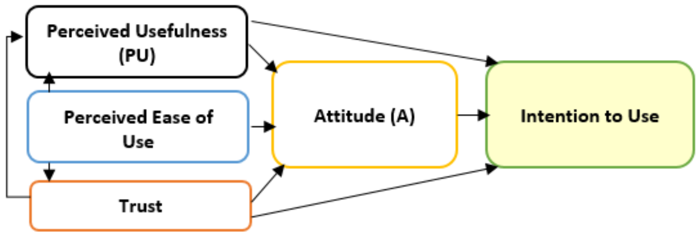


Note: Adopted from User acceptance of computer technology: a comparison of two theoretical models by Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. 35(8), p 982-1003. 1989. Copyright Management science Journal, Elsevier Ltd

The TAM is based on Psychological Attitude Paradigm and, over the years, have been extended with additional factors leading to TAM2 (Venkatesh & Davis, 2000) and TAM3 (Venkatesh et al., 2003). Belanche et al. (2012) explored causality between trust, PE, PEOU, attitude, intention to use) and suggested trust as an additional factor in TAM (Figure 3.4).

Figure 3.4

Extension of Technology Acceptance Model

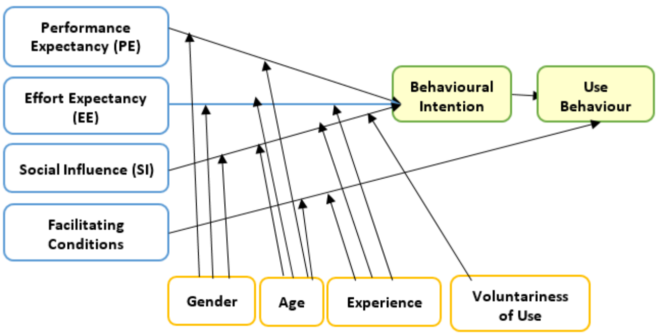


Note: Extended Technology Adoption Model adopted Integrating trust and personal values into the Technology Acceptance Model: The case of e-government services adoption by Belanche, D., Casaló, L. V., & Flavián, C. 15(4), p. 192-204. 2012. Copyright Elsevier Ltd

Ghazizadeh et al. (2012) identified trust and compatibility as additional factors affecting PU and PEOU in TAM in Automation Acceptance Model (AAM). Similarly, the UTAUT model observes effort expectancy (EE), Social Influence (SI), performance expectancy (PE), and facilitating condition (FC) as the core variables and considers that gender, age, experience, and voluntariness of use (VOU) having moderating effects on these core variables (Figure 3.5).

Figure 3.5

Unified Theory of Acceptance and Use of Technology



Note: Adapted from User acceptance of information technology: Toward a unified view by Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. p.425-478.2003. Copyright Management Information Systems Research Center, University of Minnesota JSTOR.

The TAM is the most widely used theory in various research studies in the context of driver acceptance. Xu et al. (2010) observed PU and PEOU with four other factors and modelled advanced traveller information system. Roberts et al. (2012) integrated ‘unobtrusiveness’ in the TAM to measure drivers’ distraction with automated warning systems. Reagan et al. (2017) and Kidd and Reagan (2019) highlighted that positive perceptions contribute to adopting driver assistance technologies through PU and PEOU. Park and Kim (2014) investigated the effects of attitude and PU on behavioural intention and stated in favour of their effects. Chen and Chen (2011) observed ‘perceived enjoyment’ and used ‘personal innovativeness’ to confirm its moderation on behavioural intention. Osswald et al. (2012) recommended an acceptance model based on attitude, effort expectancy, performance expectancy, and social influence, among others, as a precondition to behavioural intention. Larue et al. (2015) used TPB to model acceptance of railway level crossing warning systems and found the effect of attitude and subjective norm. Adell (2010) observed the utility of UTAT in a naturalistic study and observed significant effects of performance expectancy and social influence. Some of the models bear similar components, e.g., there are similarities between PU in TAM and PE in UTAUT; between PEOU in TAM and EE in UTAUT; and social norms in TPB and social influence in UTAUT (Rahman et al., 2018). Age and gender are the most explored demographic factors that affect acceptance (Rahman, 2016; Rahman et al., 2018).

Since the TAM was purposefully developed for IT users (Table 3.1 below), it does not account for all factors affecting HAV user acceptance (Aremyr & Jönsson, 2017). Besides, both TAM and AAM are not supported by empirical observations despite having a solid theoretical background (Rahman et al., 2018). Lately, the theoretical underpinning of trust in automation and AVs within HMI emphasizes an interdisciplinary approach to study beyond usability and perceived ease of use as explored by TAM. It asks for exploring the factors external to HMI towards social, material, cultural, and dispositional domains (Raats et al., 2020).

Table 3.1

User Acceptance major Theories and Models in the context of AD

Theory / Model	Significant Factors	Definitions	Key Studies in the domain
Technology Acceptance Model (TAM)	Perceived Usefulness (PU)	Davis (1989)“The degree to which a person believes that using a particular system would enhance his or her job performance” (p. 985).	(Ghazizadeh et al., 2012; Ghazizadeh et al., 2012b; Larue et al., 2015; Park & Kim, 2014; Roberts et al., 2012; Rödel et al., 2014)
	Attitude	Fishbein and Ajzen (1975)“An individual’s positive or negative feelings (evaluative affect) about performing the target behaviour” (p. 216).	
	Perceived Ease of Use (PEOU)	Davis (1989)“The degree to which a person believes that using a particular system would be free of effort” (p. 985).	
Unified Theory of Acceptance and Use of Technology (UTAUT)	Effort Expectancy(EE)	Venkatesh et al. (2003) “The degree of ease associated with the use of the system” (p. 450).	(Adell, 2010; Chen et al., 2020; Larue et al., 2015; Madigan et al., 2016; Osswald et al., 2012; Rödel et al., 2014)
	Performance Expectancy (PE)	Venkatesh et al. (2003)“The degree to which an individual believes that using the system will help him or her to attain gains in job performance” (p. 447).	
	Social Influence	Venkatesh et al. (2003)“The degree to which an individual perceives that important others believe he or she should use the new system” (p. 451).	
Theory of Planned Behaviour (TPB)	Attitude	Same as above in TAM	(Larue et al., 2015; Rödel et al., 2014)
	Subjective Norm	Fishbein and Ajzen (1975)“The person’s perception that most people who are important to him think he should or should not perform the behaviour in question” (p. 302).	
	Perceived Behavioural control	Ajzen (1991)“The perceived ease or difficulty of performing the behaviour” p. 188).	
Automation Acceptance (AAM) and Various Other Models	Trust	Lee and See (2004)“The attitude that an agent will help achieve an individual’s goals in a situation characterised by uncertainty and vulnerability”	(Aremyr & Jönsson, 2017; Aremyr et al., 2018; Belanche et al., 2012; Ervin, 2005; Ghazizadeh et al., 2012; Ghazizadeh et al., 2012b; Regan et al., 2006)
	Compatibility	Moore and Benbasat (1991)“The degree to which an innovation is perceived as being consistent with the existing values, needs, and past experiences of potential adopters”(p. 195).	

Theory / Model	Significant Factors	Definitions	Key Studies in the domain
	Personal Innovativeness	Agarwal and Prasad (1998)"The willingness to adopt (technology) innovations earlier than others."	
	Effectiveness	Rahman et al. (2018) "System's extent to carry out its intended tasks."	
	Affordability	Regan et al. (2006)"willing to pay to purchase, install and maintain the system"(p.141)	
	Endorsement	Rahman et al. (2018). "The willingness to approve or suggest the purchase and/or use of a driver support system."	

Note: The Table adopted from Modelling driver acceptance of driver support systems by Rahman, M. M., Strawderman, L., Lesch, M. F., Horrey, W. J., Babski-Reeves, K., & Garrison, T. *121*. p 134-147 . 2018. Copyright Journal of Accident Analysis & Prevention Elsevier Ltd.

3.2.3 Major Trust Models

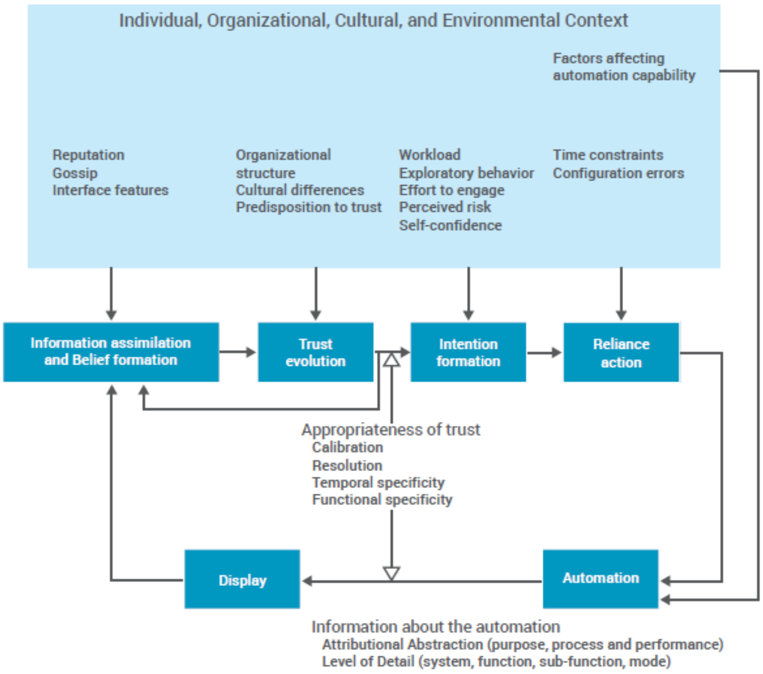
Trust is a significant prerequisite for user acceptance (Wintersberger, 2020). Trust needs treatment more than just a precondition of acceptance. It is quintessential to user behaviour during interaction (Wintersberger, 2020). In recent literature, the prominent trust model theories and taxonomies are postulated by Lee & See and Hoff & Bashir. However, several scholars studied the trust based framework in automation, including Ekman and Wintersberger (Du et al., 2021; Ekman, 2020a; Hoff & Bashir, 2015; Lee & See, 2004; Lind Oros, 2020; Okamura & Yamada, 2020; Sato et al., 2020; Sun et al., 2020; Wintersberger, 2020; Zhang et al., 2020).

3.2.3.1 Work on Trust and Appropriate Trust by Lee & See

Lee & See highlighted that it is essential to differentiate between trust as an attitude and reliance as a behaviour because people say they trust AV. Still, their actions may not reflect their statement. While describing their conceptual framework of *' A Dynamic Model of Trust and Reliance on Automation, '* Lee and See (2004) found that trust and automation interaction affect each other in a dynamic close loop in stages (**Figure 3.6**).

Figure 3.6

Trust as an Attitude Influencing Reliance

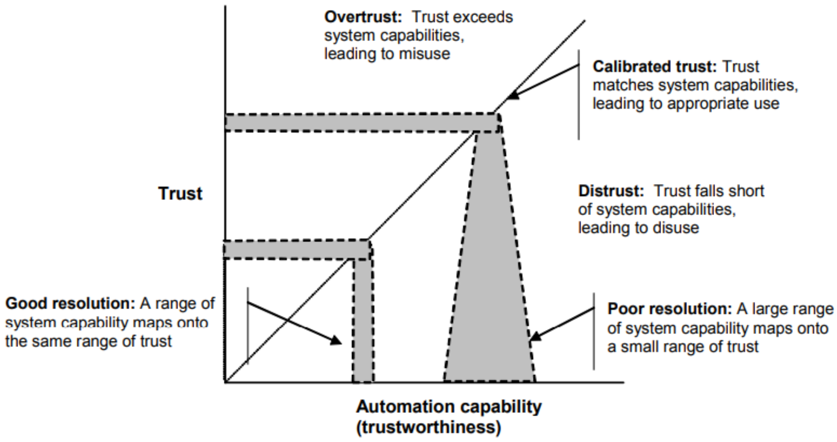


Note: Framework describing how trust as attitude may influence reliance as a behaviour adopted from Trust in automation: Designing for appropriate reliance by Lee, J. D., & See, K. A. 46(1), p. 50-80.2004. Copyright Journal of Human factors.

In stage one, user interfaces are vital to assist the user in forming a belief about automation. In stage two, trust grows with positive interaction with interfaces. Then user forms an intention to rely on automation juxtaposing other contextual factors such as workload, perceived risk, and effort to engage. In the last stage, this reliance intent guides the user's behaviour to interact with the system in time constraints and configuration errors. The misuse and disuse of automation occur once users over trust or distrusts the automaton while inappropriately relying on automation (Parasuraman & Riley, 1997). Lee and See (2004) displayed calibration with the help of a diagonal line (Figure 3.7).

Figure 3.7

The relationship between calibration, resolution, and automation capability



Note: Over trust may lead to misuse, and distrust may lead to disuse adopted from *Trust in automation: Designing for appropriate reliance* by Lee, J. D., & See, K. A. 46(1), p. 50-80.2004. Copyright Journal of Human factors.

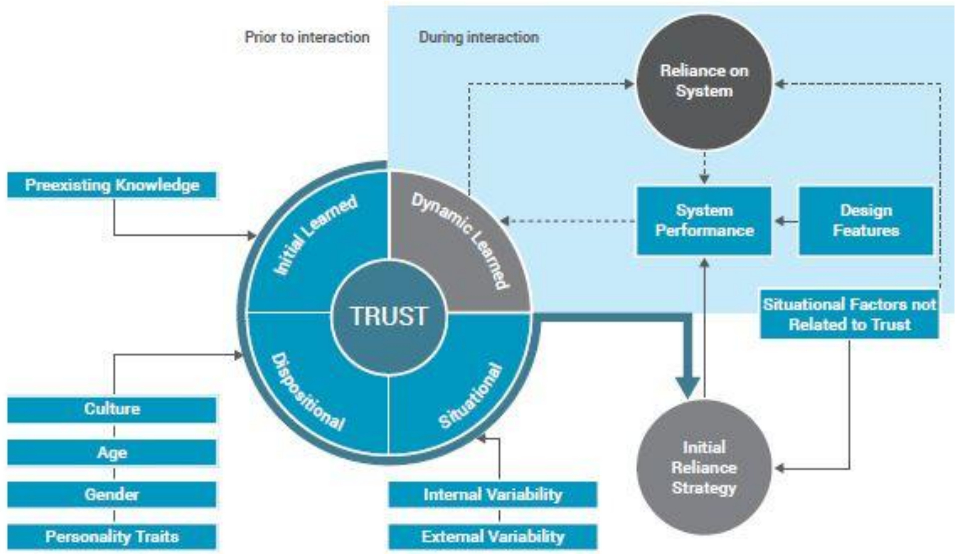
They described a relationship between calibration, resolution, and automation capability to define appropriate trust in automation, as shown in Figure 3.7. They observed that the appropriateness of trust is a function of calibration, resolution, and specificity. Lee and See (2004) stated that resolution relates to "*how precisely a judgement of trust differentiates levels of automation capability*" (p. 56), and specificity relates to "*to the degree to which trust is associated with a particular component or aspect of the trustee"* (p.55). Functional specificity is "*system-wide versus component-specific trust*" with particular emphasis on function and modes of automation. Temporal specificity describes how fast changes in performance are articulated in trust. In the trust calibration domain, Hergeth et al. (2017) displayed that prior familiarization with take-over requests can assist in dealing with over trust issues. Kraus et al. (2020) showed malfunctions decrease trust if users do not provide previous information, but these observations were based on a control group of participants. Similarly, very few papers discussed temporal or functional safety or referred to over or under trust (Bazilinskyy et al., 2018; Faltaous et al., 2018; Kunze et al., 2018). Many studies suggested using additional feedback mechanisms to support the calibration process using design features equipped with better transparency and uncertainty information (Wintersberger, 2020).

3.2.3.2 Trust Model by Hoff & Bashir

A significant work towards investigating the relevant aspects of trust is conducted by Hoff and Bashir (2015) Trust Model (**Figure 3.8**). Initially (Marsh & Dibben, 2003) presented a conceptual model highlighting three layers: dispositional, situational, and learned trust.

Figure 3.8

Model of Three Layer of Variability in Trust in Automation



Note: Adapted from Trust in automation: Integrating empirical evidence on factors that influence trust by Hoff, K. A., & Bashir, M. 57(3), p. 407-434.2015. Copyright Journal of Human Factors, the University of Illinois at Urbana-Champaign Champaign, IL 61820

The dispositional trust is influenced by the user's long term tendency to trust automation irrespective of the environment. Situational trust is related to the context of specific interaction and learned trust in which the user evaluates the system based on past experiences. Hoff & Bashir extended these layers. Their Model observed that dispositional trust is influenced by an operator's culture, gender, age, and personality traits. Situational trust displays internal variability (difficulty in task, system type and complexity, workload, potential risks and benefits, task framing, and the organizational setting) and external variability (mood, or capacity to pay attention, self-confidence, and expertise in the subject). Learned trust is based on the brand/reputation of the system, understanding and experience with similar systems, and expectations from the system. Dynamically learned trust emerges from direct system interaction (reliability, validity, dependability, predictability, usefulness, error types and their timing/difficulty) and design features such as level of control, transparency, appearance, communication style, and ease of use (Wintersberger, 2020).

All factors cumulate to shape the operator's initial reliance behaviour. And dynamically learned trust finally determines reliance behaviour (Hoff & Bashir, 2015). The initially learned trust and the behaviour lead to the performance of the whole system. The situational factors such as situation awareness, influence reliance, and cognitive workload apply to both Lee & See and Hoff & Bashir Models (Wintersberger, 2020). Several studies identified the application of the Hoff & Bashir Model discussing the aspects of training for the operator (Payre et al., 2016), self-confidence as a predictor of trust (Tenhundfeld et al., 2020), external variably in the context of risk (Li et al., 2019), the influence of driving behaviour on trust (Sonoda & Wada, 2016), and the utility of feedback in the HMI design process ensuring transparency (Hartwich et al., 2019; Körber et al., 2018).

3.2.3.3 HMI Design Aspect by Ekman

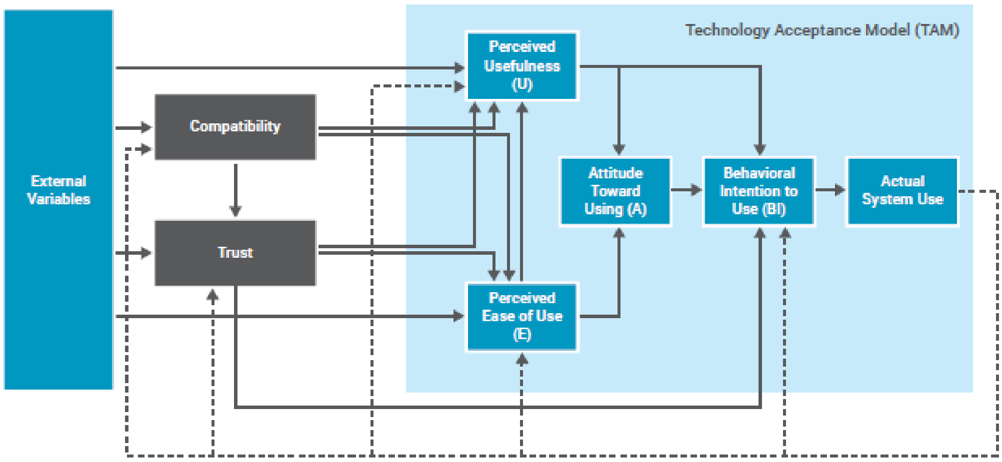
Ekman (2020a) presented an AV framework for designing appropriate trust. Ekman studied the basis for the emergence of trust in three distinct stages: pre-use, learning, and performance. The Pre-use stage occurs before interaction with AV. The learning happens during interaction with AV in a specific context once the user has learnt about the system's performance. And, the performance phase takes place while doing various road operations with AV during different changing contexts (Ekman & Johansson, 2015a). These factors comprised mental model of driver, common goals, training, expert/reputable, anthropomorphism, feedback, adaptive automation, customization, uncertainty information, why and how information and, error information. Situation awareness accounts for most of the HMI design process functions, including feedback, why and how information, error information, and uncertainty information. These processes are preconditions to acquire optimum situation awareness in automated systems with the help of various user interfaces. Similarly, it can also be summed up that anthropomorphism is a holistic term that can also have a subset of the aspects such as customization and adaptive automation.

3.2.3.4 Automation Acceptance Model (AAM)

Automation Acceptance Model, as shown in Figure 3.9, creates an integrated automation acceptance model by combing research from cognitive engineering and information systems domains (Ghazizadeh et al., 2012). AAM incorporates two more factors, including trust and compatibility to the TAM model directly influencing PU and PEOU. AAM displays trust and compatibility determinants directly influenced by external variables and shows feedback loops affecting these factors while the system is in use Perspective has been applied to the dynamic nature of trust and multiple layers of automation.

Figure 3.9

Automation Acceptance Model (AAM)



Note: Dashed line indicate AAM workflows and straight line arrows are of original TAM. Adapted from *Extending the Technology Acceptance Model to assess automation. Cognition, Technology & Work* by Ghazizadeh, M., Lee, J. D., & Boyle, L. N. 14(1), p.39 -49.2012. Copyright Springer-Verlag London Limited

Behavioural intention to use is directly influenced by trust like PU. Trust and Compatibility are directly affected by external variables such as system features and user characteristics (Davis et al., 1989). Task technology compatibility indirectly affects behavioural intention through PU and PEOU. Compatibility refers to how well the automated system performs vis-à-vis user needs and requirements in a specific context. Additionally, feedback loops are added to depict the actual system usage, affecting the loop's various factors.

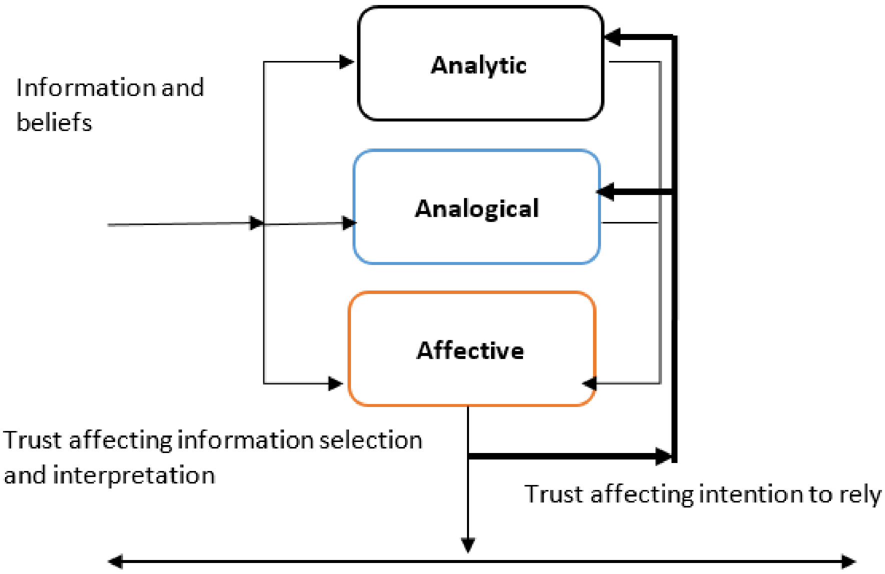
It is important to design HMI for HAV, considering the mediating effect of trust on reliance and the importance of information availability and information observability to make the right decision to rely on automation (Aremyr & Jönsson, 2017). Lee and See (2004) emphasized not to confuse trust with intention or behaviour as these elements are influenced by other human factors such as SA, workload and self-confidence. Trust in automation is a significant mediator (though not the only one) of using automation (Wintersberger, 2020). Muir (1987) two-dimensional framework in the backdrop of sociology leads to the following definition of trust in HMI:

> "Trust is the expectation, held by a member of a system, of persistence of the natural and moral social orders, and of technically competent performance, and of fiduciary responsibility, from a member of the system, and is related to, but not necessarily isomorphic with, objective measures of these qualities" (p.531)

As depicted in Automation Acceptance Model (AAM), users' closer view of the system rather than its capabilities lead to trust induced behaviour, namely reliance (Aremyr & Jönsson, 2017). In this context, Wickens et al. (2013) information processing model at the perception stage bears significance. Lee and See (2004) suggested an assimilation model that highlights the interplay of analogical, affective and analytic processes in the context of human-machine trust. The analytic paradigm relates to pragmatic thinking and evaluation of the trustee's characteristics. The analogical is based on societal norms, rules, and regulations defined by others, and affective refers to the emotional response to the expectancies. People tend to use these assimilation processes depending upon the availability of resources and the relationship between trustor and trustee. Trust is essentially an affective response though partially influenced by analogical and analytical processes (Figure 3.10). Lee and See (2004) observed that the user's trust level is based on "*the relationship between trustor and trustee, the information that is available to the trustor, and the way information is displayed*" (p.61). Therefore, it is concluded that to garner the holistic trust of users for the acceptability of AVs, users need to have trust in the governance regime based on rules and regulations. Users should be fully cognizant of AV's purpose, process, and performance to have appropriate situational awareness (Endsley, 2016; Parasuraman et al., 2008). Moreover, the user needs to trust how information is displayed and human-like mental capabilities attributed to the automation system in the backdrop of anthropomorphism (Epley et al., 2007; Waytz et al., 2014).

Figure 3.10

The interplay between the assimilation process underlying trust



3.2.4 Trust based HMI Frameworks in Earlier Studies

Numerous studies focussed on trust based frameworks while dealing with automated systems. Lee and Moray (1992) observed a passenger riding inside prototype level 2 AV that driver anxiety in critical situations may be reduced once he sees the vehicle managing different driving situations. They proposed the use of an agent and creating an emotional contact between the driver and an agent. Wintersberger (2020) observed that choice of diver gender has little effect on emotional and mental states. Häuslschmid et al. (2017b) compared various visualization overlaid on a driving scene of a chauffeur avatar, a world in miniature, and car indicators. They observed an increase in trust. Basu and Singhal (2016) suggested a framework based on user trust and agent trust to harness multi-modal sensor data from the vehicle and user's wearable handheld device using features like gaze, facial expression. Ekman et al. (2018) identified trust based on usage phases, automated driving (AD) events, factors and levels, explaining each event that trust starts long before the user's first interaction with the system and continues after that.

de Visser, Pak, et al. (2018) suggested yet another trust repair paradigm to equip AVs with better human capabilities so that trust is repaired actively after an unintended action or violation. He stressed the need to distinguish automated systems such as GPS navigation from drones and advocated a new framework based on underlying concepts of industrial psychology. The framework propagated to infuse a unique human-like ability to build and actively repair the trust into autonomous systems. Chien et al. (2018) explored a validated cross-cultural trust measure in the US, Taiwan, and China considering Honour, Face, and Dignity factors based on Leung and Cohen's theory of Cultural Syndromes and Hofstede's Cultural Dimensions. They identified that despite cultural differences, substantial commonalities were found in developing trust through a relationship between reliability and reliance. The trust dynamics vary significantly in different disciplines due to various definitions (Erchov, 2017). Therefore, it might be a reasonable attempt to examine trust following the neuro-ergonomic approach (Gramann et al., 2017).

Another study identified that a false alarm device activated different brain regions of a human compared to machines (Fedota & Parasuraman, 2010). Cho and Hansman (2018) defined a framework showing complete architecture involving driver, automation systems, and the environment. De Visser, Beatty, et al. (2018) postulated that with the increase in complex AI, developing new methods to monitor AI is necessary. They hypothesized that electroencephalograms (EEGs) could provide a trust measurement index without self-reporting. Trust can be examined in computer algorithms through the utility of neural correlates or error monitoring.

Wintersberger (2020) investigated distrust, over trust, and multitasking theoretical considerations and highlighted the significance of multi-modal and attentive user interfaces to deal with these issues. Table 3.2 displays the key trust based HMI Frameworks found in the Literature.

Table 3.2

Key Trust based HMI Frameworks

Trust Scenarios	Decisions/Result	Methods	Samples	References
Researcher Identified dimensions of trust in driving automation and trust calibration framework	Highlighted the significance of multi-modal and attentive user interfaces	Series of studies- total 7	Students and Staff of University	Wintersberger (2020)
The researcher investigated user acceptance and the willingness to use AVs	Media affect self-efficacy and subjective norms, resulting in people's trust and behaviour change	Structural Equation Modelling	173 college students of IT used survey questionnaire	Du et al. (2021)
Developed an interface for transfer of control between car and human for steering control and speed control	Simulated several modes of danger that would require manual take over and human awareness, cognitive load in drivers of AVs and their performance under multiple cognitive loads			Johns et al. (2014)
A dynamic model of human trust in automation based on Auto-regressive Moving Average was examined.	The success of collaboration (measured as efficiency) improved constantly as the operators became familiar with the plant operation	For three days, 2 hours per day sessions of running an orange pasteurizer automated plant, the authors recorded the trust dynamics of several operators	19 (male and female) undergraduate students, operators, responded to 60sets of a rating scale on a subjective rating scale and regression analysis	Lee and Moray (1992)
The impact of timing of reliability drop on real-time human trust in the machine when a human was the sole machine operator.	Real-time trust cannot be reflected by traditional trust questionnaires and is affected more by early on robot failure than by later losses of reliability	iRobot ATRV-JR robots with user interfaces	12 (male/female) participants examined the varying reliability with no explicit feedback and 16 (male/female) for dynamic reliability with	Desai et al. (2013)

Trust Scenarios	Decisions/Result	Methods	Samples	References
			feedback measured with the Muir survey.	
Modelled human trust in automation as a continuous interval representation from complete distrust to absolute trust.	Developed adaptive trust seeking robots that can predict human trust in a given situation and adapt its actions and social behaviour to improve the trust.	Developed 'OPTIMo,' a dynamic Bayesian model of trust as a function of a vehicle's performance, frequency of human interventions, the previous state of trust and self-reported trust states	Twenty-one roboticists from 7 universities were involved in two human-robot interaction scenarios to follow sequences of different boundary targets.	Xu and Dudek (2015)
Proposed a framework for integrating Human-Robot mutual trust including User trust, Agent trust, and the two fundamental components of Mutual trust.	How to harness multi-modal sensor data from the car as well as from the user's wearable or handheld device?			Basu and Singhal (2016)
Suggested a framework for implementing trust-related factors into the HMI interface.	Trust formation is a dynamic process that starts long before a user's first contact with the system and continues long after.	User study conducted using a NHTSA level 2 AV system found in a Mercedes Benz E-class. Repeated Measure Design Approach for validation	Nine participants (male/female) were observed for driving and interviewed in the user study. Then six students and four experts of Volvo for focus workshops. For validation 8 people (male/female)	Ekman (2020a); Ekman and Johansson (2015b, 2018)
A conceptual model of Trust in automation was explored.	Described the dynamics of trust, the role of context, and the influence of display characteristics.	Literature Analysis		Lee and See (2004)

Trust Scenarios	Decisions/Result	Methods	Samples	References
Presented a three-layered trust model that synthesizes existing knowledge	Three layers of variability in human-automation trust	A systematic review of empirical research on trust in automation	101 total papers, containing 127 eligible studies	Hoff and Bashir (2015)
Trust in autonomous driving can be increased by means of a driver interface in the shape of chauffer avatar, car indicators, and the world in miniature	Intelligent autopilot visualization of the car's understanding and interpretation of the situation, as well as its corresponding actions, increased trust	Questions measured trust factors on 5 point Likert scale, user experience on 7 point Likert scale, and then the Friedman test.	First, a pilot study with 6 participants to test transfer of trust and evaluated the design. Then recruited 30 persons (12 female) measure attitudes and behaviours	Häuslschmid et al. (2017b)
Investigate the key factors influencing the adoption of driverless cars in a closed environment	The ability of the driverless car to meet performance expectations and its reliability were important adoption determinants.	Embedded quantitative study (Tonsley innovation at flinders Uni) with a survey (5 point Likert scale) and confirmation in SPSS	Pretesting with 3 participants and then survey involving 101 individuals	Kaur Kaur and Rampersad (2018)
Investigated the cognitive and emotional dimensions while designing AVs	Transparent interfaces adapted to the mental system of the human are the prerequisite for the situation and system awareness in interactions with the automated system	Electronic questionnaire, The affective similarity evaluated via the semantic differential method Following the three-dimensional Euclidian distance	1000 participants	Wolf (2016)
Using QFD for designing an autonomous underwater robot	Significant users' design parameters are identified	Interviews of 30 Thai Navy officers	30 participants	Pasawang et al. (2015)

3.2.5 Public Trust in Driverless Technology via Governance / Legal Readiness Structure – A case for the regulatory ecosystem

The author would try to highlight the significance of public trust in Driverless Technology concerning the regulatory ecosystem in the country from an *institutional trust* and *structuration theory* point of view. There has been very little research in the literature regarding the role and relevance of AVs regulation in a smart urban transport system (Ljungholm, 2020). NZ Government has a vital role in maximising social welfare goals of cybersecurity regulating safety, security, and privacy. These goals are then translated into technical standards in collaboration with relevant industry stakeholders and international bodies. In the context of AVs, the security and privacy aspects need to be embedded into the holistic safety domain in the transport regulation paradigm (Anderson et al., 2018). Against this backdrop, the capacity development within the responsible organizations for successful AD is required. It comprises development of relevant standards and regulations, provision of adequate R & D funding, road codes, and formulation of documentations. These efforts will ensure that the Government is accountable to the public by elaborating rules and enforcing these rules.

Deployment of the AVs will result in the rise of new human factors issues related to safety risks at lower levels of automation, such as behavioural adaptation, over-reliance, skill loss, complacency, and inadequate process monitoring. (Fisher et al., 2020). Governments and responsible organizations need to learn from other regimes potentially shaping the regulatory ecosystem, including Australia, UK, the US, Sweden, and Norway (Hansson, 2020). And consider principle-based approaches to regulation. As advocated by earlier research scholars, interpersonal trust forges an effort to manage the relationship between humans and machines. System trust is the "*trust in the functioning of bureaucratic sanctions and safeguards, the so-called legal system*" (Lewis & Weigert, 1985). It leads to social order addressing the complexities which cannot be pursued from an interpersonal trust (Knowles & Richards, 2021).

Individuals trust that the system itself has appropriate mechanisms for ensuring trustworthiness (Giddens, 1990; Kroeger, 2017). 'Systemness' is a term dynamically embedded through dimensions of structure called 'Structuration.' It underpins the interplay between structure and its reproduction and is often termed '*Institutionalization*' (Knowles & Richards, 2021). Trusting an institution means trusting in system structures (Kroeger, 2017). Giddens (1990) described the dimensions of structure (rules and resources that govern social practices) that form institutions. These include significance, legitimation, and domination. Significance refers to symbolic actions that portray meaning concerning the institution, such as a white coat that symbolizes a doctor (Jones & Karsten, 2008). The Legitimation furnishes norms and values known to people and further reinforced with institution sanctions of failure to comply. Finally, domination is the allocation of power to the agents of an institution. The coherence of these dimensions resonates with trust emphasizing integrity (Mayer et al., 1995).

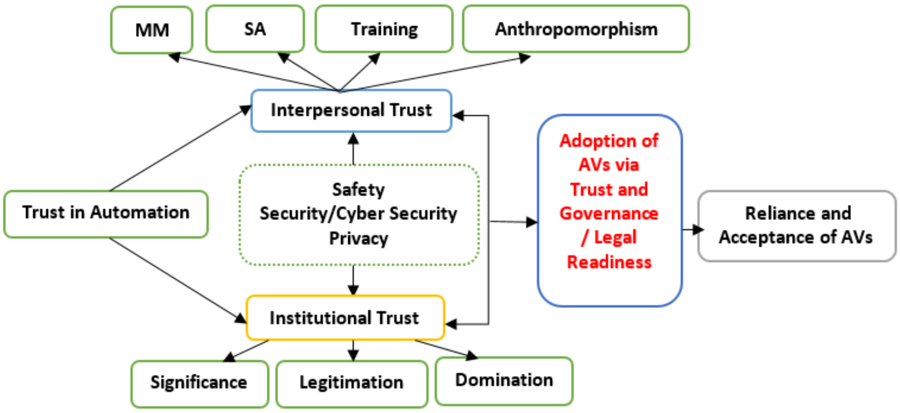
Norms in the institution lose their legitimacy and validity if individuals breaking the rules are not punished, and people working for the institution must be sufficiently empowered. Trust in an institution grows through the concept of facework identified by Goffman (1955). It signifies a person's self-presentation or transition of interpersonal trust to an institutional trust based on the conduct and behaviour of the people working in the institution. Thus lack of public trust is not only due to the user’s inability to understand AV, but it can mainly be a reaction to lack of relevant structural assurances of the trustworthiness provided by the institutions. Formulating technical standards and documents for AVs testing, certification and deployment can ensure the system's trustworthiness. Institutional trust ultimately promotes interpersonal trust, increasing the feeling of security (Spadaro et al., 2020). The concerns of safety, security/cybersecurity and privacy not only resides in the folds of interpersonal trust but also bear fundamental relevance to institutional or system trust (Anderson et al., 2018; Ljungholm, 2020; Manda & Backhouse, 2016; Taeihagh & Lim, 2019; Taeihagh et al., 2021)

Leveraging lessons from Artificial Intelligence and the deployment of drones provide evidence for the establishment of appropriate trust to mitigate the risk of user acceptance challenges (Altawy & Youssef, 2016; Cunneen et al., 2019a; Elmaghraby & Losavio, 2014; Taeihagh et al., 2021). Trust mediates people micro intentions on automation reliance and macro interactions for overall public acceptability towards the transportation system as a whole (Fisher et al., 2020)

During HMI, the trust based on user acceptance may mediate the relationship between AD influencing factors regarding the user's cognitive abilities and smooth legal readiness mechanism. In other words, interpersonal and institutional trust form a holistic trust and governance mechanism for successfully deploying AVs. Figure 3.11 illustrates the trust in the automation ecosystem where the holistic trust based on institutional and interpersonal trust influencing AD factors ensures acceptance of AVs.

Figure 3.11

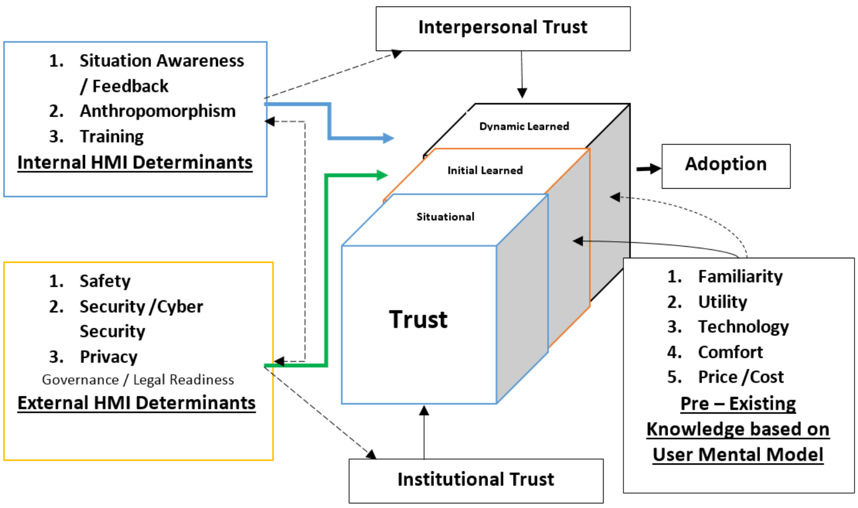
Trust in Automation Eco System



The underlying Figure 3.12 describes the holistic trust affecting AD factors based on the research study.

Figure 3.12

Holistic Trust and Governance Affecting Factors



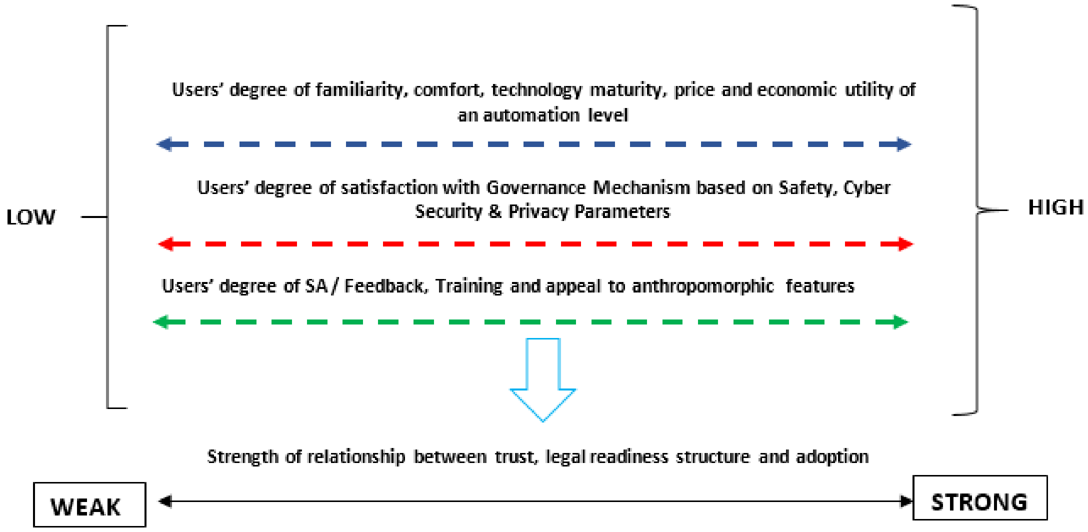
Note: Full model of factors for this research study that influence trust in AVs and long terms implementation determinants.

The graphical representation in Figure 3.12 displays the primary internal and external determinants based on interpersonal and institutional trust for the successful adoption of AVs. The internal determinants include the user's mental model, situation awareness/feedback, training, and anthropomorphism. The external determinants are based on safety, privacy, and security/cyber security. Situational trust relates to institutional trust, and dynamic trust is formed based on interpersonal trust factors. The third set of determinants indirectly relates to initial and dynamic learned trust. These determinants relate to familiarity, economic utility, price and technological maturity of automation levels that might contribute to proliferation of AVs with several other variables. These determinants can be used for predicting the futuristic impact of AVs proliferation and deployment timelines.

Based on the above discourse, this study proposes trust influencing layers to establish an appropriate trust mechanism for successfully adopting AVs in NZ. These layers describe the strength and maturity of the trust and governance framework. To establish a strong HMI relationship, users' acceptance and trust rests on optimum AD HFs and legal readiness structure. The smooth proliferation of AVs may only be achieved while resorting to the high end of the influencing layers (Figure 3.13 below).

Figure 3.13

Study Environmental Context for exploring relationship between Trust and Adoption of AVs



The undermentioned **Table 3.3** identifies all AD trust influencing factors for the successful adoption of AVs.

Table 3.3

Holistic Trust Affecting Factors

Factors	Explanation	References	Remarks/Domain
Mental Model	To rightly use the system, the user mind need to figure out the system functions and competencies for assimilation	Lee and See (2004); Toffetti et al. (2009) See rest in above paras	Interpersonal Trust, Institutional Trust, Internal HMI and External System Governance Domain
Situation Awareness & Feedback	Perception of the elements in the environment. A system agent is continuously providing output and behaving like senses.	Dekker and Woods (2002); Desai et al. (2013); Fisher et al. (2020); Lee and See (2004); Verberne et al. (2015). See rest above	Interpersonal Trust, Internal HMI Design Determinant
Training	To improve the user's knowledge, system training is conducted	Ekman (2020a); Parasuraman et al. (2008); Toffetti et al. (2009). See rest above	Interpersonal Trust, Internal HMI Design Determinant
Anthropomorphism	A system that acts more like a human in terms of voice, gender and name	Aremyr et al. (2018); Bartneck et al. (2009); Boyer (1996); Waytz et al. (2014)	Interpersonal Trust, Internal HMI Design Determinant
Familiarity	How the system performed the task was necessary for the participants to trust it	(Nieuwenhuijsen et al., 2018); Tenhundfeld et al. (2019); (Xu & Fan, 2019)	Interpersonal Trust, Internal HMI Design Determinant
Customization and Adaptive Automation	The ability to set non-critical functions as per user preferences and A system that can adapt to user's likings	Helldin et al. (2013); Hoff and Bashir (2015); Lee and See (2004); Verberne et al. (2015)	Interpersonal Trust, Internal HMI Design Determinant, Subset of anthropomorphism
Technology Maturity	Improvement in software systems 'brain' of an AV	(Abbass, 2019; Haboucha et al., 2017); Nieuwenhuijsen et al. (2018)	Interpersonal Trust, Institutional Trust, Internal HMI and External System Governance Domain
Utility	The usefulness of a product economically	Nieuwenhuijsen et al. (2018); (Wang & Zhao, 2019)	Interpersonal Trust, Institutional Trust, External System Governance Domain
Safety Features and Standards	The Government need to make safety standards around manufacturing, vehicle design, infrastructure and communications	Anderson et al. (2018); Ward (2011). See rest above	Interpersonal Trust, Institutional Trust, External System Governance Domain
Security, Cyber Security and Privacy	A self-driving car may be vulnerable to traffic incidents and interruptions, software-related security flaws, viruses and malware	Altawy and Youssef (2016); Anderson et al. (2018); Elmaghraby and Losavio (2014); Kaur and Rampersad (2018); Ljungholm (2020); Taeihagh and Lim (2019)	Interpersonal Trust, Institutional Trust, External System Governance Domain
Price	The Cost of an AV	Nieuwenhuijsen et al. (2018)	Interpersonal Trust, Institutional Trust

3.2.6 Trust via AI and Immersive Technologies Applications for AVs

The acceptance of AVs for current and potential drivers, especially older people and people with disabilities, depends on the design and accessibility of vehicle user interfaces (Ferati et al., 2017). The multi-modal approach seems pragmatic in the backdrop of the users involved in non-driving tasks such as reading or using smartphones and the users with sensory impairment (Hastie et al., 2017; Ji, 2015; Kun et al., 2016). Big data in the realm of AI and the burgeoning rise of immersive technologies comprising Virtual, Augmented and Mixed Reality (VAMR), and Electroencephalography (EEG) environments are creating non-invasive Brain Robot and Human-Computer interaction paradigms (Ma et al., 2020; Rehman et al., 2018). Their perceived utility in the context of AVs will underpin the exciting use of such technologies creating a "brain to vehicle" connectivity, improved SA, portable environment for riders, and provision of safe testing grounds in real-time conditions. Harnessing the collective prowess of these technologies will be at the forefront of predicting, developing, and deploying AVs.

Numerous well-known companies, including Google, Tesla, GM, Uber, BMW, Daimler, Toyota and Baidu, employ advanced technologies in AVs (Sun et al., 2021). AI approaches based on Machine Learning (ML), Deep Learning (DL), and Reinforcement Learning (RL) are being employed to improve the SA and human-like decision capability in AVs. The perceived opportunities and challenges are related to the application of these emerging technologies in big data, high definition maps, and high-performance computing, augmented reality (AR), virtual reality (VR), and 5G communication (Ma et al., 2020). In a recent study survey, various AVs communications (V2V, V2I, and V2X) were grouped into three categories based on transmission range (Ahangar et al., 2021). The study suggested that short-range technologies in strict latency needs, including collision warning and medium range, can be used for V2X communication, whereas C-V2X and 5G-NR were considered key enabling technologies for future intelligent transport systems.

AR can be an effective tool in enforcing conviction in autonomous driving by allowing the vehicle to perceive objects, generate a rationale for decisions, and convey its intent to the driver for manual intervention (Ng-Thow-Hing et al., 2013). It can show a planned lane change to the driver to augment its situational awareness. Additionally, AR Head-

Up Displays are likely to be the future of car navigation and enhanced control mechanisms to improve traffic safety (Basso et al., 2018). VR windshields application will remove the requirements of road signs, traffic lights, and road paintings and reconfigure multi-lane roads based on demand. Measuring the driver state during various stages of cognitive workload under the influence of affective sensing (emotions) with facial analysis and EEG can assist in envisaging the brake reaction time of a driver for designing collision warning systems for autonomous vehicles (Govindarajan, 2017). MR Lab at the University of Southern California has successfully explored human-machine teaming (USC, 2017). It concluded that the training, testing, and practice of the operator and AV algorithms with a pre-configured VR environment is necessary for the successful deployment of AVs. Well-designed user interfaces increase users' trust (Brinkley et al., 2019; Faltaous et al., 2018; Ferati et al., 2017; Helldin et al., 2013; Hock et al., 2016; Karlsson et al., 2018).

3.3 Conclusions and Research Implications

The study arrived at research conclusions and implications that affect users' trust, acceptability, deployment, and implementation timelines of AVs. The study was aimed to develop a holistic trust and governance framework for optimum acceptability and adoption of Autonomous Vehicles (AVs) in NZ. This frame of reference in Chapters 1 and 2 explored the various dimension of driverless technology in AVs. The literature review identified multiple factors, theories, barriers and enablers, perceptions of users, and the role of trust affecting the AD in NZ. The literature review was carried out to provide the solution to the following research questions.

RQ1. What is the significance and futuristic role of driverless technologies internationally and locally within AVs' context?

RQ2. How COVID -19, like pandemic crisis, can affect autonomous driving (AD) technologies?

RQ3. How can the co-evolution of regulations and technology influence the implementation of AVs in NZ and elsewhere?

RQ4. What are the perceived benefits and critical barriers for the deployment of AVs globally and in NZ?

RQ5. What is the significance of human factors (HFs) for autonomous driving (AD)?

RQ6. How do trust and user acceptance contribute to humanizing and adopting autonomous driving (AD) technologies?

RQ7. What are the key AD factors affecting interpersonal and institutional trust during human-machine interaction (HMI) for AVs deployment in NZ?

RQ 8-11. Develop an integrated trust and governance framework and examine its feasibility and validation for AVs deployment in NZ.

3.3.1 Significance of Driverless Technology within AVs Context.

Driverless technology comprising automation, electrification, and sharing is likely to alter the urban landscape and future mobility towards “mobility-as-a-service” (MaaS). ADSs will form the core of the Driverless Technology ecosystem comprising AVs, monitoring centres, and road infrastructure. AVs use Artificial Intelligence (AI), Deep Learning, and real-time HD mapping to ensure safety during driving. AVs are perceived to improve safety and environmental impacts and open new travel options for the elderly, disabled and underage persons.

3.3.2 COVID – 19 Pandemic Impact on Driverless Technology and Research

The COVID -19 pandemic and ever-evolving user and environmental demands for transportation have witnessed a proliferation in the development and deployment of AVs globally. In the aftermath of the pandemic, there is a likelihood of further increase of driverless technologies in the future. It has forced manufacturers to propel AV technology to the next level and, transit from production to R&D. COVID – 19 is likely to have a lasting impact on future mobility solutions. This disruption has created unlimited opportunities in the longer term. Intelligent Transport Systems and COVID-19 safety guidelines set sights on taking human presence out of the loop. Both pursue similar themes of keeping fewer humans in vehicles and supply lines, lower accidental deaths and illnesses, and avoidance of mass movements of people in crowded public buses, rails, and subways etc. There was a pressing need to draw parallels in order to realize a prudent outcomes of the study, though COVID-19 is not an essential component of this research study. Increase use of autonomous technologies and self-driving projects during present crisis forged increased familiarity, dependability and predictability of these technologies which ultimately impact acceptance and deployment.

3.3.3 Role of User Studies and Co-evolution of regulation and Technology.

User experience, real-time user studies, simulations, and testing will be vital in integrating the physical world into the digital world for the acceptance of AVs. Unfortunately, policymakers and industrial stakeholders have so far failed to fill the regulatory vacuum that may ultimately compromise their proliferation and hinders market share profits, reputation, and future electability. Moreover, key determinants affecting AD must be explored in real-world environments employing naturalistic and longitudinal user studies out of protocols of simulated laboratory environments to study how dynamic trust evolves through experience and interaction with technology.

3.3.4 AVs Perceived Benefits and Barriers Globally

The perceived benefits of AVs include economic and social benefits, increased safety and road capacity, reduced congestion, reduced parking costs, and energy consumption. The study found numerous other benefits comprising shared mobility, control of traffic flow, efficient road transport, increased tourism, innovative freight delivery, entertainment, attractiveness, increase in travel speed, and offer of mobility to people who cannot drive. The key barriers include trust, safety, user acceptance, privacy, security/cyber security, Legal readiness structure, and proportioning liability regime. Some others include technology and infrastructure readiness, updating road traffic signs, and associated allied costs towards automation.

3.3.5 AVs Perceived Benefits and Barriers in NZ Environment

NZ low population density, inconsistent safety infrastructure, and road markings, limited funding from private capital and government institutions are significant barriers to the wider development of AVs. NZ mostly relies on 2nd hand cars imported from Japan. There is no company involved in the manufacturing of AVs. Only one transport technology company, ‘HMI technologies,’ ran AV shuttle trials in Christchurch, Melbourne and Sydney, but manufacturing took place from imported technology. NZ supports the testing of AVs due to no explicit legislative requirement of a driver in the vehicle. However, it requires significant improvements at a higher level of automation (level 3 and above). Policy planners in NZ are struggling to imagine the consequence of driverless technology disruption and have adopted a ‘wait and see’ policy. The law changes are needed for liability clarification (criminal and product liability) in AVs offences. It includes speeding and illegal parking, voluntary self-assessment, road code and specific amendments in Land Transport Act. Similarly, AVs users cannot bring a civil action and property damages to court. Moreover, cybersecurity risks and terrorism are likely to have a dampening effect on motivation towards vehicle automation.

NZ people believe in AVs' perceived benefits in reducing accidents, improved fuel efficiency, decreased traffic congestion, reduction in emissions, mobility to disabled people, and reduced insurance premiums. However, people consider lack of trust as a predominant barrier towards acceptance of AVs. Other barriers comprise safety, lack of control, cost, fear of relieving ownership, lack of adequate road infrastructure, and 5G coverage as key barriers towards AVs deployment.

3.3.6 Significance of Human Factors (HFs) Study in Automated Driving.

The HFs knowledge addresses the safety risks and acceptability barriers relating to the deployment of AVs. Human presence in the loop results in AD challenges, including over-reliance, skill loss, handling of lower-level handover situations, complacency, inadequate process monitoring, and behavioural adaptation. It leads to injuries and deaths. It ultimately affects the trust, acceptance, and HMI design process of AVs. HFs knowledge also assists in deploying an effective legal readiness structure to ensure safety in the transportation system.

3.3.7 Significance of Trust and Key Enablers to Driverless technology in NZ.

Users’ Trust is the key enabler to the social acceptance of AVs. It is a multidimensional and multifaceted construct that perpetuates at a period of seconds to decades and acts as a lynchpin towards other enablers. The literature study observed different but theoretically related parameters from numerous areas of research affecting users’ trust in AVs. The study then categorized these parameters in two main domains: Users’ Trust HFs and Legal Readiness domains. HFs domain includes users’ mental model, situation awareness, training, and anthropomorphism. The legal readiness domain includes safety, security/cyber security, and privacy factors. Moreover, it has been observed that these determinants have inter-linkages with both domains and have a significant relationship with the users’ trust.

3.3.8 Significance of the Role of Interpersonal and Institutional Trust in NZ.

Trust mediates people micro intentions on automation reliance and macro interactions for overall public acceptability towards transportation system. System trust rest on the functioning of the bureaucratic legal system that leads to social order addressing its complexities that cannot be pursued from the interpersonal trust. Interpersonal trust forges an effort to manage the interpersonal relationship between humans and machines. This connotation of trust formation in the Driverless technology perspective deserves a relook towards the generation of holistic trust mechanism. The concerns of safety, security/cybersecurity and privacy reside in the folds of interpersonal trust and bear fundamental relevance to institutional or system trust.

3.3.9 Layers of Influence Holistic Trust and Governance in NZ.

Trust and Governance affecting AD Factors can be influenced by three layers model where Trust is the key towards user acceptance of AV technology. The first and second layers include parameters within HFs and the legal readiness domain though having interlinkages that demand investigations and validation. The third layer comprising familiarity, technology maturity, and economic utility of automation, are significant contributory factors in foreseeing the futuristic possibilities of proliferation and implementation timelines for AVs. The layers of influence also indicate the strength of the relationship between trust, legal readiness, and the adoption of AVs. High trust and mature legal readiness structure are likely to contribute towards the proliferation of AVs adoption in a given time and space.

3.3.10 Knowledge gap in Automation Technology Acceptance Models.

Trust and acceptance models and theories widely used in Literature bear their emergence to human-robot interaction or Information Technology paradigms. These theories gradually introduced trust, perceived risk based on safety requirements, personality traits, social influence, and external environment parameters. Lately, Automation Acceptance Model identified trust and compatibility. Both TAM and AAM are not supported by empirical observations despite having strong theoretical background. Theoretical underpinnings of these models do not address the semi-autonomous vehicles and performance implications of ADAS. There is still a lack of clarity and understanding regarding the effects of automation on human behaviour in the context of high autonomous vehicles (HAVs). Particularly when the user confronts a lower level of automation where the vehicle requires human input for full control. The phenomenon of trust and driver acceptance, especially in ADAS, is profoundly complex compared to its application in drones, aviation, and other industries. These theories and models need a fresh look in the backdrop of a unique split-second myriad of safety risks. No modelling theory describes the acceptance domain for AVs considering interpersonal and institutional trust.

3.3.11 Pandora's Box of Levels of Automation and Shared Design Space.

The concept of the Operational Design Domain (ODD) and levels of automation in the context of Dynamic Driving Tasks (DDT) of AVs are central to the capability of the automated driving system. However, the SAE taxonomy of LoA is relatively well defined. However, it is widely debated that automation levels should not be linked to the degree of human intervention alone. It should also be categorized as various transitory stages of the control loop where technology assists human operators. Moreover, with the increasing levels of autonomy, liabilities become blurred, and there is a need to link responsibility more closely to autonomy levels. Hence, there is greater room for deliberations in the context of driver’s SA (environmental monitoring), handover situations, and legal liability against crashes from level 2 to level 4 AVs. Few experts believe that to counter this ambiguity, especially at level 3, the responsibility needs to change to the handover timeline. This requires a further breakdown of taxonomy levels by explicitly looking at the taxonomic categorization concerning the split of liability between the vehicle driver and the autonomous system. From the HMI design perspective, a possible way forward may include moving towards full automation (FAD) and eliminating human operator input at lower levels or making shared controlled devices. Similarly, DDT may either be performed by the operator or automation, and the operator may do multitasking when automation is active, thus reintegrating cooperatively into a shared design space. Additionally, from legal readiness perspective involving liability and other issues, there may only be two levels, i.e., driving with and without human input.

3.3.12 Significance of Multi-modal User Interface.

Multi-modal user interfaces and immersive technologies of virtual, augmented, and mixed reality (VAMR) and Electroencephalography (EEG) environments are likely to create non-invasive Brain Robots and Human-Computer interaction paradigms. These will assist in garnering users' trust towards AVs.

3.3.13 Likely Best Fit AVs Deployment Business Model for NZ.

In the NZ environment, transport systems and infrastructure are likely to evolve continuously, comprising distinct variations emerging in different regions and for diverse needs of users. HAVs and shared ownership are likely to co-exist with conventional and private vehicle ownership pursuing a collaborative consumption in a multifaceted economic model. Thus it would be a social transition instead of a technological transition. Moreover, likely AVs deployment pathways could be creating fleets of AVs in contained urban spaces and incrementally increasing the number of vehicles with autonomous features on NZ roads.

3.3.14 Perceived future timelines of AVs deployment.

Earlier studies hinted optimistically towards AVs implementation timelines. AVs are likely to be commercially available in the 2030s to 2040s. However, these will be costly, providing less driver stress and independent mobility for less affluent non – drivers. The AVs are predicted to be affordable by the 2050s providing benefits of autonomous mobility to a large segment of society, cheap taxi, and micro-transit services. Moreover, it is also pointed out that half of the new vehicles and half of the vehicle fleet will be autonomous by 2045 and 2060. Still, reduced congestion will only take place with dedicated lanes that can allow platooning.

3.3.15 Further Research Implications for this Study.

This conclusion calls for qualitative and quantitative investigations to capture these complexities in the backdrop of AVs deployment in NZ. It is also essential to identify and validate user acceptance requirements addressing internal and external environments and the role of trust based on interpersonal and institutional trust in real-time live traffic conditions. There is a need to examine how and why dynamic calibrated trust develops in specific forms in particular conditions for chalking out a holistic trust and governance framework for NZ. While investigating, the focus would be on critical determinants comprising situation awareness, feedback, mental model, customization, adaptive automation, training, and anthropomorphism. These are depicted as compatibility in AAM, PE in UTAT, situational and dynamically learned trust in Hoff and Bashir Model. Moreover, the privacy, security / cyber security (depicted as FC in UTAT and linkages with Hoff and Bashir Model) specific to NZ settings affecting user trust and acceptability need investigation.

3.3.16 Comparison with Earlier Studies.

An extensive review of the existing and latest knowledge in the subject and its relevance to different aspects of a wider body of knowledge in trust, HMI, and acceptability of driverless technology has been carried out. Most of the earlier studies on the subject are based on conceptual models developed by Mayor, Hoff, and Lee and other models such as TAM, UTAT. These theories fall short of addressing the driverless or semi driverless system in the presence of ADAS in the HMI design process. These studies did not capture internal as well as external environmental factors. Trust is always considered from an interpersonal point of view (taking the lead from human to human), and no study in automaton described institutional trust. This study has attempted to follow a practical approach of creating a calibrated trust framework for AD systems within an HMI design process based on internal determinants and external determinants. Though this study bears similarity to PEOU, PU, and FC as depicted in these earlier models yet ensue a comprehensive approach adding additional factors.

3.4 The Chapter Summary

Users' Trust within the folds of interpersonal trust and institutional trust is a key enabler towards social acceptance and adoption of AVs in NZ. It is a multidimensional and multifaceted construct that perpetuates at a period of seconds to decades. It acts as a lynchpin towards other exogenous and endogenous enablers in two distinct domains, namely 'HFs' and 'Legal Readiness/Governance' categorized by this study. The trust and acceptance theories found in literature and functional levels of automation warrant a relook towards driverless technology in semi-autonomous vehicles that uses ADAS and from a legal readiness context. Policymakers need insights into the co-evolution of regulation and technology to arrive at a mature governance regime towards AV deployment and other stakeholders. Due to its unique characteristics, NZ is likely to see the rise of AVs and shared ownership in tandem with conventional and private vehicle ownership pursuing a collaborative consumption in a multifaceted economic model. Thus it would be a social transition instead of a technological one for successful deployment of AVs in NZ, as suggested by the proposed layers of influence of this Research Study.

Chapter 4 - Research Methodology

4.1 Introduction

This chapter delineates the research methodologies, tools and techniques applied to accomplish the research aim and objectives. This chapter commences with highlighting the philosophical and theoretical perspectives followed by research paradigm and design methodologies. It elaborates the ethical research process and then describes the significance and justification of research methods used in a Multiphase Design to address the research questions. These phases focus on understanding the problem, users' needs that will interact and face the problem, and the enabling context where the users and problem resides. Research aim and objectives drive the choice towards a mixed methodology approach.

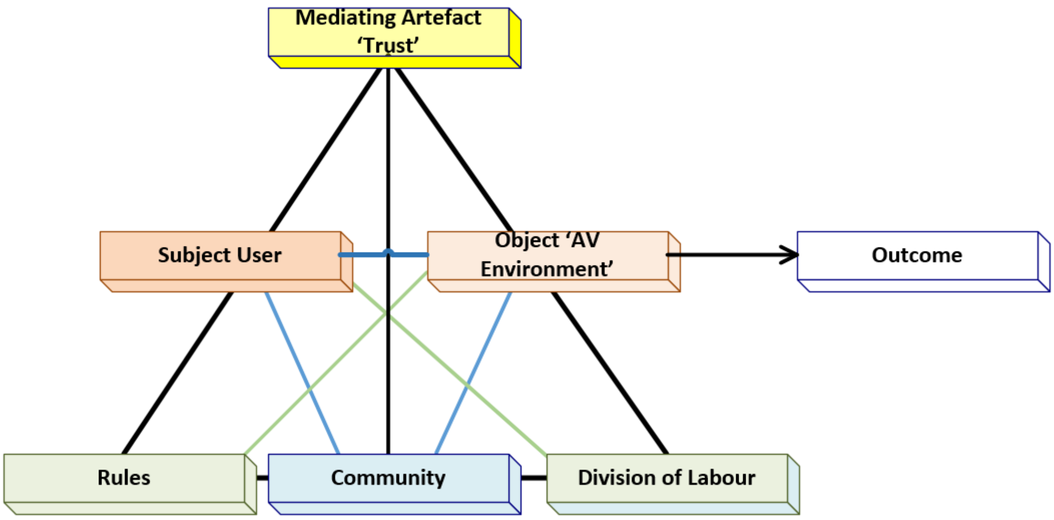
4.2 The Philosophical and Theoretical Perspective

In this objective world, it is impossible to access the truth or social reality using a single scientific method as proposed by the Positivist or Interpretivist paradigms. Instead, the truth lies somewhere pursuing the *Pragmatic paradigm* (Creswell & Clark, 2017; Yvonne Feilzer, 2010) within the folds of dialectical pluralism (Goertzen, 2010). Based on mixed methods methodology, a value laden axiology (research that benefits people), relational epistemology (research relationships are best determined by the researcher) and non - singular ontology (All individuals have unique interpretations of reality) (Kivunja & Kuyini, 2017).

Philosophical worldviews denote the "basic self of beliefs that guide actions" (Guba, 1990; Petersen & Gencel, 2013). It governs how to view the reality surrounding our world and directs the processes of the research. This study aims to realize an appropriate level of trust for optimum acceptability and implementation of Autonomous Vehicles (AVs) in NZ. The research aim and objectives can be well articulated and understood in behavioural science and design science domains due to the convergence of people, organization and technology. The behavioural science paradigm predicts human or organizational behaviour through theory development and verification, whereas the design science paradigm seeks to create innovative artefacts by extending human and organisational capabilities (Hevner et al., 2008). To understand the overall context in the human machine interaction domain, Engestrom's Activity Theory (AT) (Cao et al., 2013; Kaptelinin & Nardi, 2007; Nardi, 1996) best explains the six processes (Figure 4.1 below). It underlines the role of a user (subject) who performs activities with an object (environment i.e., AV) employing mediating artefact (Trust). The mediating artefact is a physical or psychological media that interacts with the community of people or organization (Community), rights and status of people (Division of Labour) and Rules and Regulations (Rules). Trust is a multidimensional and multifaceted construct that perpetuates at a time period of seconds to decades. A person's trust in trustee fluctuates over time with new experiences and knowledge (Ekman, 2020a). User perception is significant in finding out the trust towards deployment of AVs (cf. constructivism (Creswell & Clark, 2017) and perception may be accessed through interviews, questionnaires and mixed methods (Ekman, 2020a; Ekman et al., 2018).

Figure 4.1

The Activity Theory Framework



Note: The AT Framework adopted from *Questions of the Theory and History of Psychology, chapter Consciousness as a Problem in the Psychology of Behaviour* (p.40-41) by Vygotsky, L. S.1925. Copyright Collected Works. Moscow

4.2.1 Research Paradigm, Methodology and Methods

The study is through the lens of the Pragmatic Paradigm, the theoretical perspective of the Design Science Research approach utilizing mixed methods Multiphase Design. The Pragmatic Paradigm supports mixed methods. It seeks to interrogate practical and pluralistic approaches that allow a combination of methods to articulate the actual behaviour of participants, the beliefs and consequences that follow from their behaviour (Kivunja & Kuyini, 2017) which is the main aim of this research study. It is impossible to access the ‘truth’ about the world solely by a single scientific method postulated by the positivist paradigm theorists (Mertens, 2012) or determine social reality as propagated by the Interpretivist paradigm.

Moreover, this paradigm allows methodological pluralism in a concurrent embedded and convergent design methods allowing the convergence of qualitative and quantitative data, thus ensuring validity and reliability (Cresswell & Cresswell, 2018). Epistemologically, it assists in utilizing the logic of inquiry through deduction (testing of hypothesis and theories developed during the process), achieving complementary strengths (Brierley, 2017). Ontologically, it helps realize the significance of the physical and the evolving social and psychological worlds. The pragmatic paradigm rules this research study methodology, i.e. Design Science Research, towards the formulation of research questions, instruments, data collection and analysis. The study is justified using a user study, evaluated by statistical equation modelling (SEM) considering case study of AVs in NZ. It is further explored by systemic dynamic (SD) modelling and semi structured experts’ interviews for overall interpretation and research outcomes.

4.2.1.1 Multiphase Design

The Multiphase Design involve various qualitative and quantitative studies sequentially or concurrently building on one another to address the overarching research question (McBride et al., 2019). The mixed methods Multiphase Design is used to “supplement research strategies to collect data that would not otherwise be obtainable by using the main method” (Morse, 1991, p. 191) and ‘’for the broad purposes of breadth and depth of understanding and corroboration” (Johnson et al., 2007, p. 123). In Phase 1, Concurrent Embedded Design Correlational Model comprising study – 1 (AV user study) and 2 (SEM) is used. In Phase 2, Convergent Parallel Design Model comprising study – 3 (SD) and 4 (Experts’ interviews) is pursued (Figure 4.2). Multiphase Design aims to address the incremental research questions and provide an overarching methodological trust and governance framework for AVs adoption in NZ. The research problem in this study has various dimensions needing different samples, procedures and approaches. Hence, this design seeks to holistically design, develop, test and evaluate the framework through iterative studies in multiple phases (Almeida, 2018; Baran & Jones, 2016; Creswell & Clark, 2017).

4.2.1.1.1 Concurrent Embedded Design Correlational Model

In an embedded design, the quantitative and qualitative studies seek solutions regarding two different research questions within a study (Creswell & Clark, 2017; Fonner et al., 2021) sequentially or concurrently. One form of the data is used in a subservient role and embeds into the main experimental or correlational study (Harrison, 2013). A correlation model is another variant of embedded design where the researcher obtains qualitative data to develop predicting relations in a larger correlation study (Creswell & Creswell, 2018; Creswell et al., 2003). The timings of mixing qualitative and quantitative components are significant in the backdrop of simultaneity and dependence (Guest, 2013). According to Schoonenboom and Johnson (2017), the concurrent design may use dependant data analysis, and sequential could employ independent data analysis.

In this study, the qualitative data (user study – 1 in a supporting role) addresses the primary question in the predominant quantitative study (SEM/CFA study – 2). The qualitative data is embedded in the study – 2 to shape and develop the intervention and use correlations to identify relationships between trust affecting variables. It assisted in explaining the predictive relationships and the trust and governance phenomenon in the implementation of AVs in NZ. The quantitative methodology primarily serves to answer the research question 8 in objective 2. The quantitative methodology provides a solution to research question 9 in objective 3 for identification and evaluation of key trust affecting AD factors during human-AV interaction and discussion of the outcomes. A single data source was not considered sufficient enough. The interpretations were drawn from the convergence of findings and analysis from qualitative and quantitative data. This research design revolves around the social acceptance of AVs in NZ. It has a fundamental bearing on knowing the NZ people aspirations and observing the users' level of trust in real traffic conditions with an AV. Due to the availability of several trust influencing factors in AD in the current literature, the complementary user study was necessary to arrive at the most significant influencing factors for AD in NZ. The final results constitute interpretation and findings against two separate studies as per the design.

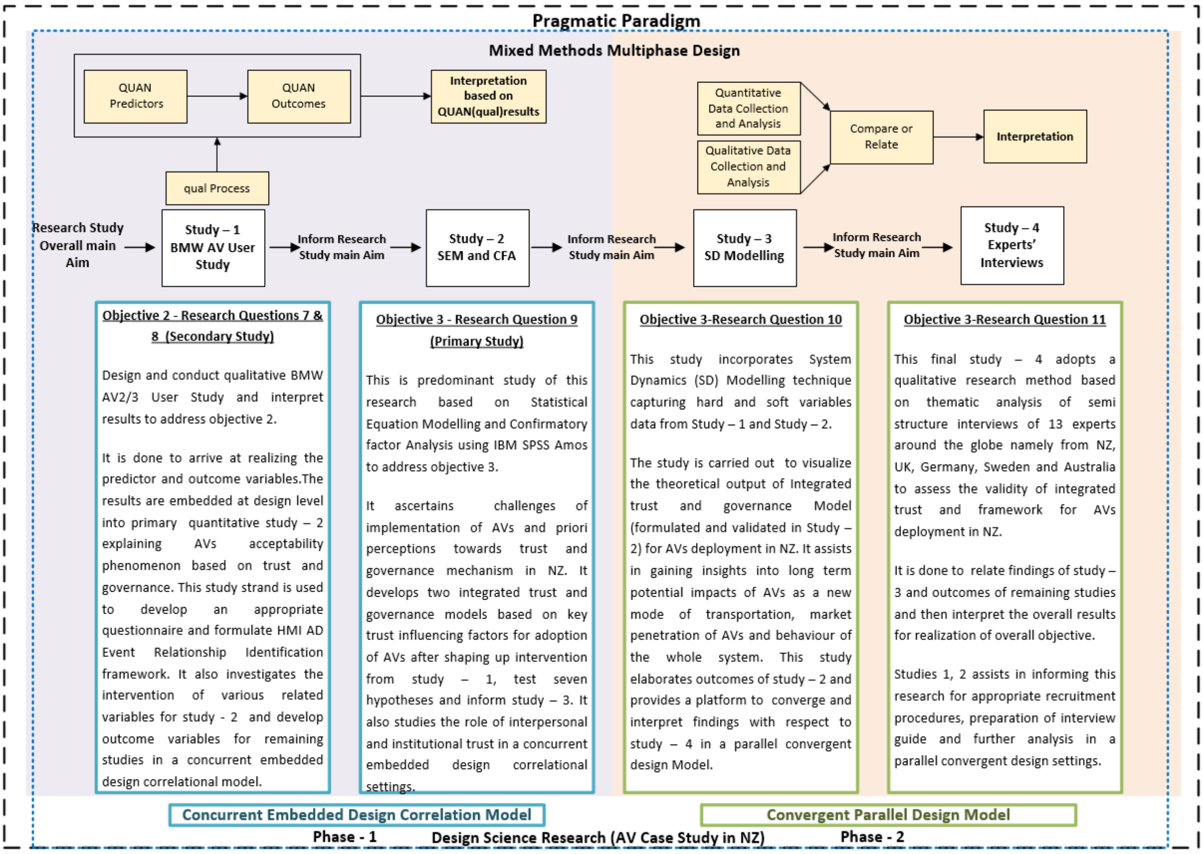
4.2.1.1.2 The Convergent Parallel Design.

It is also known as the concurrent triangulation design (Castro et al., 2010). This research design seeks to "obtain different but complementary data on the same topics" (Morse, 1991). It incorporates simultaneously prioritizing qualitative and quantitative phases (Harrison, 2013; McBride et al., 2019). The integrated results are triangulated during interpretation (Tashakkori & Creswell, 2007). Thus, it harnesses the strengths and dilutes the weakness of independent qualitative and quantitative research (Creswell & Creswell, 2018). This design method is similar to concurrent embedded design, except equal weights are given to both the data sources (Castro et al., 2010).

This design is used to realize all the research questions and objectives. The interpretations provide a complete understanding of the realized benefits, challenges, co-evolution of regulation and technology, diffusion timelines and likely proliferation road map for AVs in NZ. In this design phase, study – 3 incorporates quantitative System Dynamics (SD) modelling technique, and study – 4 uses semi structured experts' interviews capturing follow up data from study – 1 and study – 2. The data and results from study – 3 and study – 4 are collected simultaneously and merged in the research implications. In the end, these interviews and convergence of data assisted in inclusive research analysis and interpretations (Albsoul, 2021). The studies realize the theoretical output of integrated trust and governance framework (developed in Study – 2) in practical ways and give policy guidelines for AVs deployment in NZ. It illustrates the quantitative result with qualitative findings in the next 100 years' timeline chart from 2021 to 2121. This design provides a holistic understanding of AVs deployment phenomenon comparing multiple levels within a system.

Figure 4.2

Research Paradigm, Methodology and Methods



4.2.2 Theoretical perspective – Situating AV Case Study within Design Science Research (DSR) approach

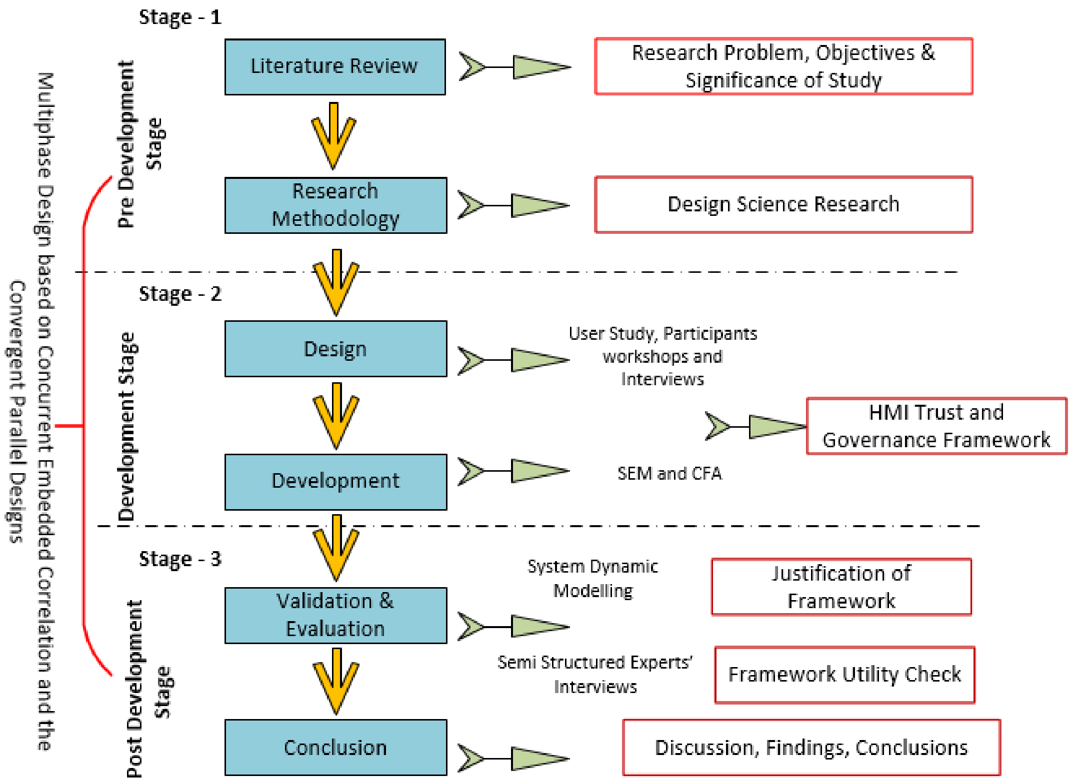
Design Science Research (DSR) is a well-known research approach within the Information Systems (IS) and Business and Management Studies (BMS). It is used to create innovative artefacts, link theory and practice, and develop scientifically grounded solutions to solve real-world problems (Costa et al., 2016; Rocha et al., 2012). The artefact may include conceptual constructs (Peffers et al., 2012) and system design and guidelines (Offermann et al., 2010). DSR is also employed for social innovations and new technical and architecture design theories and practices (Costa et al., 2016). The DSR comprises the construction of a viable artefact (Hevner et al., 2004), the rigorous evaluation of the artefact (Peffers et al., 2012), and the knowledge contribution (Gregor & Hevner, 2013).

In multidisciplinary research, case study research (CSR) can be applied in DSR at *ex ante evaluation* (user study interviews and questionnaires) and ex post evaluation (experts' interviews from various industrial sectors) for naturalistic evaluation/interpretation of the artefact design (Vahidov, 2012). CSR is one of the evaluation methods in DSR. The iteration, design, development and evaluation of artefact occurs in the design cycle of DSR in parallel with CSR. In ex post evaluation, the same procedures for data collection, analysis and validations are applied as ex ante evaluation stage. The difference happens in the selection of new participants for interviews, with the modification made according to the feedback obtained. This approach reinforces the artefact's validation process and generalization of findings (Costa et al., 2016). The knowledge obtained from the existing theories, artefacts and needs from actual case studies transform research objectives to design and development (Yildiz & Møller, 2021). A case study is an "*empirical research method used to investigate a contemporary phenomenon, focusing on the dynamics of the case, within its real life context*" (Yin, 2018). Case studies are generally performed where (1) "how" or "why" questions are used, (2) the researcher has no control or little control over events, or (3) the contemporary phenomena with a real-life context is being explored. CSR is used for inductive, deductive and abductive research (Costa et al., 2016).

The fundamental DSR requirements accepted by all schools of thought is to validate the artefact development using existing theories and guidelines (Österle et al., 2011). In a socio-technical context, the artefact is influenced by the environment in which it operates. This research is in the realm of socio-technological interaction where trust of the people, HMI and AVs deployment phenomenon is being explored. Design Research is significant in IT based hybrid intelligence system artefacts and HMI (Ostheimer et al., 2021). DSR in IS employs designs, analysis, reflection and abstraction in pre-development, development and post development stages for addressing the knowledge gaps (Vaishnavi & Kuechler, 2015). In the first stage of the process, the research proposal is an output of the problem awareness. While the last two steps involve justification using SEM and the framework utility using SD and experts' interviews for validation and evaluation (Benfell, 2021). In DSR, all research strategies should be included, as anyone can be valuable depending upon characteristics and goals, including surveys, action research, grounded theory, experiments, case studies and ethnography (Johannesson & Perjons, 2014). A core research criterion is to set a framework based upon the connection between relevance (context of design) and rigor (the business/environment) and the scientific knowledge. (Cash & Piirainen, 2015; Drechsler & Hevner, 2016; Hevner, 2007; Hevner et al., 2008).

Figure 4.3

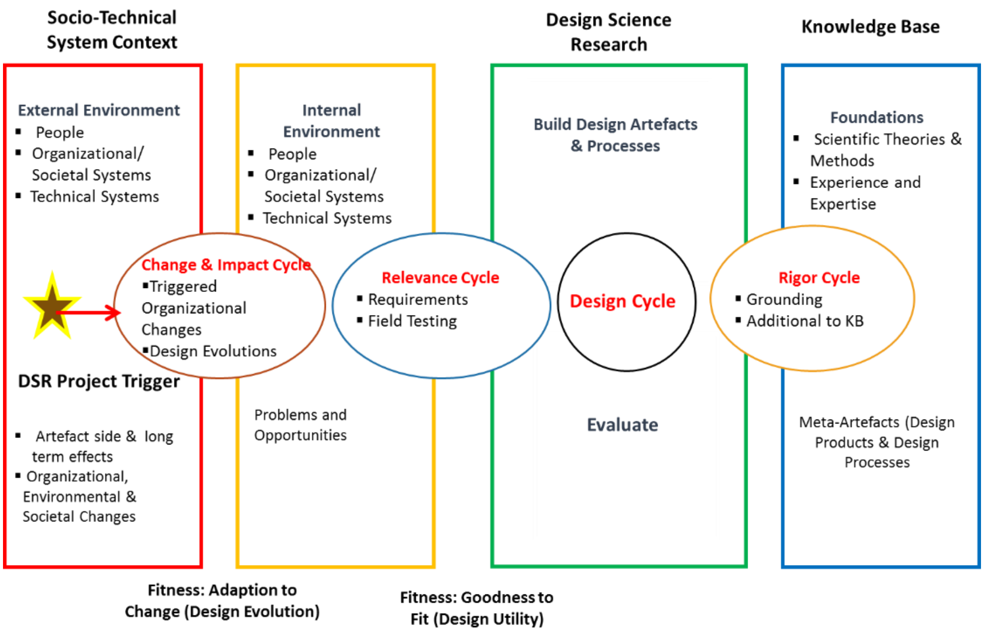
Research Framework



The DSR facilitates the research process by outlining a cyclical development and validation process, thus initially defining the issue in the environment and subsequently evaluating it to be successful for its intended users and environment. After observing the Change and Impact Cycle, design problems, constraints and requirements are identified and fed by the relevance cycle linking the environment with the design (Figure 4.4 below). In the next design cycle, the artefact is synthesized and evaluated until it satisfies the criteria set for design. The last rigor cycle links DSR and the scientific knowledge base feeding the principles of form and function to the design and findings of the evaluation of the artefact back to the knowledge base (Piirainen, 2016). In this model, the design commences with the awareness of the problem occurring due to innovation, i.e. factors affecting AD and lack of trust in AV technology as a critical barrier in acceptability of AVs in NZ. The solution is provided by developing an integrated trust and governance model for the successful proliferation and diffusion of AVs in NZ. Problem is identified from existing knowledge and theory, and development of artefact is done through user study and survey. At the same time, evaluation and validation are carried out through system dynamic modelling and expert's interviews.

Figure 4.4

A Four Cycle View of Design Science Research (DSR)



Note: Adapted from. *A four-cycle model of IS design science research: capturing the dynamic nature of IS artefact design* by Drechsler, A., & Hevner, A. 2016. Copyright Breakthroughs and Emerging Insights from Ongoing Design Science Projects: the 11th International Conference on Design Science Research in Information Systems and Technology (DESRIST) St. John, Canada.

4.3 Research Ethical Approval

This section delineates the research ethical and moral considerations in the study. Ethical approval was sought from Auckland University of Technology (AUT) Ethics Committee (AUTEC). This involved preparing participant information sheets and consent forms, experts' interview guide, details of 'zoom' session methodology, user study and a survey questionnaire, and safety protocols during AD session in a live traffic environment. Details of these are attached as appendices. Moreover, a separate agreement was also prepared and signed between BMW NZ Group and the user study participants, including the author. The approval from the AUT's Ethics Committee (AUTEC), with approval number: 19/282 occurred before the commencement of data collection.

The study ensured that no confidential information regarding the identification of the participants is disclosed unless the participants consent permission (AUTEC, 2020a, 2020b; Petrova et al., 2016). The complete data was anonymised so that it is impossible to reveal the identity of individual responses. No information of the project study was employed for purposes other than the study's objectives (AUTEC, 2020c; Mittelstadt & Floridi, 2016). The accrued information was analysed and reported in which confidentiality of the information is fully guaranteed (Williams & Pigeot, 2017). The project information was shredded, and a small size of data was secured in password protected folder at the end of the research (AUTEC, 2020a). The access was restricted to only the research and supervisory team directly involved in research and data analysis. These research practices were pursued during the entire research process implementing the research approach and theoretical framework.

4.4 Research Methodology

Figure 4.5 describes the detailed research process underpinning multiphase design mixed methods research. It employs the concurrent embedded correlational design in Phase 1 and the convergent parallel design in Phase 2, as discussed above. The study involved four studies in four stages (two studies in Phase 1 and two in Phase 2 concurrently). Stage – 1 comprised a user study with BMW AV level 2, with most of the features of level 3 in an exploratory setting. Stage – 2 involved a quantitative survey and SEM, Stage – 3 SD Modelling and Stage – 4 is based on semi structured experts' interviews. Qualitative analysis reinforced the quantitative analysis process in four stages and two design phases. All phases contributed towards answering the underlying research aim and objectives as below:

Main Research Aim: To develop a holistic trust and governance framework for optimum acceptability and adoption of Autonomous Vehicles (AVs) in NZ.

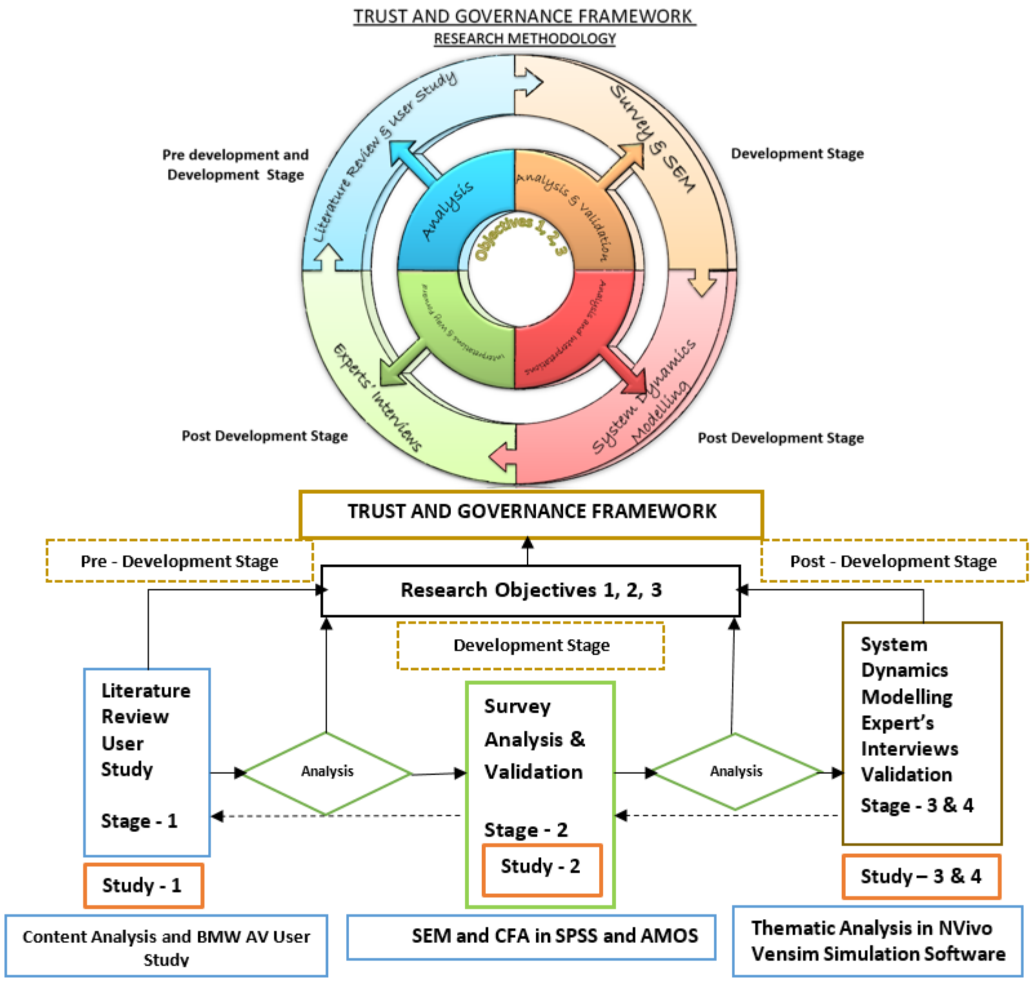
Research objective – 1: To examine the critical perspectives of driverless technologies in the backdrop of the deployment of AVs

Research objective – 2: To analyse the role of key AD factors affecting trust based on significant HMI and governance determinants for the implementation of AVs in NZ.

Research objective – 3: To develop and assess an integrated trust and governance framework for the successful adoption of AVs in NZ.

Figure 4.5

Research Study Methodology in Detail



4.5 Study – 1: Literature Review and Complementary User Study

In Stage – 1, the literature review explores the meaning, composition and correlation of constructs by considering the facts and evidence within the area of study in a specific context (Adlbrecht et al., 2021). Creswell and Poth (2016, p. 15) observed that qualitative research is an inquiry embedded in distinct methodological traditions to explore a social or human problem and is based upon the observations and interpretations of people's perception of various events in a natural setting (Guba & Lincoln, 1994). The literature review assisted in gaining an understanding of how various theoretical constructs relevant to the study relate to each other (Wolfswinkel et al., 2013). Hence, the study synthesized the literature, identified the gaps in the knowledge and provided a theoretical foundation for the proposed research for further knowledge contribution (Paré & Kitsiou, 2017; Sylvester et al., 2013).

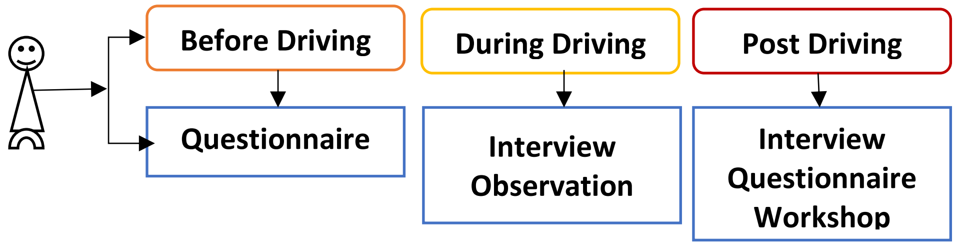
Since the proposed study revolved around social acceptance of AVs in NZ, it has a fundamental bearing on identifying the users' level of trust and perceptions in realistic live traffic conditions. It needed to explore the significant events during interaction with AV having complementary trajectories in HMI trust and governance to generate an appropriate level of trust and HMI design guidelines. Therefore, an AV case study research in the form of a complementary user study with BMW X5 xDrive40i SUV Autonomous Level 2 having most of the functions of level 3 was conducted. Against this backdrop, the users' comments and perceptions form the unit of analysis. The user study furnished context specific input on *what, how* and *when* trust factors affect user's trust besides confirming the relevance of events in user – AV interaction scenarios taking inspiration from few earlier studies (Aremyr & Jönsson, 2017; Aremyr et al., 2018; Ekman, 2020b; Ekman & Johansson, 2015a; Ekman et al., 2018). The goals of the literature study pertaining to user study were to further explore and identify significant theoretical constructs relevant to AVs in HMI and Governance Domain affecting user trust (Kaur & Rampersad, 2018; Parasuraman et al., 2008). The aim of the user test was twofold, first to find out the answer to (1) What are the key AD factors affecting interpersonal and institutional trust during human-machine interaction (HMI) for AVs deployment in NZ?, (2) What HMI AD events are affected by key trust affecting factors during human – AV interaction?

4.5.1 Study 1 – User Study Methodology

User studies delineates people, behaviour and contexts. These adopt qualitative and quantitative approaches to articulate the holistic view and the robust data required to triangulate and validate data collected (Banwell & Coulson, 2004). User studies are effective ways of evaluating everything from visualization methods (Sanyal et al., 2009) to complex environments, including aeroplane cockpits (Sarter, 2006; Sarter & Woods, 1994), surgical simulators and AVs (Ekman, 2020a; Garzon, 2012; Walch et al., 2015). The objective was to develop a guiding framework for holistic trust related factors and design guidelines for successful HMI. Therefore, this exploratory user study comprised users' questions, interviews, brain storming ideation workshops and the use of affinity diagrams (Figure 4.6 and Figure 4.7) during various test sprints. The qualitative data is embedded in study – 2 to identify the relationship between trust affecting variables at the design level in a concurrent embedded correlational design. It assisted in explaining the predictive relationships, and the trust and governance phenomenon in the implementation of AVs in NZ. Its ultimate goal was to find and evaluate context specific factors, events and constructs for the following stages of the study.

Figure 4.6

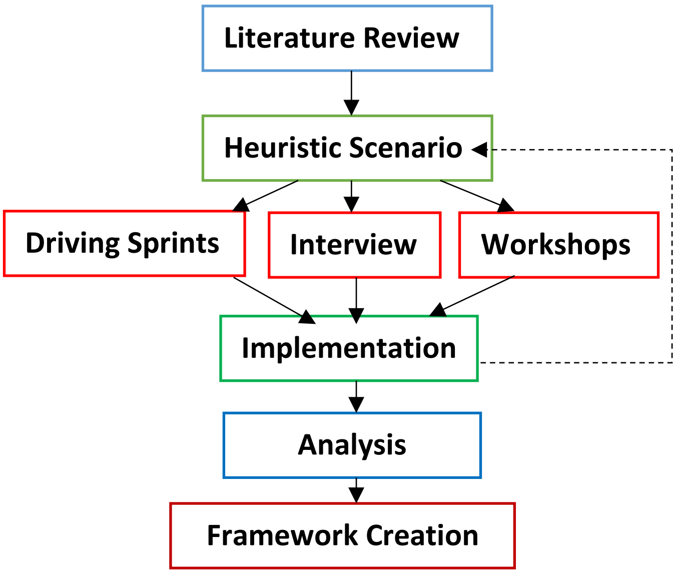
User Study Method Design including Three Phases



The User Study was carried out in collaboration with BMW NZ Group using an Autonomous Level 2 BMW X5 xDrive40i SUV vehicle with most of the functions of Level 3 as this was the only company having AV level 2 vehicles in Auckland. The study was used as a supporting study to embed data in the primary study – 2 and assist in developing predicting relations in identified trust variables. The BMW AV had forward collision warning, automated emergency braking, lane change warning system, parking assistant, driving assistance with adaptive cruise control, auto pilot (ranging from few seconds to a minute). The user study comprised driving sprints/trials in Auckland on high, medium and low density vehicle roads in live traffic conditions.

Figure 4.7

User Study Methodology



The study approach warranted a small, efficient test sample having basic know how of driving to be sensitive enough to detect behavioural changes when exposed to different conditions (Ekman & Johansson, 2015a). Besides, fewer participants can improve their performance while undergoing a scenario number of times. The age and gender of the population most likely to be the early adopters of AVs technologies were kept while selecting participants. In ethnographic HMI based user usability tests, a sample of 5 to 10 participants is considered adequate as one sample can expose 80% usability challenges in 3 - 4 user tests (Rubin & Chisnell, 2008; Stadler et al., 2020).

The user study consisted of a sample of 6 participants: five males and one female, 23-45 years old, holding a full driver’s license and in good physical health, randomly selected after putting an advertisement on social medial. Auckland University of Technology Ethics approval process was followed. Before driving, the participants were informed that they would undergo several ideation workshop sessions. They would be observed during the driving sessions for various autonomous functions, including adoptive cruise control, auto pilot, automated parking assistance and lane keeping assistance and be interviewed. An agreement between participants, including the researcher and the BMW NZ Group, was signed regarding the loaned vehicles formalities and insurances before each user study driving sprint. None of the participants drove level 2 autonomous vehicles earlier, and since they were not experts of AD system, their observations were novel to research.

The BMW X5 SUV Vehicle has almost all characteristics of a level 3. Including the Driving Assistance Plus package with adaptive cruise control (ACC) and lane keeping assist, except that the auto pilot function is switched on from a few seconds to a few minutes depending upon the vehicle’s speed. The BMW system reliably detects hands on the steering wheels and never prompts the user to place hands on wheels. Initially, a BMW training officer drove the vehicle and showed the autonomous functions to the author besides giving a training workshop session to the participants. All sessions with the expert were video recorded. After the introductory sessions, the participants were taken to an initial warm-up driving sprint to get accustomed to the user interface and the vehicle’s driving style. During actual driving sprints, the participants were subjected to questions before, during and post driving sessions. The data was gathered on their driving experience, attitudes towards AD, finding out critical challenges and their perceptions/tendencies to various trust affecting factors. After inquiring about the demographics, the participants' questions were organized around Trust, Anthropomorphism, Safety, Security, Privacy, Legal readiness, Customization, and Adaptive Automation before, during and after driving test runs. The participants were subjected to a number of random conditions. These were (1) pedestrian crossing, (2) lane change, (3) stop light intersection, (4) roundabout, (5) cyclist crossing, (6) stop light intersection, (7) passing other cars opposite lanes. See the detailed user study questionnaire attached in the appendices.

4.5.2 User Study Data Collection, Ideation and Evaluation

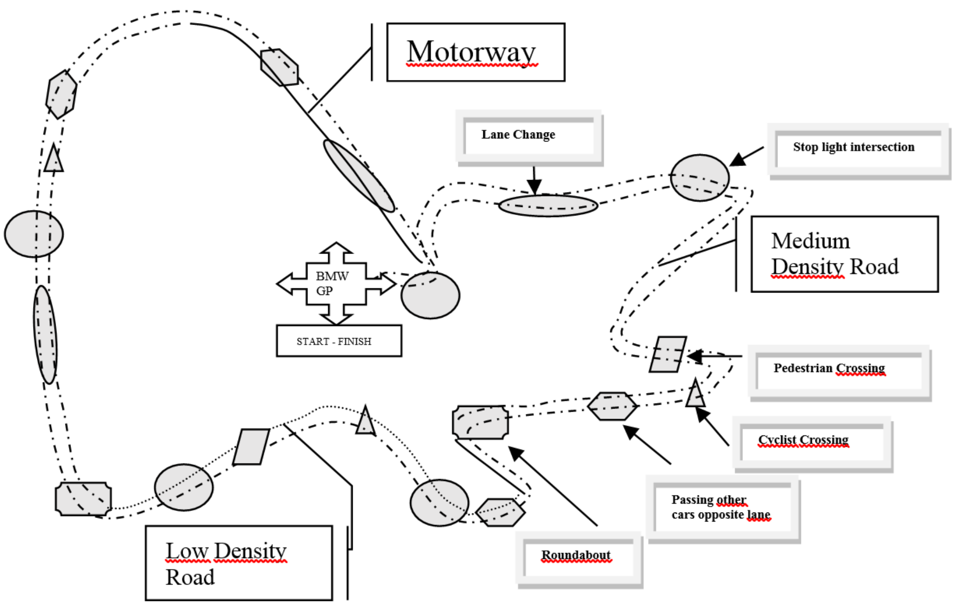
An evaluation study was carried out using Heuristic Scenario based evaluation followed by sketching and storyboards. Heuristic evaluation method was adopted to explore and measure user interfaces usability in independent test runs and report issues for further improvements (Naujoks et al., 2019; Nielsen, 1994; Parkhurst et al., 2019). A scenario is created to explain current user interactions and future perceived interactions to generate and evaluate ideas and communicate solutions (Aremyr & Jönsson, 2017). A storyboard was used as an aid to communicating ideas through graphical representation of a sequence to present interactions (Owensby et al., 2018; Spadafora et al., 2016).

Users brief semi structured interviews were carried out with a view to collect data on their experiences, attitudes and opinions (Aremyr & Jönsson, 2017; Holtzblatt et al., 2005). To understand the users' needs and to reflect on the first-hand experience regarding the context, naturalistic as well as participatory *observations* were noted (Aremyr & Jönsson, 2017). To facilitate users semi structured interviews and observation noting process, an online questionnaire using google forms comprising closed ended, open ended questions was also prepared (Hanington & Martin, 2019). Data analysis was carried out through Ideation workshop sessions comprising affinity diagrams, brain storming and brain writing (6-3-5) exercises after each driving sprint. An affinity diagram is used to assist in categorizing large and diverse verbal data in formulating an overview of themes after sorting, segregating and combining similar ideas of the users (Tague, 2005). The *design sprints* of user driving tests were articulated in consecutive six steps of iterations, including understand, define, diverge, decide, prototype, and validate (Direkova, (2015) as cited in Nashrulloh et al., 2019).

15 workshops involving a BMW training expert and participants were carried out to understand and formulate a Trust and Governance affecting AD factors and Driving Sprint Events Relationship Identification Framework. After resorting to brain writing 6 – 3 – 5 (6 participants, 3 ideas and 5 minutes) and brain storming sessions. In brain writing 6 – 3 – 5 sessions, participants created three ideas each during five minutes before these were passed to the next participant for further development in several repeated times based on brain storming rules (Wilson, 2013). In brain storming sessions, participants' ideas were written down on sticky notes. After the first ideation session, ideas were collected for the participants to review for improvements before a new session started to generate other ideas. Users were subjected to within – subject tests, where all participants were exposed to all conditions of the driving tasks in order to gather large number of observations and reduce the error variance related to individual differences (Charness et al., 2012; Psy330, 2021). The driver test trials with BMW X5 xDrive40i SUV Vehicle were held on medium, low, and high density roads in Auckland to explore various conditions during each user study sprint (Figure 4.8).

Figure 4.8

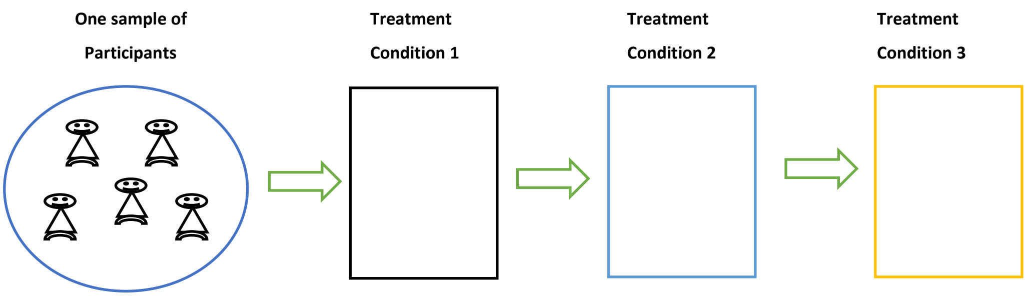
Conditions imposed during Driving Sprints- Low, Medium and High Density Roads



In each driving sprint, 'within-subjects' design was used (Figure 4.9). There are two advantages of 'within-subjects' as compared to 'between-subjects' method. Within-subject design permits more observations and decreases the error variance related to the individual differences (Aremyr & Jönsson, 2017; Charness et al., 2012; Faas et al., 2021).

Figure 4.9

Within – Subjects Design Method



A heuristic scenario was defined by the researcher ideating around two questions; (1) what should be the planned actions of the vehicle during manual and AD mode translated into events? (2) What trust factors / key determinants are to be selected against those events? Moreover, vehicle actions were also defined as a result of these events in the real time environment along driving courses. Then various events, including before driving, entering the vehicle, activating vehicle, manual mode 1, automated mode, manual mode 2, exiting vehicle and continuous usage, were defined in workshop sessions. The researcher assisted the participants during their drives and various workshop sessions (Aremyr & Jönsson, 2017; Aremyr et al., 2018; Ekman, 2020b; Ekman & Johansson, 2015b; Ekman et al., 2018). The participants commenced driving in the manual mode, later activated the auto pilot (transition from human driving stage to autonomous driving), then back to manual mode after deactivating the auto pilot. However, during the drive, the participants activated the auto pilot system, adaptive cruise control and lane change a number of times. Before and during the driving scenarios, the users were asked various event specific questions to get to know their feelings, trust and confidence in the system. Next, these were mapped onto the timeline of a driving scenario using sticky notes to make it more tangible. Later categories/ trust factors were defined: mental mode, anthropomorphism, adaptive automaton, customization, safety, privacy, security, training, and feedback. After selection, categories were ranked based on their relevance to the research question. Later a matrix was constructed to find the relative importance of these factors/categories against various events to finalize key determinants.

4.6 Study – 2: Structural Equation Modelling (SEM)

An exploratory survey "Humanizing Driverless Technology" was designed on 5 point Likert scale (Kinnear et al., 1993), embedding data from user study after the driving sprints. The survey was analysed using Structural Equation Modelling (SEM) with the main focus to address research objective 3. This study developed and validated the integrated trust and governance model based on identified latent trust constructs (unobserved variables) and their observed (manifested) variables.

4.6.1 Significance of Study – 2.

This study assisted in knowing the aspirations of the NZ general public towards AVs, challenges towards implementation and prior perceptions on trust and governance mechanisms. It assisted in the validation of trust affecting factors regarding the adoption of AVs in NZ. SEM is used at this stage to carry out an analysis of conceptual theory developed in this research relevant to the phenomenon of trust and AVs adoption in NZ. This analytical technique statistically estimates and confirms the interrelationships between various trust corroborating latent factors (through observed variables), examine dependencies and test hypotheses (Hair et al., 2010). The SEM has already been applied in acceptance of the driverless technologies domain in number of earlier studies (Kaur & Rampersad, 2018; Nastjuk et al., 2020; Nordhoff et al., 2021; Yuen, Huyen, et al., 2020; Zhang et al., 2020). Ali et al. (2018) highlighted the advantages of SEM in testing latent constructs, statistical assumptions and relationships. SEM has been selected and justified for this study, keeping in view the main aim of this research and associated advantages.

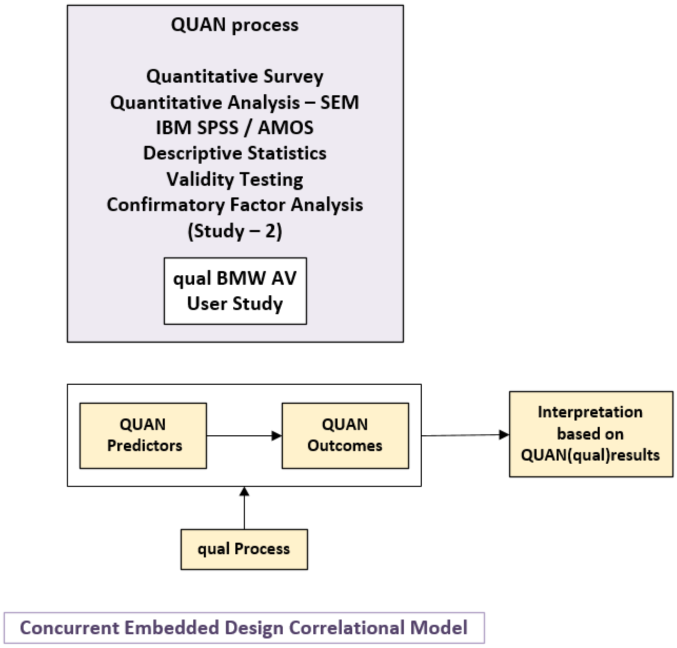
The research study articulates and tests seven hypotheses, correlation between user factors and governance factors on adoption of AVs in NZ. It also validates the role of trust as a mediator in this relationship. For descriptive statistics, SPSS V26 and for statistical analysis, AMOS version 26 is used. Statistical analysis is divided into two parts, i.e. a first measurement model and then a structural model. Validity, Average Variance Extracted (AVE), discriminant validity, and outer lodgings were identified and discussed in the measurement model. Furthermore, the bootstrapping procedure was run to check the structural model. The constructs and measures that are proposed and employed in this study form a significant contribution to the literature.

4.6.2 Survey Design and Data Collection Methodology

Study – 2 is based on a quantitative survey conducted within the AV case study in NZ in a concurrent embedded correlational design setting. The data for qualitative Study – 1 and quantitative Study – 2 were collected concurrently. A survey design includes data collection and analysis (Cooper & Schindler, 2013), which logically links data to the initial research questions (Yin, 2018) and explores trust factors observed in literature review and complementary user study. Quantification enhanced theory development adds transparency, reliability of measurement and application in various industries (Blaxter et al., 2010; Veal, 2005). Figure 4.10 illustrates the research design of Study – 2 within the overall research design of this study.

Figure 4.10

Research Design for Study – 2



A questionnaire survey on online Qualtrics platforms was administered anonymously, comprising 18 questions (see appendix). Respondents were asked various demographics, concerns regarding AVs implementation in NZ, their adoption preferences, factors affecting adoption, and their relative priorities. The strategy operated on statistical sampling, thus choosing a representative sample from the population (Fellows & Liu, 2015). According to Fowler Jr (2013), the minimum sample sizes could be focused on instead of estimating the total population. For example, a sample of 150 people can describe a population of 15,000 or 15 million with the same degree of accuracy. To have balanced views, a random sampling was done as "each individual in the population has an equal probability of being selected" (Creswell & Creswell, 2018). 429 respondents in NZ replied from July to Sep 2020, having a minimum of one year of driving experience. The questionnaire was designed using a 5-point Likert scale (Allen & Seaman, 2007; Brown, 2011) from strongly agree to strongly disagree, strongly concerned to strongly unconcerned, very likely to very unlikely on an adopted scale. Likert scales are a simple, straightforward method to collect responses (Kinnear et al., 1993). Multiple choice questions were used for demographic information. The Likert scale contained various symmetric agree-disagree items representing the strength of the responses and indicating stating users level of agreement (Likert, 1932). For easy assimilation and answering of survey questions by the general public in NZ in a short time bracket 5 point Likert scale was used in this research.

4.6.3 Theoretical Framework Development for Integrated Trust Model and Hypotheses of the Study

There are several factors identified in the literature (Chapter 2) affecting AD from earlier studies and technology acceptance theories. However, these factors vary geographically due to distinct barriers in the implementation of driverless technologies. A number of research studies ventured into capturing these factors. However, due to the limited scope, uncertainty in a higher level of automation, reliance on public surveys or simulations alone, none of the studies have explored these factors fully. Moreover, earlier studies did not identify interpersonal and institutional trust linkages from integrated trust and governance views. Additionally, public surveys are unable to provide true acceptability preferences as people never used such technologies. Similarly, simulation studies cannot substitute live traffic user studies to predict driver behaviour in the absence of any risk. Hence, it was necessary to comprehensively examine these factors globally and subsequently in NZ enabling environment in the backdrop of peculiar challenges. And then explore and verify AD factors in a realistic user study. Therefore, an extensive literature review was done to provide a detailed account of key barriers leading to significant trust affecting factors for AD in NZ. These factors were then further reorganized and verified by the user study.

Next a conceptual, theoretical model was constructed having three second order latent (unobserved) constructs, namely safety, security/cyber security and privacy in the legal readiness domain. Whereas six first order latent constructs were identified, namely trust, adoption, legal readiness, training, situation awareness and anthropomorphism, and three second order constructs i.e. safety, security and privacy. These constructs were analysed through 46 indicator items (manifested variables) (Table 4.1) and seven hypotheses. Considering the interrelationships of the trust affecting constructs among each other towards adoptions of AVs in NZ, two conceptual integrated models were developed. In the first integrated model, six hypotheses were tested without keeping construct 'trust' as a mediator between legal readiness and adoption (Figure 4.11). In the second integrated model, hypothesis 2a was tested to estimate and verify the 'trust' role as a mediator between legal readiness and adoption (Figure 4.12) and to confirm interpersonal and institutional trust linkages towards the adoption of AVs in NZ.

Model A *(without Trust role as mediator)*

H1: There is a positive and significant relationship between legal readiness and adoption.

H2: There is a positive and significant relationship between legal readiness and Trust.

H3: There is a positive and significant relationship between situation awareness and trust.

H4: There is a positive and significant relationship between training and trust.

H5: There is a positive and significant relationship between Anthropomorphism and trust.

H6: There is a positive and significant relationship between trust and adoption.

Model A *(with Trust role as mediator)*

H2a: Trust mediates the relationship between legal readiness and adoption.

Figure 4.11

Model A (without mediator)

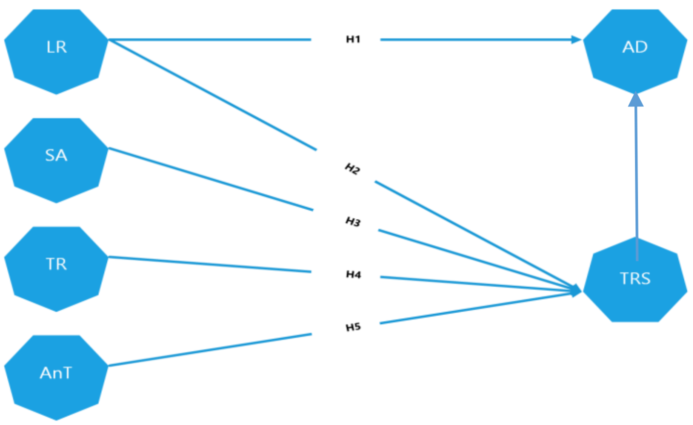
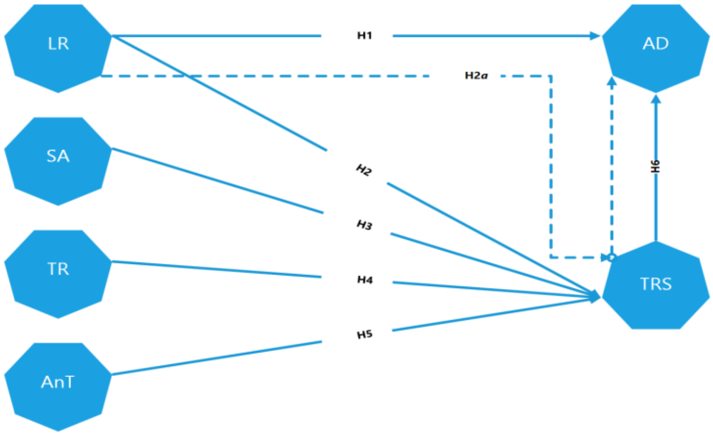


Figure 4.12

Model B (With Mediator)



4.6.4 Operationalization of Constructs and Theoretical Framework

Key constructs were identified based on extensive literature review, determinants affecting AD in NZ and an AV user study (identified in Table 3.3 and Table 2.3). Hence finalized latent constructs (unobserved) explored in the study – 2 and their manifested (observed) variables are as below (Table 4.1).

Table 4.1

Constructs and Manifested Variables Study – 2

Latent/ Constructs First Order	**Construct Second Order**	**Manifested Variables**	**Abbreviations used in Model**
Governance Structure/ Legal Readiness (LR)	**Privacy (PRI)** (Glancy, 2012; Schoettle & Sivak, 2014a)	(1) Data Privacy (Personal and location information) of the Users (2) Personal Autonomy (Making your choices instead of AV) (3) Personal information Privacy (4) Targeted Surveillance	PRI_1 PRI_2 PRI_3 PRI_4
	Safety (SAF) (Kaur & Rampersad, 2018; Venkatesh et al., 2003)	(1) Enough Safety safeguards (Equipment and personal) to make user feel comfortable while driving AV (2) Reliability of underlying technologies and user interfaces in AVs (3) Assurance from Government to protect user from problems associated with AVs	SAF_1 SAF_2 SAF_3
	Security (SEC) (Schoettle & Sivak, 2014a)	(1) Probability of Software failure during operation of AVs (2) Probability of hardware failure (3)Vehicle and System Security (hacking/terrorist activity) (4) Network security with transport infrastructure and other AVs	SEC_1 SEC_2 SEC_3 SEC_4
Trust (TRS)	(Helldin et al., 2013; Kaur & Rampersad, 2018)	(1) I feel safe if I own a self-driving car? (2) I will trust the self-driving car in heavy and light traffic conditions? (3) I am willing to give up control to an autonomous car? (4) Driverless cars can provide a robust and safe mode of transport. (5) I put faith in autonomous cars. (6) I think autonomous cars are reliable. (7) I trust self-driving cars.	TRS_1 TRS_2 TRS_3 TRS_4 TRS_5 TRS_6 TRS_7
Training (TR)	Hancock et al. (2020); Reason et al. (1990) Lajunen and Summala (1995), Spolander (1983)	(1) I think continuous training on the AV systems can make me more proficient in handling unexpected situations (2) I think regular testing of my driving skills would assist me in taking control back from the AV.	TR_1 TR_2
	(Filip et al., 2016)	(1) The car's capability of "sensing" its surroundings would influence my trust in it (accuracy of the sensors)	SA_1

Latent/ Constructs First Order	Construct Second Order	Manifested Variables	Abbreviations used in Model
Situational Awareness (SA)		(2) The ability to take back control from the vehicle in less than 20 seconds would influence my trust in it.	SA_2
		(3) Effectiveness of the car's learning curve (making judgments on the information received) would influence my trust in it.	SA_3
		(4) Amount of information that the car can access would influence my trust in it	SA_4
		(5) Amount of roadway information available to the car (weather, traffic, constructions, etc.) would influence my trust in it.	SA_5
		(6) Feedback (audio, visual, haptic or combined) would influence my trust in it.	SA_6
Anthropomorphism (Human like features) (AnT)	Aremyr and Jönsson (2017), Bartneck et al. (2009) Helldin et al. (2013)	(1)I would like to drive the AV if it carries human like voice to interact	AnT_1
		(2)I would put faith in AV if during transfer of control I get visual, auditory and haptic cues like vibration alerts	AnT_2
		(3)I think the autonomous vehicles are reliable	AnT_3
		(4)I like a self-driving car having user interface with eye tracking, emotion detection, gesture and biometrics	AnT_4
Adoption (AD)	(Kaur & Rampersad, 2018)	(1) Taxis that are fully self-driving	AD_1
		(2) Social Activities (dinner, events etc.)	AD_2
		(3) Daily commute (work, University)	AD_3
		(4) Closed areas (University, Airports)	AD_4
		(5) High Pedestrian activity	AD_5
		(6) Congested Traffic	AD_6
		(7) City Streets	AD_7
		(8) Drive on High ways and then driver takes over control of AV	AD_8
		(9) Public transport or shuttle bus with chaperone	AD_9
		(10) Drive on Freeway / Highway	AD_10
		(11) Car with No driver	AD_11
		(12) Long Road Trips(holidays) on country roads	AD_12
		(13) Finding a Car park	AD_13
		(14) Riding in a vehicle with no driving controls available like no street wheel, no brake pedal, no accelerator	AD_14

Latent/ Constructs First Order	Construct Second Order	Manifested Variables	Abbreviations used in Model
		(15) Drop off or pickups by children	AD-15
		(16) self-driving vehicle moving on themselves from one location to another	AD-16
		(17) Public transport or shuttle with no driver chaperone	AD_17

4.6.5 Pre-test and Hybrid Structural Equation Model Development

For initial testing of the survey instrument, a pre-test was done to ensure reflective measurement development of the constructs, content validity and the questionnaire's semantics (Chen & Yan, 2019). Experts in the field of investigation having theoretical / practical experience are often asked to provide a review or critique of likely measurement error and an answering breakdown structure in a questionnaire (Ikart, 2019). The expert reviewers range from 2, 3 to over 20 (DeMaio & Landreth, 2004; Olson, 2010). In this study, 7 experts were initially selected and approached through the LinkedIn platform. However, 3 experts agreed and signed the consent form. The experts were given access to the survey questions. Later, a brief interview was also arranged on zoom technology for clarification and detailed note taking. One expert suggested the significance and calibration of trust as a mediator and the importance of governance legal readiness and regulatory structure incorporating safety, security and privacy in the questionnaire as a second order construct. Another expert pointed few amendments in two demographic questions to make these distinct and adequately measurable.

The central purpose of the dataset rests on testing the research models that diagnose the impact of Trust and Governance Structure on the successful adoption of AVs and the mediating role of the 'trust'. After formulating the conceptual framework, the structural equation model (SEM) for this research is developed using IBM SPSS and Amos version 26 software. IBM® SPSS® Amos™ is an easy-to-use SEM software that tests interrelationships among observed and latent (unobserved) variables and tests hypotheses quickly in a confirmatory approach (IBM, 2021). A hybrid structural equation model integrated the measurement part and the structural model. With this model, the study understood which variables were included in the quantified model, and the expected theoretical and observed empirical relationships. The measurement model section explained the theoretical interactions between unobserved/latent variables and the observed/measurable variables. A structural model part examined the open links within the constructs and explained the direct and indirect causal relationships.

4.6.6 Study – 2 Data Analysis

Before performing an analysis, data screening was executed to check missing values. Microsoft MS-Excel was used, applying the COUNTBLANK formula. Preliminary descriptive analysis was undertaken using SPSS V26 to understand the respondents' profile, concerns and willingness to adopt AVs by finding out mean and standard deviation to analyse and rank the data (Kaur & Rampersad, 2018)**.** The data were checked for normality and evaluated for reliability and validity. The normality was checked against skewness and kurtosis for bias (Andersen & Kumar, 2006; Anderson et al., 2018; Hair et al., 2006). Skewness indicates the symmetry while kurtosis pertains to peakedness of distributions, with maximum acceptable levels of 2 and 7 (Stephen G West et al., 1995)**.**

Then the data is statistically analysed by applying exploratory and confirmatory factor analysis (CFA) using Amos software followed by hypothesis testing to determine the influence of each trust factor on the adoption of AVs (Bentler & Bonett, 1980; Costello & Osborne, 2005). The analysis commenced with exploratory factor analysis to comprehend the structure of the variables, and find out the instrument's correlation and validity for the NZ region. Next CFA, was performed to confirm the factor structure and specify how each construct is measured. This process assists the research to test the hypothesis that a relationship between observed variables and their underlying construct exists (Suhr, 2006)**.** After screening of data, checks for the validity and reliability of constructs were done. Reliability refers to the level of consistency and exactness of the measurement, whereas validity indicates the level of accuracy (Nunnally, 1970). The constructs needed to exceed the minimum value of 0.7 (Kline, 2016). Similarly, reliability is also calculated using data outputted AMOS on standardized item loadings and error measurement, and it exceeded the minimum threshold of 0.7 (Hair et al., 2006). Items loadings are also found above the acceptable level of 0.5 for convergent validity for all factors (Steenkamp, 1991).

The applicability of the proposed model is examined by observing data employing various popular indicators and recommended threshold standards (Awang, 2012; Bentler & Bonett, 1980; Hu & Bentler, 1999; Moss, 2009). The EFA analysis is based on principal axis factoring and rotation method on Promax with Kaiser Normalization. The specific acceptable threshold value for the goodness-of-fit measures, including chi-square value X2, Root Mean Square Error of Approximation RMSEA, Standardized Root Mean Square Residual SRMSR, Normed fit index NFI, Tucker-Lewis coefficient Index TLI and Comparative-fit-index CFI and others were met. Construct Reliability, Indicator Reliability, Discriminant validity and Convergent Validity for CFA (second order) were also evaluated. Through hypothesis testing, the results provided the empirical evidence of the trust factors (details in Chapter 4).

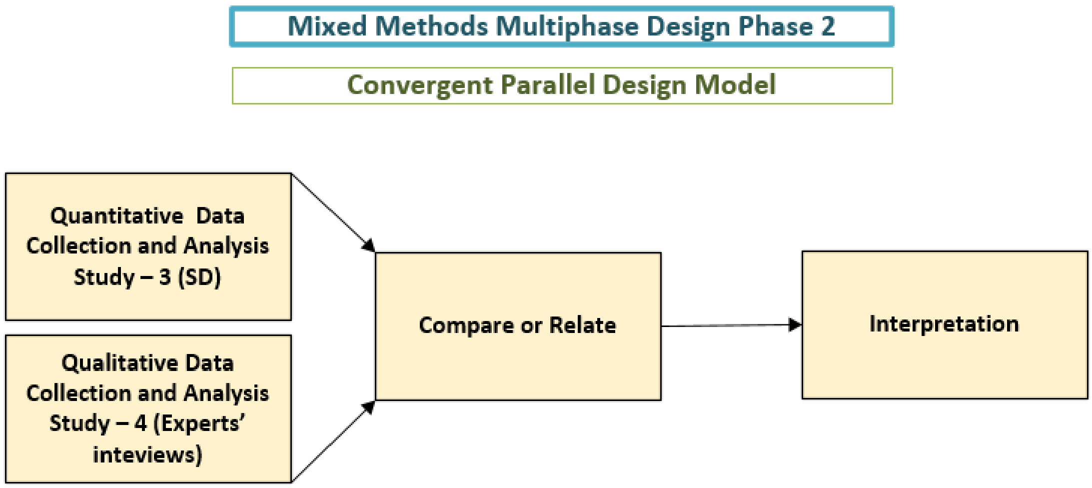
4.7 Study – 3: System Dynamics Modelling

Study – 3 incorporates System Dynamics (SD) modelling technique capturing hard and soft variables data from Study – 1 and Study – 2. Study – 3 is pursued concurrently with Study – 4 in a convergent parallel design in Phase 2 of the Multiphase Design. The study is carried out to visualize the theoretical output of the holistic trust and governance framework (formulated and validated in Study – 2) for AVs deployment in NZ. It assists in gaining insights into the long term potential impacts of AVs as a new mode of transportation, market penetration of AVs and behaviour of the whole system. Moreover, it provides a pragmatic realisation of policies utilizing the theoretical framework as a basis for designing policy interventions and transport investment decisions in NZ.

This SD study developed a unique simulation model for NZ depicting dynamic interrelationships among significant identified construction in a quantitative way (details in Chapter 4). The model utilizes innovation diffusion theory for the adoption of AVs in NZ. SEM is applied to SD modelling using Vensim software to include 'soft' variables of trust, situation awareness, training, anthropomorphism, and legal readiness into the feedback model. The model then investigates the relationship between the soft variables and additional observable variables such as familiarity, comfort, technological maturity, price and vehicle change etc. The study categorises AVs in six SAE automation levels (discussed in Chapter 2) on a functional basis characterising each level with its fleet size, technology maturity, average purchase price and utility (based on trust, legal readiness, comfort and familiarity).

Figure 4.13

Research Methodology for Multiphase Design Phase 2



4.7.1 Justification of SD Study

This study explores the real time quantitative insights into the market penetration of AVs in NZ over a long time horizon based on significant determinants observed in studies -1 and 2. Hence, it needed to apply a modelling approach that can be applied to uncertain, dynamic and complex systems as forged by this innovative technology. AVs are an entirely new phenomenon that is at the start of the product life time cycle. Its futuristic demand and deployment need realistic articulation in the backdrop of trust and sound technological and legal readiness structures. To observe the speed and direction of the deployment of AVs over a longer time, it is necessary to study the aggregated system behaviour. Several research methodologies were studied. However, simulation seems more appropriate. These simulation approaches are generally based on Agent Based Simulation (ABM) (microscopic) and System Dynamics modelling SD (macroscopic) (Nieuwenhuijsen et al., 2018). ABM is suitable once there is less data available regarding macroscopic behaviour and more data regarding individual behaviour of agents (Borshchev & Filippov, 2004). This study accrued more knowledge about the aggregate phenomenon of overall structure and assumptions and less on detailed behaviour of individual AVs. Hence the SD Modelling approach was pursued to focus on the behaviour and interaction of variables.

4.7.2 Significance of SD Study and Dynamic Synthesis Methodology

SD technique incorporates both qualitative and quantitative methods for analysing complex systems, as identified by Jay Forrester at MIT in 1957 (Kunc, 2018; Lane, 2000, 2006, 2010). It discovers and represents the feedback processes, stock and flow structures, nonlinearities and time delays to find the dynamics of a system. Most complex behaviours usually arise from the interactions (feedback) among various parts of the system (Sterman, 2000). In 2000, Lane highlighted the SD Modelling approach as follows:

> 'SD has three characteristics. First is the concept of information feedback loops of causal links comprising delays and non-linearities as well as processes of accumulation and draining. The second is rigorous computer and the third is to engage with mental models of the decision makers for improved ways of managing a system'. (pp.4)

This study endeavours to venture into a rare research design of integrating SD modelling and AV Case Study, which has not frequently been applied in engineering process modelling and improvement requirements (Finkelstein, 1994; Sydenham, 1982; Williams, 2002). To study the real world diffusion and deployment of AVs in NZ and the following sequence of events, the research followed Dynamic Synthesis Methodology. Dynamic Synthesis Methodology (DSM) describes the amalgamation of theoretical concepts, configuring parts and components of a process over time to constitute a formal functional entity for improved synthesis and assimilation of literature, social theories, and stakeholder concerns (Williams, 1999). The utility of SD Modelling in DSM is its ability to harness 'hard' and 'soft' concepts into a formal model, thus articulating theoretical constructs that impact the research phenomenon under investigation by the modeller (Gable, 1994; Randers, 1980). Wynekoop (1992) recommends that 'micro level' quantitative analysis be fused with qualitative 'macro-level' analyses to observe the individual variables' behaviour impact on an organisational phenomenon. The DSM thrives on six iterative steps, namely: Problem statement, Field studies, SD Model Building, Case studies, Simulation experiments and Model Use and Theory Extension (Williams, 1999). System Dynamics (SD) Modelling is used to observe the AVs adoption based on the complexity of various relevant interrelated human factors and technological determinants through a functional pathway. The functional pathway is based on a gradual transition from basic or no automation towards partial, high and full automation of AVs. Spatial pathway relates to specific operational design domains of highways as a sudden step from no automation to full automation. This study's functional pathways include level 0 (no automation) to level 5 (full automation) based on the SAE standards.

The AVs diffusion is based on an innovation system where 'the innovation and diffusion of technology are collective and individual acts' (Edquist, 2001). It is not limited to a specific country or region. It thrives on Technology Specific Innovation System (TSIS) described by Hekkert et al. (2007), where economic and institutional systems affect the rate and direction of innovative technology. The automobile fleet size, current infrastructure and population growth rate and GDP of a particular region or country are significant determinants of the adoption rate and market penetration of ADAS. This study model is generally prepared in the backdrop of Nieuwenhuijsen modelling approach (Nieuwenhuijsen et al., 2018) and is intended to be within the limits of the advanced world. However, it focuses specifically on New Zealand dynamics due to the enormity and complexity of data availability.

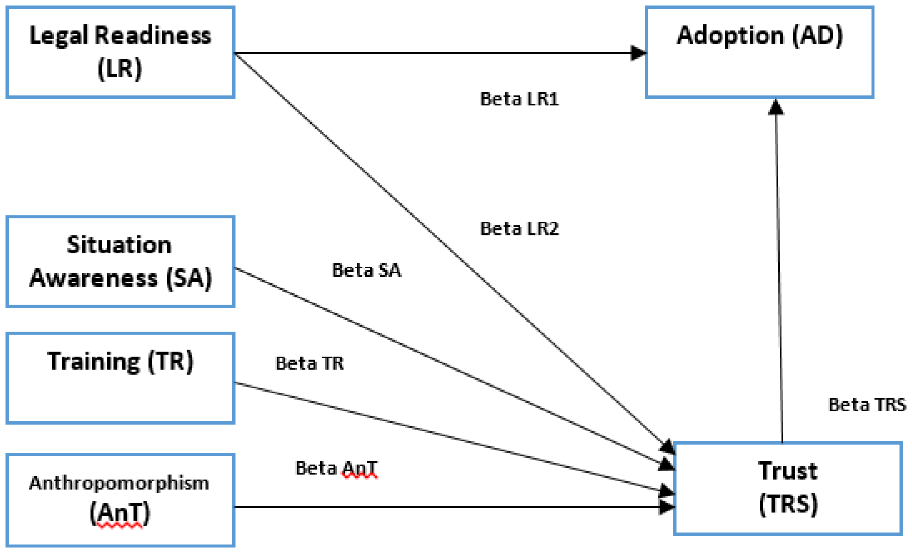
Moreover, the study required testing the model within the folds of AVs deployment case study in NZ. Therefore, the model was applied to the NZ for *a* Base, optimistic High Automation with high trust and Governance mechanism and conservative Low Automation with low trust and Governance mechanism Scenarios. Base scenario values were mainly chosen from study – 1 and study – 2. For optimistic scenario, high trust and legal readiness variables were simulated. Whereas, for conservative scenario low trust and legal readiness variables were simulated (see Chapter – 4).

4.7.3 Data Inclusion from SEM to SD Modelling

Three types of data, namely numerical, written and mental, are used to formulate and structure decision rules in models as per the priority significance of data (Forrester, 1980). During the formulation of the simulation model, SEM is applied to the SD Modelling containing soft variables into feedback loops while identifying the relationships between unobservable, observable and auxiliary variables (Houghton et al., 2014; Medina-Borja & Pasupathy, 2007). In study – 3, constructs identified in earlier studies are used. In this way, SEM assisted in drawing association among abstract concepts and constructs, which otherwise would have been extremely difficult. The finalized beta values from SEM for various variables in conjunction with other unobserved variables (Figure 3.12 and Figure 3.13 Chapter 2) are controlled according to the mental model of the author during the SD Modelling process (Figure 4.14). The detailed SD process is given in Chapter 4.

Figure 4.14

Data Inclusion SEM to SD for Quantified Constructs



Hypothesis	Relationship	Std. Beta
H1	LR → AD	Beta LR1
H2	LR → TRS	Beta LR2
H3	SA → TRS	Beta SA
H4	TR → TRS	Beta TR
H5	AnT→ TRS	Beta Ant
Trust AVn	Situation Awarness AVn*Beta SA(t)+ anthropomorphism*Beta Ant(t)+Legal Readiness AVn* Beta LR(t) + Training AVn* Beta TR(t)	

4.8 Study – 4: Experts' Interviews

4.8.1 Justification of Study – 4

Study – 4 based on qualitative semi structured experts' interviews carried out concurrently with Study – 3. The interpretations from both studies in the final phase provides a complete understanding of the AVs implementation benefits and barriers, way forward for co-evolution of regulation and technology, and deployment roadmap for the AVs in NZ. It assisted in validating the proposed integrated trust and governance framework.

This study explored these dimensions and interpreted the findings of the complete research for the successful adoption of the proposed trust and governance framework in NZ. 'In-depth interview is ideally suited for gaining an understanding of people's behavior, its context, and the meaning of that behaviour (Gubrium & Holstein, 2002; Seidman, 2019). As a prospective study on the trust – Adoption of AVs relationship, this study adopted a semi structured interview approach widely known for spontaneous communication (Bogner et al., 2009). These semi structured interviews are in between the structured and unstructured interviews. Covering a range of topic areas where the replies are recorded, following predetermined standard questions with some probing questions for clarification and explanations (Blumberg et al., 2011; Fellows & Liu, 2015).To remove bias, study – 4 is an appropriate tool for gaining an in-depth exploratory understanding of the under investigation phenomenon and comparing a different set of evidence (Bojke L et al., 2021; Cutello et al., 2021; Erthal et al., 2021). According to Cohen et al. (2011), qualitative data analysis based on interviews is distinguished by 'Merging of analysis and interpretation, and often by the merging of data collection with data analysis.' (pp. 537)

4.8.2 Study – 4 Research Methodology

Semi structure interviews took place with 13 experts around the globe, namely from NZ, UK, Germany, Sweden and Australia. Consisting AV industry professionals, manufacturers, CEOs, academicians, policy makers and human factor experts in the AD domain. It includes randomized purposeful sample selection, recording the discourse, following standardized rules of transcription, and employing software tools for thematic analysis. Moreover, the interpretations are validated in theory context and structure, and full transcripts were made available for review along with summary and excerpts (Waitzkin, 1993).

The study employed the thematic analysis method as detailed in Braun and Clarke (2006) to validate the holistic trust and governance framework. Validation can be performed in various ways, including face and content validation (Mousavi et al., 2018), administration of a survey or utilizing knowledge of experts' interviews in the field

(Inglis, 2008). Qualitative inquiry delineates phenomena in the backdrop of the informants, explores multiple realities and ensues holistic understanding within a specific context (Hilal & Alabri, 2013). Utilizing qualitative data from semi-structured interviews on zoom technology assisted in greater assimilation of the problem than just analysing data on a large scale (Malakolunthu, 2007). NVivo 11 software assisted in gathering, organising and grouping evidence into similar ideas and further validating data at a more specific level. It improved the rigours of the analytical stages.

4.8.3 Interview Sampling.

The interviewees were selected carefully through a purposeful sampling approach known as a judgmental or qualitative sample. In this method, the researcher selects the samples based on their judgment (Tongco, 2007). Based on Dworkin (2012), 5-50 participants are suggested as adequate. The researcher targeted 40 experts in this study and subsequently formally contacted 30 experts by sending a request via the LinkedIn message service. Snowball sampling was also used (Noy, 2008), as few recruited participants recommended some of their colleagues potentially suitable and interested for the study. Twenty experts responded, and 13 interviews were conducted on zoom technology. To select an appropriate expert and achieve meaningful results (Walton, 2016), the study looked at the field of expertise and degree of seniority for a reasonable advice. Also, experts are expected to be in a position to apply their personal analyses in practice (Bogner et al., 2009). The codes representing each expert interviewee comprised a field identifier (CO for AV domain consultant, IM for AV industry manufacturer, GO for a government official, AC for academician, IP for AV industry professional) and a number for each expert within this group.

4.8.4 Interview Sessions.

Interviews took place from Sep 2020 to Jan 2021. 90% of the experts occupy senior management positions, and 70% of respondents had a title of Dr or Professor in the AD domain. Interviews were guided by a semi-structured interview schedule. The questionnaire developed were based on open and closed ended techniques. Open ended questions are the main types of questions in the interviews to obtain new kinds of information (Creswell et al., 2003) and closed ended questions are made as these are easy to complete and enhance the (Dlakwa, 1990 as cited in Rahman et al., 2014) response rate. Questions related to the participants' professional experience and diverse dimensions of challenges and benefits of AVs, key determinants for user acceptance, future directions for AVs deployment, and the role of naturalistic real-time studies. These questions inquired perspectives on AV-HMI paradigms and the significance of Human Factor Engineering. Interviews were audio recorded and transcribed. Participants had the option to review the draft of the transcribed interview and withdraw the data if required. High level and sub themes were based on interview scheduled questions identified deductively and inductively (Braun & Clarke, 2006).

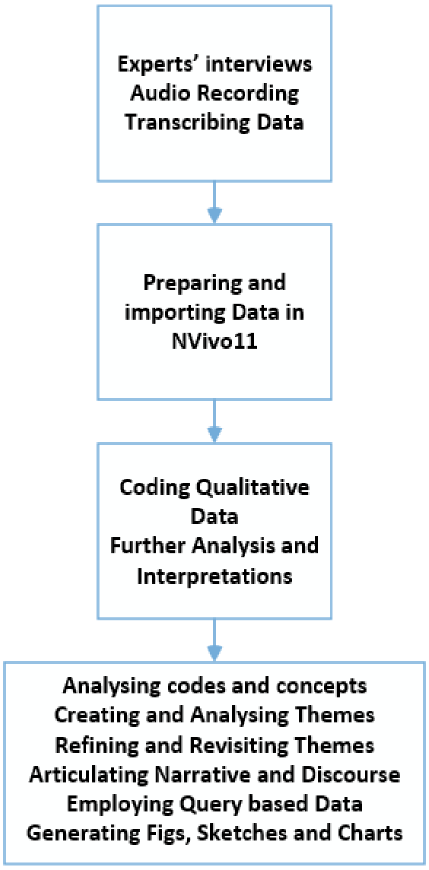
4.8.5 Method of Interview Analysis

Interview feedback data was recorded, analysed, transcribed and decoded using the thematic analysis. Thematic analysis has repeatedly been employed in transport research (Alyavina et al., 2020; Gössling et al., 2016; Hafner et al., 2017). The thematic analysis method collects datasets and explains patterns of themes in a greater detail that emerged during an interview and enables the researcher to draw a meaningful conclusion from the interview (Braun & Clarke, 2006). In this analysis method, six steps were followed to reach a detailed conclusion. These steps included familiarizing, generating initial codes, searching, reviewing, defining and naming themes, and the final report. In this way, the study resulted in a credible and valid process (Nowell et al., 2017).

Based on research questions, the data was generated from interviews and then put into codes based on raw quotes of the interviewees. Bazeley (2007) mentioned five tasks of NVivo during the analysis of data that include; (1) manage data, (2) manage ideas, (3) query data, (4) modelling visually, (5)and reporting (Hilal & Alabri, 2013). The data condensation into manageable codes. By combining codes, the themes were compiled. The study evolved into 200 ideas and then classified into 20 themes. The themes were reviewed, and relationship was built. Few themes had overlapping dimensions and some of the quotes underpinned more than one theme. These were further analysed and revisited thorough iterative process and validate concepts were developed through the formation of matrices of ideas into 5 main themes. The detailed procedure is illustrated in Figure 4.15.

Figure 4.15

The Procedure followed for Interviews Data Analysis



4.9 The Chapter Summary

This chapter delineates the research methodologies and tools applied to accomplish the research aim and objectives. It commences with the philosophical and theoretical perspective and highlights the significance of the Pragmatic Paradigm philosophically and the Design Science Research approach theoretically in a Multiphase Design approach. The research harnessed mixed research methodologies utilizing concurrent embedded correlational and the convergent parallel design models within AVs case study in NZ. The chapter then delves into the research process inquiry, and justification of research methodologies. It informs regarding the data collection and analysis techniques for developing a holistic Trust and Governance Framework in NZ for successful deployment of AVs. The studies include a literature review and User Study, SEM, SD and Experts interviews. A detailed account of the Research Ethical process is also given. The next Chapter will focus on detailed findings and results.

Chapter 5 – Findings and Analysis

5.1 Introduction

This chapter presents the findings, qualitative and quantitative results, to answer the research aim and objectives, and formulate a Trust and Governance Framework for successfully deploying AVs in NZ. The chapter delineates results and analysis of four studies, i.e., Study – 1: AV User Study, Study – 2: Statistical Equation Modelling, Study – 3: System Dynamic Modelling and Study – 4: Experts' Interviews. Since all studies are carried out in a Multiphase Design approach taking interpretations from one to another; hence each Study bears significant qualitative and quantitative linkages to the other studies within the context of the Literature.

5.2 Study – 1: AV User Study

The study was carried out to determine how an appropriate level of user trust in an AV can be evolved during user–AV interaction. This was achieved by identifying and analyzing critical AD affecting during HMI. The Literature revealed various AD factors/determinants from numerous research studies affecting users' trust in AVs. This complementary user study assisted in confirming the significance of these factors in different usage phases of an AV and classifying them into two groups. The first cluster of key determinants was grouped into trust influencing HFs domain, and the other related to trust influencing Governance/Legal readiness domain. The Study also assisted in the formulation of the HMI AD Event Relationship Identification Framework. The Study is a significant step towards the conceptualization of the holistic Trust and Governance Framework in NZ.

5.2.1 AV User Study Findings and Evaluation

The user study demographic data and coding of the user test subjects are shown below.

Table 5.1

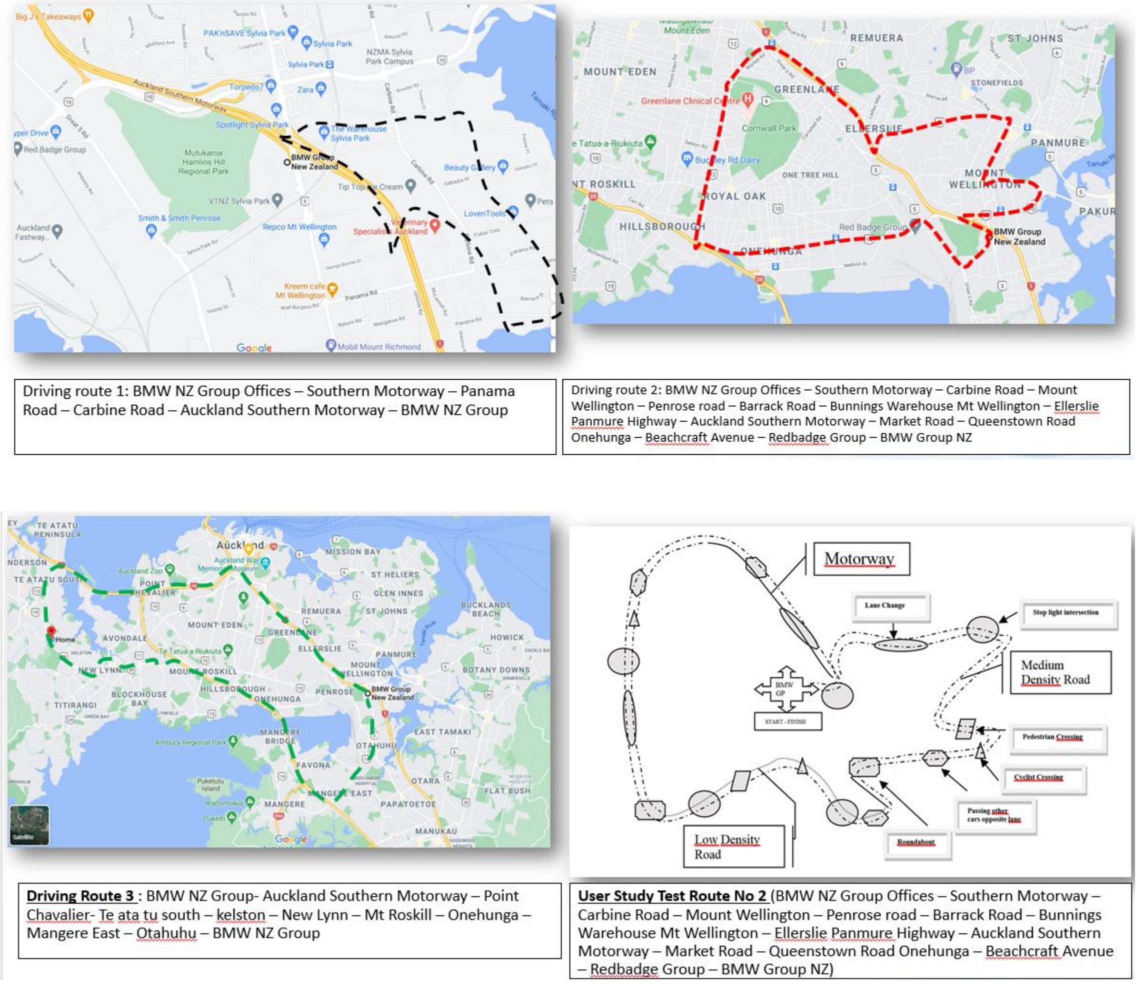
Subjects Recruited for AV User Test

Subject	U1	U2	U3	U4	U5	U6
Age (Y)	23	25	36	37	44	45
Gender	M	M	M	M	F	M
Driving Experience	3	3	8	10	10	15

The driver's test trials with BMW X5 xDrive40i SUV Vehicle were held on medium, low, and high density roads (highway, motorway and city roads) in Auckland (see route maps in Figure 5.1). The results from the analysis of AV user study data and critical findings from the brainstorming session used to analyze qualitative data are delineated in this section.

Figure 5.1

Driving Routes



Driving route 1: BMW NZ Group Offices – Southern Motorway – Panama Road – Carbine Road – Auckland Southern Motorway – BMW NZ Group

Driving route 2: BMW NZ Group Offices – Southern Motorway – Carbine Road – Mount Wellington – Penrose road – Barrack Road – Bunnings Warehouse Mt Wellington – Ellerslie Panmure Highway – Auckland Southern Motorway – Market Road – Queenstown Road Onehunga – Beachcraft Avenue – Redbadge Group – BMW Group NZ

Driving Route 3 : BMW NZ Group- Auckland Southern Motorway – Point Chavalier- Te ata tu south – kelston – New Lynn – Mt Roskill – Onehunga – Mangere East – Otahuhu – BMW NZ Group

User Study Test Route No 2 (BMW NZ Group Offices – Southern Motorway – Carbine Road – Mount Wellington – Penrose road – Barrack Road – Bunnings Warehouse Mt Wellington – Ellerslie Panmure Highway – Auckland Southern Motorway – Market Road – Queenstown Road Onehunga – Beachcraft Avenue – Redbadge Group – BMW Group NZ)

The theory of reasoned action (Fishbein & Ajzen, 1975) and the trust model by Lee and See (2004) identify the users' trust in automation. Media campaigns and communications initially shape the users' trust before interaction with AV. Hence the Study identified a trust phase named 'pre–use' before interacting with AV. Then user trust is affected during the on job interaction and learning about the automation, which is called as 'use phase' in this Study. After having enough knowledge and interaction with the automation system, the user trust matures further during the 'performance phase.' The pre-use phase involved what happened before the first physical interaction with the AD system. The use phase lasted until the participant learned how the AD system works. The performance phase took a long term perspective during the use phase and performance phase through continuous usage of the AD system. Three phases were based on the dynamic nature of trust over time during AV test trials.

The heuristic scenario was defined around two questions; (1) *What should be the planned actions of the vehicle during manual and AD mode that can be translated into events? (2) What trust factors / key determinants are to be selected against those events?* Participant reactions to various situations and hazards were observed in live traffic conditions. The Study finalized *three* phases, namely (1) pre-use, (2) use, and (3) performance, and *eight* events, namely (1) information before driving, (2) entering vehicle, (3) activation, (4) manual mode 1, (5) auto mode, (6) manual mode 2, (7) exit vehicle, (8) and continuous usage (see Table 5.2). The participants commenced driving in the manual mode, later activated the autopilot (transition from human driving stage to autonomous driving), then back to manual mode after deactivating the autopilot. However, during the drive, the participants activated the autopilot system, adaptive cruise control and lane change.

Table 5.2

Driving Scenarios Event Content and Structure

Phases	Events	Description	Significance
Pre-use	Information before driving	It starts before the driving scenario. A prospective user receives passive information from advertisements and active information from AV dealers. The user needs to calibrate his mental model appropriately to know how the system works.	How information is being portrayed to a potential user for their buy-in. Any over or under information can severely affect users' confidence and future use of AV.
Use	Entering Vehicle	This phase occurs during the initial use of the driver and includes six events. In the first event, the user enters the vehicle for the first time and gains a first impression of the vehicle controls.	Anthropomorphic features, including welcome voice and interior aesthetics, etc., play a crucial role in improving user confidence.

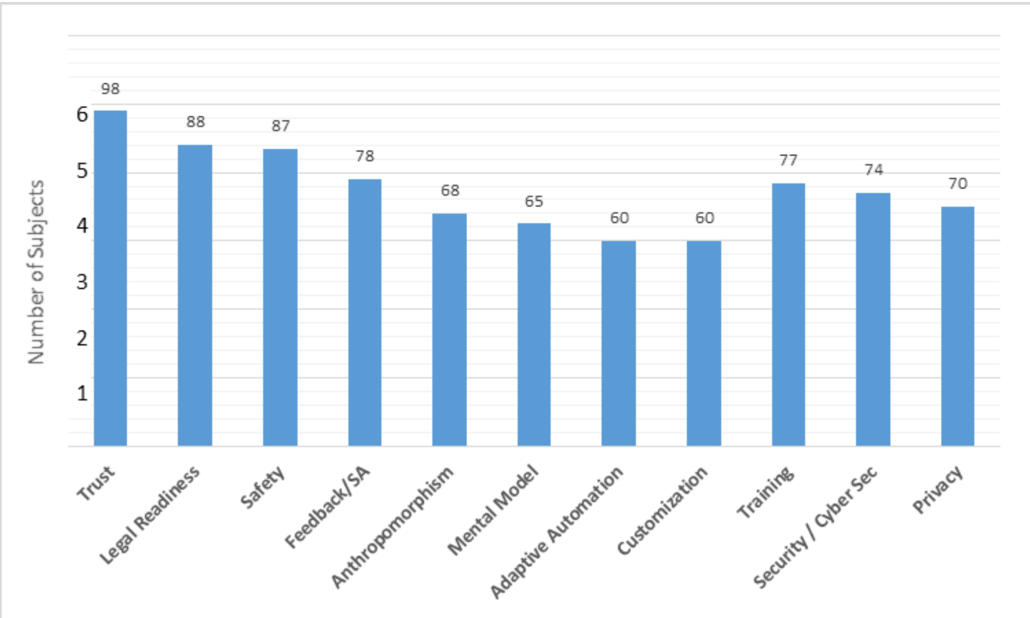
Phases	Events	Description	Significance
	Activation	It includes assimilation and interpretation of systems functions while activation of the engine by the user	The system must be commensurate with the user's mental model, personality, culture, expert level and SA.
	Manual Mode 1	Driving on the road without an AD system. A user receives first-hand knowledge about the system in use, functions, external environment regarding road infrastructure, other road users, traffic regulations, and understanding when to switch to AD mode.	AV system feedback during this phase is critical, especially while transiting and anthropomorphic features and adaptive automation. The safety, security and privacy of the user further affect his confidence.
	Auto mode	The user operates AV in AD mode, knows about functionalities, interprets feedback, and remains alert for transfer back control from AV to the user.	AV adaptive system continuously provides information and feedback. The anthropomorphism affects user understanding and confidence. The AV system must display its limitation. The policy regarding safety, security and privacy remains effective.
	Manual Mode 2	System control is handed back to the driver, and he remains vigilant of any critical condition. The user needs to know and interpret functions at the control transition stage and deactivate the AD system.	During the critical intervention, feedback, anthropomorphism, customization, and adaptive automation play their role. Safety, security and privacy rules remain deployed. Feedback from user interfaces must not overstrain the user while transiting.
	Exit Vehicle	The driver leaves the system and turns off the engine. The user must understand the system at this stage.	Polite communication is vital. Hence anthropomorphism plays the role.

Phases	Events	Description	Significance
Performance	Continuous Usage	The user carries out various driving trips on AV, improves upon his mental model, and gets in sync with the AV AI model. The user remains alive to changes in infrastructure, traffic, regulations, the behaviour of other road users and how to react in system failure critical situations.	Generally, all factors depicted in the final relationship matrix remain dominant during this phase.

Before and during the driving scenarios, the users were asked various event specific questions to get to know their feelings, trust and confidence in the system. Next, these were mapped onto the timeline of a driving scenario using sticky notes to make it more tangible. The most frequently evaluated concepts explored during the user study trials and brainstorming sessions are illustrated in Figure 5.2. The user interview findings and observations are shown in Table 5.3.

Figure 5.2

Most Frequently Evaluated Concepts during AV User Driving Test Sprints



Note: The graph displays the concepts most frequently mentioned, brainstormed and evaluated by the subjects during the tests.

Table 5.3

Key Determinants / Influencing Factors for AD in NZ

Key Determinants	Description	User study Observations & Quotes	Analysis and Interpretations from User Study
Trust in HMI	'Trust mediates relations not only between humans but human and automation and is a key challenge in the adoption of AVs' (Bansal et al., 2016; Kyriakidis et al., 2019; Sheridan & Hennessy, 1984).	"U4: User acceptance will heavily depend on trust on AVs as well as the legal frameworks comprising safety, security and data privacy." "U3: I think the AV industry needs to make investments on building confidence and user trust." "U1 and U5: My trust can increase phenomenally if we can further increase situation awareness, feedback, voice and haptic control, especially during control transition stages while driving." "U2: I think improving driver training can increase his/her trust in the AV". Moreover, the trust predominantly increased before driving to after driving sessions.	1. Perception and self-reported trust increased incrementally from pre-use stage to use and performance stage. It may be a key determinant in mediating the relationship between human factors and governance structure for the successful adoption of AVs. 2. Trust and Legal Readiness/Governance structure are essential to the successful deployment of AVs. 3. Anthropomorphism, driver training, and situation awareness significantly impact user acceptance and trust in AVs. 4. Protecting the Safety, Security, Cyber Security, and Data Privacy of users are a 'must needs' to improve trust and legal readiness mechanism in NZ.
Training	'To improve the user's knowledge, system training is conducted before and after first usage' (Parasuraman et al., 2008; Toffetti et al., 2009).	"U1: The driver should be provided training on how to use and interact with the system." "U3: The driver should be given information about AV system reliability and its relation to the context." "U4: At least from my experience, the user must be given information about the connectivity in the car." "U6: The vendor education and training is the key to understanding the	Due to increased training of users on AVs on various driving scenarios, their performance improved. The training assists in appropriate mental model maturity and achievement of calibrated trust.

		functionality and performance of AV and also improves user trust." "U2: I think user-centred education is key to the success of AVs, and workshops could be helpful."	The AV industry and stakeholders should promote AV education through campaigns, workshops and trials.
Anthropomorphism	'A system which acts more like human in terms of voice, gender and name' (Epley et al., 2007; Hoff & Bashir, 2015; Waytz et al., 2014).	"U5: An anthropomorphic behaviour including visual and auditory cues created focus and enhanced my attention." "U6: I think AV should leverage the human tendency to interact socially with technology and interface must facilitate the formation of appropriate confidence and trust in the system."	Anthropomorphic features should be designed for an appropriate calibrated trust and situational awareness (SA) and not over the trust. It should communicate intentions, processes, and actions to keep the driver in the loop without overloading the resources with additional modalities.
Mental Model	To rightly use the system, the user mind need to figure out the system functions and competencies for assimilation(Lee & See, 2004; Toffetti et al., 2009)	The significance of an appropriate mental model is found more pronounced in the pre-use phase. "U1: Training workshop assisted me in calibrating my mental model." "U6: If AV reactions do not correspond to driver mental model, then it may lead to a negative reaction."	An insufficient mental model of the user and the AI mental model of the car may result in negative reactions and uncertainty.
Feedback / Situational Awareness	'A system agent continuously providing output and behaving like senses' (Dekker & Woods, 2002; Lee & See, 2004; Toffetti et al., 2009; Verberne et al., 2015) The SA is the 'perception of the	Subjects noted that visual and haptic feedback is necessary at traffic lights and intersections for increased situational awareness. "U2: The interface should provide the driver with context information as understood by the AV for user assimilation of car's intent and SA." "U6: I think AV must communicate its intentions, processes, and actions to keep me in the loop."	1. Correct and timely feedback regarding AV status and intentions enhances the SA of the driver. It must also communicate the limitations of automation to avoid mismatch (mode confusion) between driver mental model and car AI mental model. 2. It was also suggested that SA and Feedback terminologies are significantly interrelated and hence grouped.

	elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future.'(M. Endsley, 1995)		
Adaptive Automation & Customization	'A system which can adapt to user's likings' (Helldin et al., 2013; Hoff & Bashir, 2015). 'The ability to set non-critical functions as per user preferences. (Broek et al., 2011; Saffarian et al., 2012; Verberne et al., 2015)	"U4: I strongly think that we should adopt the modalities of communication based on outside road environments as well as internal AV cabin environment." "U3: The interface should allow customization of expert and novice usage and adapt to communication style based on information about the user."	1. The AV interface needs to articulate its customization and transform its adaptability based on the experience and expert level of the driver in terms of communication style and other multi-modal interactions. 2. User study participants observed that combining HD mapping, G5 communication, sensor data, and electroencephalography will assist in AVs' acceptability. 3. It was suggested that anthropomorphism is a wholesome term that also encompasses adaptive automation and customization.
Safety	The Government need to make safety standards around manufacturing, vehicle design, infrastructure and communications	"U03: AV needs to know how to deal with edge cases that programmer can't necessarily predict." "U04: I am more concerned about the sustainability and safety of myself, my parents and my children while driving AV."	1. Certain measured are deemed to be necessary to be taken to ensure the safety, security and privacy of users in AVs in the NZ context. Besides legal readiness comprising testing, training and liability regime is also needed. These measures may be highly

	(Binfet-Kull & Heitmann, 1998b; Huntington, 2018; Ward, 2011)	The participants were not found fully confident while sharing road with non-AVs during test runs from safety point of view. They observed that road safety can only be improved with an effective traffic governance regulations and constructing infrastructure comprising separate lanes for AVs and non-AVs.	required to garner the trust and acceptability of the user. 2. Safety is one of the primary factors in end-user adoption of AVs. A sound legal structure is a must to counter unsafe situations and other hacking issues.
Security/Cyber security & Privacy Invasion	A self-driving car may be vulnerable to traffic incidents and interruptions, software-related security flaws, viruses and malware. (Kaur & Rampersad, 2018).	"U05: Regulations and licensing are a must for AVs to inspire and enable a trust." "U04: Legislation is foremost for cyber security and technology challenges, and I need to know what extent legal protection is provided for using AVs." "U01: I think end-user need to be aware of the potential consequences of cyber security and data privacy challenges." While Participants noted that they are somewhat safe in data and personal privacy and security. And ranked the following as most important for acceptability of AVs (1) well-developed laws (2) affordable cost (3) Data Privacy (4) system and network security	

The author assisted the participants during their drive and also during various workshop sessions (Figure 5.3).

Figure 5.3

Pictorial – Driving Scenarios

Note: These pictorial images relate to various driving scenarios and events, brainstorming and ideation workshop sessions, BMW head-up display and auto/manual modes during different user test driving sprints.

5.2.2 AVs User Study – Analysis and Results

The key AD influencing factors after detailed user interviews and brainstorming sessions were categorized into *nine* trust influencing factors, i.e., (1) mental mode, (2) training, (3) feedback, (4) anthropomorphism, (5) safety, (6) privacy, (7) security, (8) customization, (9) and adaptive automation. The details of critical determinants are ensued in Table 5.3 above. Each driving scenario and other sessions were translated into a matrix indicating events and categories during various driving modes. After fifteen iterations, the finalized matrix was formalized and tested to formulate the HMI AD Events Relationship Identification Framework (HMI - ADERIF).

5.2.3 HMI AD Events Relationship Framework (HMI - ADERIF) Development

To explore the relationship and identify a framework, the trust factors were matched against AD events in various usage phases based on user study and interviews. Trust influencing factors and AD events were already identified in Table 5.2 and Table 5.3 above. Due to the dynamic nature of trust, few factors may be matched with more events and some with less. However, all events were subjected to identify essential trust – human factors – governance determinants. The underlying Framework identified nine trust-affecting factors (Mental Model, Training, Feedback, Anthropomorphism, Safety, Privacy, Security, Customization and Adaptive Automation) used against 8 HMI AD events and three phases during AD events Table 5.4.

Table 5.4

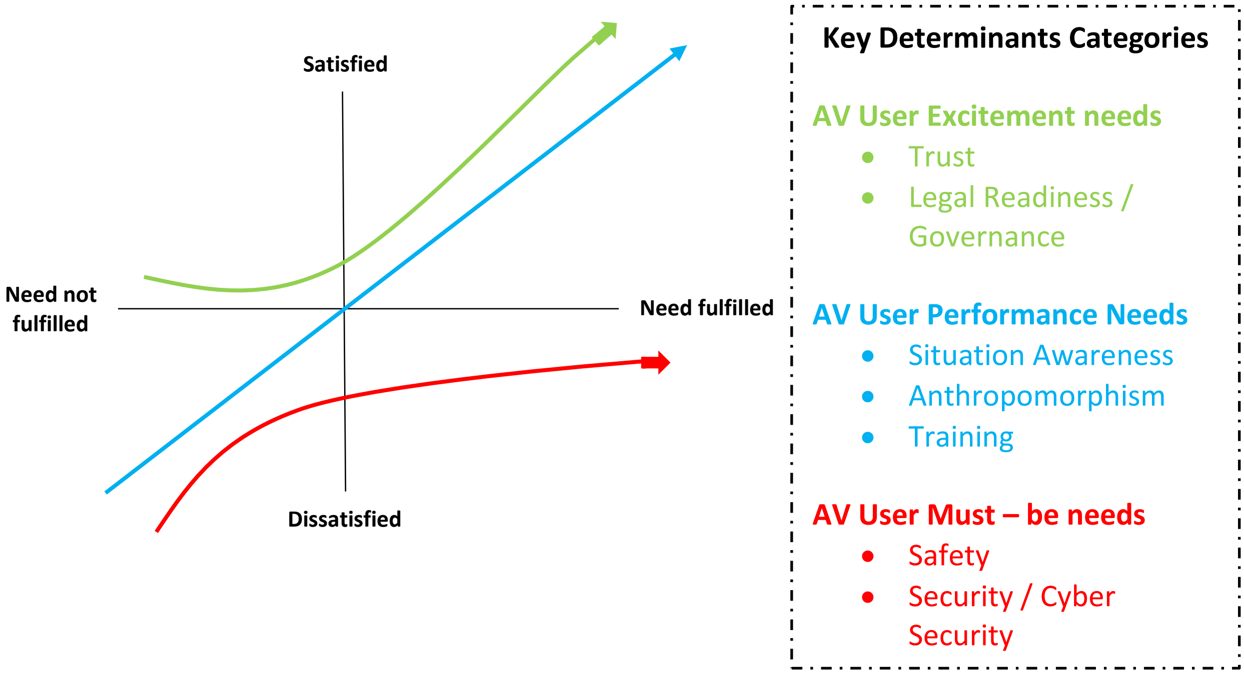
Key Determinants - HMI AD Events Relationship Identification Framework

Phases	Pre-Use	Use Phase						Performance Phase
Events → Factors ↓	Info before driving	Entering Vehicle	Activation	Manual Mode 1	Auto Mode	Manual Mode 2	Exit Vehicle	Continuous Usage
Mental Model	xxx							
Training	xxx		xxx		xxx			xxx
Feedback			xxx	xxx	xxx	xxx		xxx
Anthropomorphism			xxx	xxx	xxx	xxx		xxx
Safety		xxx	xxx	xxx	xxx	xxx	xxx	xxx
Privacy			xxx	xxx	xxx	xxx		xxx
Security		xxx	xxx	xxx	xxx	xxx		xxx
Customization				xxx	xxx	xxx		
Adaptive Automation				xxx	xxx	xxx		xxx

A Kano model was employed to prioritise user preferences relating to key determinants to classify these AD influencing factors. The Kano Model (Kano, 1995) is used to develop attributes that benefit users and can be employed to evaluate existing design criteria and serve as a basis for developing new concepts. In Figure 5.4, the model visualizes eight categories which are classified as AV User *"Excitement needs," "Performance needs,"* and *"Must – be needs"* according to the relative importance of each category.

Figure 5.4

Mapping of AVs Users Needs and Categorization of Key Determinants

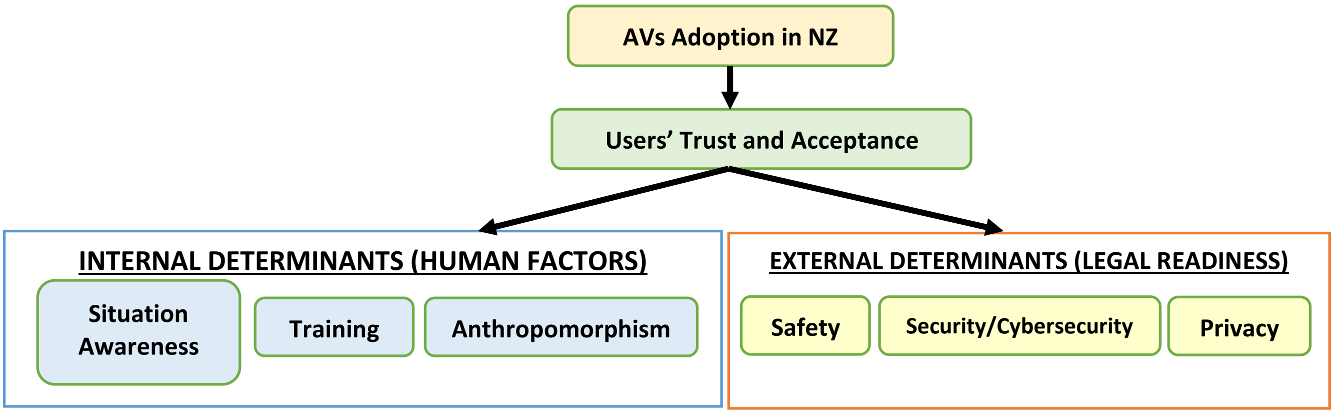


Note: The diagram depicts the holistic Trust and Governance requirements categorized on to Kano Model representing "Excitement needs"(Green), "Performance needs"(Blue) and "Must – be needs" (Red) according to the relative importance of each category.

Excitement needs are the overarching Trust and Governance Requirements, which further depend on HMI Performance needs, i.e., Situation Awareness, Training and Anthropomorphism and Must – be needs incorporating Safety, Security/Cyber Security and Privacy requirements. Must–be needs related to the Governance/Legal Readiness domain. The Performance needs relate to the HFs domain. However, all needs have linkages to ensure the appropriate trust is garnered for the successful deployment of an AV (Figure 5.5 below). To simplify the preferences, it was decided to include customization and adaptive automation in anthropomorphism and feedback into situation awareness. Due to the prominent roles of these influencing factors in the related determinants and improving the overall mental model and trust (personal as well as institutional) of the users.

Figure 5.5

Autonomous Driving Adoption in New Zealand – (Internal and External Determinants)



5.2.4 Conclusion Study – 1

This Study identifies critical determinants affecting user acceptance and trust employing BMW vehicle user study, giving insights to early test case environments. The Study achieved its objectives by verifying the trust influencing factors for AD in NZ. It also assisted in confirming the significance of these varying factors in different usage phases of an AV and classifying these into two groups. The first cluster of key determinants was grouped into HFs and the other cluster into the Governance/Legal readiness domain. The Study has also formulated an HMI AD Event Relationship Identification Framework that can be studied further to deploy AVs User studies and HMI design guidelines in NZ.

5.3 Study – 2: Structural Equation Modelling (SEM)

An exploratory survey "Humanizing Driverless Technology" was deployed and analysed using Structural Equation Modelling (SEM) concurrently with the User study utilizing concurrent embedded design correlational model approach. The main focus of the study was to address research objectives 2 and 3. This study assisted in knowing the aspirations of the NZ general public towards AVs, challenges towards implementation, and the perceptions on trust and governance mechanisms. The study tested seven hypotheses, found correlations, and validated key AD trust influencing factors for the successful adoption of AVs in NZ. The Study also identified the role of trust as a mediator.SEM is an advanced statistical technique that employs a confirmatory approach to analysing developed theory in a study relevant to some phenomenon (Byrne, 2016). Traditional multivariate methods are incapable of assessing measuring errors. In contrast, SEM takes care of measurement errors and assists in examining the influence of predictor variables on numerous dependant variables (Byrne, 2016).

5.3.1 Findings and Analysis

The following sections display the different analyses of this study, i.e., descriptive statistics, the respondent's demographic attributes, and hypothesis testing. Initially, a general analysis of collected data is done. And then, the consequences of assessing the structural and the measurement model by applying different statistical techniques are presented.

5.3.1.1 Response rate

A total of 510 questionnaires were distributed among different respondents in NZ from Jul-Sept 2020. The primary platform used was Qualtrics. Four hundred twenty-nine research questionnaires were collected, which generated an 84.1% response rate. Table 5.5 below compiles the response rate of this Study.

Table 5.5

Response Rate of Questionnaire

Total sent	Total received	Response rate (%)
510	429	84.1%

5.3.1.2 Data Screening and Descriptive Analysis

Before performing an analysis, data screening was executed to check missing values. In Microsoft MS-Excel, the COUNTBLANK formula was applied. Some values were found missing, which were replaced by mean scores using SPSS V26. Rows having extreme missing values were removed. Next, unengaged responses were also checked in Microsoft MS-Excel with the help of the STDEV.P formula. In this step, 22 unengaged responses were removed from the questionnaire. At the end of the data screening process, there were 389 useable responses. With the help of SPSS V26, this study created a profile of all respondents based on race, gender, education, age, income.

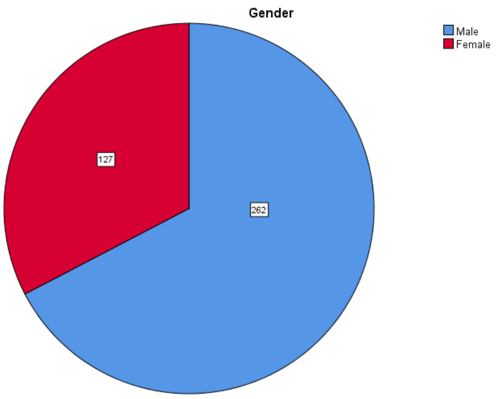
5.3.1.3 Gender

The present study had 389 respondents, of which 32.6% were female, and 67.4% were male. The following Table 5.6 shows the detail.

Table 5.6

Gender of Respondents

Gender	Quantity	Percentage (%)
Female	262	67.4
Male	127	32.6
Total	389	100.0



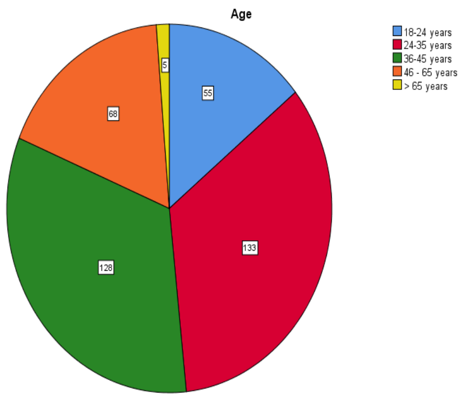
5.3.1.4 Age

Age distribution was divided into five categories. It starts from 18 to above 65 years old. It means that the present Study covers 80% of respondents. Furthermore, 34.2% of respondents were 24 to 35 years old, and 1.3 percent were more than 65 years. Table 5.7 provides complete details.

Table 5.7

Age of Respondents

Age	Quantity	Percentage (%)
18-24 years	55	14.1
24-35 years	133	34.2
36-45 years	128	32.9
46 - 65 years	68	17.5
> 65 years	5	1.3
Total	389	100.0



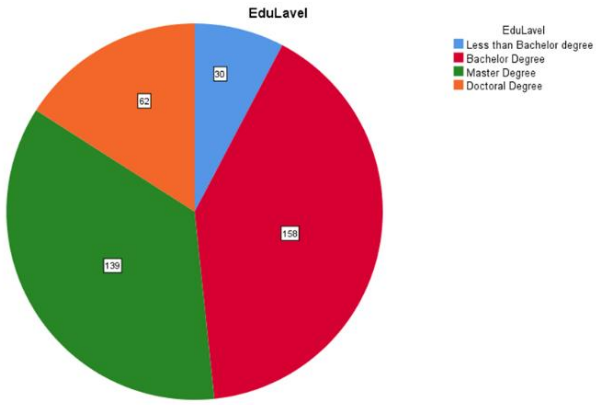
5.3.1.5 Education

In terms of the education level of respondents, most of them had a bachelor's degree. The Study had 7.7.0% diploma holders, and 40.6% respondents had their Bachler degree. The following Table 5.8 signifies the educational characteristic of this Study.

Table 5.8

Education Level of Respondents

Education level	Quantity	Percentage (%)
Less than Bachelor degree	30	7.7
Bachelor Degree	158	40.6
Master Degree	139	35.7
Doctoral Degree	62	15.9
Total	389	100.0



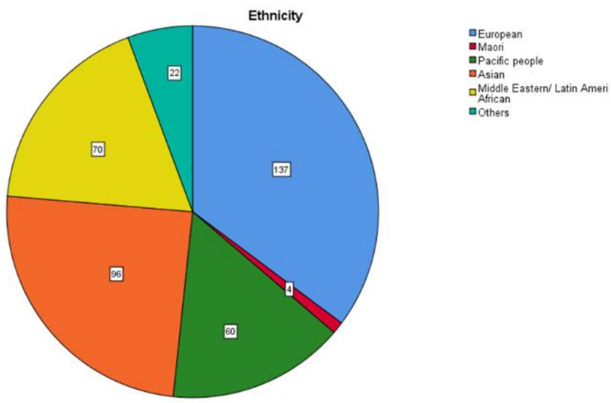
4.3.1.6 Ethnicity

Most of the participants were from European backgrounds, almost 35.2%. Table 5.9 provides the complete detail of the ethnicity of this Study.

Table 5.9

Ethnicity

Ethnicity	Quantity	Percentage (%)
European	137	35.2
Maori	4	1.0
Pacific people	60	15.4
Asian	96	24.7
Middle Eastern/ Latin American/ African	70	18.0
Others	22	5.7
Total	389	100.0



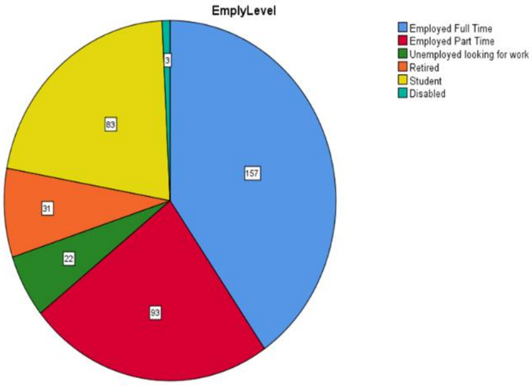
5.3.1.7 Employment Level

Most of the persons who participated in this Study are full-time employees, i.e., 40.4%. However, the data was collected from almost every type of employment, i.e., part-time employee, 23.9%, unemployed looking for work were 23.9%, etc.

Table 5.10

Employment Level

Employment Level	Quantity	Percentage (%)
Employed Full Time	157	40.4
Employed Part Time	93	23.9
Unemployed looking for work	22	5.7
Retired	31	8.0
Student	83	21.3
Disabled	3	0.8
Total	389	100.0



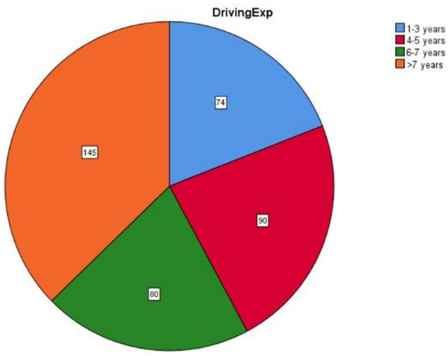
5.3.1.8 Driving Experience

The driving experience is divided into four categories. Table 5.11 provides the complete details of the driving experience for this Study.

Table 5.11

Driving Experience

Driving experience	Quantity	Percentage (%)
1-3 years	74	19.0
4-5 years	90	23.1
6-7 years	80	20.6
>7 years	145	37.3
Total	389	100.0



5.3.1.9 Major Concerns in Human Factors for AVs Deployment

The Study found that people generally considered trust the most dominating HF challenge for the implementation of AVs in NZ, i.e., 26.5%, followed by well-developed regulation/governance regime and Situation Awareness, Anthropomorphism and

Training which is in line with the context of Study – 1 and literature review. The details are depicted in Table 5.12 and Figure 5.6.

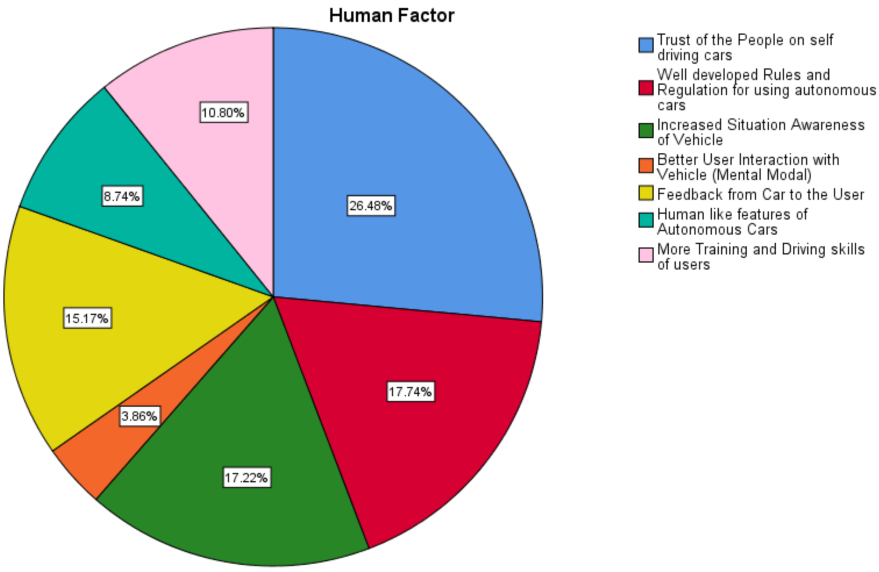
Table 5.12

Human Factors Concerns

Human Factors	Quantity	Percentage (%)
Trust of the People on self-driving cars	103	26.5
Well-developed Rules and Regulations for using autonomous cars	69	17.7
Increased Situation Awareness of Vehicle	67	17.2
Better User Interaction with Vehicle (Mental Modal)	15	3.9
Feedback from Car to the User	59	15.2
Human-like features of Autonomous Cars	34	8.7
More Training and Driving skills of users	42	10.8
Total	**389**	**100**

Figure 5.6

Human Factors Concerns



5.3.1.10 Safety, Security / Cyber Security and Data Privacy Concerns

The survey found that NZ people consider safety as the foremost challenge, i.e., 31.9%. Followed by the ability to take back control from AV, Cyber security, Personal and Data

Privacy, as shown in Table 5.13 and Figure 5.7, which again confirms the concerns and challenges discussed in the literature review and Study – 1.

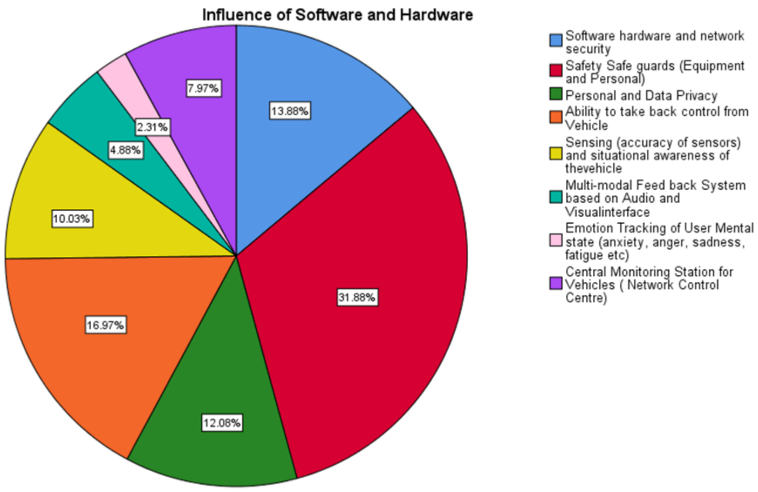
Table 5.13

Safety, Security and Privacy Concerns

Software and Hardware	Quantity	Percentage (%)
Software hardware and network security	54	13.9
Safety Safeguards (Equipment and Personal)	124	31.9
Personal and Data Privacy	47	12.1
Ability to take back control from Vehicle	66	17
Sensing (accuracy of sensors) and situational awareness of the vehicle	39	10
Multi-modal Feedback System based on Audio and Visual interface	19	4.9
Emotion Tracking of User Mental state (anxiety, anger, sadness, fatigue etc.)	9	2.3
Central Monitoring Station for Vehicles (Network Control Centre)	31	8
Total	**389**	**100**

Figure 5.7

Safety, Security and Privacy Concerns



5.3.1.11 Situations Most Likely to Adopt AVs

Preliminary descriptive analysis was also taken to determine situations where people are most willing to adopt AVs in NZ. It was found that people prefer using AVs in closed areas, drive on freeways and highways, congested traffic, drop off and pickups of children, and social activities. The slightly less preferable situations include city streets, cars with no driver, fully self-driving taxis, public transport or shuttle with no driver chaperone etc. Figure 5.8 and Table 5.14 depict the gender-based adoption preferences.

Figure 5.8

Situations Most Likely to Adopt AVs – Males Vs. Females

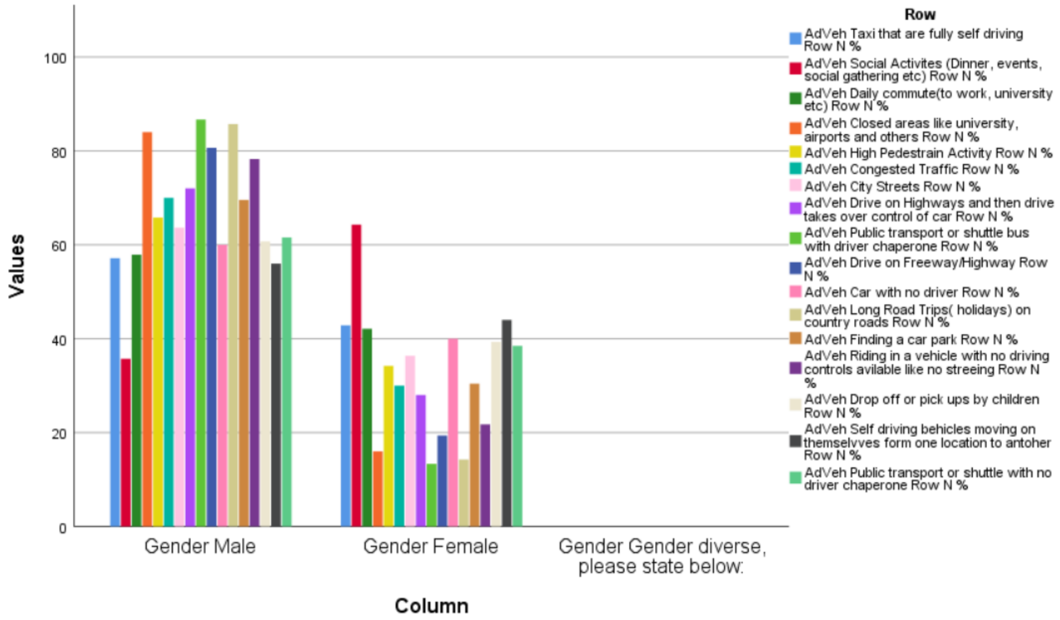


Table 5.14

Situations Most Likely to Adopt AVs – Males Vs Females

Adoptions Situation Preferences	**Gender**	
	Male	**Female**
Taxi	57.10%	42.90%
Social Activities	35.70%	64.30%
Daily commute	57.90%	42.10%
Closed areas	84.00%	16.00%
High Pedestrian Activity	65.80%	34.20%
Congested Traffic	70.00%	30.00%
City Streets	63.60%	36.40%
Drive on Highways	72.00%	28.00%
Public transport with driver chaperone	86.70%	13.30%
Drive on Freeway/Highway	80.60%	19.40%
Car with no driver	60.00%	40.00%
Long Road Trips	85.70%	14.30%
Finding a car park	69.60%	30.40%
Vehicles with no driving controls, Like steering	78.30%	21.70%
Children Drop off or pick-ups	60.70%	39.30%
Self-driving vehicles moving one place to another	56.00%	44.00%
Public transport with no driver chaperone	61.50%	38.50%

Note: This table concludes that Males in NZ prefer AD more than Females.

5.3.1.12 Distribution of Feedback on each Measurement

On each measurement construct, the respondents' responses were recorded on the 5 point Likert scale. The study also observed the correlation between concerns and the Adoption of Vehicles as found from the survey data. It was concluded that there is a negative relationship between both the measures. Hence the adoption of AVs can only take place once the concerns and issues of the people are addressed. See Table 5.15, where concerns and issues, i.e., CI = lack of trust and rules and regulations vs. Adoption correlation, are depicted. This is fundamental for the validation of the Trust and Governance Framework for AVs.

Table 5.15

Concerns and Issues for Adoption of AVs

Correlations		
	AD	CI
AD	1	-.547**
CI	-.547**	1
** Correlation is significant at the 0.01 level (2-tailed).		

Note: Ad = Adoption, CI = Concerns and issues

5.3.2 Descriptive Statistics

The constructs were measured on five point Likert scale from 1- strongly disagree to 5 - strongly agree. Table 5.16 demonstrates Mean, Minimum, Maximum, Standard deviation, Skewness, and Kurtosis. Evaluation of normality of data against skewness and Kurtosis shows that data is unbiased and exhibited acceptable levels of skewness (ranging from -1.089 to 0.883), and kurtosis (ranging from -1.456 to 1.116) are well below the threshold levels of 2 and 7 for these two tests (Stephen G. West et al., 1995). It is concluded that the data set has no multivariate outliers' issues and is fairly distributed.

Table 5.16

Descriptive Statistics

	N	MIN	MAX	Mean	Std. Deviation	Skewness	Kurtosis
Gender	389	1	2	1.33	0.47	0.743	-1.456
Ethnicity	389	1	9	3.23	2.093	0.883	0.864
Age	389	1	5	2.58	0.978	0.102	-0.704
Employment level	389	1	6	2.48	1.611	0.645	-1.19
Education level	389	1	4	2.6	0.846	0.098	-0.674

	N	MIN	MAX	Mean	Std. Deviation	Skewness	Kurtosis
Driving experience	389	1	4	2.76	1.145	-0.288	-1.373
SA_1	389	1	5	3.72	1.016	-0.758	0.384
SA_2	389	1	5	3.74	1.039	-0.884	0.584
SA_3	389	1	5	3.72	0.997	-0.705	0.296
SA_4	389	1	5	3.75	1.035	-0.918	0.663
SA_5	389	1	5	3.77	1.038	-0.911	0.62
SA_6	389	1	5	3.78	1.02	-0.918	0.666
TRS_1	389	1	5	3.69	1.072	-0.851	0.375
TRS_2	389	1	5	3.63	1.055	-0.762	0.29
TRS_3	389	1	5	3.67	1.017	-0.803	0.398
TRS_4	389	1	5	3.7	1.095	-0.874	0.353
TRS_5	389	1	5	3.65	1.061	-0.847	0.422
TRS_6	389	1	5	3.7	1.102	-0.874	0.339
TRS_7	389	1	5	3.67	1.084	-0.923	0.496
PRI_1	389	1	5	3.71	1.05	-0.939	0.547
PRI_2	389	1	5	3.69	1.041	-0.904	0.504
PRI_3	389	1	5	3.65	1.037	-0.769	0.292
PRI_4	389	1	5	3.68	1.053	-0.752	0.186
SAF_1	389	1	5	3.7	1.081	-0.807	0.221
SAF_2	389	1	5	3.69	1.082	-0.925	0.459
SAF_3	389	1	5	3.7	1.044	-0.792	0.256
SEC_1	389	1	5	3.66	1.055	-0.864	0.444
SEC_2	389	1	5	3.65	1.048	-0.849	0.431
SEC_3	389	1	5	3.74	1.097	-0.885	0.323
SEC_4	389	1	5	3.65	1.056	-0.929	0.565
AD_1	389	1	5	3.69	1.002	-0.806	0.414
AD_2	389	1	5	3.67	1.077	-0.984	0.628
AD_3	389	1	5	3.72	1.042	-0.817	0.322
AD_4	389	1	5	3.69	1.027	-0.797	0.351
AD_5	389	1	5	3.66	1.069	-0.882	0.316
AD_6	389	1	5	3.6	1.111	-0.852	0.214
AD_7	389	1	5	3.57	1.141	-0.888	0.21
AD_8	389	1	5	3.66	1.144	-0.85	0.116
AD_9	389	1	5	3.63	1.078	-0.811	0.193
AD_10	389	1	5	3.67	1.163	-0.856	0.083
AD_11	389	1	5	3.61	1.099	-0.882	0.285
AD_12	389	1	5	3.67	1.128	-0.849	0.136
AD_13	389	1	5	3.68	1.092	-0.827	0.158
AD_14	389	1	5	3.62	1.086	-0.753	0.088
AD_15	389	1	5	3.61	1.087	-0.804	0.178
AD_16	389	1	5	3.65	1.109	-0.861	0.213
AD_17	389	1	5	3.63	1.104	-0.874	0.254
AnT_1	389	1	5	3.8	0.954	-0.871	0.763
AnT_2	389	1	5	3.77	1.003	-0.852	0.652
AnT_3	389	1	5	3.83	1.028	-1.089	1.116
AnT_4	389	1	5	3.75	1.04	-0.953	0.82
TR_1	389	1	5	3.6	1.093	-0.935	0.428
TR_2	389	1	5	3.65	1.094	-0.784	0.147

Note: Ad = Adoption, TRS = Trust, SA = Situational Awareness, SEC = Security, Pri = Privacy, AnT = Anthropomorphism, SAF = Safety, TR = Training, LR = Legal Readiness.

5.3.3 Exploratory Factor Analysis

Subsequently, the Study employed exploratory factor analysis (EFA) to test the validity and applicability of the instrument in the NZ region. Although there are two forms of rotation in EFA (Orthogonal and Oblique), principal axis factoring was directed on the 47 items through the Oblique rotation method (Promax). It is argued that since the factor inter-correlations are common in social sciences, the oblique rotation is always a suitable and appropriate method. And if the factors ensue to be uncorrelated, both orthogonal and oblique produce the equivalent result (Costello & Osborne, 2005). For factor loadings for each item, this Study follows the criterion of Hair et al. (2010) grounded on sample size where a sample size of 192 for EFA, the significant factor loadings are 0.40. Kaiser-Meyer-Olkin (KMO) assists in measuring sampling adequacy. This Study also used a fixed number of factors to extract. The results regarding the statistical assumption for EFA are as follows:

- The sample size is 389, enough to conduct EFA (Tabachnick & Fidell, 2013).
- Bartlett's Test of Sphericity is Sig. ($p < 0.001$) (Field, 2013).
- Kaiser-Meyer-Olkin (KMO) value is 0.946, which is marvellous (Hutcheson & Sofroniou, 1999; Kaiser, 1974).
- Communalities value for each item is > 0.5 (Field, 2013).

The pattern matrix in Table 5.17 depicts the factor loadings afterwards rotation. The items that constellation on the indistinguishable components indorse that factor 1 denotes an adoption (29.074% of the total variation), factor 2 trust (9.263%), factor 3 situational awareness (7.926%), factor 4 security (6.110%), factor 5 privacy (4.678%), factor 6 Anthropomorphism (3.652%), factor 7 safety (2.685%), and factor 8 training (2.263). All factors explained 59.695% of the total variation. Out of the 22 items, none were removed.

Table 5.17

Pattern Matrix

	Pattern Matrix Factor							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
AD_17	0.837							
AD_10	0.825							

Pattern Matrix								
	Factor							
	1	2	3	4	5	6	7	8
AD_14	0.823							
AD_11	0.82							
AD_7	0.817							
AD_5	0.811							
AD_6	0.806							
AD_13	0.8							
AD_9	0.8							
AD_15	0.796							
AD_8	0.776							
AD_12	0.772							
AD_2	0.766							
AD_16	0.745							
AD_1	0.708							
AD_3	0.697							
AD_4	0.685							
TRS_6		0.838						
TRS_3		0.811						
TRS_4		0.809						
TRS_5		0.802						
TRS_7		0.783						
TRS_2		0.739						
TRS_1		0.73						
SA_5			0.81					
SA_2			0.796					
SA_1			0.788					
SA_4			0.769					
SA_3			0.765					
SA_6			0.743					
SEC_4				0.86				
SEC_2				0.812				
SEC_3				0.757				
SEC_1				0.741				
PRI_4					0.857			
PRI_3					0.803			
PRI_2					0.789			
PRI_1					0.767			
AnT_4						0.817		
AnT_3						0.808		
AnT_2						0.805		
AnT_1						0.785		
SAF_3							0.857	
SAF_1							0.811	
SAF_2							0.773	
TR_2								0.9
TR_1								0.879

Note: Extraction Method: Principal Axis Factoring, Rotation Method: Promax with Kaiser Normalization, a Rotation converged in 6 iterations and Factor loading less than 0.4 suppressed. : Ad = Adoption, TRS = Trust, SA = Situational Awareness, SEC = Security, Pri = Privacy, AnT = Anthropomorphism, SAF = Safety, TR = Training

There is no cross-loading in EFA (meaning that a person understands each factor as a separate entity).

5.3.4 Measurement Model Assessment and Confirmatory Factor Analysis (CFA)

CFA is a type of SEM that gauges the degree of accuracy of measurement of the measuring tool, i.e., the relationship between observed indicators/measures and latent factors/variables (Brown & Moore, 2012). A factor is a latent variable that influences more than one observed measure and accounts for correlation among them as they share a common cause. Hence CFA gives a parsimonious understanding of the covariation among a set of measures as the number of factors are lesser than the measured variables.

It is also noteworthy that once the initial model estimation process is done, the model is often required to do a model verification process (Gadisa & Zhou, 2020). In SEM, numerous fitness of indexes reveals how fit the model is to the data at hand. Hair et al. (2010) endorses the use of at least one fitness index from each category of model fit, of which there are three, namely "parsimonious fit," "incremental fit and absolute fit." The absolute fit indices display that the chi-square is not significant. But the model still fits because when large samples are used, the chi-square statistic nearly always rejects the model (Bentler & Bonett, 1980). The model index symbolizes the change in the value of chi-square for the model's fitness if that particular parameter is changed. In this study model, the model verification process was implemented using AMOS modification indexes. One second-order construct, i.e., propensity to trust PRT and the observed values (PRT_1 to PRT_6), were found causing duplicity were removed during modified measurement model estimation procedure due to low loadings. Resultantly, the goodness of fit measures improved significantly. Table 5.18 demonstrates the goodness-of-fit indices for the measurement model and the level of acceptance.

Moreover, SEM model validity measurement testing is also crucial, which is generally measured using construct validity, convergent validity and discriminant validity. SEM validity measurements testing improves the correctness of the constructs in the conceptual model seeks to match it with the real world and measures to what degree the theoretical ideas are rooted (Gadisa & Zhou, 2020). Convergent validity explains the relationship between two variables and determines the extent to which the measured variables are correlated with their construct (Malhotra & Dash, 2011). In comparison, the discriminant validity identifies correlations of the model constructs among themselves and is the measure of distinctness of two similar concepts. Each individual construct is expected to measure its anticipated objective satisfactorily. The reliability describes the extent to which measure of a construct is dependable or consistent.

5.3.4.1 Model fit indicators for measurement Model and CFA (Second-Order)

The present study confirmed the measurement model for Legal Readiness LR (second-order) using AMOS 26. The results display that the LR construct is multidimensional and consists of three factors (PRI, SAF, and SEC). Graphical representation of the second-order model illustrated in Figure 5.9 also found that fit indices for the multidimensional construct are acceptable and within recommended levels (Hair et al., 2010). For instance, X 2 = 47.659, df = 41, X 2/df = 1.162, p = 0.200, comparative fit index (CFI) = 0.996, Tucker–Lewis index (TLI) = 0.995, incremental fit index (IFI) = 0.996 and root mean square error of approximation (RMSEA) = 0.020. Table 5.18 represents the model fit indexes criteria. Furthermore, the evidence for composite reliability (CR) and discriminate validity (average variance extracted – AVE) is illustrated in Table 5.19. Table 5.20 and Table 5.21 provide the details of the convergent and discriminant validity. The present Study found that the loading value is higher than 0.70 for each item (Fornell & Larcker, 1981) and that the AVE for all constructs was higher than the squared correlation coefficients between them (Anderson & Gerbing, 1988). Hence there is no problem in reliability and validity in this study data.

Table 5.18

Model Fit Indicators

Fit Index	Fit criteria	Results	Fit (Yes/No)	References
X2		47.659		
DF		41		
P value	>.05	0.200	Yes	
X2/DF	1.00 - 5.00	1.162	Yes	(Kline, 2016)
RMSEA	<.08	0.020	Yes	(Steiger, 1990)

Fit Index	Fit criteria	Results	Fit (Yes/No)	References
SRMR	<.08	0.0279	Yes	(Hu & Bentler, 1999)
NFI	>0.80	0.975	Yes	(Bentler & Bonett, 1980)
PNFI	>.0.05	0.727	Yes	(Bentler & Bonett, 1980)
IFI	>.0.90	0.996	Yes	(Bollen, 1990)
TLI	>.0.90	0.995	Yes	(Tucker & Lewis, 1973)
CFI	>.0.90	0.996	Yes	(Byrne, 2016)
PCFI	>0.50	0.743	Yes	(James et al., 1982)

5.3.4.1.1 Construct Reliability (Second order)

The second order individually construct Cronbach's alpha coefficients of the three main dormant variables, i.e., privacy, safety and security (0.844, 0.806 and 846), were more than the suggested level of 0.7 (Kannan & Tan, 2005; Nunnally, 1994) (Table 5.19). Then, the composite reliability (CR) of all the second order constructs was checked, i.e., privacy, safety and security (0.844, 0.806 and .846) and the values were found within the recommended value of 0.7 (Gefen et al., 2000; Hair et al., 2010; Kline, 2016), demonstrating sufficiently that construct's reliability is established. Hence, the Cronbach's Alpha and CR for all second order constructs were achieved and deliberated as adequately error-free (Table 5.19).

5.3.4.1.2 Indicator Reliability

High loadings on a construct indicate that the associated indicators have much in common captured by the construct (Hair Jr et al., 2016). On the other hand, if the indicators display small or low loadings below 0.40, these must be eliminated from the scale. However, the loadings ranging from 0.4 to 0.7 have to be considered for removal only when improving the CR value or average variance extracted (AVE) (Hair Jr et al., 2016). In this Study, all the indicators have their loadings surpassed the recommended value of 0.5 (Hair et al., 2010). There is no indicator with loading below 0.70 (Table 5.19). All items satisfied the requirements without any removal item from the scale.

5.3.4.1.3 Convergent Validity

As already highlighted above, convergent validity is the extent to which a measure correlates positively with alternative measures of the same construct. To establish convergent validity, researchers consider the AVE (Hair Jr et al., 2016). AVE with a value equal to or higher than 0.50 indicates that, on average, the construct explains more than half of the variance of its indicators. On the contrary, AVE with a value less than 0.50

indicates that, on average, more error remains in the items than the variance explained by the construct. Table 5.19 delivers the convergent validity of the construct.

Table 5.19

Loading, Cronbach's Alpha, CR and AVE for zero-order model

Indicator	Direction	Construct	Factor Loading >0.5	S.E.	t-Value	P-Value	α >0.7	CR >0.7	AVE >0.5
PRI_1	←	PRI	0.781				**0.844**	**0.845**	**0.575**
PRI_2	←	PRI	0.773	0.066	14.893	***			
PRI_3	←	PRI	0.726	0.066	13.987	***			
PRI_4	←	PRI	0.755	0.067	14.547	***			
SAF_1	←	SAF	0.735				**0.806**	**0.806**	**0.583**
SAF_2	←	SAF	0.83	0.081	13.933	***			
SAF_3	←	SAF	0.718	0.074	12.739	***			
SEC_1	←	SEC	0.743				**0.846**	**0.847**	**0.581**
SEC_2	←	SEC	0.75	0.072	13.956	***			
SEC_3	←	SEC	0.76	0.075	14.128	***			
SEC_4	←	SEC	0.794	0.073	14.713	***			

Note: Confirmatory factor analysis for Legal Readiness (LR) **α=** Cronbach's alpha; **CR** = Composite reliability, **AVE** = Average variance extracted, Ad = Adoption, TRS = Trust, SA = Situational Awareness, SEC = Security, Pri = Privacy, AnT = Anthropomorphism, SAF = Safety, TR = Training, Significant at ***p < 0.001

5.3.4.1.4 Discriminant Validity (by Fornell-Larcker criterion)

As highlighted above, discriminant validity means "the extent to which a construct is truly distinct from other constructs by empirical standards"(Fornell & Larcker, 1981). The constructs have adequate or acceptable discriminant validity if the square root of the AVE for each construct is larger than the correlation between the construct and any other construct in the model. In this Study, two methods were used to access discriminant validity. First, the Fornell Larcker criterion is frequently applied in numerous research (Aimran et al., 2017; Al-Maroof & Al-Emran, 2018; Hilkenmeier et al., 2020; Isaac et al., 2017; Ong et al., 2021; Seok-Soo, 2021). And second, the utmost acclaimed approach is HTMT (Henseler et al., 2015). Table 5.20 delivers the details of discriminant validity through the Fornell-lacker method.

Table 5.20

Discriminant Validity (by Fornell-Larcker criterion) for second order model

Construct	1	2	3
1.PRI	**0.762**		
2.SAF	0.605	**0.759**	

3.SEC	0.662	0.562	**0.763**

Note: Diagonals represent the square root of the average variance extracted while the other entries represent the correlations. SEC = Security, Pri = Privacy, SAF = Safety

5.3.4.1.5 Discriminant Validity (by HTMT)

Henseler et al. (2015) suggested HTMT as an innovative approach to evaluating the discriminant validity and claimed that this approach is more solid and predictable than the Fornell Larcker criterion. Henseler et al. (2015) suggested that the HTMT value beneath 0.85 designates an acceptable and tolerable discriminant validity. In this Study, HTMT values of all the constructs were found below the threshold value. Therefore, all constructs have their distinct concepts. The following Table 5.21 provides the details of discriminant validity through the heterotrait-monotrait method.

Table 5.21

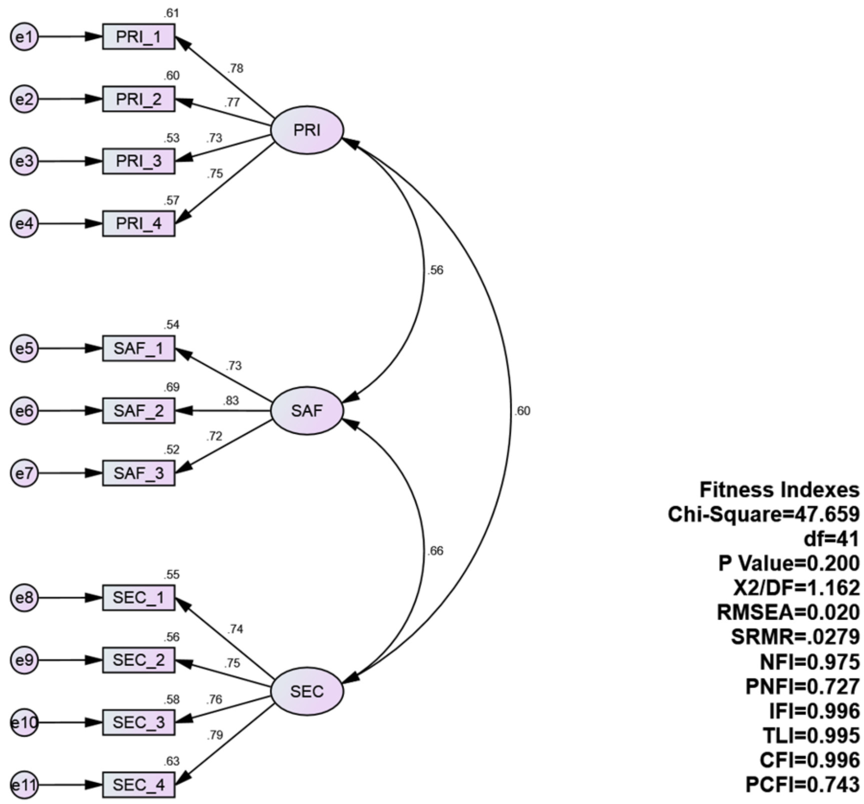
Results of discriminant validity by HTMT criterion method for second order model

Construct	**PRI**	**SAF**	**SEC**
1.PRI			
2.SAF	0.558		
3.SEC	0.612	0.653	

Note: Thresholds are 0.850 for strict and 0.900 for liberal discriminant validity. SEC = Security, Pri = Privacy, SAF = Safety.

Figure 5.9

Graphical Representation of Second Order Model



5.3.4.2 Model fit indicators for measurement Model and CFA (Zero-Order)

In zero order measurement model, all eight latent variables i.e. Adoption, Trust, Situational Awareness, Security, Privacy, Anthropomorphism, Safety, and Training were included. CFA results publicized that X 2 = 1187.0, df = 1006, X 2/df = 1.180, p = 0.000, comparative fit index (CFI) = 0.982, Tucker–Lewis index (TLI) = 0.981, incremental fit index (IFI) = 0.982 and root mean square error of approximation (RMSEA) = 0.022. The Table 5.22 shows the model fit indexes.

Table 5.22

Model fit indicators (Zero Order)

Fit Index	References	Fit criteria	Results	Fit (Yes/No)
X2			1187.0	
DF			1006	
P-value		>.05	0.000	No
X2/DF	(Kline, 2016)	1.00 - 5.00	1.180	Yes
RMSEA	(Steiger, 1990)	<.08	0.022	Yes
SRMR	(Hu & Bentler, 1999)	<.08	.0366	Yes
NFI	(Bentler & Bonett, 1980)	>0.80	0.894	Yes

PNFI	(Bentler & Bonett, 1980)	>.0.05	0.832	Yes
IFI	(Bollen, 1990)	>.0.90	0.982	Yes
TLI	(Tucker & Lewis, 1973)	>.0.90	0.981	Yes
CFI	(Byrne, 2016)	>.0.90	0.982	Yes
PCFI	(James et al., 1982)	>0.50	0.914	Yes

Note: X2 = Chi-Square, DF = Degree of freedom, CFI = Comparative-fit-index, RMSEA = Root Mean Square Error of Approximation, SRMR: Standardized Root Mean Square Residual, NFI = Normed fit index, IFI = the increment fit index, TLI = Tucker-Lewis coefficient Index, PNFI = Parsimony Normed Fit Index. These are recommended since they are frequently reported in the literature (Awang, 2012).

5.3.4.2.1 Construct Reliability (Zero order)

In the zero-order construct, the Cronbach's alpha coefficients of the eight main variables, i.e., adoption, trust, situational awareness, security, privacy, anthropomorphism, safety, training, are measured (0.961, 0.905, 0.871, 0.846, 0.844, 0.820, 0.806, 0.765 simultaneously). All the constructs achieved greater than 0.7 values (Table 5.23).

5.3.4.2.2 Indicator Reliability (Zero order)

In the zero order model, eight variables were included for checking indicator reliability. The outer loading of all the zero order construct have greater than 0.7(see Table 5.23).

5.3.4.2.3 Convergent Validity

The average variance extracted for all eight constructs in zero order must be greater than 0.5, indicating a convergent validity between the construct (see Table 5.23).

Table 5.23

Loading, Cronbach's Alpha, CR and AVE for zero order model

Indicator	Direction	Construct	Factor Loading >0.5	S.E.	T-Value	P-Value	α >0.7	CR >0.7	AVE >0.5
AnT_1	←	AnT	0.694				**0.820**	**0.820**	**0.534**
AnT_2	←	AnT	0.754	0.093	12.266	***			
AnT_3	←	AnT	0.717	0.094	11.848	***			
AnT_4	←	AnT	0.755	0.097	12.284	***			
TR_1	←	TR	0.866				**0.765**	**0.772**	**0.631**
TR_2	←	TR	0.715	0.183	4.516	***			
SA_1	←	SA	0.732				**0.871**	**0.871**	**0.530**
SA_2	←	SA	0.742	0.076	13.737	***			
SA_3	←	SA	0.699	0.072	12.941	***			
SA_4	←	SA	0.735	0.075	13.601	***			
SA_5	←	SA	0.745	0.075	13.781	***			
SA_6	←	SA	0.715	0.074	13.233	***			
TRS_1	←	TRS	0.751				**0.905**	**0.905**	**0.576**

Indicator	Direction	Construct	Factor Loading >0.5	S.E.	T-Value	P-Value	α >0.7	CR >0.7	AVE >0.5
TRS_2	←	TRS	0.757	0.066	15.036	***			
TRS_3	←	TRS	0.746	0.064	14.782	***			
TRS_4	←	TRS	0.777	0.068	15.473	***			
TRS_5	←	TRS	0.763	0.066	15.16	***			
TRS_6	←	TRS	0.753	0.069	14.947	***			
TRS_7	←	TRS	0.765	0.068	15.209	***			
PRI_1	←	PRI	0.784				**0.844**	**0.844**	**0.575**
PRI_2	←	PRI	0.774	0.064	15.187	***			
PRI_3	←	PRI	0.725	0.064	14.164	***			
PRI_4	←	PRI	0.75	0.065	14.687	***			
SAF_1	←	SAF	0.748				**0.806**	**0.807**	**0.583**
SAF_2	←	SAF	0.817	0.077	14.226	***			
SAF_3	←	SAF	0.722	0.072	13.02	***			
SEC_1	←	SEC	0.749				**0.846**	**0.847**	**0.581**
SEC_2	←	SEC	0.749	0.07	14.101	***			
SEC_3	←	SEC	0.757	0.074	14.245	***			
SEC_4	←	SEC	0.793	0.071	14.888	***			
AD_1	←	AD	0.728				**0.961**	**0.961**	**0.592**
AD_2	←	AD	0.725	0.074	14.415	***			
AD_3	←	AD	0.693	0.072	13.739	***			
AD_4	←	AD	0.67	0.071	13.258	***			
AD_5	←	AD	0.798	0.073	15.955	***			
AD_6	←	AD	0.798	0.076	15.964	***			
AD_7	←	AD	0.816	0.078	16.356	***			
AD_8	←	AD	0.775	0.079	15.479	***			
AD_9	←	AD	0.791	0.074	15.82	***			
AD_10	←	AD	0.787	0.08	15.726	***			
AD_11	←	AD	0.798	0.075	15.972	***			
AD_12	←	AD	0.8	0.077	15.999	***			
AD_13	←	AD	0.767	0.075	15.301	***			
AD_14	←	AD	0.763	0.075	15.228	***			
AD_15	←	AD	0.782	0.075	15.622	***			
AD_16	←	AD	0.787	0.076	15.723	***			
AD_17	←	AD	0.786	0.076	15.717	***			

Note: Confirmatory factor analysis for Zero order Model, α= Cronbach's alpha; CR = Composite reliability, AVE = Average variance extracted, Ad = Adoption, TRS = Trust, SA = Situation Awareness, SEC = Security, Pri = Privacy, AnT = Anthropomorphism, SAF = Safety, TR = Training, Significant at ***p < 0.001

5.3.4.2.4 Discriminant Validity (By Fornell-Larcker)

Table 5.24 shows the discriminant validity for all eight constructs. There is no discriminant issue within the zero order model.

Table 5.24

Discriminant validity by Fornell-Larcker criterion (Zero order model)

Construct	1	2	3	4	5	6	7	8
1.AD	**0.769**							
2.AnT	0.102	**0.730**						
3.TR	0.095	-0.011	**0.794**					
4.SA	-0.002	-0.033	-0.057	**0.728**				
5.TRS	0.491	0.139	0.150	0.153	**0.759**			
6.PRI	0.410	-0.005	-0.080	-0.003	0.544	**0.759**		
7.SAF	0.447	0.031	0.022	-0.067	0.379	0.563	**0.763**	
8.SEC	0.337	-0.117	0.090	0.039	0.469	0.605	0.661	**0.762**

Note: Diagonals represent the square root of the average variance extracted while the other entries represent the correlations. Ad = Adoption, TRS = Trust, SA = Situation Awareness, SEC = Security, Pri = Privacy, AnT = Anthropomorphism, SAF = Safety, TR = Training.

5.3.4.2.5 Discriminant Validity (By HTMT)

As highlighted above, the HTMT values must be lesser than 0.85. Table 5.25 provides the details of HTMT of the zero order model.

The graphical representation of the zero order model is depicted in Figure 5.10.

Table 5.25

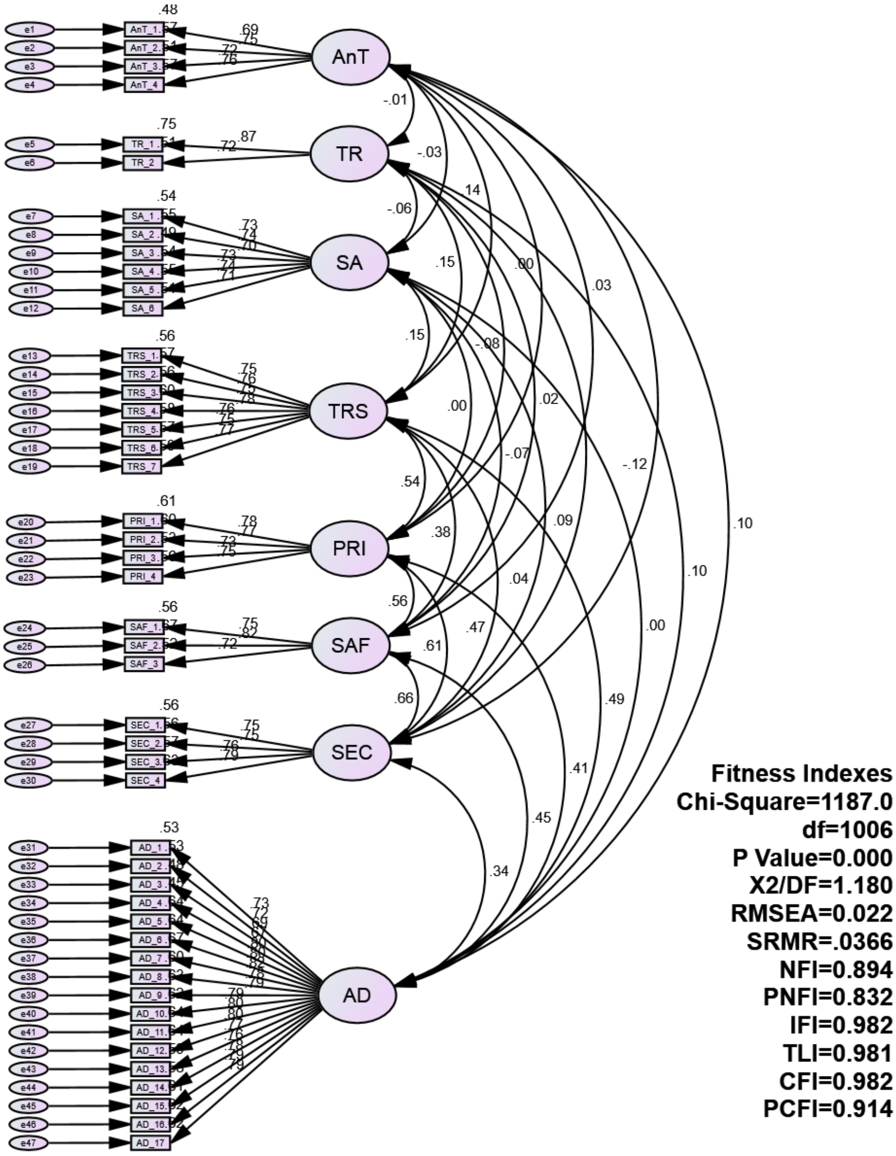
Discriminant Validity (By HTMT) Zero Order

Construct	AnT	TR	SA	TRS	PRI	SAF	SEC	AD
AnT								
TR	0.004							
SA	0.034	0.071						
TRS	0.14	0.15	0.154					
PRI	0.001	0.073	0.005	0.54				
SAF	0.051	0.018	0.082	0.372	0.558			
SEC	0.111	0.096	0.038	0.473	0.612	0.653		
AD	0.102	0.104	0.005	0.492	0.413	0.45	0.343	

Note: Thresholds are 0.850 for strict and 0.900 for liberal discriminant validity. Ad = Adoption, TRS = Trust, SA = Situation Awareness, SEC = Security, Pri = Privacy, AnT = Anthropomorphism, SAF = Safety, TR = Training

Figure 5.10

Graphical representation of Zero Order Measurement Model



5.3.4.3 Model fit indicators for full measurement Model and CFA (Zero order + Second order)

In full measurement model, all six latent variables i.e. Adoption, Trust, Situational Awareness, Anthropomorphism, Legal readiness and Training are included. CFA results publicized X 2 = 1230.6, df = 1016, X 2/df = 1.211, p = 0.000, comparative fit index (CFI) = 0.979, Tucker–Lewis index (TLI) = 0.977, incremental fit index (IFI) = 0.972 and root mean square error of approximation (RMSEA) = 0.023. Table 5.26 demonstrates the model fit indexes.

Table 5.26

Model Fit Indicators (Full Model)

Fit Index	References	Fit criteria	Results	Fit (Yes/No)
X2			1230.6	
DF			1016	
P-value		>.05	0.000	No
X2/DF	(Kline, 2016)	1.00 - 5.00	1.211	Yes
RMSEA	(Steiger, 1990)	<.08	0.023	Yes
SRMR	(Hu & Bentler, 1999)	<.08	0.0413	Yes
NFI	(Bentler & Bonett, 1980)	>0.80	0.890	Yes
PNFI	(Bentler & Bonett, 1980)	>.0.05	0.836	Yes
IFI	(Bollen, 1990)	>.0.90	0.972	Yes
TLI	(Tucker & Lewis, 1973)	>.0.90	0.977	Yes
CFI	(Byrne, 2016)	>.0.90	0.979	Yes
PCFI	(James et al., 1982)	>0.50	0.920	Yes

5.3.4.3.1 *Construct Reliability (Full Model)*

Finally, the final model Cronbach's alpha coefficients of the six primary constructs, i.e., legal readiness, adoption, trust, situational awareness, anthropomorphism, training, is checked (0.872, 0.966, 0.905, 0.871, 0.813, 0.765 simultaneously) (Table 5.27).

5.3.4.3.2 *Indicator Reliability*

In the final measurement model, the indicator reliability was also achieved. All items have greater than 0.7 outer loadings. No item was deleted in the final model. Table 5.27 provides the details of factor loading.

5.3.4.3.3 *Convergent Validity*

In the full model, the second-order constructs convergent validity is measured by the validity of the set of sub-dimensions through AVE, which can be premeditated by averaging the squared multiple correlations for the first-order indicators (MacKenzie et al., 2011). Table 5.27 confirms the result of the convergent validity via AVE.

Table 5.27

Loading, Cronbach's Alpha, CR and AVE for full model

Indicator	Direction	Construct	Factor Loading >0.5	S.E.	t-Value	P-Value	α >0.7	CR >0.7	AVE >0.5
PRI	←	LR	0.783				**0.872**	**0.824**	**0.610**
SAF	←	LR	0.761	0.102	9.203	***			
SEC	←	LR	0.798	0.102	9.573	***			

Indicator	Direction	Construct	Factor Loading >0.5	S.E.	t-Value	P-Value	α >0.7	CR >0.7	AVE >0.5
AnT_1	←	AnT	0.694				**0.820**	**0.820**	**0.534**
AnT_2	←	AnT	0.754	0.093					
AnT_3	←	AnT	0.717	0.094	11.848				
AnT_4	←	AnT	0.755	0.097	12.284				
TR_1	←	TR	0.866				**0.765**	**0.772**	**0.631**
TR_2	←	TR	0.715	0.183					
SA_1	←	SA	0.732				**0.871**	**0.871**	**0.530**
SA_2	←	SA	0.742	0.076					
SA_3	←	SA	0.699	0.072	12.941				
SA_4	←	SA	0.735	0.075	13.601				
SA_5	←	SA	0.745	0.075	13.781				
SA_6	←	SA	0.715	0.074	13.233				
TRS_1	←	TRS	0.751				**0.905**	**0.905**	**0.576**
TRS_2	←	TRS	0.757	0.066					
TRS_3	←	TRS	0.746	0.064	14.782				
TRS_4	←	TRS	0.777	0.068	15.473				
TRS_5	←	TRS	0.763	0.066	15.16				
TRS_6	←	TRS	0.753	0.069	14.947				
TRS_7	←	TRS	0.765	0.068	15.209				
PRI_1	←	PRI	0.784				**0.844**	**0.844**	**0.575**
PRI_2	←	PRI	0.774	0.064					
PRI_3	←	PRI	0.725	0.064	14.164				
PRI_4	←	PRI	0.75	0.065	14.687				
SAF_1	←	SAF	0.748				**0.806**	**0.807**	**0.583**
SAF_2	←	SAF	0.817	0.077					
SAF_3	←	SAF	0.722	0.072	13.02				
SEC_1	←	SEC	0.749				**0.846**	**0.847**	**0.581**
SEC_2	←	SEC	0.749	0.07					
SEC_3	←	SEC	0.757	0.074	14.245				
SEC_4	←	SEC	0.793	0.071	14.888				
AD_1	←	AD	0.728				**0.961**	**0.961**	**0.592**
AD_2	←	AD	0.725	0.074	14.415	***			
AD_3	←	AD	0.693	0.072	13.739	***			
AD_4	←	AD	0.67	0.071	13.258	***			
AD_5	←	AD	0.798	0.073	15.955	***			
AD_6	←	AD	0.798	0.076	15.964	***			
AD_7	←	AD	0.816	0.078	16.356	***			
AD_8	←	AD	0.775	0.079	15.479	***			
AD_9	←	AD	0.791	0.074	15.82	***			
AD_10	←	AD	0.787	0.08	15.726	***			
AD_11	←	AD	0.798	0.075	15.972	***			
AD_12	←	AD	0.8	0.077	15.999	***			
AD_13	←	AD	0.767	0.075	15.301	***			
AD_14	←	AD	0.763	0.075	15.228	***			
AD_15	←	AD	0.782	0.075	15.622	***			
AD_16	←	AD	0.787	0.076	15.723	***			
AD_17	←	AD	0.786	0.076	15.717	***			

Note: Confirmatory factor analysis for full model (Zero order + Second order), α= Cronbach's alpha; CR = Composite reliability, AVE = Average variance extracted Ad = Adoption, TRS = Trust, SA = Situation Awareness, SEC = Security, Pri = Privacy, AnT = Anthropomorphism, SAF = Safety, TR = Training, LR = Legal Readiness, Significant at ***$p < 0.001$

5.3.4.3.4 Discriminant Validity

The Table 5.28 results demonstrate that the overall fit indices for the full measurement model are satisfactory and incremental fit. Parsimony fit indices are also achieved. Hence, the evaluation of the measurement model psychometric properties regarding construct reliability, CR, indicator reliability, convergent validity (AVE), and discriminant validity were achieved. The Summary of Reliability, Composite reliability, AVE and Discriminant validity is given in Table 5.29. The graphical representation of the full model is depicted in Figure 5.11.

Table 5.28

Discriminant Validity

Constructs	1	2	3	4	5	6
1.LR	**0.781**					
2.AnT	-0.047	**0.731**				
3.TR	0.020	-0.005	**0.787**			
4.SA	-0.007	-0.033	-0.069	**0.728**		
5.TRS	0.599	0.139	0.153	0.153	**0.759**	
6.AD	0.504	0.102	0.104	-0.002	0.491	**0.769**

Note: Diagonals represent the square root of the average variance extracted while the other entries represent the correlations. Ad = Adoption, TRS = Trust, SA = Situation Awareness, AnT = Anthropomorphism, TR = Training

Table 5.29

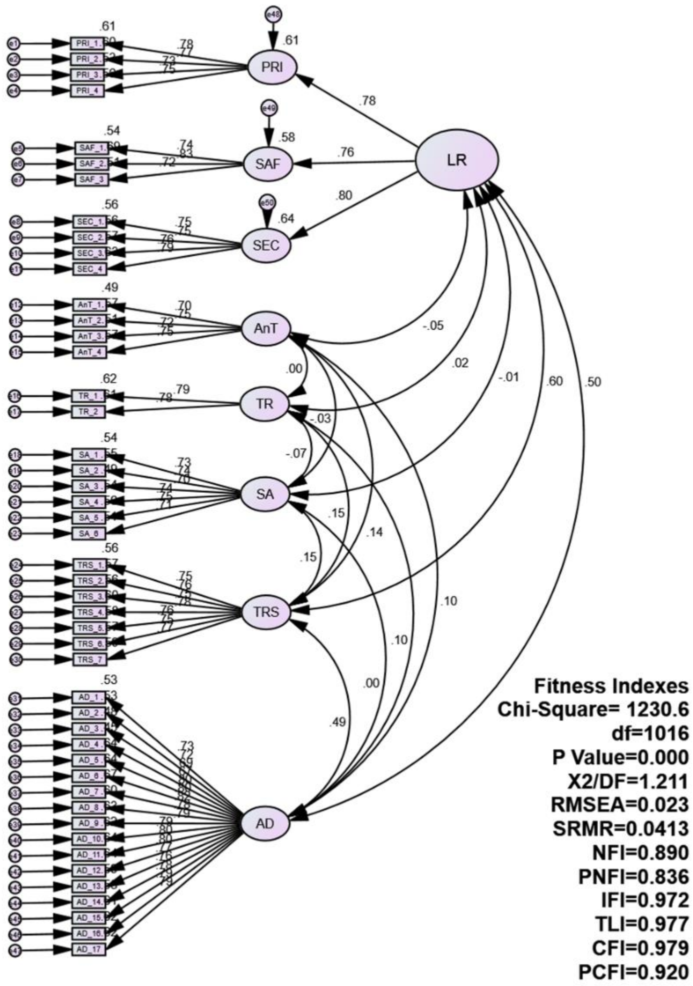
Summary of Reliability, Composite reliability, AVE and Discriminant validity

Construct	**α**	**CR**	**AVE**	**Discriminant validity**
	>0.7	**>0.7**	**>0.5**	**Yes/NO**
Legal Readiness (LR)	0.872	0.824	0.610	Yes
Anthropomorphism (AnT)	0.820	0.820	0.534	Yes
Training (TR)	0.765	0.772	0.631	Yes
Situational Awareness (SA)	0.871	0.871	0.530	Yes
Trust (TRS)	0.905	0.905	0.576	Yes
Privacy (PRI)	0.844	0.844	0.575	Yes
Safety (SAF)	0.806	0.807	0.583	Yes
Security (SEC)	0.846	0.847	0.581	Yes

Adoption (AD)	0.961	0.961	0.592	Yes

Figure 5.11

Graphical Representation of Full Model



5.3.5 Structural Model and Hypotheses Verification

According to Hair et al. (2010), all the construct measures of this research have been confirmed as reliable and valid in the above paras. The next stage is to address the assessment and valuation of structural model outcomes and results. This procedure involves examining the model’s predictive and analytical capabilities and the relations between all the constructs. For confirming hypothesis testing, the bootstrap procedure run with 5,000 samples at a two-tailed significance level is 0.05. The test was done by AMOS software V.26. In this research study, it was vital to study the causal effects of latent constructs of Trust and Legal Readiness determinants on the Adoption construction to examine the phenomenon of successful adoption of AVs in NZ and formulation of validated Trust and Governance framework. This Study resorted to another step of SEM where the role of ‘Trust’ as mediator was investigated to conclude and explain how independent constructs of (Legal Readiness) LR and Situation Awareness (SA), Anthropomorphism (Ant), Training (TR) influences Adoption (AD). A mediator is considered a transporter of information along the caused chain of effects (Little et al., 2007). In the research studies, moderation and mediation are the means to an end, i.e., fundamental analytical tools to test hypotheses (Sardeshmukh & Vandenberg, 2017). Moderation happens when a third variable affects the strength of the relationship between the predictor variables and the outcome variables. Therefore, this Study – 2, Hypotheses testing involves the Study of two models. Model A (where trust does not act as a Mediator) to get insights into the causal effects of variables of LR, SA, Ant and TR on Trust and then adoption, and to study the effect of LR on adoption AD. Model B (where Trust acts as a Mediator) between all other constructs and adoption.

5.3.5.1 Model A (Without Mediator)

In the graphical representation shown in Figure 5.12, the Hypotheses constructs are tested without the "Trust" construct as a mediator.

Figure 5.12

Model A (Without Mediator)

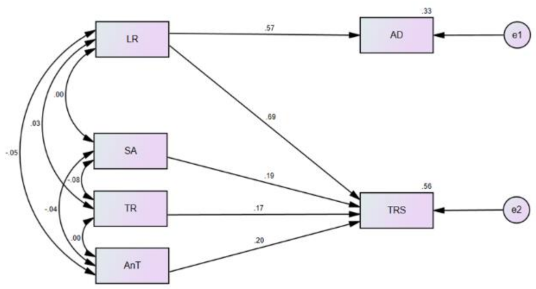


Table 5.30

Hypothesis Testing (Model A)

Hypothesis	Relationship	Std. Beta	Std. Error	*t-value*	*p-values*	Decision
H1	**LR → AD**	0.571	0.050	13.714	0.000	Supported
H2	**LR → TRS**	0.688	0.040	20.510	0.000	Supported
H3	**SA → TRS**	0.192	0.040	5.696	0.000	Supported
H4	**TR → TRS**	0.170	0.038	5.047	0.000	Supported
H5	**AnT→ TRS**	0.197	0.045	5.874	0.000	Supported
H6	**TRS → AD**	0.248	0.052	4.443	0.000	Supported

Note: *indicates significant paths:*p<0.05, **p<0.01, ***p<0.001, ns = not significant

Table 5.30 demonstrates the analysis of the structural model. The results revealed that H1 outcome i.e., LR (Legal Readiness) was positively related to AD (Adoption) and statically significant at the 5% level (Beta = 0.571, t = 13.714, p = 0.000). H2 also confirmed the significant relationship between LR (Legal Readiness) and TRS (Trust) (Beta = 0.688, t = 20.510, p = 0.000). The H3 hypothesis confirmed the relationship between SA (Situation Awareness) and TRS (Trust) (Beta = 0.192, t = 5.696, p = 0.000). The relationship among TR (Training) and TRS (Trust) was also confirmed at (Beta = 0.170, t = 5.047, p = 0.000) (H4). The H5 displays significant and positive relationship between AnT (Anthropomorphism) and TRS (Trust) (Beta = 0.197, t = 5.874, p = 0.000). Finally, the direct relation between TRS (Trust) and AD (Adoption) is also accepted (Beta =0. 248, t = 4.443, p = 0.000). Overall, it is confirmed that Trust (based on Legal readiness, Situation Awareness, Anthropomorphism and training of users) and Legal Readiness (Governance based on safety, security/cyber security and privacy) affects the successful deployment of AVs in NZ. Moreover, Trust and Governance framework is validated in the light of H1 to H6 Hypotheses.

5.3.5.2 Model B (With Trust as a Mediator)

In the graphical representation shown in Figure 5.13, Hypothesis 2a is tested with the "Trust" construct as a mediator.

Figure 5.13

Model B (With Mediator)

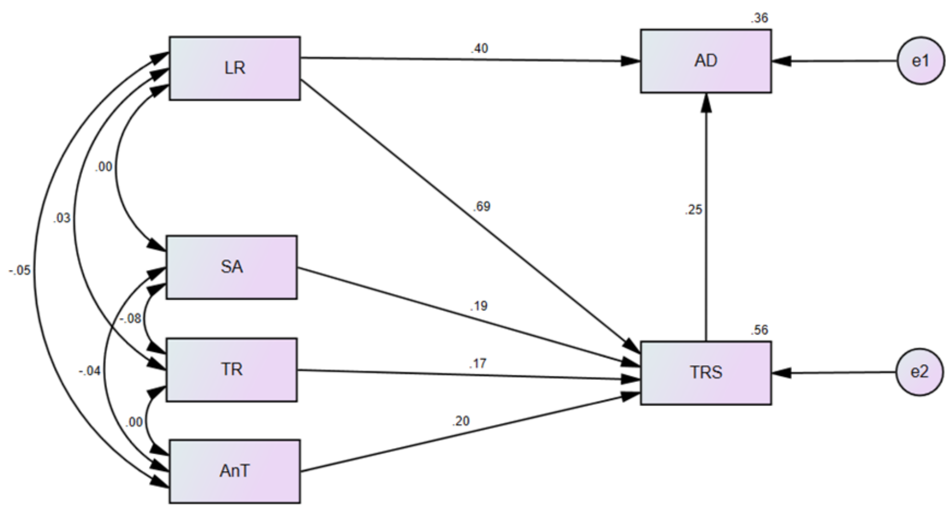


Table 5.31

Mediation Analysis

Indirect Path	Relationship	Std. Beta	Std. Error	Lower Limit	Upper Limit	p-values	Decision
H2*a*	**LR➔TRS➔AD**	0.170	0.066	0.048	0.360	0.033*	Supported

Note: *indicates significant paths:*p<0.05, **p<0.01, ***p<0.001, ns = not significant

In this step, the Study tested and explored the Trust (TRS) variable mediation process between the variables of the LR and AD. The lower limit achieved a 0.048 value, whereas the upper limit has 0.360. Thus, no zero value falls between the lower limit and upper limit. Hence, hypothesis H2a is also confirmed and supported (Beta = 0.170 p = 0.033). LR has direct causal relationships with AD, and Trust also mediates this relationship towards AD. It can be concluded with confidence that people's trust is quintessential for the successful implementation of AVs in NZ. And this trust is increased by the maturity of legal readiness structures and policies based on assuring the public's safety, security/cyber security, and privacy. The trust is also increased by the user's situation awareness, human-like abilities in the AV and training of users.

5.3.5.3 R squared

Another significant criterion for assessing and evaluating the structural model is the R squared or R2 value, which is correspondingly known as "the coefficient of determination" (Hair et al., 2010; Hair et al., 2006; Hair Jr et al., 2016). R square is a "measure of the proportion of an endogenous construct's variance that is explained by its predictor constructs." R-square values (R^2) 0.25, 0.50, and 0.75 related to endogenous constructs might be interpreted as weak, moderate or substantial. The following Table 5.32 shows R2 values.

Table 5.32

R^2 values

CONSTRUCTS	R SQUARE
AD	0.36
TRS	0.56

5.3.5.4 Variance inflation factor (VIF)

Multicollinearity occurred when two or more constructs were highly correlated, and multicollinearity can lead to unstable regression results. Therefore, the variance inflation factor (VIF) was also considered to confirm that it is below the threshold limit.

Usually, the VIF value should not be greater than 10 (Hair et al., 2006; Hair Jr et al., 2016). As displayed in Table 5.33, VIF for all the constructs was found below the limit, indicating no multicollinearity issues in this Study.

Table 5.33

VIF

	VIF Table					
Construct	**AD**	**TRS**	**SA**	**TR**	**AnT**	**LR**
1. AD	-	1.555	1.596	1.587	1.573	1.394
2.TRS	2.296	-	2.176	2.234	2.2	1.492
3.SA	1.092	1.008	-	1.071	1.08	1.059
4.TR	1.074	1.024	1.06	-	1.074	1.048
5.AnT	1.093	1.035	1.097	1.102	-	1.032
6.LR	2.091	1.517	2.321	2.324	2.23	-

5.3.5.5 Summary of Hypotheses

Table 5.34

Summary of Hypotheses Verification

	Hypotheses	**Accepted/ Rejected**
H1	There is a positive and significant relationship between legal readiness and adoption.	**Accepted**
H2	There is a positive and significant relationship between legal readiness and Trust.	**Accepted**
H3	There is a positive and significant relationship between situational awareness and trust.	**Accepted**
H4	There is a positive and significant relationship between training and trust.	**Accepted**
H5	There is a positive and significant relationship between Anthropomorphism and trust.	**Accepted**
H6	There is a positive and significant relationship between trust and adoption.	**Accepted**
H2*a*	Trust mediate the relationship between legal readiness and adoption.	**Accepted**

5.3.6 Conclusion Study – 2

Study – 2 validates the Trust and Governance framework for successfully adopting AVs in NZ and verifies all the hypotheses. This is the first-ever study that gauges the human factors empirically in the backdrop of gaining insights into the most significant determinant in the successful implementation of AVs in NZ. This study also ventured into the significant determinants in the Legal Readiness domain. The study has gone a step further and found that Trust is a fundamental factor that mediates all other AD factors towards adoption and proves interpersonal and institutional trust linkages. A detailed explanation of the results will be discussed in the next Chapter.

5.4 Study – 3: System Dynamics Modelling

Study – 3 utilizes System Dynamics (SD) modelling approach in Vensim PLE software harnessing data from Study – 1 and Study – 2 within the context of literature. It is carried out to examine the diffusion of AVs in the NZ market and simulate in real-time the theoretical output of trust and governance framework (validated in Study – 2). It is also carried out to assist policymakers in NZ in shaping future transportation governance regimes for driverless technology. The study categories AVs in six SAE automation levels on a functional basis, i.e., AV0 to AV5. Study – 2 final beta values for auxiliary variables (see Table 5.35) of Trust, Legal Readiness, Situation Awareness, Training, and Anthropomorphism accrued from Table 5.30 above are used with other endogenous/exogenous variables. These variables include Fleet size of AVs (AV0-AV5), Vehicle Purchase, trade-up and abandonment, Utility of AVs, and others explained in the succeeding paragraphs.

Table 5.35

Beta Values SEM to SD for Auxiliary Variables

Hypothesis	Relationship	Std. Beta
H1	**LR → AD**	0.571
H2	**LR → TRS**	0.688
H3	**SA → TRS**	0.192
H4	**TR → TRS**	0.170
H5	**AnT→ TRS**	0.197
H6	**TRS→AD**	0.25

The current research study model is significantly influenced by Nieuwenhuijsen et al. (2018), who modelled the uptake of AVs levels for the Netherlands using a systems dynamics model. The author's proposed model containing the feedback loops between observed and unobserved values forms a dynamic behaviour in this research. The model links trust and legal readiness to technology adoption and fleet size of AVs influencing their implementation timelines in NZ. Technology development is a trade-off between AVs' reliability, performance, and diffusion, which proliferates with the increase of people's trust. The need for a comprehensive legal readiness structure addressing safety, privacy and cybersecurity concerns are quintessential for public Trust and ultimately acceptability of AV technology. These soft variables have already been embedded into legal readiness stock while formulating Study - 2.

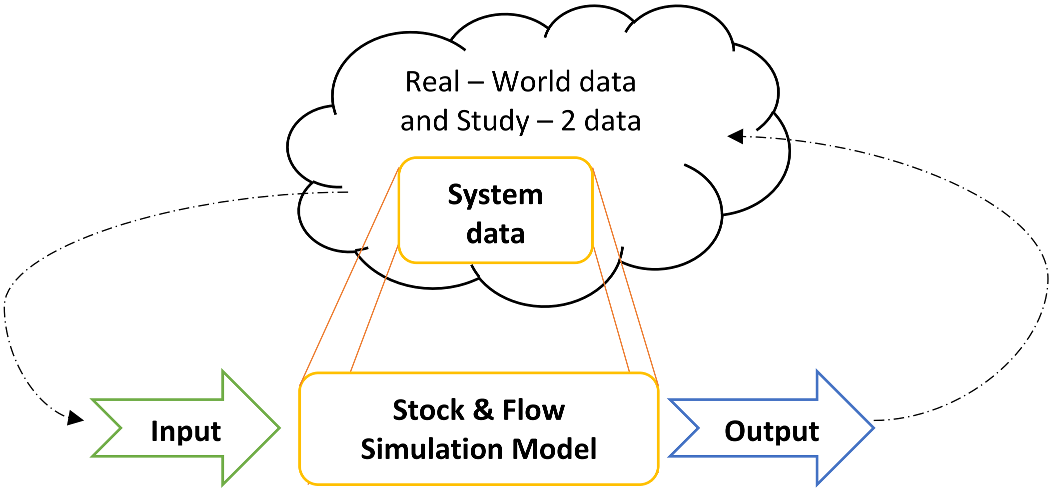
This SD study visualizes and simulates that with the growth of the fleet size of a specific AV level technology, i.e., AV0 to AV5, the probability of end users' familiarity increases. People are more likely to look for using this level of automation. Similarly, with the rise of media hype due to the proliferation and maturity of AV technology, the AVs sales would grow and fleet size increase, especially in AVs' early product life cycle. The end-users will gain more trust in the performance and reliability of this specific level of AV technology, and it will speed up adoption due to an increase in observability (Rogers, 2010). The model is applied to NZ enabling environment both for the base and high/low Automation with high/low trust and Governance mechanism scenarios. In this model, trust and legal readiness (Governance) are modelled as S curves with a growth rate that enables the model to run the required scenarios. It is assumed that the NZ AV market is not generally based on manufacturing and adopts global AV technology as and when available. Vehicle sales in NZ are unlikely to push technology frontiers to that extent. Presently transportation ecosystem comprising driverless technology is highly unpredictable, oscillating greatly with the particular scenario and the chosen policy measures. In this study, the '*High Automation with High Trust and Legal readiness*' ecosystem for AVs deployment is linked with the proliferation of market technology maturity and market penetration at higher levels of automation.

5.4.1 Model Assumptions and High-Level Description

The study model explores the diffusion and substitution trajectories of various levels of AVs in New Zealand. The model shows fleet sizes of the six levels of AVs (AV0 to AV5) that change over the model time horizon. These interactions are theorized to impact the decision of users to purchase AVs or adopt higher AV technologies. The endogenous variables comprise differential equations identifying the real-world system, including parameters filled with real-world data (Figure 5.14), and are time-dependent. The model structure is then compared with known theory. The model simulates the run over time from the year 2021 to the year 2121 (100 years). All the components incorporated in the model are studied within the literature and study – 2 to observe causalities between the components and the real world. The model is built in Vensim PLE 8.2.1. The Euler integration is used, and the time step is set to 0.0156, portraying a week duration. The system components are modelled for each AV level (0 – 5), meaning that each automation level has its own maturity, fleet size, price, and trust etc.

Figure 5.14

Real-World System and SD Model Structure



Note: Diffusion of Automated Vehicles by Nieuwenhuijsen, J., 2015. Master of Science Thesis, Department of Transport, Infrastructure and Logistics, Copyright Delft University of Technology, The Netherlands.

Main dynamics include a number of variables. The Trust variable is fed by situation awareness, legal readiness, anthropomorphism, and training that affects the rate at which the population adopts higher AVs levels. The situation awareness and anthropomorphism variables are linked with technological maturity. The perceived utility (composite weighted variable comprised of price, attractiveness and trust in AV) regulates the adjustment rates between AV levels over time. An increase in a particular AV fleet size represents more people trading in their cars of the old AV type level for a new higher level AV type and upgrading their vehicles. Similarly, the increase in fleet size of a particular AV type affects the rate of adoption of car sharing and the rate of abandonment of cars for people who are sharing cars.

The modelling done in this study is in the context of passenger cars and does not consider commercial vehicles like trucks. Though the model spans 100 years, it doesn't consider major changes in demography or the economy. Adoption of AVs depends on Trust and Legal Readiness (auxiliary variables acquired from SEM), where trust has proven to be the primary determinant. Legal readiness is theorized to mature as an S curve. The user can specify the growth rate of legal readiness and its initial value for scenario testing. Policymakers can create a better regulatory environment and push training towards consumers/end users. The impact of AV sales influences the legal readiness environment in the country and puts pressure on the government to upgrade legal and physical infrastructure. Technological Maturity increases according to the S curve, whereas the price of AVs decreases proportionally to the improvement in technology. The utility function includes legal readiness and trust as weighted factors that affect car purchases. The exogenous growth factor behaves in a manner so that the cars abandoned by car-sharing people who own cars did not grow the fleet sizes but reduce them. New cars per AV level are added as a variable to account for AV buying pressure where there will be no growth in car-sharing or an increase in the abandonment of vehicles by car sharers.

The testing of model behaviour is done in seven steps to explore the model's validity in line with guidelines described by Sterman (2000). First, the boundaries of the model are identified within the context of literature review and scope of the Study – 3. Next, the units and dimensions are aligned and checked for consistency and validity of all the parameters. The data was chosen to set the values for the input parameters, and later parameters were ranked according to the uncertainty. The dependencies of the variables and equations are checked by exploring the structural assessment of the model. All these steps are static, whereas the dynamic steps comprise simulating the model. Then, a set of performance indicators are selected to assess model behaviour. Sensitivity analysis is done to check the model's sensitivity to minor changes in the parameters within the range of +-10% and observe the behaviour of significant variables. Lastly, uncertainty analysis is performed to analyse the behaviour of these performance indicators. Table 5.36 classifies variables as modelled endogenously and exogenously in the SD model.

Table 5.36

Model Boundary

S/No	Endogenous	Endogenous Variable notation	Exogenous
1	Fleet size (AV0-AV5) – the number of vehicles in use on New Zealand roads disaggregated according to the category of AV	AV0(t),… ,AV5(t)	AV comfort – some ordinal value indicating the

S/No	Endogenous	Endogenous Variable notation	Exogenous
			relative comfort of each type of AV.
2	Vehicle purchases (AV0-AV5) – the number of vehicles purchased per year (either second hand or new) disaggregated according to the category of AV	Ci0(t),…, Ci5(t)	The initial vehicle purchase price for each AV level – this is how much any given level of AV is theorized to cost in the year 2020
3	Vehicle trade up – The number of vehicles of a particular AV category (AV0-AV4) that are abandoned for another vehicle of a higher AV category	C01(t),……,C05(t) C12(t),…….,C15(t) C23(t),……,C25(t) C34(t),……,C45(t)	Rate of technology maturity per AV– the rate at which the AV technology matures.
4	Vehicle abandonment – the number of people owning a vehicle that choose to get rid of their vehicles in favour of car sharing or public transport per year	CV(t)	Initial technology maturity value per AV – the initial rate of the technology maturity.
5	The number of cars that per AV type that are taken off roads due to their owners refusing to drive any longer	erg0(t),…… erg5(t)	The rate of car abandonment by car-sharing people
5	Population – the number of people living in New Zealand at any given time	N(t)	the rate of population growth in NZ
6	Utility (AV0-AV5) – the utility of people with a particular type of AV vehicle. This utility function is modelled as a function of the price, the “attractiveness”, the trust for a type of AV and the Legal readiness for AVs.	U0(t),……, U5(t)	The initial value for the number of vehicles in use in NZ
7	Vehicle price – Modelled as falling in proportion to the maturation of technology for a type of AV	p0(t),…..,p5(t)	The growth rate for car sharing
8	Technology maturity – modelled as a logistics function with a growth rate and initial value that the user determines. This function ranges between 0 and 1, where 0 is immature, and 1 is fully mature.	M0(t),……,M5(t)	
9	AV attractiveness – modelled as a weighted additive function of AV category comfort and AV category familiarity	a0(t),…..,a5(t)	
10	AV familiarity – modelled as the proportion of an AV category to the total number of vehicles on the road.	F0(t),….,F5(t)	
11	Legal readiness – grows by a growth rate defined by the user and an initial value defined by a user according to a logistics curve.	LR(t)	
12	Trust for AV (1-5) is modelled as the additive function of Legal Readiness, anthropomorphism, training and situational awareness. The equation derived in an earlier chapter is plugged into the model to account for how quantified trust	T1(t),…, T5(t)	

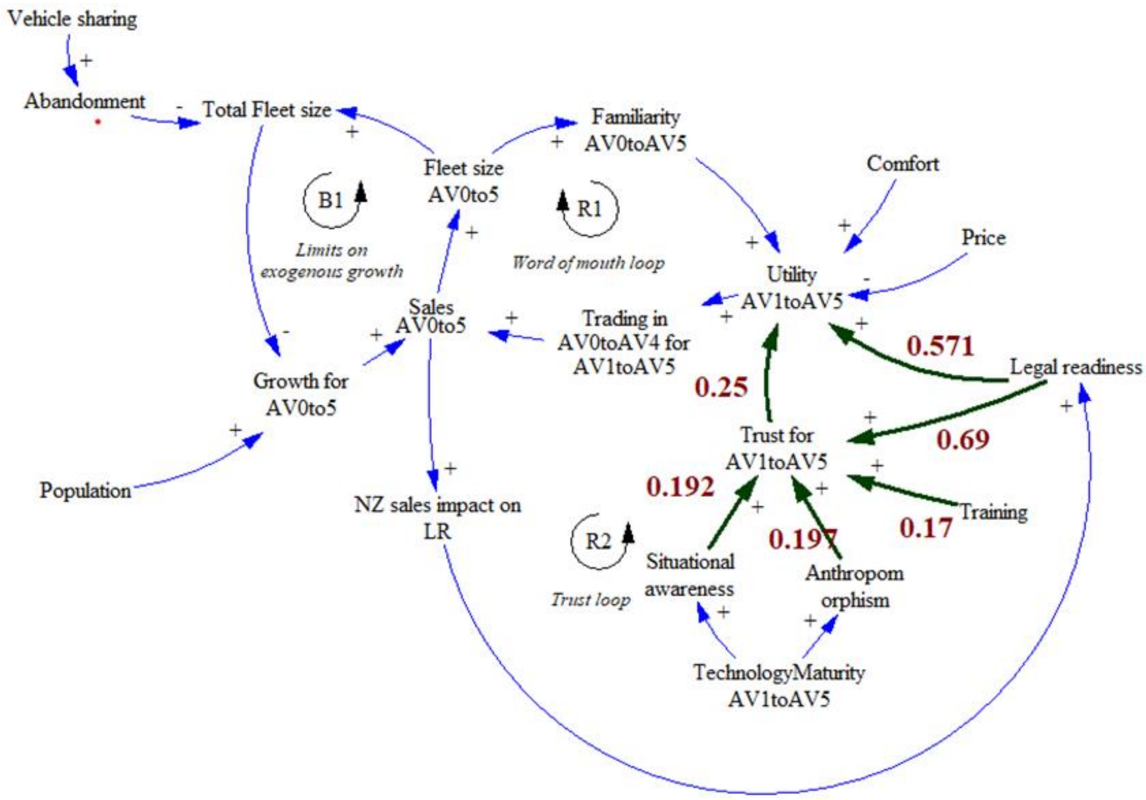
S/No	Endogenous	Endogenous Variable notation	Exogenous
	changes in NZ in response to these four variables.		
13	Situational awareness for each AV type –has an initial value defined by the user and grows in proportion with the technology maturity of that type of AV	SA1(t),….., SA5(t)	
14	Anthropomorphism for each AV type –has an initial value defined by the user and growth in proportion to the technology maturity of that type of AV	Ant1(t),….., Ant5(t)	
15	Training – with a growth rate and an initial value defined by the user according to a logistics curve.	Tr(t)	
16	The number of people that share cars in NZ	A(t)	
17	The number of car-sharing people in NZ that own a vehicles	Ac(t)	
18	The number of car-sharing people in NZ that do not own a car	Aw(t)	
19	The number of people per year that abandon their vehicles in favour of car sharing	arcs(t)	
20	Cars issued to first time drivers – as the population grows, young adults become first-time car owners choosing to purchase some AV Level	NewAV0(t),………., New AV5(t)	

5.4.2 Model Dynamics

This study model is built on the Limits to Success systems archetype and use exogenous and endogenous variables and their dynamics. These constructs are considered and acknowledged by a number of researchers due to their significance in the backdrop of understanding the adoption of AVs by the general public (C. Liu et al., 2019; Nieuwenhuijsen et al., 2018; Stanford, 2015; Zhang & Qin, 2014). Figure 5.15 graphically illustrates the main feedback structures of the proposed study model.

Figure 5.15

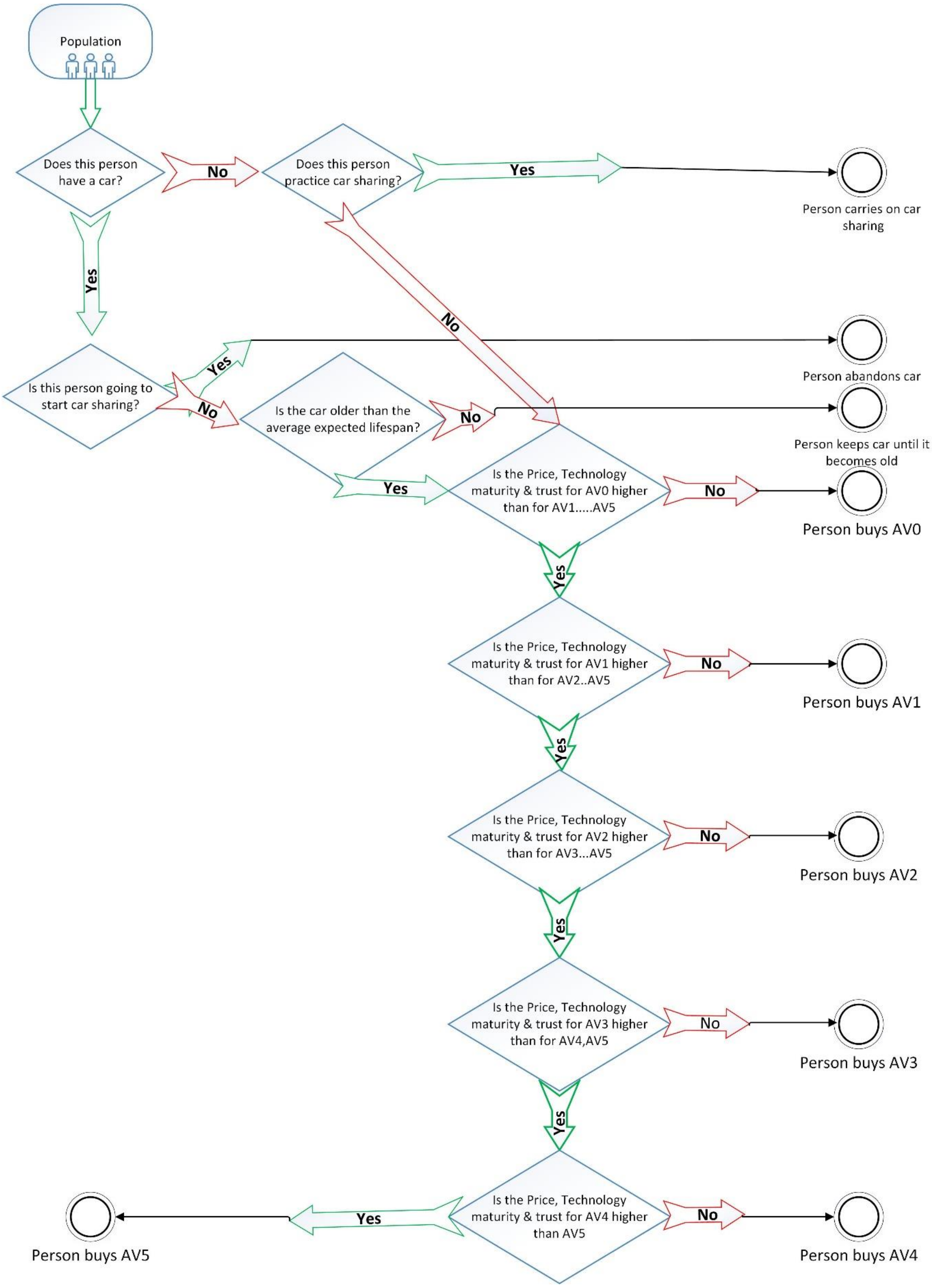
CLD – System Components and Dynamic Loops



Vehicle sales are encouraged by trust and utility (price, familiarity, technology Maturity) and are limited by the size of the population and the behaviour of vehicle sharing. There are two reinforcing feedbacks and one balancing feedback. Any attempt to encourage sales of an AV level will set into motion reinforcing feedback (R1), which promotes further sales. However, the rate of this sales growth is determined by consumers' market size and behavioural appetites. The balancing feedback B1 (called the limits on exogenous growth feedback) ensures that the system cannot issue cars indefinitely or maintain a shortage of cars for long periods of time. B1 ensures that total fleet size is always brought back to equilibrium where the vehicle ownership is tied to the population and their car sharing behaviour. Figure 5.16 decision tree illustrates this user behaviour around AV purchases and how each AV level's fleet sizes and vehicle sales are calculated across time.

Figure 5.16

Model Decision Tree – AV purchases



Note: This diagram illustrates the decisions modelled around car purchases. The consumer is modelled to go through this decision structure. This is how the fleet sizes and vehicle sales for each AV level is calculated across time.

The growth of AV(0-5) demand increases proportionally to population leading to car sales that increase the fleet size for each level of AV and the total fleet size in the country. The uptake of car sharing will reduce fleet size through vehicle abandonment (as a mode of transport and part of the users' lifestyle). As the fleet size increases, the pressure on the demand for AV (0-5) is reduced (is satisfied), and fewer cars of various AV levels are sold, causing the car sales to slow down.

Reinforcing feedback R1 (called the word of mouth loop) works on the principle that the more someone sees an AV type and the more common it is to own any AV type, the higher the utility a person would experience in owning that AV type. This assumption is taken from Nieuwenhuijsen et al. (2018), who identified it as the main dynamic. An AV level is more familiar than another AV levels if the proportion of that AV to the total fleet size of vehicles on the road is more significant. The more sales of a particular AV type, the more familiar it will become. This will put pressure through the user utility function to purchase more of that AV type or to trade in vehicles of lower AV levels. This dynamic helps create periods of AV accumulation and slows down the transition towards AV5. Reinforcing feedback R2 (called the trust loop) puts pressure on the government and society to accommodate a certain level of AV. This could include upgrading laws, infrastructure, or supporting services to implement the technologies successfully. As the sales of higher-level AV increase, the model assumes that there is an upwards pressure on the rate at which Legal readiness (LR) matures. If the sales of higher AV types slows down, then the growth rate of LR also slows down. A change in legal readiness will have an impact on the trust for higher-level AV. It will have implications for the utility function of the user and the substitution between AV levels as a result. The model dynamics did not consider R&D expenditures on AVs as in Nieuwenhuijsen et al. (2018) because NZ will have a minimal impact on the development of this technology. NZ is mainly an adopter of new AV technologies due to less manufacturing base. Secondly, this research is on the importance of Trust and LR in determining the uptake of AV in society and not on the indirect impact of trust and LR on R&D.

5.4.2.1 Fleet size

Fleet size is determined by the number of vehicles used at a certain time specific to a particular region. All six levels of automation (0 to 5) are represented by their fleet sizes, have their respective market share and penetration. Each specific market level is characterized by the average price of vehicles multiplied by the number of vehicles sold. Increase of each fleet size automation takes place through sales. In the backdrop of marketing theory and practice, there will be varying adoption rates among the population. Initially, the early enthusiastic, especially the younger generation, would be keen to adopt a new technology followed by a more significant population group. As the technology matures, people develop more confidence and resultantly it is depicted in a positive effect in sales. At the next stage, a larger section of society would adopt the technology due to increased trust and legal readiness, technical maturity, and perceived economic utility. It will result in an 'S' shaped adoption rate of the curve.

In this study, each specific automation level market penetration is specified as the percentage of the fleet size of this AV level compared to the total AV fleet size. The sum of level 0 to level 5 market penetration rate is 100% at any specific time. Total fleet size is defined as the sum of all six fleet sizes. This diffusion of the AVs innovative technology is depicted in a dynamic feedback loop between the fleet size of AVs and technology development in this study where fleet size is increased by sales and adoption rate represents the relative speed. In the year 2021, each AV fleet size has an initial size AVx(0).

The fleet size for a particular level of AV increases (Cix where x=0,1,2,3,4,5 refers to the level of AV) either through people who trade their older AV level cars for newer AV level cars (c01(t),c02(t),c03(t),c04(t),c05(t),c12(t),c13(t),c14(t),c15(t),c23(t),c24(t),c25(t),c34(t),c35(t),c45(t),), or for the first time car owner who purchases a vehicle (NewAV0(t),NewAV1(t),NewAV2(t),NewAV3(t),NewAV4(t),NewAV5(t),). The equation for Cix is:

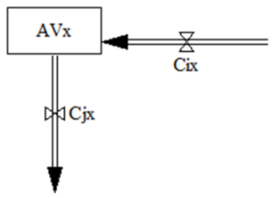
$$Cix = \sum_{0}^{x-1} cix + IfThen\ Else(NewAVx(t) > 0, NewAVx(t), 0) \qquad (1)$$

Sales portray a transition in the number of AVs in the total fleet from one automation level to another Figure 5.17. This may happen due to cars being disposed of in favour of new cars or cars being retrofitted towards a higher automation level. Sales are found out through perceived economic utility, technical maturity, trust and legal readiness (which is essentially an adoption rate in a particular level of automation times the potential for car sales). The vehicle changes from a lower to a higher level of automation.

In other words, the actual sales of AV1 is the sum of first time car buyers choosing to buy an AV1 (potential for car sales times the adoption rate of AV1) with the addition of all the people who have changed “dumped” their AV0 car for an AV1 car.

Figure 5.17

Stock and Flow for Fleet Sizes



The following change of vehicle variables are calculated (marked with x) as shown in Table 5.37.

Table 5.37

Change of Vehicles

	Change for AV0	**Change for AV1**	**Change for AV2**	**Change for AV3**	**Change for AV4**	**Change for AV5**
AV0		X	X	X	X	X
AV1			X	X	X	X
AV2				X	X	X
AV3					X	X
AV4						X
AV5						

This means that a person possessing an AV1 vehicle can at any time choose to purchase an AV2, AV3, AV4 or AV5 vehicle. Due to the prices and rate of technology development, it is unlikely that a person possessing an AV1 vehicle will purchase an AV5 vehicle immediately (perhaps later on when prices fall and technology matures). Trust is added to this equation, suggesting that if the trust for AV1 is high, people will be more willing to trade in their old AV0 cars for AV1 cars. If the trust in AV1 is low, then it is less likely for them to trade in their AV0 car for an AV1 car. Moreover, as per Nieuwenhuijsen Model, the relative utility, the technological maturity, and the average useful life between two AV types will tell what percentage of the old type of AV fleet will be traded for a higher AV type in any given year.

The equation for any cij is calculated as a function of one over alpha (the average lifespan of a vehicle), the technology maturity for that AV type, the utility of the higher AV level over the sum of the utilities of the higher and current AV level and the fleet size for the current AV level. If the utility of the higher AV level car is greater than the utility of the existing AV level cars, then more people are likely to substitute the old AV level car for a new one. If the technology maturity of the higher AV level car is more, then there will be more substitution in any given period towards the higher technology AV level car. Suppose the average lifespan of a vehicle (the average length of time that a person keeps a car) is larger. In that case, there will be less substitution to higher AV technologies happening at any given time. These terms described above multiplied together give a fraction of a type of AV that the user trades in for higher AV technologies.

$$cij = \frac{1}{alpha} Mj(t) \frac{Uj(t)}{(Uj(t)+Ui(t))} * AVi(t) \quad (2)$$

When the maturity increases, the users will acquire more confidence and trust in the reliability and performance of an AV and will be more likely to change the AV type from i to j. Similarly, if the utility grows with respect to i for any AV type, the likelihood of users to favour level j over level i increases. This study encapsulates the entire modelling environment from AV0 to AV5. However, for easy assimilation, three AVs levels are depicted in illustrations.

The variable NewAVx (where x=0,1,2,3,4,5 represents the level of automation) is zero whenever the total fleetsize (Vtot) exceeds the difference between the number of people in New Zealand (N) and the number of car-sharing people who do not own a car (Aw). This difference also forms a variable 'nd' in the model such that N(t)-Aw(t)= nd(t). This would provide a number for the number of people in New Zealand who own cars (both car-sharing car owners and car owners that do not share). If multiplied by vehicles per person fc(t), this would provide a number for the number of vehicles in New Zealand. Suppose the total fleet size is smaller than the number of people in New Zealand who should own cars. In that case, the change in the number of theoretical car users (nd -ndt where ndt is the delayed number of theoretical car owners) is added to the particular level of AV in proportion to the current ratio of the specific level of AV to the total fleet size. NewAV can be negative (should nd-ndt <0 or rather, if there was a decrease in the size of nd from one period to the next). If it is negative, then no new cars for first-time drivers are required. Instead, new drivers are assumed to be car sharers until they become car owners:

$$NewAVx(t) = If\ then\ Else(Vtot < \left(N(t) - Aw(t)\right), \left(nd(t) - ndt(t)\right) * fc(t), 0) * AVx(t)/Vtot(t) \quad (3)$$

The stock for fleet size is calculated with the following equation:

$$\frac{dAVx}{Dt} = Cix - Cjx \quad (4)$$

The fleet size (Cjx) for a particular level of AV would decreases because people adopt car-sharing and would never own another vehicle (ergx) or traded AVs for higher level AVs (Cix). In this way, the six AV stocks are linked (as there is a flow from AV0 to AV1-5 and a flow from AV1 to AV2-5 and a flow from AV2-AV4 etc.).

$$Cxj = \sum_{x+1}^{5} cxj + ergx(t) \quad (5)$$

The adoption of car-sharing leading to vehicle abandonment ergx(t) is calculated as the product of the total fleet size (Vtot), the number of vehicles abandoned for car-sharing (CV) and the ratio of an AV level fleet size to the total fleet size.

$$ergx(t) = Vtot(t) * CV(t) * AVx/Vtot \quad (6)$$

The number of vehicles abandoned for car sharing is calculated by the product of fc (the fraction of the population that owns a car calculated as Total fleet size Vtot, divided by Population N) and the ratio of the number of car-sharing people who abandon their cars annually to the total fleet size. This gives a ratio of the number of car-sharing people who abandon their cars annually to the population of New Zealand. This ratio multiplied by the total fleet size gives the number of cars abandoned. Then, taking the product with the proportion of any AV level to total fleet size, the equation calculates the number of any type of AV abandoned by car sharers each year. In calculating ergx(t), it is assumed that equal proportions of AV0-AV5 car-sharing car owners choose to abandon their cars each year.

$$CV(t) = fc * abr/Vtot \quad (7)$$

5.4.2.2 Maturity and Price

The purchase price is modelled as the product of the initial price (ipx where x=0,1,2,3,4,5 represents a level of AV) and the extent to which the technology can still mature. This will force the price to become cheaper as the technology matures.

$$Px = \mathrm{ipx} * (1 - \mathrm{Mx}) \quad (8)$$

The technology maturity at any level x of AV is modelled as a sigmoidal curve. The initial value calibration variable assumes various numbers to shift the curve and ensure that the initial value specified for Mx is modelled. The technology growth factor is an exogenous variable that allows the user to adjust the speed at which AV technology matures.

$$Mx(t) = \frac{1}{(1 + e^{-Technology\ growth\ factor * \frac{(t - start\ year\ value)}{Time\ Step}})^{initial\ value\ calibration}} \quad (9)$$

Technology maturity is a trade-off between AVs reliability and performance, which influences Situation Awareness and Anthropomorphism parameters. As the technology progresses for each AV level type (AV0 and AV1 are generally constant), the Anthropomorphism and Situational Awareness variables also increase. Hence there is a direct relationship between these parameters and technology maturity. Moreover, with the maturity in technology, the price of AVs fall, hence there is an inverse relationship. However, this study incorporates a growth rate for technology maturity that can speed up or slow down the technology maturity process for each AV type. NZ remains largely a technology adopter of global automotive innovation besides having a love to own a car.

5.4.2.3 Utility, Trust and Attractiveness

A theoretical average user utility is modelled for each level of AV (0-6), and these utility functions are used to model the adoption of AV over the time horizon. If the utility of a higher level of AV exceeds that of a lower level of AV, the population will adopt the higher level of AV to the extent of the difference in utilities. As the trust variable is only defined for AV (1-5), the equation describing Uo(t) will assume a price weight of 0.5 and an attractiveness weight of 0.5 and a trust weight and LR weight with a value of 0. For other levels of AV, utility is modelled as the additive weighted function of normative price (pnx(t) where x=0,1,2,3,4,5 represents a level of AV), attractiveness (ax(t) where x=0,1,2,3,4,5 represents a level of AV), legal readiness (LR(t)) and trust T(t). The effect of trust and legal readiness on the users' adoption of AVs has already been studied and verified in Study – 2 above. This SD model study analysis includes beta values of all constructs comprising the net effect of trust.

$$Ux(t) = pnx(t) * Price\ weight + ax(t) * Attractiveness\ weight + LR(t) * legal\ readiness\ beta * LR\ weight + Tx(t) * Trust\ beta * Trust\ weight \quad (10)$$

The normative price is calculated as the ratio of the price at time t to the sum of the initial price and the initial retrofit price (irpx(t) where x=0,1,2,3,4,5 represents a level of AV).

$$pnx(t) = \frac{(px(t))}{(ipx(t)+irpx(t))} \quad (11)$$

Attractiveness is the weighted sum of Comfort Cx(t) and Familiarity Fx(t), where Familiarity is calculated as the ratio of the fleet size to total fleet size.

$$ax(t) = Cx(c) * Comfort\ Weight + Fx(t) * Familiarity\ Weight \quad (12)$$

Legal readiness / Governance is theorized to mature as an S curve, and the user can specify the growth rate of legal readiness and the initial value of legal readiness for scenario testing. Legal readiness is modelled as the product of this logistics function and a variable called "impact of AV1-5" sales on LR, which is calculated as the $\frac{\sum_1^5 Cix(t)}{Vtot}$. If the proportion of AV1-5 sales to the total fleet size increases, pressure is put on the government to upgrade laws and infrastructure to enable the growing use of AV1-5.

$$LR(t) = (1/(1 + EXP(-Growth\ Legal\ readiness * (Time - start\ year)/TIME\ STEP)))\verb|^|(1/initial\ legal\ readiness) * "Impact\ of\ AV1 - 5\ sales\ on\ LR" \quad (13)$$

Trust is calculated as the weighted sum of situational awareness, Anthropomorphism, legal readiness and training.

$$Tx(t) = max(0, situational\ awareness\ AV5 * Beta\ SA + anthropomorphism\ AV5 * Beta\ Ant + Beta\ LR * legal\ readiness + Beta\ tr * training) \quad (14)$$

Anthropomorphism and Situational awareness are both calculated as a function of the maturity of AV5 technology and a variable that adjust the initial values of

$$Antx(t) = M5 + Calibrate\ Trust\ variable \tag{15}$$

$$SA(t) = M5 + Calibrate\ Trust\ variable \tag{16}$$

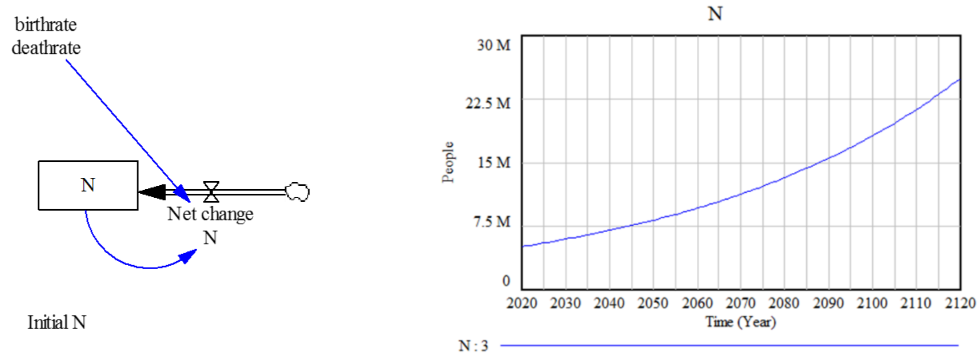
5.4.2.4 Population

Population (N(t)) is the stock of the NZ people that grows over the 100-year simulation horizon by a fixed percentage a year with an initial value for the year 2021 (Figure 5.18).

$$\frac{dN}{dt} = N(t) * birthratedeathrate \tag{17}$$

Figure 5.18

Stock and Flow Structure for Population



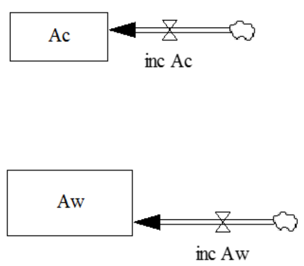
Note: With an initial value N(0)= 5.1e+006, birth rate death rate is equal to 0.016 % per year. The estimates depict that the population of NZ is growing from a 5.1million in the year 2021 to approximately 24.94 million in the year 2121.

5.4.2.5 Car Sharing

To understand the car-sharing market, a stock is identified with the number of people with car-sharing. This study modelled how many people had cars, how many didn't have cars, and how many were car-sharing. The people who weren't car-sharing and didn't own cars are potentially like to buy a new car. The total population stock varies with the flow of births and death, i.e. birth rate minus death rate. Initial car share users modelled as an initial fraction of people car sharing. The cars sharing people stocks, with and without a car, both increase through the same construction. The car-sharing users stock is integral to the adoption rate of car-sharing times the fraction of the users with a car over time. Abandonment is the movement and flow of users with a car to users without a car. Car sharing without a vehicle is the number of people in NZ who practice car sharing at any given time but do not own a vehicle. The total number of car-sharing people A(t) is calculated as the sum of the car-sharing people with a car Ac(t) and the car-sharing people without a car Aw(t). With an initial value of 0.25* 5.1e+006, it is assumed that at least a quarter of the population of NZ will be sharing cars without owning one, as happens in the case of children. Ac(t) stock is calculated as the integral of the cars per person fc(t) multiplied with the growth in the number of people who have adopted car-sharing arcs(t) minus the number of people who are car sharers and have abandoned their car ownership abr(t). The stock of car-sharing users who do not own a car is calculated as the integral of the cars per person fc(t) multiplied with the growth in the number of people who have adopted car-sharing arcs(t) plus the number of people who are car sharers and have abandoned their car ownership abr(t) in that period (Figure 5.19).

Figure 5.19

Stock and Flow Structures for Car Sharing with Cars and Car Sharing without Cars



$$\frac{dAc}{dt} = fc(t) * arcs(t) - abr(t) \quad (18)$$

$$\frac{dAw}{dt} = abr(t) + arcs(t) * fc(t) \quad (19)$$

Cars per person are calculated as the quotient of the total fleet size over the total population size:

$$Fc(t) = Vtot(t)/N(t) \quad (20)$$

The number of car-sharing people who have abandoned their cars in a given time is calculated as the stock Ac(t) multiplied by the annual rate of car abandonment among car sharers sr:

$$Abr(t) = sr * Ac(t) \tag{21}$$

The number of people who have adopted car sharing is calculated as the product of the growth rate in car-sharing g(t), the number of car-sharing people A(t) and the percentage of the population that car still adopts car-sharing PA(t)/N(t). PA(t) is calculated as the number of people in the population minus the number of people who are car sharing.

$$Arcs(t) = g * PA(t)/N(t) * A(t) \tag{22}$$

The growth rate in car sharing is calculated as the sum of some initial growth rate gm and the sum of some additional growth rate tm which only comes into effect once the level of technology maturity reaches a certain level. This equation was taken from Nieuwenhuijsen et al. (2018) and the 0.4 reflects their estimations.

$$g(t) = gm + IfThenElse(M5(t) > 0.4, tm, 0) \tag{23}$$

5.4.3 Static and Dynamic Testing of the Model

In the above paragraphs, all the major equations used to build the model are displayed. A complete set of equations is given in this study's appendix. Few equations used static parameters as an input for the model. And a set of parameters values are selected to run base and other scenarios simulating the start time of 2021. As discussed earlier, all the model parameter values have been based on Study – 2 and the literature review.

5.4.3.1 The Model Parameters and Checks

Before running the model scenarios, a parameter check is performed against sensitivity and uncertainty during the model testing process (Nieuwenhuijsen et al., 2018). Uncertainty analysis is carried out during static testing of the model and sensitivity analysis during dynamic testing of the model. Uncertainty means the non-existence of an extensive range of values or non – availability of data in the literature leading to imprecise estimates. In contrast, sensitivity analysis is referred to the changes of all input parameters in the model by -10 to +10%. These changes are checked against the suitable performance indicators, and numerical and behavioural sensitivity is monitored. In other words, the sensitivity analysis quantifies the effects of varying parameter values and structural assumptions (Ford, 2009; Tian et al., 2016). The model's sensitivity for these input parameters is low if the indicators do not change by altering a specific input parameter. However, if there is a numerical change, then sensitivity is medium, whereas if there is a behavioural change, then the sensitivity of the specific input parameter is high. Similarly, uncertainty is classified into low, medium and high. The low means the high existence of historical, consensus and literature data. The medium refers to the availability of few studies and some agreement on the data range in the literature, and high means few to no data availability in the studies. Table 5.38 displays the various parameters used in the modelling process.

Table 5.38

The Model Parameters

Parameters	Notation	Value	Unit	Uncertainty	Sensitivity
Initial Maturity Level 0	$M_{0,0}$	1	Dmnl	Low	Low
Initial Maturity Level 1	$M_{0,1}$	0.62	Dmnl	High	Low
Initial Maturity Level 2	$M_{0,2}$	0.547	Dmnl	High	Low
Initial Maturity Level 3	$M_{0,3}$	0.02	Dmnl	Medium	Low
Initial Maturity Level 4	$M_{0,4}$	0.1	Dmnl	Low	Low
Initial Maturity Level 5	$M_{0,5}$	0.0001	Dmnl	Low	Low
Initial fleet size Level 0	$V_{0,0}$	4.4e+006	Car	Low	Low
Initial fleet size Level 1	$V_{0,1}$	3000	Car	Medium	Low
Initial fleet size Level 2	$V_{0,2}$	300	Car	Medium	Low
Initial fleet size Level 3	$V_{0,3}$	0	Car	Low	Low
Initial fleet size Level 4	$V_{0,4}$	12	Car	Low	Low
Initial fleet size Level 5	$V_{0,5}$	0	Car	Low	Low
Initial price Level 0	$ip_{0,0}$	18315,1	NZD/Car	Low	Low
Initial price Level 1	$ip_{0,1}$	23808,4	NZD/Car	Low	Low
Initial price Level 2	$ip_{0,2}$	36630,19	NZD/Car	Medium	Low

Parameters	Notation	Value	Unit	Uncertainty	Sensitivity
Initial price Level 3	$ip0,3$	109890,6	NZD/Car	Medium	Low
Initial price Level 4	$ip0,4$	366301,9	NZD/Car	High	Low
Initial price Level 5	$ip0,5$	915757,9	NZD/Car	High	Low
Initial car-share users modelled as initial fraction of people car sharing	A_0	0.2	Dmnl	Medium	Low
Initial population	N_0	5.1e+006	Person	Low	Low
Price weight		0.25	Dmnl	High	Medium
Attractiveness weight		0.25	Dmnl	High	Medium
Familiarity weight		0.5	Dmnl	High	Low
Comfort weight		0.5	Dmnl	High	Low
Trust weight		0.25	Dmnl	Low	Low
LR weight		0.25	Dmnl	Low	Low
Trust beta		0.25	Dmnl	Low	Low
LR beta		0.69	Dmnl	Low	Low
Ant beta		0.2	Dmnl	Low	Low
SA beta		0.19	Dmnl	Low	Low
Tr beta		0.17	Dmnl	Low	Low
The average lifetime of a car	a	10.4	Year	High	High
Average household size	shh	2.2	Person/household	Low	Low
travel demand per person	ptd	10000	km/year/person	Low	Low
Growth of the car-sharing market	g_{cs}	0.05	Dmnl	High	High
Technology multiplier	tm	0.1	1/Year	High	Medium
Percentage of car shedding among car share users	sr	0.05	Car/person	High	Low

Note: Most of the notations/abbreviations are adopted from Nieuwenhuijsen et al. (2018) to keep the reader's similarity and general understanding purposes. However, their values, uncertainty and sensitivity analysis are calibrated for this Study – 3.

5.4.3.2 Dimension Check

During the static testing of the model, all the units are counter checked for consistency and their existence in the real world. Most of the model variables have a real world counterpart with dimension. However, certain auxiliary variables are dimensionless. These include trust, legal readiness, anthropomorphism, situation awareness, training, familiarity, comfort, and attractiveness. These variables have their underpinnings and significance to the diffusion of AVs within the context of literature. The unit checking tool in Vensim is used to find out dimension errors.

5.4.3.4 Structure Assessment Check

It is also a static test of the model to confirm the dependencies of the model components according to the structure articulated in the literature (Bala et al., 2016; Ding et al., 2018; Senge & Forrester, 1980). It is about users' preferences on the adoption of AVs, technology diffusion, choice behaviour and innovation systems. The trust and legal readiness framework are already validated in Study – 2, dynamics of adoption of car-sharing is modelled as delineated by Sterman (2000). The utility function depending on price and attractiveness, as identified by Rogers (2010), and the trust highlighted in Study – 2. Similarly, the technology maturity of AVs based on Situation Awareness and Anthropomorphism influenced by the logarithmic curve is considered within the literature in the HMI context. The effect of the car on ownership, baseline price, fleet size adoption, growth of the car-sharing market, a lifetime of the car, initial maturity, and the effect of car-sharing on car ownership is taken from Nieuwenhuijsen et al. (2018). All these studies are highly regarded and well-cited. Hence it is concluded that the structure assessment criterion is fully established during the model building process.

5.4.3.5 Performance Indicators

The chosen performance indicators involved in dynamic testing have a clear counterpart in the real world and are in line with the purpose of this model study. The stocks are also generally used as performance indicators. These include total fleet size (AV0 to AV5) and their market penetration etc.

5.4.3.6 Sensitivity Analysis

One of the model validation dynamic tests is the behavioural sensitivity test. Its purpose is to observe the model behaviour by changing the parameters (Bala et al., 2016; Senge & Forrester, 1980). Highly uncertain and sensitive parameters have a high impact on the behaviour of the model. A Monte Carlo simulation is done in multiple simulations defining the certainty range of 10 % to selected parameters. The Monte Carlo simulation simulates 1000 runs and uses Latin Hypercube sampling. Generally, the model is not very sensitive to 10% changes in the parameter values, and the model possesses a low sensitivity to most of the parameters. Some of the illustrations while testing parameter values for alpha (average life span of vehicle 1 – 20 years), technology growth factor (0 – 20% per year), Legal Readiness growth (0 – 20% per year), Price weight (0.1 – 0.5) and trust weight (0.1 – 0.5) are shown from Figure 5.20 to Figure 5.24 below.

Figure 5.20

Behavioural Sensitivity Test for Alpha (Average Lifespan of Vehicle 1-20 years)

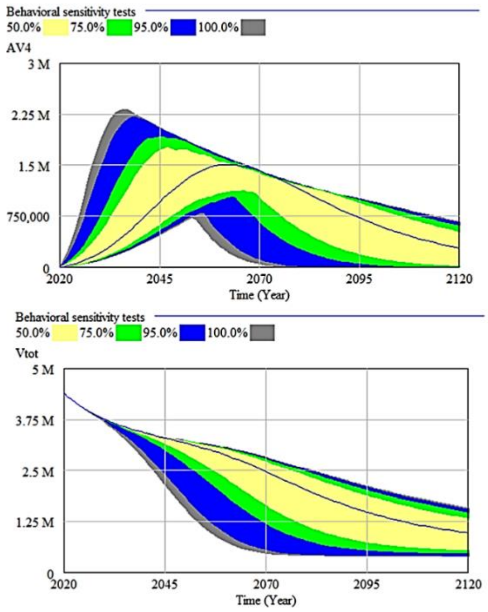


Figure 5.21

Behavioural Sensitivity Test for Technology Growth Factor (0-20% per year)

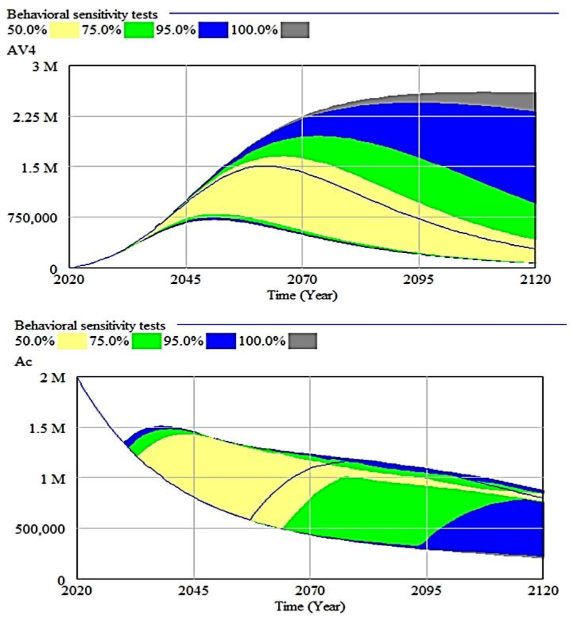


Figure 5.22

Behavioural Sensitivity Test for Price Weight (0.1-0.5)

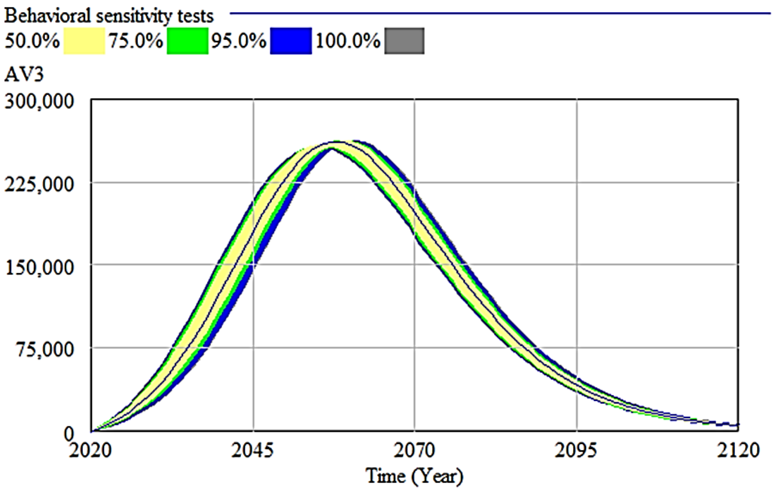
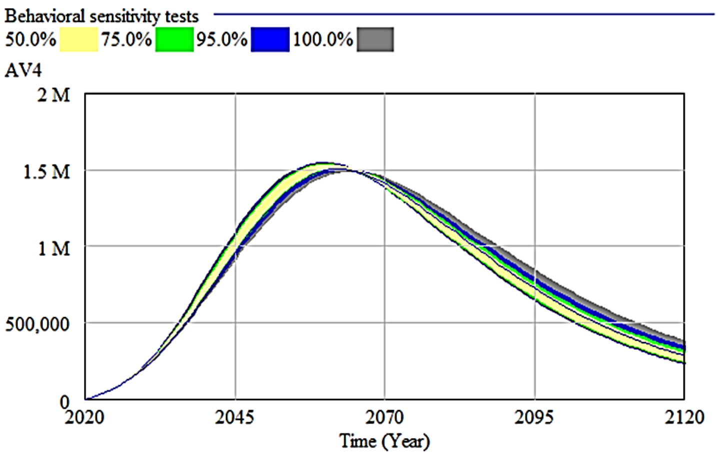


Figure 5.23

Behavioural Sensitivity Test for LR Growth Rate (0-20% per year) and LR Weight (0.1-0.5)



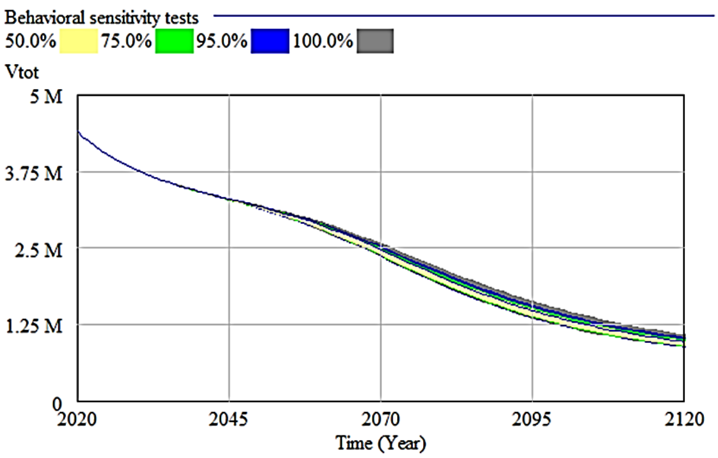
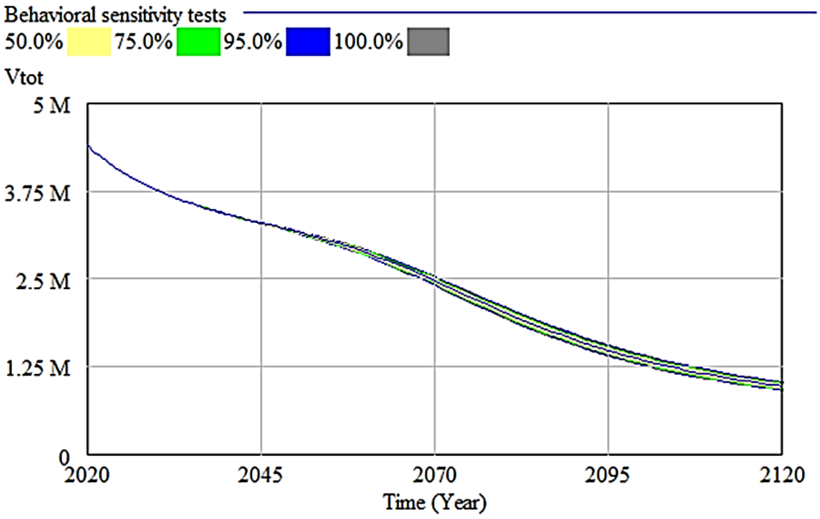


Figure 5.24

Behavioural Sensitivity Test for trust weight (0.1-0.5) and SA, Ant (0.3-0.5)



It is seen from the results above that the Monte Carlo sensitivity testing around values for alpha (average lifespan of vehicle 1-20 years) indicate that the model is very sensitive for this parameter. It is influential as it will determine how many vehicles are bought and how quickly vehicles will be changed for a higher AV technology. Alpha represents a delay or slowdown in vehicle adoption. Moreover, the quickest way of ensuring the uptake of AV technologies would be to shorten the average lifespan of a vehicle (the turnover time).

The Technology growth factor (0-20% per year) impacts the various levels of AV, total fleet size and the car-owning population of car sharers. The model is very sensitive around the rate of technology maturity. The model is not very sensitive to changes in the price weight, LR growth rate (0-20% per year) and LR weight (0.1-0.5), trust weight (0.1-0.5) as well as in the calibration parameter (SA and Ant) (0.3-0.5).

5.4.4 Running Scenarios

To evaluate the output of this study modelling process, three scenarios are presented below, i.e. Base run, High Automation and High Trust & Governance Mechanism, and Low Automation with Low Trust and Governance Mechanism. High Automation and High Trust and Governance postulate that there is generally a more significant trust of the NZ people on AVs backed up with progressive governance/legal readiness regime. The rate of AV technology maturity is also higher. The Low Automation and low trust and governance regime generally consider a low level of trust, and a conservative governance regime prevailing in the country besides technology maturity is also low (Figure 5.25). The Base run is a middle range of scenario analysis between high and low that includes the beta values of trust and legal readiness framework. The simulation runs from the year 2021 to 2121. For the Base run, the study runs several simulations to observe the impact of trust, governance, technology maturity, price reductions through subsidies, extra funds and comparing various car-sharing structures on the market penetration of the different AV levels. In the AV high scenario, the main focus was towards positive trust and legal readiness policy impacts towards AV5, since AV5 is high automation driverless technology that needs to be harnessed to accrue maximum societal benefits.

Figure 5.25

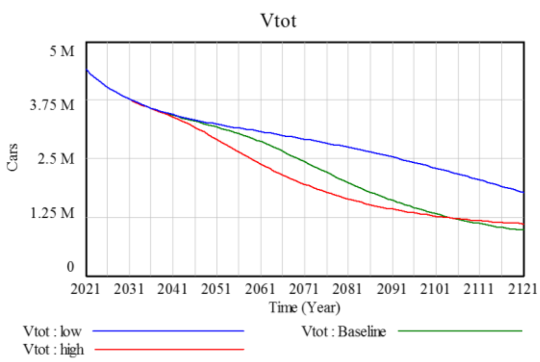
Perimeter Settings for Different Scenarios

<u>**Parameters**</u> *Based on Customer Attitude, Economic Growth, technology Maturity, Utility, Trust and Legal Readiness/Policy*	**Default Base run**	**High Automation with high trust and Governance mechanism**	**Low Automation with low trust and Governance mechanism**
rate of technology maturity	0.05	0.1	0.02
Initial value Trust (towards automation in general)	0.25	0.85	0.05
Calibrate trust variable	-0.3	0.54	-0.5
Initial Legal Readiness (use the initial trust value to calibrate)	0.69	0.95	0.6
Initial Training(use the initial trust value to calibrate)	0.17	0.85	0.17
Growth rate legal readiness	0.05	0.1	0.02
Growth rate training	0.05	0.1	0.02

Note: Beta values of Trust, Legal readiness, Anthropomorphism, and Training acquired from Study – 2 has already been integrated into the equations of the SD Model.

Figure 5.26

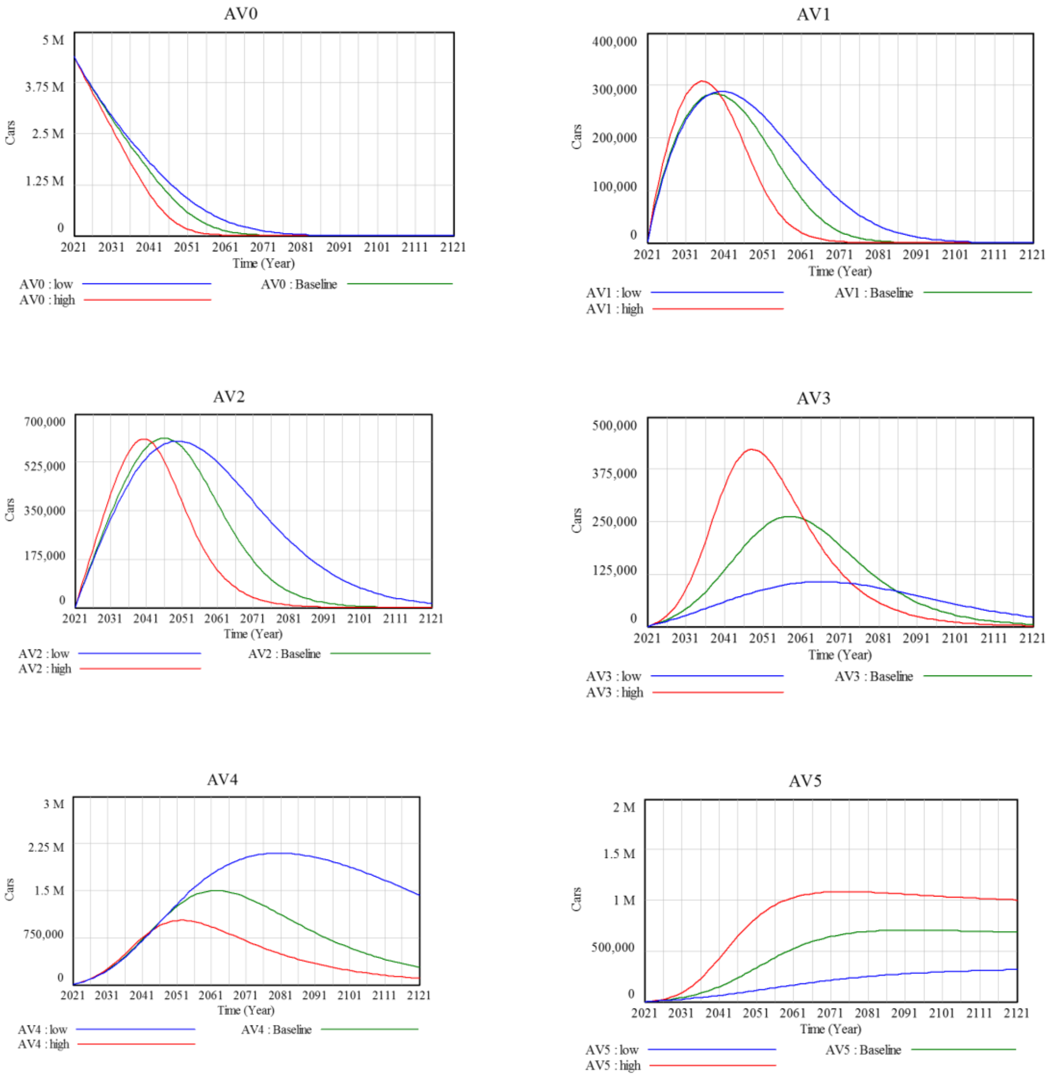
Total AV Fleet Size Behaviour (2021 – 2121)



It can be seen from Figure 5.26 that in High Automation and High Trust Scenario, the Total AV Fleet size decreases much earlier (from 2031 – 2111) than the Low Trust and Low Automation Scenario and Baseline Scenarios. It means that once people have more trust in technology supported by progressive governance regimes and high technology maturity, they will buy AV higher levels much earlier. The people are likely to trade in their old cars and old AV models much faster in favour of higher levels and car-sharing practices instead of owning. Therefore, the diffusion of AV technology will be higher in NZ. Individual fleet size behaviour from AV 0 to AV5 is as below.

Figure 5.27

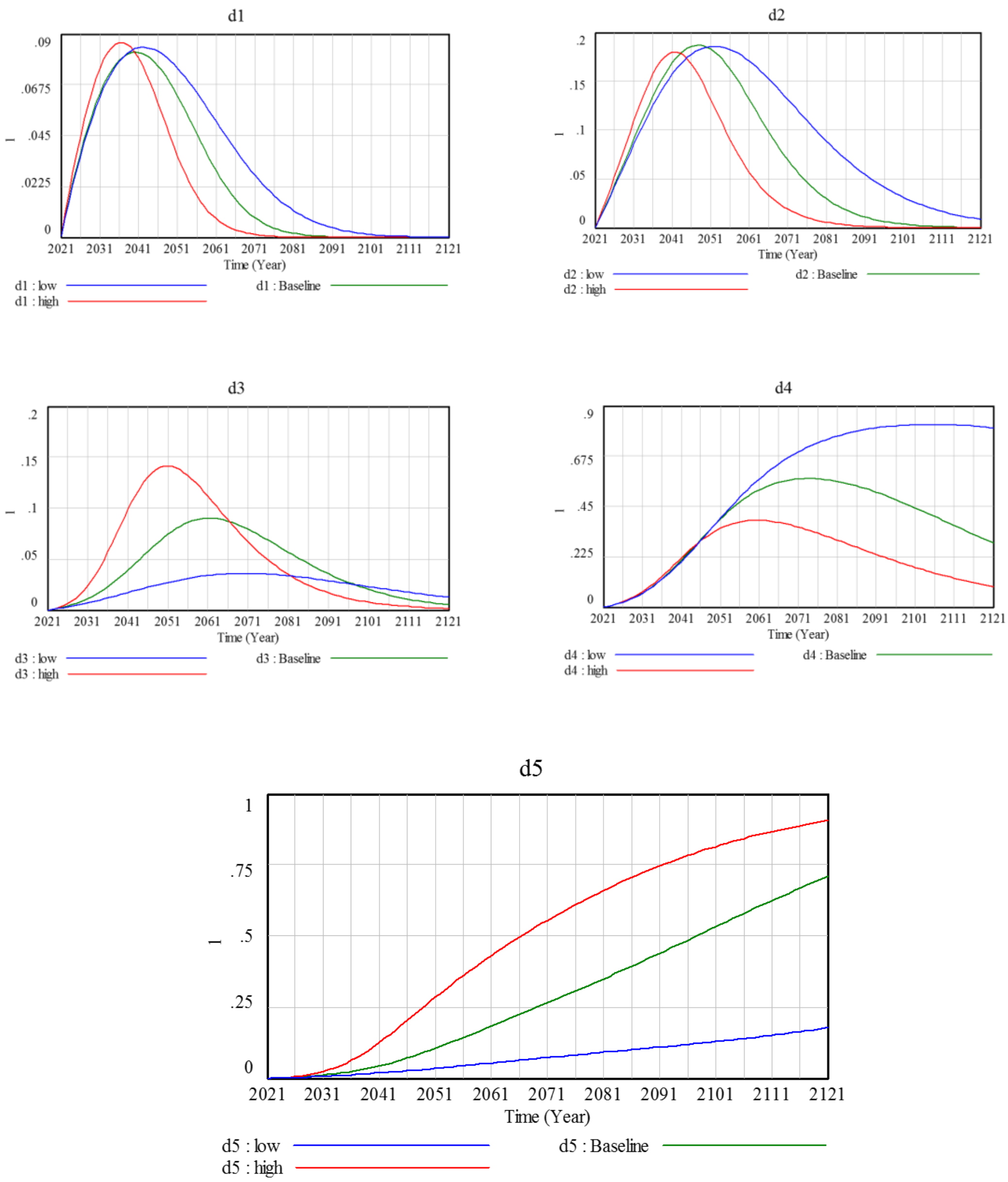
Individual AV Level Fleet Behaviour (2021 – 2121)



The results show that AV0 fleet size finishes in 2051 (high trust scenario), then AV1 in 2070, AV2 in 2081, AV3 in 2111. The AV4 fleet stock decreases in 2121, and AV5 takes birth around 2031 and will continue to proliferate beyond 2121 (Figure 5.27).

Figure 5.28

Individual AV Level fleet Market Penetration (2021 – 2121)



The market penetration of each level (d1 – d5) is given as the percentage of the fleet size of that specific AV level compared to the total fleet. The sum of the market penetration of all levels (AV0 to AV5) is 100% at any given time. The adoption of AVs depicts a dynamic feedback loop in the model between trust, technology maturity and fleet size of AVs. This fleet size increased through sales, where relative speed is the adoption rate. The market penetration in the high AV Scenario shows that AV3 reaches maximum penetration around 14% in 2045 – 2055, AV4 around 43% around the year 2061 and then subsides steeply. AV5 achieves the most dominant market penetration above 90% in 2121. Whereas market penetration of AV4 and AV5 in Low AV Scenario only reaches around 20% in 2121. In both scenarios, the market penetration of AV1 and AV2 drops very rapidly after 2041 and these AV levels hardly any significant proportion of market penetration later (see Figure 5.28).

Figure 5.29

Price Reduction Behaviour AV4 through Tax Reduction or Subsidy

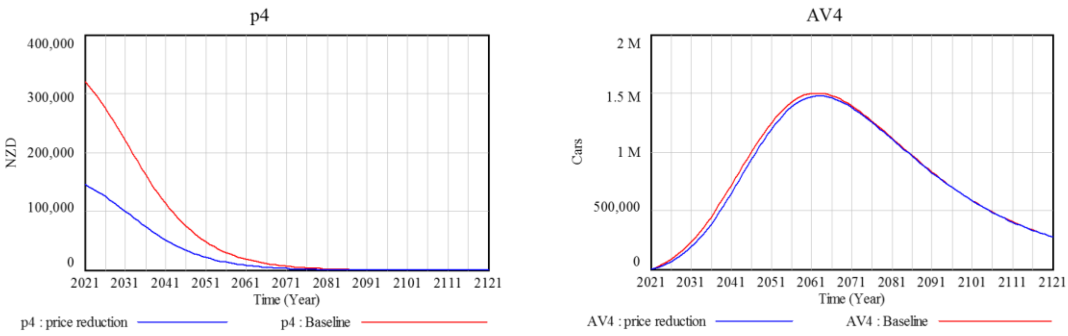
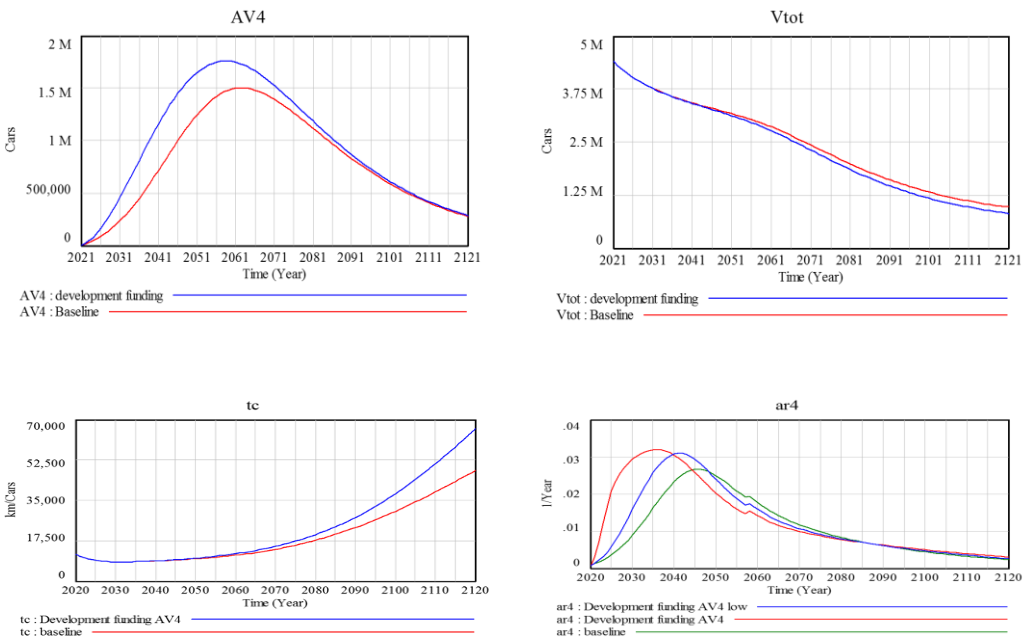


Figure 5.30

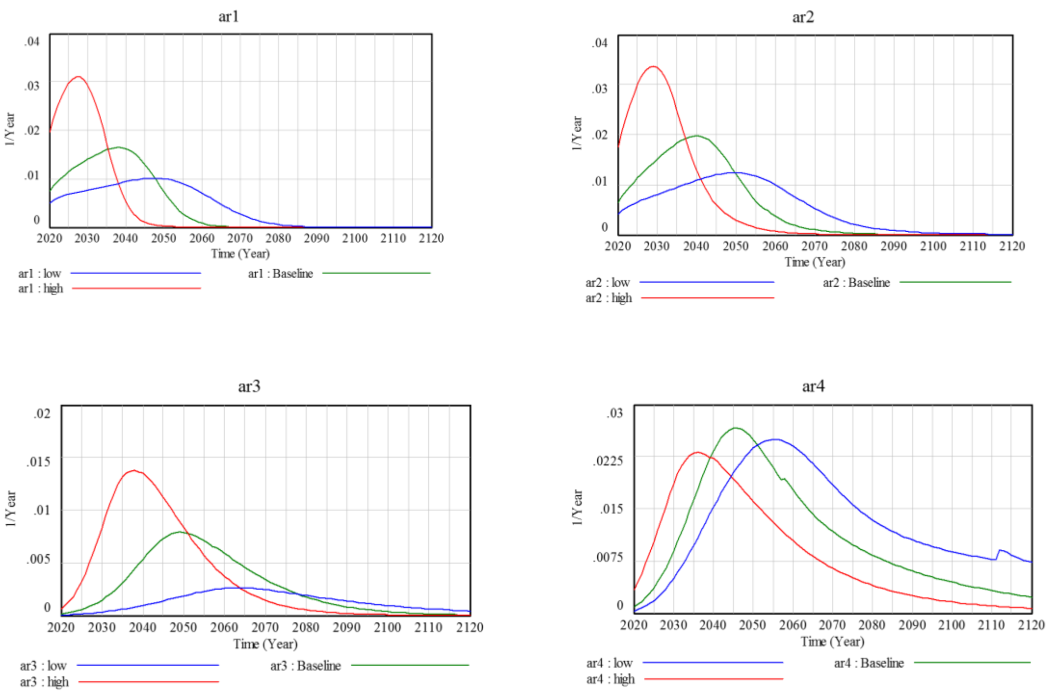
AV4 Behaviour for Provision of Development Funds

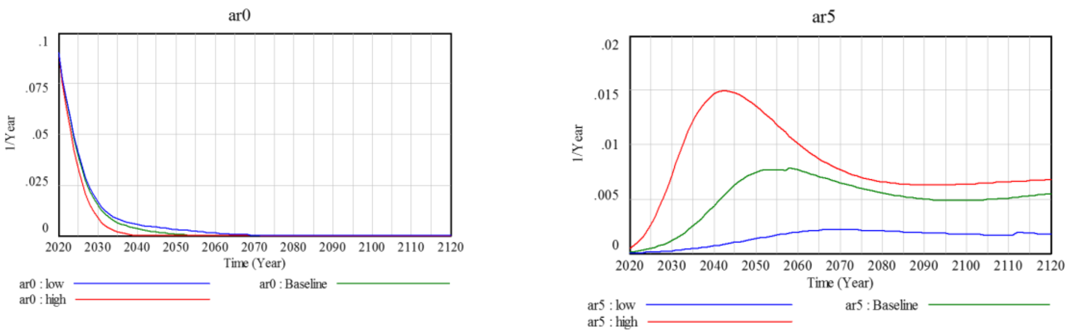


Keeping in view the small manufacturing base of AV4 shuttle in NZ, a scenario is developed in Figure 5.29 and Figure 5.30. An AV4 behaviour is noticed due to government subsidies or tax benefits and pumping in external development funds to AV4 manufacturing companies in NZ by changing formulae. It is observed that price reduction resulted in earlier diffusion of AV4 and faster movement towards car sharing growth, resulting in the adoption of higher-level AV5 by AV4 users. However, it doesn't have a marked impact on the total AV4 fleet level. Similarly, by providing external government development funds, the total AV4 fleet size rose from 1.5M to 1.9 M in 2058. However, the overall AV fleet size curve did not show any marked difference, meaning no observable change was identified in the overall AV fleet size in the country. It has also been concluded that AV4 vehicles travelled greater km/cars around 68000 than without external funds. Similarly observing the adoption rate ar4 of AV4, it can be concluded that with high trust and automation scenario and pumping of external funds, the AV4 diffusion technology is much faster in the society. It reaches a maximum in the year 2030 than in a low scenario where it grows slower and peaks in 2045 with a lesser percentage.

Figure 5.31

AV Levels Adoption Rate Behaviour (AV1 – AV5)

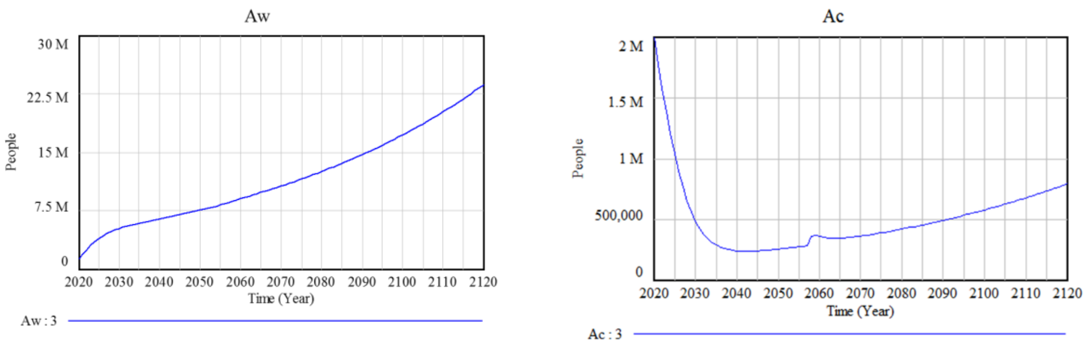




It is evident from Figure 5.31 that the AV0 adoption rate seizes in 2040, AV1 in 2049, AV2 in 2060, AV3 in 2085, AV4 in 2120 and AV5 adoption rate continues after 2120 (high AV scenarios). Hence, the lower AV technologies cease to exist over time in favour of higher technologies and car-sharing growth rate. Even in a low conservative scenario, the same phenomenon is observed. The maximum adoption rate of AV0 has already passed in the year 2021 and is now decreasing. However, the AV1 – AV5's maximum adoption peaks in 2025, 2030, 2035, 2036 and 2045, respectively, for high AV scenarios.

Figure 5.32

Car Sharing Behaviour



As highlighted in the above paras, Ac is the number of people who practice car sharing but own a car. The number of car-sharing people who do not own a car in NZ has increased over 100 years (Figure 5.32). The maturity of AV5 technology will influence the growth of car sharing in the population. Another value sr, dictates how many car-sharing people shed their cars. The shedding of cars feeds back into the model affects the various AV0-AV5 fleet sizes, which will impact trust. It impacts trust through the familiarity variable, which will affect the sales of AV2-AV5 technologies, resultantly influencing LR and Trust. So the sr variable puts pressure on the LR variable. The more people shed their cars and opt for car-sharing, the more pressure is placed on the government to ensure that the infrastructure etc., is geared for higher AV technologies.

The model does not allow any car owner to purchase downwards (AV5-down) but only upwards. Initial value of car-sharing users that own a vehicle =2e+006. The amount of car-sharing users that own a car falls (dramatically) between the years 2020 to the year 2035 and then slowly increases again. The fall is dramatic because of the 20% annual growth in car-sharing and the 23 % annual trend in car shedding.

5.4.5 Overview of the Market Penetration of AVs

A detailed overview of the market penetration of various levels of AVs (AV1 to AV5) is illustrated in Table 5.39. It highlights the penetration ranges concerning baseline, High Trust, Governance & Automation and Low Trust, Governance and Automation Scenarios. Moreover, it provides estimates regarding the time frame of market penetration and transfer of low AV technologies to higher technologies and the growth of the car-sharing phenomenon. The most valuable insights achieved in the realm of deployment and market penetration of AV3, AV4 and AV5 while giving special attention to AV level 5 technology. With the high trust and progressive governance regime in NZ, it is predicted that the AV3 market achieves under 20% diffusion in the year 2045 – 2055 and then seizes to exist in the year 2085. In between, people have already transferred to AV4 and AV5 and car-sharing business model. AV3 market penetration never reaches above 20%. In the case of AV4, the market penetration is achieved 43% around the year 2061, and the adoption rate seizes in the year 2120. AV0, AV1, and AV2 adoption rates seize in the year 2041, 2049 and 2060. The most useful AV5 technology achieves 90 % market penetration in 2121, and the adoption rate continues after that. People are most likely to adopt AV1 to AV5 in 2025, 2030, 2035, 2036 and 2045.

Table 5.39

Summary Table for Market Penetration of AVs

Variable	Range	Baseline model	High scenario	Low Scenario	Remarks
Market Penetration of AV1	0 - 20% 20 - 50% 50 - 75% 75%- 90%	2021-2121 AV1 market share never reaches any of these levels			Shifted to car-sharing and higher AV technology
Market Penetration of AV2	0 - 20% 20 - 50% 50 - 75% 75%- 90%	2021-2121 AV2 market share never reaches any of these levels			Shifted to car-sharing and higher AV technology
Market Penetration of AV3	0 - 20% 20 - 50% 50 - 75% 75%- 90%	2021-2121 AV3 market share never reaches any of these levels			Shifted to car-sharing and higher AV technology
Market Penetration of AV4	0 - 20%	2021-2040	2021-2040; 2096-2120	2021-2041	
	20 - 50%	2041-2058	2041-2095	2042-2056	
	50 - 75%	2059-2092	AV4 market share	2057-2078	
	75%- 90%	AV5 market share never reaches this level	never reaches this level	2079-2121	Shifted to car-sharing and higher AV technology in High Scenario after 2095 achieving 50% market penetration and Base Scenario after 2092 after 75% market penetration
Market Penetration of AV5	0 - 20%	2021-2063	2021-2045	2021-2121	
	20 - 50%	2067-2097	2046-2067	AV5 market share never reaches this level	
	50 - 75%	2098-2121	2067-2091		
	75%- 90%	AV5 market share never reaches this level	2092-2120		Shifted to car-sharing and higher AV technology in Low Scenario after 2121 after 20% and in Base Scenario after 76% market penetration

5.4.6 Model Augmentation for Insights into Technology Maturity and Utility

It is noteworthy that presently there is no counterpart in the real world to reflect any level of autonomous technology maturity, and it is challenging to configure exact value. Therefore, the initial maturity level considered in this extended model is based on the generalized information available in 2021 and, as observed by Nieuwenhuijsen et al. (2018). However, it is a known fact that nowadays, AV2 technologies are being commercially provided by several OEMs, whereas AV3 to AV5, very little information is available regarding the R&D process and their actual performance. Moreover, AV Companies are hesitant to share information.

As already noted above, AV systems are a conglomeration of dynamic interaction between various components, including customer attitudes, technology development, Governance and Policy measures and economic factors (Milakis et al., 2017a; Milakis et al., 2017b). After more deliberations and due diligence, the model is augmented to study the impact of various weightings of utility components (including Trust, Legal Readiness, Attractiveness and Price) on the adoption of AV technology. Accordingly, the model is altered in two ways:

- by the growth in vehicle sharing and the growth in the abandonment of cars among vehicle sharers endogenous;
- By making the technology maturity for each level of AV endogenous

Table 5.40

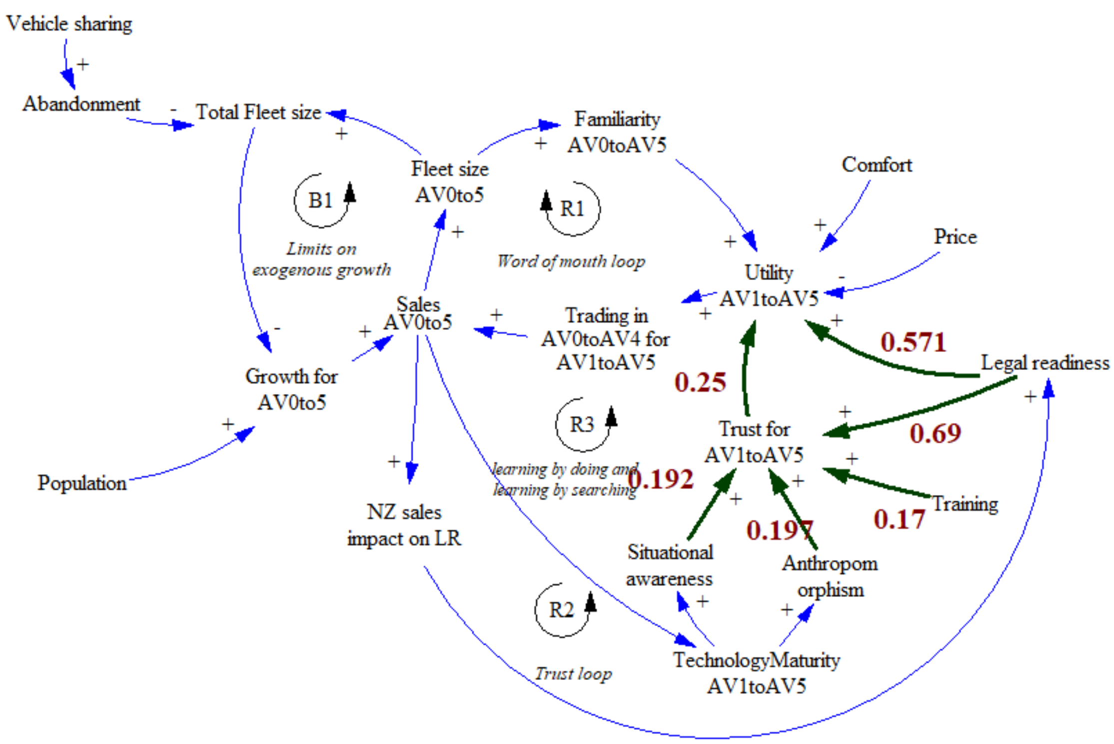
Levels of Market Maturity

AV Levels	Remarks	Market Maturity
AV0	Conventional vehicles are in the market for more than 100 years	100 %
AV1	These are available in the market at relative higher purchase prices.	50 to 80% High
AV2	Provided by Volvo, BMW, Ford, Daimler, Toyota etc. OEMs invested in ADAS systems and are available in the market in medium to low quantities.	30 to 65% Medium
AV3	Not available in the market except few claims by Tesla. See Chapter 2 literature for the latest developments and R&D investments by various OEMs.	1 to 15% Low
AV4	Technology is in operation in the shape of shuttles and trams in China, Europe, the UK, Australia and NZ.	10 to 20% Low
AV5	Not being tested and not available in market	Less than 1% Very Low

The premise in this extended SD Model is that the autonomous technologies mature with the new sales of autonomous vehicles as a proportion of total sales for a particular year. The model is reconfigured to include a delay (called technical delay) that accounts for the efficiency of knowledge transfer and technology development. It is depicted in a simplified version of the learning by searching and learning by doing effects loop (R3) compared to Nieuwenhuijsen et al. (2018). In an earlier study, Lundvall (1992) conceptualizes a technology maturity model by exploring the interaction between R & D, learning by searching, a knowledge stock and emergence of innovative ideas that lead to technology proliferation. In this augmented model, the rate of tech maturity is modelled as a Stock variable dependent on the sales of new cars (for each specific level of AV). A reinforcing loop R4 is also included, which simplifies the stated relationship for the growth in vehicle sharing and causes it to depend more directly on the rate at which technology matures. The feedback loop also depicts the rate of car abandonment amongst car sharers dependent on legal readiness. It is assumed that as the regulatory and physical infrastructure becomes more accommodating for AV5 technology, there is an increase in car abandonment among car sharers. The casual Loop Diagram (CLD) is shown in Figure 5.33.

Figure 5.33

CLD 2 – System Components and Dynamic Loops



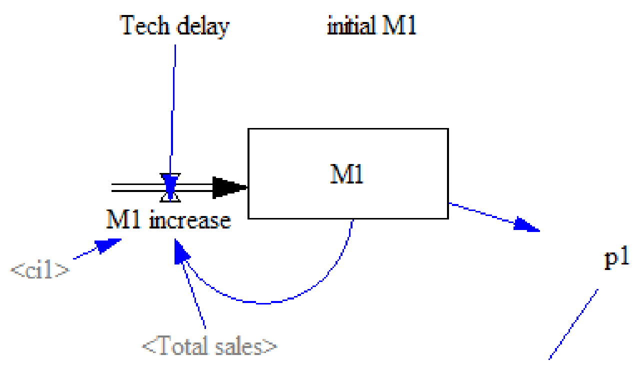
In any innovation process, the knowledge is gathered via the R&D process during the initial innovation cycle of the technology through research organisations and universities to develop the technology (Kamp, 2002). During this cycle, purchase prices remain high (Abernathy & Utterback, 1978). However, by gaining more knowledge using R&D over time, price reduction occurs through learning by searching effects. Perceived gains of the technology drive amount of R&D expenditure and the market size. The technology maturity range (1- 100%) indicates the state of readiness for technology (Newes et al., 2011; Vimmerstedt et al., 2016). As highlighted earlier, when the fleet size of a particular level of automation increases, it results in additional experience and lowering the purchase price. With the decrease in price, the utility increases and fleet size is increased. The fleet size of any AV level grows through sales. Sales depend upon the utility and the maturity of a specific level of automation, illustrating the flow of AVs from lower to higher levels. As technology gets more mature, it gives trust and confidence to the user, which positively affects sales. Hence the new CLD diagram (Figure 5.33) incorporates these effects where diffusion of innovation results from a dynamic feedback loop between fleet size and technology development. Technology maturity further affects Situation Awareness and Anthropomorphism, resultantly affecting the trust and utility of AV technologies. The literature informs that the technology maturity takes in an S-shaped curve and is a trade-off between reliability and performance (Mahajan & Peterson, 1985; Sterman, 2000). S-shaped curve depicts the increase in marginal costs with maturity in technology.

Presently, several OEM Firms are developing different driverless technologies and are in various stages of the product life cycle depending upon the R& D amount available. In the reconfigured model, the specifications of the learning curves are adopted from Sterman (2000)and Nieuwenhuijsen et al. (2018). The maturity range is between 0 and 1. Technology Maturity for AV1 to AV5 is modelled as a stock variable retaining the initial values for M1-M5 as depicted in equation 9 and Table 5.38 above. For each level of AV (1-5), Technology Maturity increases by the flow variable “Mx increase” (where x =1, 2,3,4,5 refers to levels of AV). The equation 24 of Mx increase depends on the sales of that AV type in a particular year cix(t), divided by the total vehicle sales for all the AV levels in a specific year, all multiplied by the remaining potential for maturity (1-Mx) subject to sometime delay. The value for the time delay we specify as five years.

$$Mx\ increase\ (t) =\ cix(t)/Total\ sales(t) * (1 - Mx(t))/Tech\ delay \ldots\ldots\ldots\ldots\ldots \text{(24)}$$

Figure 5.34

Maturity Stock



The augmented model involved few behavioural element changes as well. The equation for the growth in car sharing g(t) is changed to directly relate to the technology growth of AV5 variable M5(t). The car abandonment among car-sharing people sr(t) is also changed to depend on some initial rate of car-sharing and the Legal Readiness factor as under:

$$g=gm*(1+M5\ (t)) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(25)}$$

$$sr(t)=Initial\ Sr*(1+LR) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(26)}$$

Maturity stock has an inflow, but no outflow since technology only grows. The equation parameters were endogenized based on the present stage of AV technologies within the context of literature. It is assumed that the AV1 and AV2 technology made significant progress over the last 20 years, whereas AV3 technology is hard to estimate as it is happening behind doors. AV5 technology maturity is extremely low.

Three scenarios were run (baseline, high and low) to compare the augmented model with the original. Additionally, three more scenarios (baseline, high and low) for different utility function weightings, namely trust, Legal readiness, price and attractiveness, were run. In the first model and for the three scenarios produced with it, the weightings were kept equal. With the augmented model, the outcomes of changing the weightings were studied. The weights kept with the rationale are shown in Table 5.41.

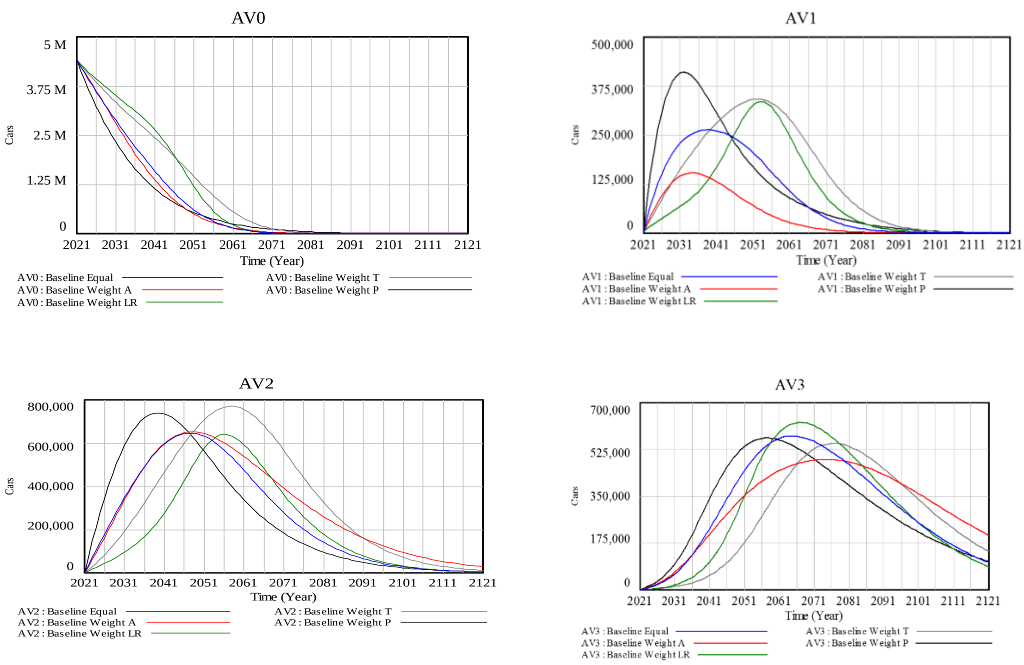
Table 5.41

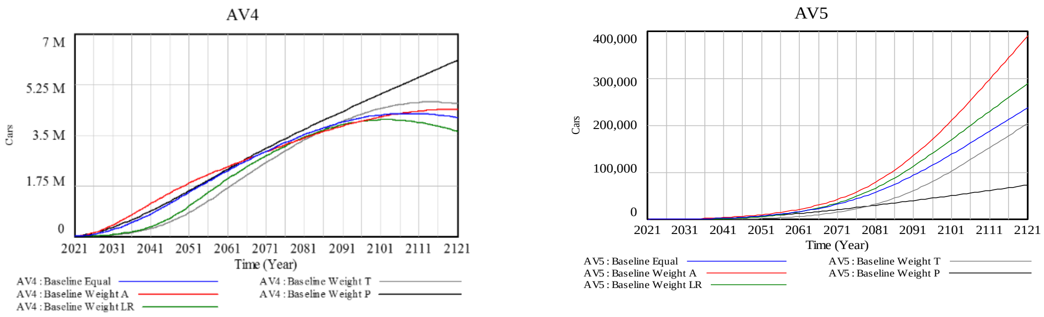
Utility function weights and Rationale

#	Price	Attractiveness	LR	Trust	Rationale
1	0.25	0.25	0.25	0.25	The population is influenced equally by price, attractiveness, legal readiness and trust
2.	0.85	0.05	0.05	0.05	When choosing a car, the population is chiefly influenced by the price of the level of AV.
3.	0.05	0.85	0.05	0.05	When choosing a car, the population is chiefly influenced by the attractiveness (comfort and familiarity) of the level of AV.
4.	0.05	0.05	0.85	0.05	When choosing a car, the population is chiefly influenced by the legal readiness and physical infrastructure that exists for that level of AV.
5.	0.05	0.05	0.05	0.85	When choosing a car, the people are chiefly influenced by their trust for that AV level.

Figure 5.35

Fleet Size Behaviour

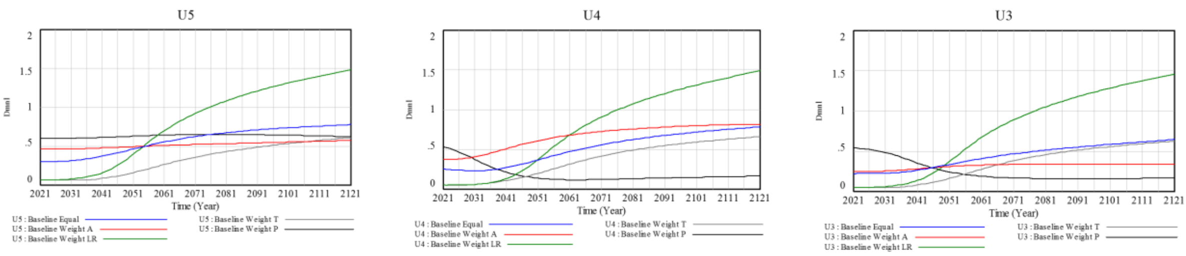




The first two graphs above show the modelled fleet sizes for AV1 and AV0 under a baseline set of parameters with five utility weight variations. For the population that buys the AV technology as soon as they can afford it (Baseline Weight P), the progression from AV0 to AV1 is the fastest. It is also the circumstance that will allow AV1 to perform the best. AV1 technology is predicted to perform the worst in the population that makes car purchase choices based on Attractiveness (comfort and familiarity). In a people with a heavy reliance on the LR provided by the government for making decisions on vehicle purchases, the use of AV0 is the most "sticky". AV2 performs comparably well in all populations but marginally better when the population makes car purchase/ownership choices on the merit of trust and price. AV3 likewise performs comparably well under all population types but slightly more so in the population more sensitive to the Legal Readiness Structure before choosing a car. AV4 seems to perform best in a society that values price above all else in making car purchase/adoption choices. AV5 does not perform well in a society that values price in making car ownership choices. AV5 is taken up to the greatest extent by the society that values attractiveness above all else.

Figure 5.36

Utility Behaviour



The utility of AV5 is relatively constant for societies that emphasize price and attractiveness but vary considerably over time in societies that prioritize LR and trust when making their choices in car purchases. Whereas in societies that value price above everything else when making choices about car ownership, the attractiveness of AV3 and AV4 falls dramatically over time (choices are made relative to alternatives explaining the adoption of AV4 being so high and AV5 adoption being so low in societies putting great emphasis on Price). Summary Table 5.42 depicts various preferences sensitives of people in terms of various automation levels.

Table 5.42

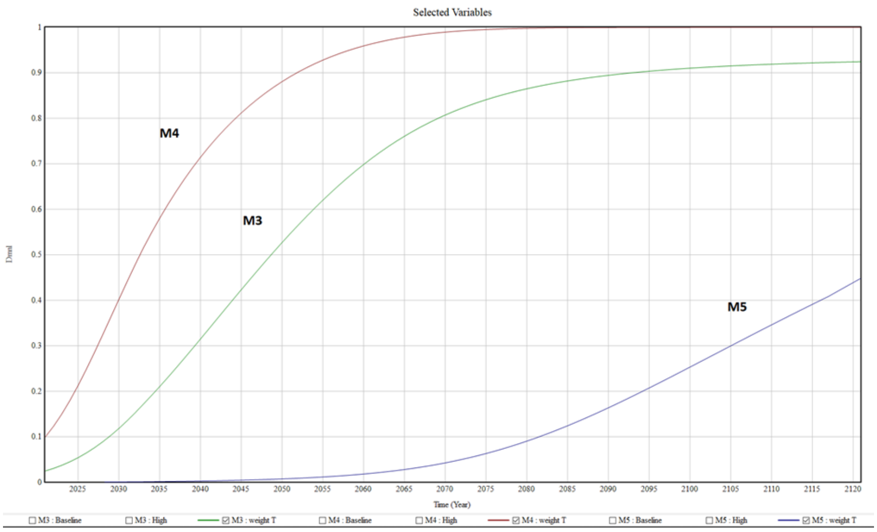
Preference Sensitivities of People Relative to Automation Level

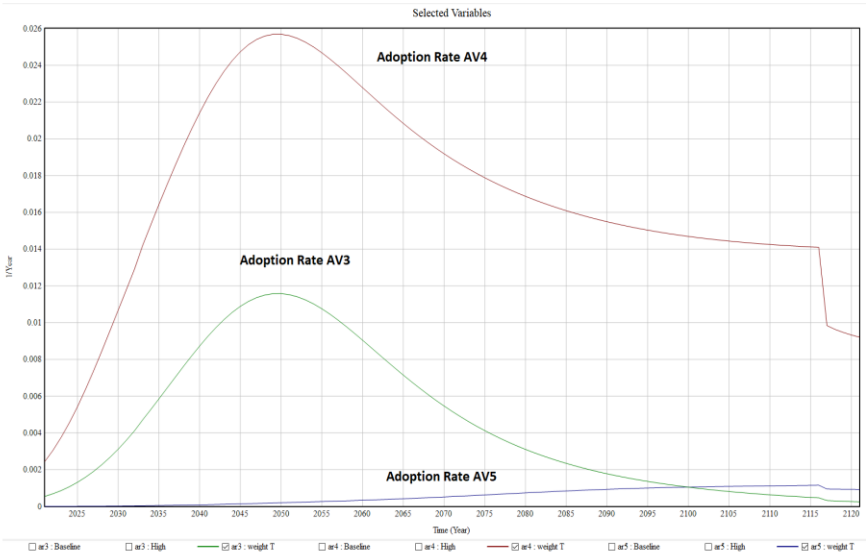
AV Levels	Preferences fleet size behaviour	Preferences Utility behaviour
AV0	People adopt based on affordability and not on Legal Readiness. Progress from AV0 to AV1 is faster due to the affordability of the price.	
AV1	People adopt based on affordability and not on attractiveness, i.e. comfort & familiarity.	
AV2	People generally adopt more based on car purchase/ownership choices on the merit of trust and price.	
AV3	People adopt AV3 marginally more based on Legal Readiness Structure followed by trust of the people in the country.	Attractiveness falls overtime giving more preferences to price on car ownership
AV4	People adopt based on price affordability.	Attractiveness falls over time, giving more preferences to price on car ownership. It is fascinating to note that the utility with AV4 for heavy price-weighted society is the lowest, yet the car ownerships for AV4 are the highest. So for a community in which people make car choices based on price, they end up stuck with dominating AV4 technology, causing them relatively low satisfaction. So there is likely to be an unhappy future of AV4 users in countries where price dominates purchase and adoption choices. One is happier when you buy something because you have trust in it than it is cheap.
AV5	People generally adopt more based on legal readiness and trust.	Utility varies considerably over time in societies that prioritize LR and trust when making their choices in car purchases. Hence the utilities for AV3 to AV5 are the highest for societies that adopt AVS based on Trust and Governance / LR. These societies that make choices become relatively happier over time with the AV technologies than those that rely on price and attractiveness (comfort and familiarity).

It is also noteworthy that once an effort has been made to study AVs technologies' technology maturity and adoption rate, no behavioural change or sensitivities were observed by altering the weights of utility functions in various scenarios. Figure 5.37 and Table 5.43 depict a constant technology maturity and adoption rate pattern without any effect of changing weights of trust, legal readiness, price, and attractiveness. It can be concluded that it is either because the technology maturity function is not fully captured in the model, obviously because of so many unknowns. Similarly, an increase in the adoption rate can only take place by giving subsidies or tax reductions to lower the cost, thus making the technology more affordable. Moreover, it should be taken into account that the model may contain some limitations in terms of full data availability to simulate complete model components. Also, certain initial values of various stocks are incorporated as needed to be set in SD Model to start the simulation, which may not be the exact representation of real-world systems as AV3, AV4, and AV5 are still not available in the market.

Figure 5.37

Technology Maturity and Adoption Rates





From the above graphs, it can be concluded that 40% technology maturity of AV3 is likely to happen in 8043, AV4 in 2030 (earlier than AV3), AV5 in 2116, whereas 95 – 100% maturity is likely to take place for AV3 in 2110, AV4 in 2080 and AV5 kept growing. Moreover, AV3 is likely to achieve maximum adoption rate in 2050, AV4 in 2048, whereas AV5 remains steady after 2121.

Table 5.43

Technology Maturity and Adoption Rates

Technology Maturity and Adoption Rates	AV3	AV4	AV5
40% maturity	2043	2030	2116
95%-100% maturity	2110	2080	growing
Maximum adoption rate	2050	2048	-

5.4.7 Conclusion Study - 3

This novel Study – 3 has further validated the Trust and Governance framework (after Study – 2). And quantitatively measured the real-time theoretical output of the framework to have insights into to diffusion timelines of AVs in NZ. The model is applied in NZ enabling environment considering three scenarios. The baseline scenario is mainly based on beta values of trust and governance framework adopted from Study – 2 and few other parameters. The High Automation and High Trust and Governance Scenarios displaying a greater trust of NZ people backed up with a progressive AV regulating regime in the NZ. And the Low Automation and Low Trust and Governance Scenarios showing a generally lower trust of NZ people and a conservative AV regulating regime in NZ. It has successfully tested the design framework's applicability and brought in significant predictions. These relate to AVs market maturity, people's preferences to dispose of old AV technologies favouring the newest AVs technologies, and switching to car-sharing. The study has generated profound clues for policymakers and provided a road map to restructure the overall AV governance regime in the country and prepare the AV infrastructure accordingly. The model simulates that with the growth of the fleet size of a particular AV level technology, the probability of end users' familiarity with this specific AV type increases. As a result, people are more likely to look for adopting or using this level of automation. Similarly, with the rise of media hype due to the proliferation and maturity of AV technology, the AVs sales would grow and fleet size increase, especially in AVs' early product life cycle. The end-users will gain more trust in the performance and reliability of this specific level of AV technology, and it will speed up adoption.

5.5 Study – 4: Validation through Experts' Interviews

Study – 4 adopts a qualitative research methodology based on thematic analysis of semi-structured interviews of 13 experts (see Table 5.44) around the globe, namely from NZ, UK, Germany, Sweden and Australia. These experts comprise AV industry professionals, manufacturers, CEOs, academicians, policymakers, and human factor experts in the AD domain. This Study carried out complete validation exercise of the objectives accrued in previous studies and examined the suitability of the proposed integrated trust and governance framework (Study-2) for deployment of driverless and semi-driverless systems in NZ. Study – 4 explores and validates the diverse dimensions. These include the challenges and benefits of AVs implementation, user acceptance key determinants for AD, NZ Environment for the diffusion of AVs, Long term future directions and Timelines for AVs deployment and Trust and Governance Framework through the lens of AVs experts.

Table 5.44

Participation Profile and Classification

Person	Age Group	Company	Country	Domain	Education	Experience
GO	41-49	MOT	NZ	Strategy	Master	17 years
IP5	50-59	BMW	Germany	Robotics	Ph.D.	25 years
AC1	35-40	Chalmers	Sweden	Human Factors	Ph.D.	8 years
CO4	41-49	KTN	UK	Human Factors	Ph.D.	10 years
IP2	41-49	CEVT	Sweden	Electric Architecture	Master	14 years
IP3	51-59	CEVT	Sweden	Electro Mobility	Ph.D.	25 years

Person	Age Group	Company	Country	Domain	Education	Experience
CO2	41-49	Corrections	NZ	Law	LLB	17 years
		Autonomous				
CO1	51-59	Consulting	NZ	Law	LLB	20 years
IM	60-70	HMI	NZ	AV	Master	30 years
CO3	60-70	Level 5 Design	Australia	Transport	Bachelor	30 years
CO5	51-59	Reed Mobility	UK	Psychology	Ph.D.	25 years
IP4	41-49	Volvo	Sweden	Connected Solutions	Bachelor	18 years
IP1	41-49	CEVT	Sweden	Robotics	Ph.D.	15 years

Note: CO=Consultant, AC= Academician, IM= Industry Manufacturer, and IP=Industry Professional

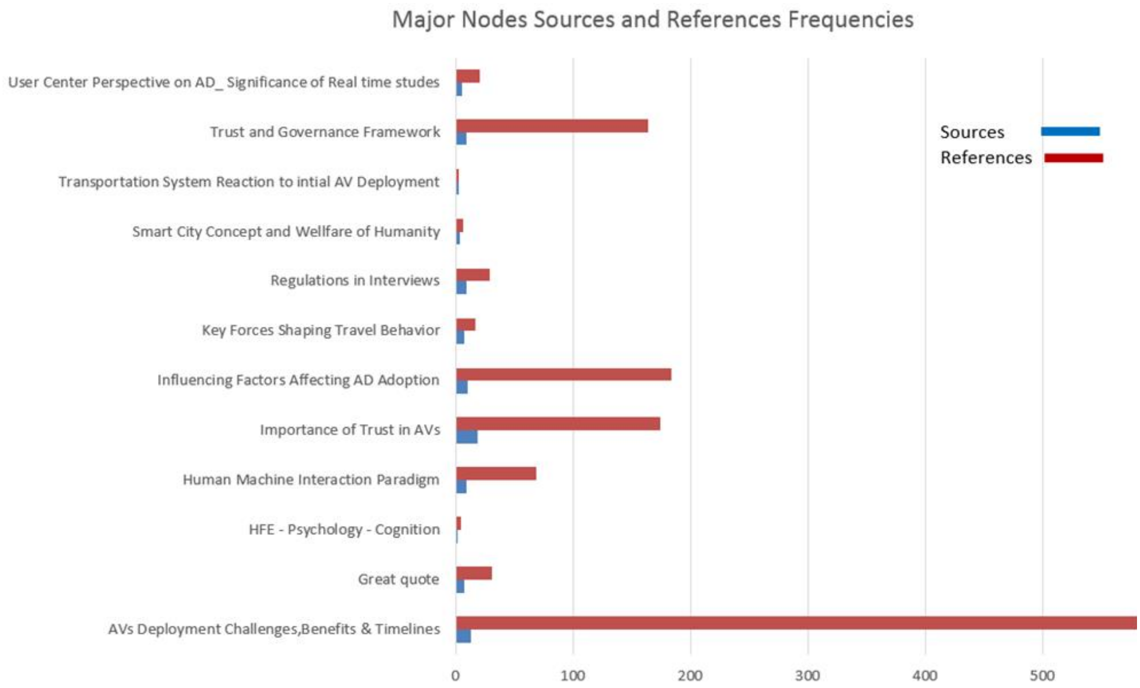
5.5.1 Summary of Results

The Themes analysis confirmed earlier findings, and these are narrated in succeeding paras. See Figure 5.38 for primary nodes sources and references frequencies as prepared in NVivo 11.

The findings indicate perceived benefits of AVs due to (1) less travel cost, (2) better user experience, (3) less pollution and crashes/injuries, (4) more time and freedom to do other leisure activities, (5) availability of additional money to invest in other businesses, (6) more safety, (7) security, and (8) car-sharing practices. Moreover, other findings include AV potential benefits in various fields. These include the economic and social field, increased road capacity, reduction in parking costs and energy consumption, shared mobility, control of traffic flow, and efficient road transport. Few other benefits include increased tourism, innovative freight delivery, entertainment, increase in travel speed and the offer of mobility to people who are unable to drive.

Figure 5.38

Major Categorization of Nodes



Name	Sources	References
AVs Deployment Challenges, Benefits & Timelines	13	582
Great quote	8	31
HFE - Psychology - Cognition	2	5
Human Machine Interaction Paradigm	9	69
Importance of Trust in AVs	13	174
Influencing Factors Affecting AD Adoption	10	184
Key Forces Shaping Travel Behavior	8	17
Regulations in Interviews	9	29
Smart City Concept and Wellfare of Humanity	4	7
Transportation System Reaction to intial AV Deployment	3	3
Trust and Governance Framework	9	164
User Center Perspective on AD_ Significance of Real time studies	6	21

NZ people likely expect AVS to reduce accidents, improve fuel efficiency, decrease traffic congestion and emissions, mobility to disabled people and reduced insurance premiums. All these perceived benefits have already been studied in Study – 1.

There are several findings related to the critical barrier in AVs implementation. This includes people trust (85%), pragmatic governance structure (77%), improvement in technology (75%), the requirements of realistic user and simulation studies (74%), the study of human and market penetration of AVs (72%). Few other findings comprise the challenges in the technical domain, including HMI, data privacy (56%), security and safety of people (98%), situation awareness (71%), anthropomorphism (56%), IT and physical infrastructure (68%), and over projection of media (35%). Few participants pointed towards co-evolution of regulations and technology and pragmatic legal readiness regime addressing liability, data privacy, and cybersecurity (77%) to ensure the appropriate trust of people.

The key findings regarding NZ's environment conclude that NZ is not well prepared in the regulatory and infrastructure domain for the complete diffusion of AVs due to its small market and low manufacturing base. The challenges are primarily in the domains of (1) criminal and civil liability, (2) safety, (3) property damages, and (4) infrastructure readiness which is in line with our findings in Study – 1 and Study - 2. Recommendations include (1) law amendments in the highlighted sectors, (2) defining ODD, (3) preparedness of infrastructure and, (4) road code, and (5) regulations dealing with human-driven cars and cars without humans.

The experts were not exactly sure about higher automation level deployment on roads shortly. Still, they all agreed regarding amendment in the legal readiness structure, improvement in infrastructure, making a performance measure criterion for AVs, Defining ODDS for different AVs levels and, focusing on smart driverless public transport in the shape of small shuttles, trams, pods and supernodes.

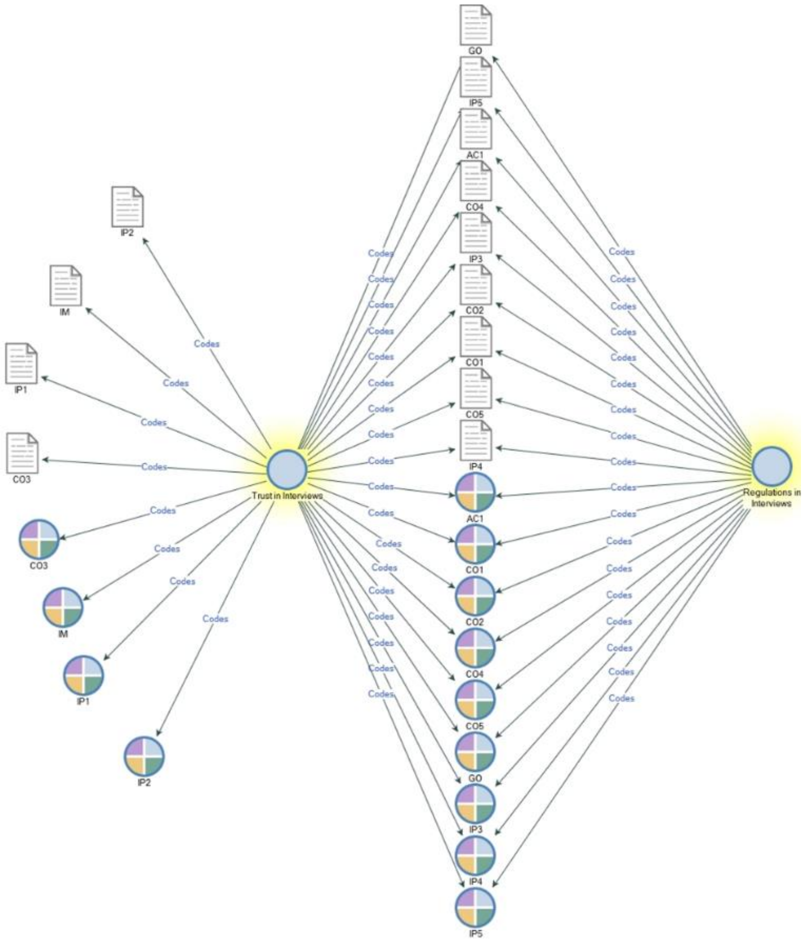
The experts believed that in NZ, a road map could be designed where creating additional lanes as per ODDs, AVs can co-exist with driver-controlled vehicles. Moreover, there is a need to pursue private car ownership and collaborative driverless car sharing mechanisms complementing each other in a multifaceted economic model. This can be later transformed into driverless pods and supernodes controlled by transport hubs as transport systems evolve.

The experts supported the critical contours of the suggested integrated trust and governance framework developed in study-2. They highlighted that trust is the crucial parameter in user acceptance based on HFs and the legal readiness domain. Findings relate to various KPIs for utilization of framework. These comprise (1) safety, (2) security, (3) data and cyber security, (4) privacy, (5) situation awareness, (6) education and training of users, (7) reliability, (8) transparency, (9) user-friendliness, (10) cost, and (11) need of appropriate legislation. SAE levels interpretation has different connotations. Few experts believed there should be only two dimensions of law, i.e. one dealing with cars with humans and the other without humans. Overall the findings validated our proposed Trust and Governance Framework of this study and its main variables. Figure

5.39 indicates the participants' cluster comparison analysis concerning the significance of trust and governance in their interviews. It can be seen that all the participants highlighted the user acceptance, trust issues, and need for progressive rules and regulations regime as a key to the successful deployment of AVs.

Figure 5.39

Coding Comparison of Experts' Views on Trust and Governance



5.5.2 Theme – 1: AVs Perceived Benefits and Critical Barriers

AV potential benefits were generally found similar among all the participants (95%), with slight societal benefits and driverless technologies variations. They all advocated the perceived benefits of less travel cost, better user experience, less pollution and crashes/injuries, more time and freedom to do other leisure activities, and the availability of additional money to invest in other businesses. In addition, the experts, believed in more safety, security, and car-sharing practices due to AVs. The interviewees had different views on reducing congestion (5%), but they all agreed on AVs perceived benefits to the elderly, disabled, rural people and children. Table 5.45 below indicates the Transcript and participant ID, participant's Quotation, the author comment, subcodes, main code/theme and reference. Figure 5.40 and Figure 5.41 illustrates the word cloud nodes and cluster by coding similarity, respectively, in NVivo 11.

Figure 5.40

NVivo 11 Word Cloud AVs Deployment Challenges

Figure 5.41

Nodes Clustered by Coding Similarity- AVs Deployment Challenges

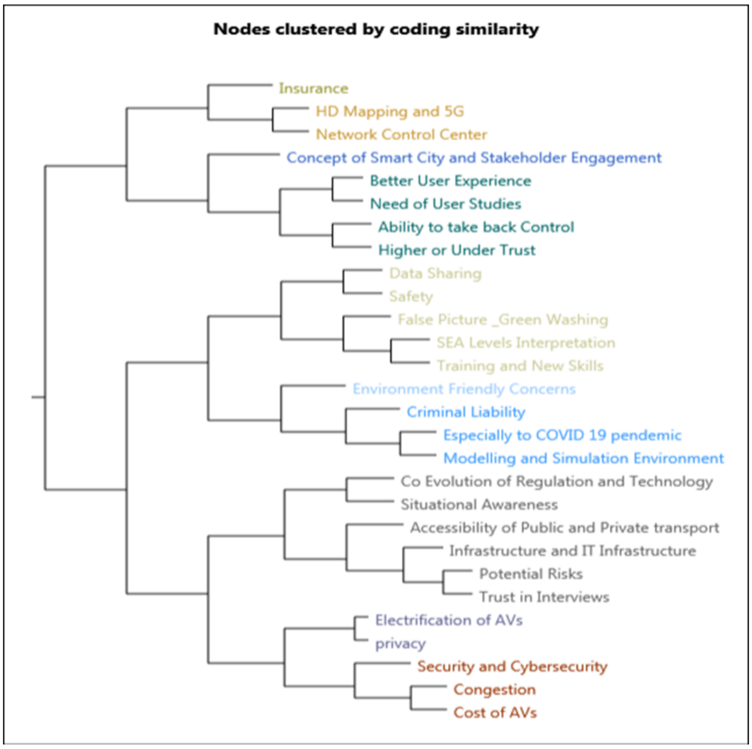


Table 5.45

AVs Perceived Benefits

ID / Transcript	Datum/Quotation	Comment	Sub Code	Main Code/Theme	Ref
AC1 Transcript-3	I think we can create a better user experience, and this could help put aside more time for other types of activities to work and more time for leisure activities.	Better User experience, More time for other leisure activities	Social Benefits	Potential Benefits of AVs / AV Deployment Challenges and Benefits	1/2
AC1 Transcript-3	Single individual needs will be fulfilled like going to the hospital, education, less cost involved and less pollution. With AVs, we can have overall banking and housing system benefits.	Less travel costs, less pollution	Social Benefits	-Do-	2/2
CO1 Transcript-8	We can do a better job by utilizing AV Robo taxis instead on infrastructure.	Less travel cost and eco-friendly	Social Benefits	-Do-	1/4
CO1 Transcript-8	We'll see transport be transformed by electric vehicles.	Eco - friendly	Social Benefits	-Do-	2/4
CO1 Transcript-8	Maintain your safety not only to deliver you safely from point A to point B but to make sure that something bad hasn't happened.	Safety	Social Benefits	-Do-	3/4
CO1 Transcript-8	I think people generally will have more money at their discretion to invest in a new business, rental properties, travelling or furthering education.	Additional money to invest in other business	Social Benefits	-Do-	4/4
CO2 Transcript-7	They can reduce traffic accidents. They can help with congestion.	Fewer crashes and congestion	-Do-	-Do-	1/5
CO2 Transcript-7	Convenient mobility for everyone. Especially disabled people.	Mobility for disabled	-Do-	-Do-	2/5
CO2 Transcript-7	Release lots of lands that would have been used for parking	Less space for Parking	-Do-	-Do-	3/5
CO2 Transcript-7	Not everyone will have to own a car anymore.	Reduced cars ownership	-Do-	-Do-	4/5
CO3 Transcript-10	Improvement in first and last-mile operation, which	Reduce travel time	-Do-	-Do-	1/2

	can complement public transport.				
CO4 Transcript-14	So it's not about necessarily giving the people mobility, because they can take a bus. It's about independence, the creation of high skilled jobs and access to people in rural areas.	Jobs creation More freedom Reach to rural areas Accessibility	-Do-	-Do-	1/7
IP1 Transcript-13	Because of digital IT technologies, we hope, together with connectivity, that the flow of the traffic would be best managed actually. And they will have greater safety and security and less footprint towards the environment.	Smooth flow of traffic, Safety and Security	-Do-	-Do	1/4
IP1 Transcript-13	Quite promising for visually disabled personal and other disabilities like cerebral disabilities.	Disable people benefits	-Do-	-Do-	2/4
IP1 Transcript-13	Benefits to the child going to a daycare, or older adult with more health risks like saving them from cardiac arrest, sudden other disease, diabetics, persons and similarly all other diseases.	Use of non-invasive and other AV interface technologies	Emotion ware – Elderly people	-Do-	3/4
IP5 Transcript-2	We can achieve more work-life balance.	Health and Welfare	-Do-	-Do-	1/8
CO4 Transcript-14	We can progress towards Mobility as a Service business model quickly	Maas	Use of Social Robots	-Do-	1/1

The majority of the participants (85%) had similar views regarding challenges in the deployment of AVs. They were found concerned about the requirements of more realistic user studies (74%), knowing about users' preferences and analysis of human factors in the backdrop of broader application of AV technologies, and market penetration of AVs (72%). Some argued (77%) that the most significant challenges are in the technical domain, including HMI, data privacy, security and safety of people, situation awareness and anthropomorphism, and IT infrastructure. Many participants (9/13) showed their concerns towards the psychological domain. They think that appropriate trust of people is quintessential in the successful deployment of AVs besides pointing fingers towards false media and OEMs hype in over projecting these driverless technologies. The participants stressed the need for co-evolution of regulations and technology. They unanimously agreed to pursue a progressive and pragmatic legal structure addressing liability, data privacy and cybersecurity issues to ensure the appropriate trust of people in AVs. All of them were of the view to have a structure mechanism and framework with standard metrics to measure self-driving cars' performance, reliability, applicability, and success ratio. The majority of participants (74%) highlighted the need for realistic simulations to get insights into the phenomenon in the successful proliferation of AVs and behaviour of driver and AV, especially in edge cases. See Table 5.46 illustrating the gist of concerns by the participants.

Table 5.46

AVs Implementation Challenges

ID / Transcript	Datum/Quotation	Comment	Sub Code	Main Code/Theme	Ref
AC1 Transcript-3	User needs to understand what cues automate the vehicle sense fully? And, like, what are the cues that a user needs to be aware of? Before I hand over?	How to ensure Better situation awareness, especially AV3 and User needs	Ability to take back control HMI Situation Awareness Trust Training Anthropomorphism	AV Deployment Challenges and Benefits	1/2
AC1 Transcript-3	To give information or in advance that handover is near.	Better Situation Awareness	Ability to take back control	-Do-	2/2
AC1 Transcript-3	I would say to have a lot of transparent communication between developers, politicians, and traffic organizations in each country.	The smooth and honest flow of information between stakeholders	Co-evolution of regulation and technology Legal readiness	-Do-	1/1
AC1 Transcript-3	Stakeholders need to create this framework and model of how the big system will be built.	Creation of a framework for the deployment of AVs	Concept of Smart City Trust and Governance Framework	-Do-	1/1

ID / Transcript	Datum/Quotation	Comment	Sub Code	Main Code/Theme	Ref
AC1 Transcript-3	One of the key aspects that people like to talk about is that the introduction of automated vehicles will lower the number of vehicles on the streets, but I don't believe that. Yeah, it might it may not?	Congestion may not be solved	Congestion	-Do-	1/2
AC1 Transcript-3	It's about fully understanding the system to have the correct mental model. And to achieve that, you need a fully transparent system.	Mental Model of driver and need of a fully transparent system to convey the correct information	Mental Model of driver Anthropomorphism	-Do-	1/2
AC1 Transcript-3	Like I would say, overly positive expectations about self-driving cars that these cars are more or less waiting around the corner due to developers and media created a false picture.	False picture by media and manufacturers	False Picture-Green Washing People expectations	-Do-	1/2
AC1 Transcript-3	I still believe that the biggest issue or barrier is not giving enough time and effort to understand what user needs and prefers.	Need of user studies and knowing users' preferences	Need of User studies	-Do-	1/2
IP1 Transcript-13	AV cost is one of the issues, more or less. If you buy AVs hand free functionally, that would be less costly. If you buy an AV that can give you medical or social, or	The cost of AV will be out of reach	Cost of AVs	-Do-	1/1

ID / Transcript	Datum/Quotation	Comment	Sub Code	Main Code/Theme	Ref
	economic benefits, the feature will be expensive.				
CO1 Transcript-8	Even using 5G is probably not going to be reliable enough, and also HD mapping integration.	Data connectivity and sharing	Data Sharing	-Do-	1/1
CO1 Transcript-8	Part of the challenge is you need more robust infrastructure and IT infrastructure	Need of Road and IT infrastructure	Infrastructure and IT Infrastructure	-Do-	1/3
CO4 Transcript-4	UN is probably to decide what safety-critical data and what's commercially sensitive data and basically enact that companies need to share safety-critical data such as speed direction.	Need for Data Privacy and Safety	Data Sharing Safety Data Privacy, Cyber Security and Legal Readiness	-Do-	1/1
CO4 Trancript-4	There are big issues in public transport and the trust of the people regarding their own safety and the safety of people and their families who actually use public transport.	Safety Trust of People	COVID-19 pandemic	-Do-	1/4
IP5 Transcript-2	Requirement of open platforms, more shared data and the security side of things. Also sharing data and excellence and building a trust also through legislation, lots of processes are needed.	Need of Legislation involving Trust Data Sharing	Trust and Legal Readiness Data sharing Safety Security	-Do-	1/2

ID / Transcript	Datum/Quotation	Comment	Sub Code	Main Code/Theme	Ref
IP5 Transcript-2	You can simulate in a way where realistic situations with statistically sound parameters are derived from seeing driver behaviour in the real world.	Need of realistic conditions simulations and knowing driver behaviour	Modelling and Simulation	-Do-	1/1
IP5 Transcript-2	For the wider adoption in the general public, I think it's essential to study and integrate human factors.	Significance of Human Factors studies in AVs	HFE-Psychology-Cognition	-Do-	1/3
IP3 Transcript-6	I think the biggest challenge is infrastructure, then socio-economic, psychological, cyber security and privacy.	Need for infrastructure	Infrastructure Cyber security Privacy Trust	-Do-	1/2

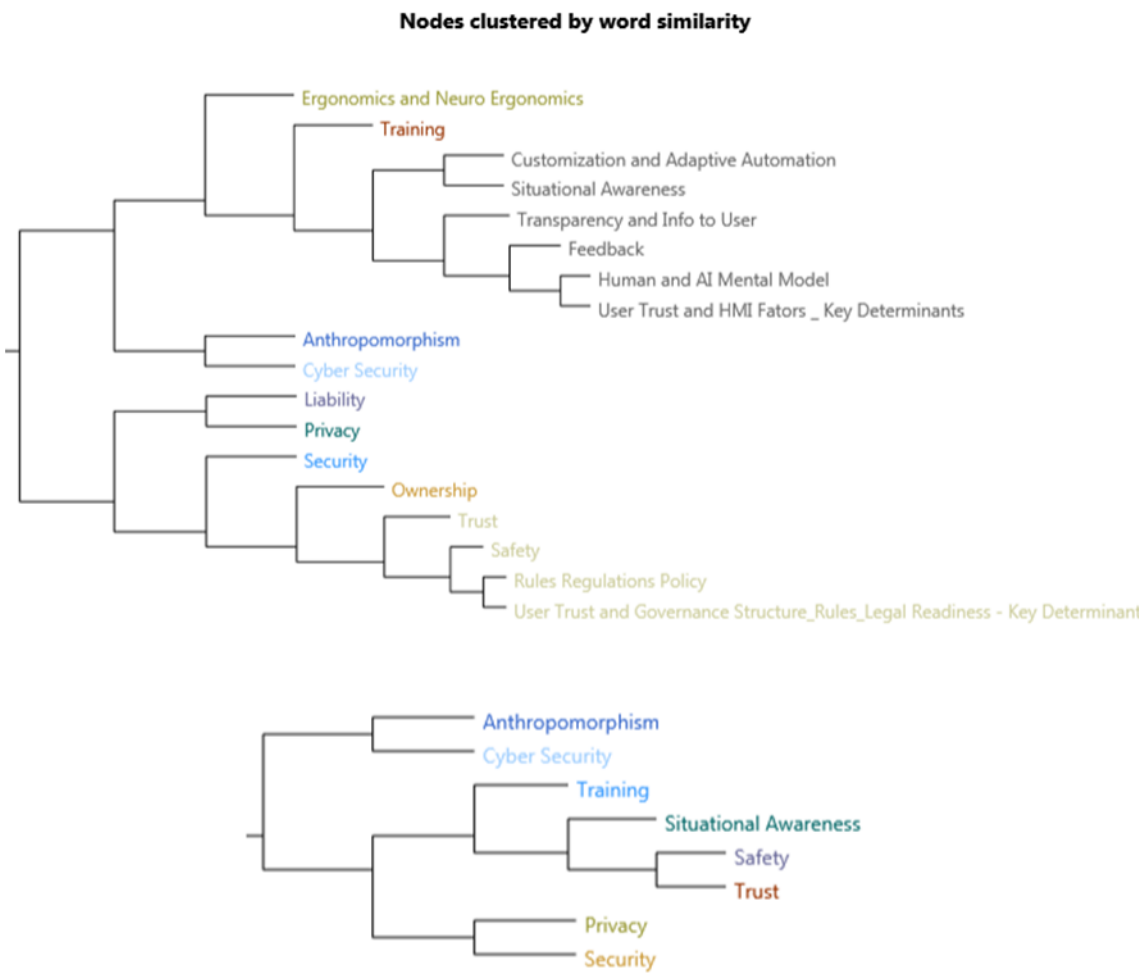
5.5.3 Theme – 2: Significant Trust Affecting Factors in Autonomous Driving

The majority of the participants (85%) thought that appropriate user trust in AV technologies is critical for AD. Some of the participants argued several different factors for the successful implementation of AVs. They had the unanimous opinion that users' acceptance and trust is the lynchpin among other HMI factors like Situation Awareness, (2) Training and Anthropomorphism and, Governance factors including Safety, Cyber Security and Privacy. The participants highlighted few other factors. These comprise customization (10%), adaptive automation (8%), transparency (10%), liability (77%), and ownership cost (10%). But they laid more stress on key determinants.

All participants stressed the need for a regulatory framework incorporating safety, security, and privacy parameters to ensure the optimum welfare of the users. They delineated that real-time user studies instead of just simulations and public demonstration of key AV technologies are key to their successful social diffusion. They also pointed out that some AV manufacturers are over projecting and creating a false picture of these technologies, creating a higher level of trust which lacks transparency and cheating the public (35%). They described the significance of a high degree of situation awareness of the user and correct mental model, especially in hand over situations through user-friendly cues. Driver mental models can be trained over time once they are made to undergo various simulations, driving licensing exams, and other such measures to assess the AV maturity and decision-making paradigm. Figure 5.42 highlights all the significant parameters base on coding for AD in NVivo 11.

Figure 5.42

Nodes Clusters for Factors Affecting Autonomous Driving in NVivo

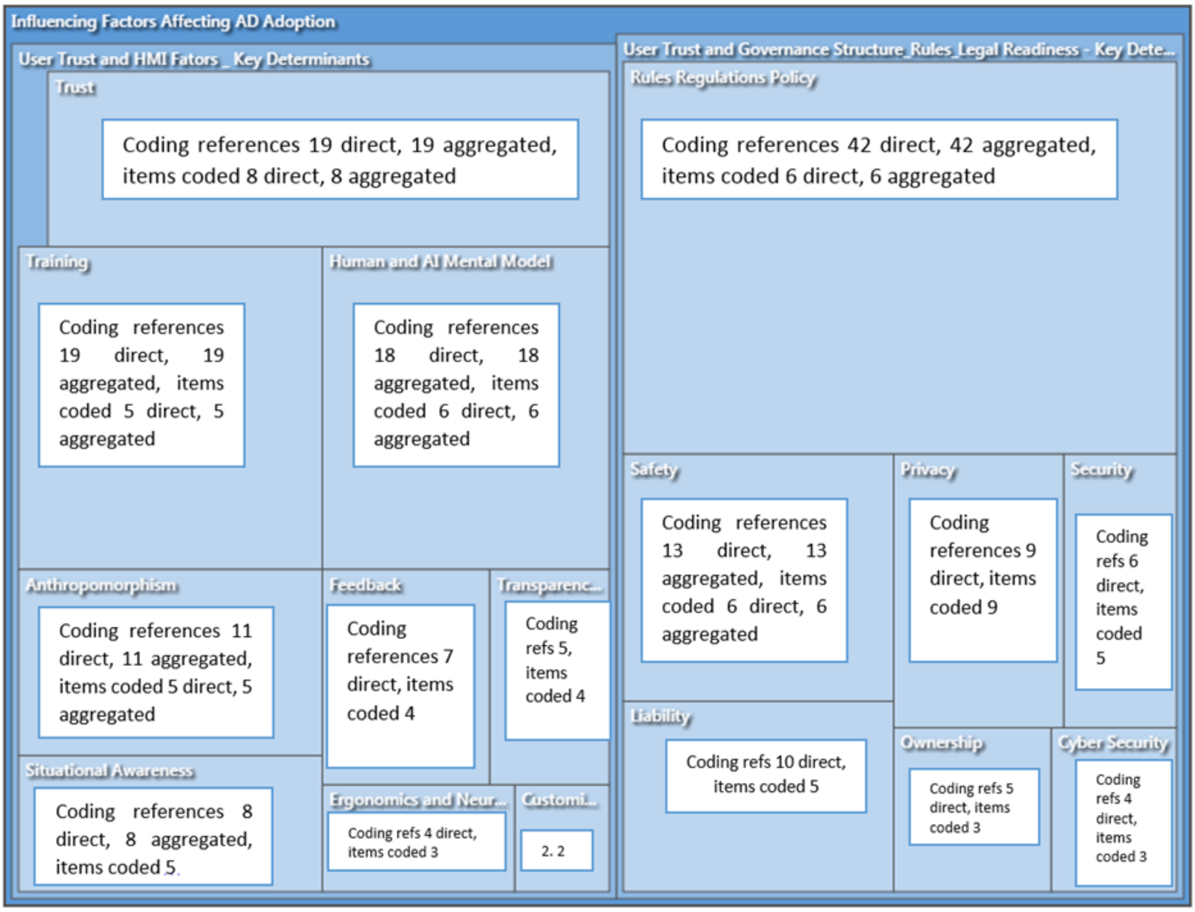


Note: Finalized Factors for Autonomous Driving based on Sources and References Frequency

Few participants (40%) did not agree with SEA/NHSTA topologies of AV levels, and some believed that there should be some kind of full-back automation before level 5 instead of 50/50. Other experts mainly belonging to OEM domains highlighted that there should be only two levels, i.e. cars requiring human supervision and those that don't, instead of 5 levels of automation. The majority of the participants described the significance of the EU GDPR regulatory framework, 'euroncap', WP25 and WP29 are appropriate measures to address cybersecurity and other challenges in safety. One of the participants also stressed the need to have open platforms, HD mapping, more shared data among OEMs to assist in making appropriate legal readiness structure. One of the consultants thinks there is no need to invoke a separate safety assessment rule instead, there should be voluntary safety assessment for all AVs. Figure 5.43 highlights the key determinants based on nodes categorization in NVivo 11 for factors influencing AD in two major domains, i.e. User Trust and HMI; (2) User Trust and Governance Structure in NVivo 11.

Figure 5.43

Significant Factors Affecting AD Driving – Hierarchy Chart NVivo 11



In the light of all these views, it can be concluded that trust and user acceptance of these technologies is critical to address significant challenges due to present-day transport and ensuring the successful diffusion of AVs. The appropriate level of trust can exist if the users feel satisfied with HMI determinants, especially situation awareness, anthropomorphism and training to ensure correct mental model. And on the other hand, Government ensures a progressive legal readiness and governance domain to address challenges of data privacy, safety, security/cyber security etc. Table 5.47 below illustrates the key view of the participants on factors affecting AD.

Table 5.47

Theme 2: Key Influencing Factors Affecting Autonomous Driving

ID / Transcript	Datum/Quotation	Comment	Sub Code	Main Code/Theme	Ref
CO4 Transcript-4	The biggest challenge is basically related to overtrust and having the wrong mental model above the level of automation.	Ensuring appropriate Trust and Mental Model	Trust Mental Model	User Trust and HMI Factors – Key Determinants	1/5
CO4 Transcript-4	I wouldn't say that I trust AV because it is user friendly, but I trust it because the user-friendliness gives me the information I need to maintain that trust.	Appropriate Trust, Anthropo-morphism	Trust	-Do-	2/5
CO4 Transcript-4	Public demonstration is the biggest factor influencing people trust.	Demonstrating Trust	Trust	-Do-	3/5
CO5 Transcript-11	A significant challenge is acceptance and Trust.	User Acceptance and Trust	Trust	-Do-	1/2
CO5 Transcript-11	So I think you're depending on trust between the regulator and the manufacturer over the performance of the system.	Legal Readiness and Trust Mechanism	Trust	-Do-	2/2
IP5 Transcript-2	So I would say that to build trust, maybe, to focus on processes, there need to be very strong processes to avoid cheating and severe punishment.	Trust of People Rules and Regulations	Trust	-Do-	1/4
AC1 Transcript-3	Because the problem regarding trust is people or users have a really bad or low understanding about what the abilities of these technologies are.	Users Understanding of AV technologies, Human Factors study in AVs	Trust	-Do-	1/6
AC1 Transcript-3	The results from simulator studies on trust is not that valid, I would say, because the simulator study	Simulator study to measure Trust	Trust	-Do-	2/6

ID / Transcript	Datum/Quotation	Comment	Sub Code	Main Code/Theme	Ref
	studies do not pose the risks that are needed for users to have the appropriate amount to have trust at all	is not good enough			
AC1 Transcript-3	In the backdrop of SAE levels 1,2,3 etc. you need to be able to ask the user what happens around him, to compare what type of information he gets from the surroundings, in relation to what type of information he gets from the AV and to help him to understand what he can trust, what is safe, what cues should he listen from the environment or AV because the AV will make mistakes and user needs to be aware of what is happening around him to take the last decision.	Users understanding of the system, Situation Awareness. Trust	SA	-Do-	1/3
AC1 Transcript-3	You need to have a correct mental model, which you can achieve by training by usage over time in several different ways, by learning or held by the automated system itself to give you hints, and they can give you cues. Feedback is also important	Training for ensuring the correct mental model	Training	-Do-	1/2
AC1 Transcript-3	Training can involve different types of driver license exams, some kind of theoretical questions, and simulation where you can try different types of traffic situations and training related to the actual capabilities of the automated vehicle.	Users Training and Driver Exams	Training	-Do-	2/2
AC1 Transcript-3	I believe that anthropomorphism is a way to convey information that affects trust using	Anthropo-morphism Trust	AnT	-Do-	1/3

ID / Transcript	Datum/Quotation	Comment	Sub Code	Main Code/Theme	Ref
	anthropomorphic features to ease the communication between machine and user and as a direct effect on trust.				
CO1 Transcript-8	Train lawyers on soft insurance and liability in case of software or hardware failure on camera accidents.	Training of Lawyers	Training	-Do-	1/2
IP5 Transcript-2	In terms of fallback routine, I think this awareness of what the system is doing and thinking, here you need some kind of displays to show the environment and build up the system's trust.	Situation Awareness Anthropo-morphism Training Trust	Training AnT	-Do-	1/2
AC1 Transcript-3	The User trust will be affected if the user perceives a high level of security and safety incorporated into AVs. So based on the governance structure, of course, that will increase the people trust in the design technology, and in this case, then AVs. But if it's the other way around, it could also affect the trust negatively.	Safety and Security into Governance/ Legal Readiness Structure to increase Trust of People	Safety	User Trust and Governance Structure-Legal Readiness – Key Determinants	1/2
CO2 Transcript-7	I don't think we need to make any laws for safety assessment. I think we can make that voluntary.	Safety rules	Safety	-Do-	1/1
CO5 Transcript-11	I see the technical challenges of getting the systems to work include cybersecurity, encrypted privacy and then regulations. So you need regulations to enable the use of these vehicles so that society considers them safe. I see them as being interlinked, but I think that the best way to address them is through collaboration between	Rules and Regulations around Public Safety, Cyber Security, Privacy. Linkages with Trust and Legal Readiness	Security/ Cyber Security	-Do-	1/1

ID / Transcript	Datum/Quotation	Comment	Sub Code	Main Code/Theme	Ref
	industry and the public sector, academia, and the R&D sector.				
IP1 Transcript-13	EU GDPR is addressing privacy and the integrity of the person when it comes to cybersecurity. We are already working with the WP 25/ WP 29 standard to know the challenges in areas or technology gaps that AVs could be hacked or could have our security threats. There is one document which is guiding called 'euroncap' actually when we buy our vehicle.	Privacy, Cyber Security Challenges	Privacy	-Do-	1/1

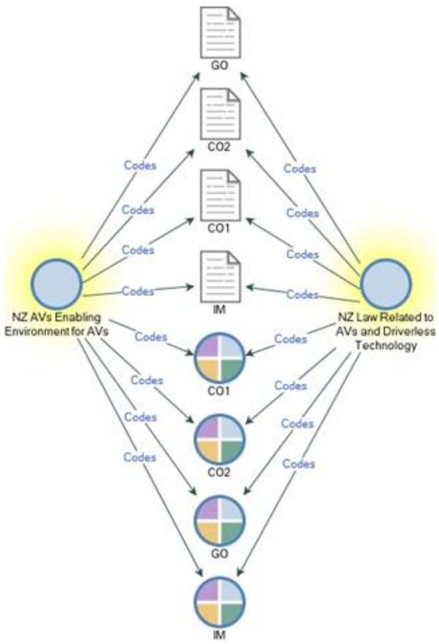
5.5.4 Theme – 3: NZ Enabling Environment for Deployment and Governance Mechanism for AVs

This theme was explored and validated by the experts residing in NZ. All the participants believed that NZ is not doing much as far as the deployment of AV technologies is concerned. They pointed out that in recent years, the NZ authorities had laid back on policies relating to AVs, and there is so much work to do in this regard. NZ is leading the world in technology innovations and now sitting and watching what will happen. This is underestimating the resources and the ability of New Zealanders to be part of the solution in the world. They remarked unanimously that NZ authorities don't see an urgent need, partly because they don't have the funds set aside to deal with it. And they don't know the value of it because NZ is so small. They also observed that the NZ transportation system is neither prepared for this gigantic advent from a regulatory standpoint nor an infrastructure preparedness domain. They believed that there are risks associated if we don't communicate the law correctly to international companies. They'll be too frightened to introduce AVs in NZ. The legal expert said that though there is no driver requirement in the car in NZ, and the law is currently adequate to deal with cars that require human supervision, it is not sufficient to deal with vehicles without humans. He further highlighted that in NZ, there is a high level of prescriptive compliance requirements through the New Zealand Transport Authority (NZTA) that says the vehicle has to comply with all of these conditions to be on the road. The expert pointed out that though the Ministry of Transport says that driverless cars are currently lawful in NZ, he thinks that there is a risk that the courts would not agree to this opinion once the matter goes to them. All the participants agreed that the significant challenges in NZ are relating safety, civil and criminal liability, property damage and personal injury while using AVs. The legal consultant thought that there is no need to have special laws for driverless vehicles on privacy, cyber security, and ethics or for safety assessment which should be voluntary. However, he observed that NZ lawmakers need to make few amendments to criminal law. Currently, it does not make it clear who is liable when a driverless vehicle has an accident? And civil liability. In his view, the liability should rest with OEM, operator or licensor of the vehicle but not with the driver or people in the vehicle. Liability needs to rest with corporate and criminal liability should be from a symbolic point of view. The participant highlighted that If we follow Australia's approach, the risk is that there would be a long time before we get AVs in NZ because no one would ever be approved. He suggested that NZ should follow the existing system used by the federal government in the US. They also recommended that (1) we need changes in building code, (2) explicit lane marking on roads, (3) congestion charging schemes, (4) requirement of a new road code, and (5) digital WOF. The experts highlighted the need to define the operational design domain (ODD) by the regulator describing which AVs can drive on the state highway and only operate in cities or outside cities. The majority of the participants agreed that there should be only two laws, one for Model T ford to advance Tesla requiring human input and the other dealing with cars with no human involvement.

However, the response from NZ government officials was that NZ is a technology taker in the vehicle space and not a manufacturer or builder of the AV technology. He further highlighted that NZ authorities have made it reasonably clear that NZ is open to any AV company from any country to test AVs in NZ. He remarked that governments are just coming out of COVID – 19, so there's a high likelihood that most nations would be knocking down our door again to test and trial in a couple of years. However, most testing and trialling is primarily being done in the country of origin. He informed that in NZ, there are around 900 AV3 Tesla Model AV that has an autopilot function, and NZ regulatory authorities are working with the police to be clear about what the enforcement should be. He highlighted the challenges of understaffing and funding due to the small market. He observed that the whole Ministry of Transport constitutes only 170 people. He further remarked that the Ministry is looking after road transport and regulates maritime rail and aviation. However, he thought that for levels 2 and 3, there are enough people in the organization to focus on those regulatory issues. Figure 5.44 shows NZ Experts comparison coding in NVivo 11.

Figure 5.44

Experts Comparison Coding Diagram Theme 2



Overall it can be concluded that NZ, due to its small market and low manufacturing base, is not well prepared in the regulatory and infrastructure domain for full diffusion of AVs. The challenges are mainly in the fields of criminal and civil liability, safety, property damage. There are NZ laws that effectively cover privacy and cybersecurity domains to some extent. Recommendations include law amendments in the highlighted sectors, defining ODD, preparedness of infrastructure and road code, and explicitly dealing with cars with humans and cars without humans. Table 5.48 below highlights the views of the participants.

Table 5.48

NZ Enabling Environment Theme 3

ID / Transcript	Datum/Quotation	Comment	Sub Code	Main Code/Theme	Ref
CO1 Transcript-8	NZ authorities don't see an urgent need, partly because they don't have the funds set aside to deal with it. And they don't see the value in it because NZ is so small. I think the transportation system is not prepared for this. It's not ready from a regulatory standpoint and is not prepared from an infrastructure standpoint.	NZ is adopting a wait and see policy, and has an ill-prepared infrastructure	NZ AVs Enabling environment	AVs Challenges and Future directions	1/9
CO1 Transcript-8	Lane Stripping for AVs in NZ is inadequate. Lane marking for AVs and pick up points have to be notable.	Require physical infrastructure	-Do-	-Do-	2/9
CO1 Transcript-8	Ohmio is making AV shuttles which are actually made in France named 'Nadya'.	NZ shuttle manufacturers	-Do-	-Do-	3/9
CO1 Transcript-8	There are risks associated that if we don't communicate the law correctly to international companies, there'll be too frightened to introduce vehicles in NZ. So particularly about criminal liability and also civil liability.	Lawmaking required in criminal and civil liability	Criminal and Civil liability	-Do-	4/9
GO Transcript-1	We have nearly 900 Tesla Models that have an autopilot function, which is	Tesla operation in NZ	NZ AVs Enabling environment	-Do-	1/8

ID / Transcript	Datum/Quotation	Comment	Sub Code	Main Code/Theme	Ref
	effectively a level three capability.				
GO Transcript-1	We're working with the police. So the police are clear about the enforcement.	NZ Police Enforcement regarding AVs	NZ AVs Enabling environment	-Do-	2/8
GO Transcript-1	We should also be clear that NZ is a technology taker in the vehicle space, so we don't manufacture or build the technology. We have input into UN regulations that we set.	No AVs manufacturing base in NZ	NZ AVs Enabling environment	-Do-	3/8
GO Transcript-1	We've made it reasonably clear that we are open to any company of any country approaching us or New Zealand transport agency and saying we would like to test a vehicle in NZ. Countries are just coming out of COVID – 19, so there's a high likelihood that we will be another couple of years before countries are knocking down our door again to test and trial. However, most testing and trialling is primarily being done in the country of origin.	Test and Trials in NZ	-Do-	-Do-	4/8
GO Transcript-1	Now the challenge we've got in NZ is that the whole Ministry of	Low staff in Ministry	-Do-	-Do-	5/8

ID / Transcript	Datum/Quotation	Comment	Sub Code	Main Code/Theme	Ref
	Transport is 170 people. We are not only looking after road transport but also regulate maritime rail and aviation. For levels 2 and 3, we've got enough people in the organization to focus on those regulatory issues.				
GO Transcript-1	Significant challenges are around again, safety and liability, those vehicles on the road, who is using the autopilot function, and where are they using it? And how are they experiencing it? Are the users and other drivers happy with it? Does it do what they expect it to do?	Safety and Liability	-Do-	-Do-	6/8
IM Transcript-9	Unless we come up with an agreed road code for these autonomous vehicles, how will we implement them and introduce them to the network?	Requirement of Road code	NZ law related to AVs	-Do-	1/3
IM Transcript-9	Last three, four years, the Ministry had done absolutely nothing, no policies. We should have been leading the world and now sitting and watching what will happen around this is absolutely underestimating the resources and the ability of New	Need to gear up resources	-Do-	-Do-	2/3

ID / Transcript	Datum/Quotation	Comment	Sub Code	Main Code/Theme	Ref
	Zealanders to come up out to be part of the solution in the world.				
IM Transcript-9	I would like to have AVs in NZ, then work from that date backwards, start to really look into the aspects of safety into that one. And put a plan for four years ahead to establish what the requirements for that program are?	Recommendation for Road Map	-Do-	-Do-	3/3
CO2 Transcript-7	The law is currently adequate to deal with the situation of cars requiring human supervision. It is not adequate to deal with when the manufacturer says that this car can drive itself without any human.	NZ law presence of a driver in AV	-Do-	-Do-	1/36
CO2 Transcript-7	We need to sort out civil liability, property damage and personal injury we need to sort out criminal liability. And we need not to regulate ethics. Ohmio shuttle does not comply with vehicle compliance requirements for on-road damage.	NZ Legal readiness challenges	-Do-	-Do-	2/36
CO2 Transcript-7	There should be only two laws, one for Model T ford to advance Tesla requiring human input and other dealing with cars with no human involvement	NZ law relating to human presence	-Do-	-Do-	3/36

ID / Transcript	Datum/Quotation	Comment	Sub Code	Main Code/Theme	Ref
CO2 Transcript-7	I don't think we need special laws for driverless vehicles on privacy, cyber security, and ethics or for safety assessment which should be voluntary. Besides, I didn't think we should mandate vehicle connectivity or radio spectrum use.	NZ Legal readiness	-Do-	-Do-	4/36
CO2 Transcript-7	We do need to make changes to criminal law. Our current law doesn't make it clear. Who is liable when a driverless vehicle has an accident? We need to make clear about criminal liability and civil liability. Liability rests with OEM, operator or licensor of the vehicle but not with the driver or people in the vehicle. Liability needs to rest with corporate and criminal liability should be from a symbolic point of view.	Criminal and Civil Liability in case of AVs crash	-Do-	-Do-	5/36
CO2 Transcript-7	If we went to Australia's approach, the risk is that there will be a long time before we get driverless vehicles in NZ and because no one will ever approve them. Ministry of Transport says that driverless vehicles	NZ Legal readiness	-Do-	-Do-	6/36

ID / Transcript	Datum/Quotation	Comment	Sub Code	Main Code/Theme	Ref
	are currently lawful in NZ. But I think there's a risk that the courts would say, No, they're not.				
CO2 Transcript-7	I think the existing system used by the federal government in the US is the way to go.	NZ Legal readiness	-Do-	-Do-	7/36
CO2 Transcript-7	It might be good if we could have congestion charging schemes in NZ because there is a risk that driverless vehicles could actually increase congestion	Congestion	-Do-	-Do-	8/36
CO2 Transcript-7	Building code is inefficient. In that, if you build a new apartment building or something in NZ, you have to provide parking as part of it. We can build driverless vehicles parking buildings, much lower and without any insulation or space for walking	NZ Legal readiness	-Do-	-Do-	9/36
CO2 Transcript-7	Our current law actually doesn't distinguish between whether or not the vehicle is operating in autonomous mode and whether or not the driver is driving it. But we have a high level of prescriptive compliance requirements through the New Zealand Transport	NZ Legal readiness	-Do-	-Do-	10/36

ID / Transcript	Datum/Quotation	Comment	Sub Code	Main Code/Theme	Ref
	Authority that actually says the vehicle has to comply with all of these conditions to be on the road.				
CO2 Transcript-7	We're not overly concerned about AV4 at the moment. We need a framework that gives clarity around when vehicle takes control of driving function. There is a need to define the operational design domain by the regulator describing which AVs can drive on state highway and which can only operate in or outside cities.	NZ Legal readiness	-Do-	-Do-	11/36

5.5.5 Theme – 4: Future Directions and Timelines

While exploring and validating Future implementation direction and diffusion timelines of AVs, the participants had varying views. They were not sure about higher automation level deployment on roads shortly (Table 5.49 below). However, they all agreed that for successful deployment of AVs, there is a need to improve and amend the legal readiness structure and improve infrastructure and AV user interfaces technologies for better sensing and fallback routine procedures. Furthermore, they stressed the need to formulate a performance measure criterion for AVs, defining operation design domains and focusing on intelligent driverless public transport in the shape of small shuttles, trams, pods and super nodes. Following significant suggestions were received:

- As a first step, deploy a driverless tram in coming years in NZ
- Preparation of ‘Road Code’ for driverless vehicles in NZ
- Defining Operation Design Domain (ODD) for AVs in NZ

- Making dedicated driverless vehicle lanes
- Utilizing AV ‘Robo taxis’ in conjunction with public transport in Auckland and Canterbury within a geo-fenced area
- Transforming to electric vehicles (EVs) and incentivising poor
- Creation of in-service safety systems and the real-time monitoring of AVs software and hardware
- Deploy AVs in retirement communities or planned communities, especially in areas like the north of Christchurch called Pegasus.
- AVs in shaper of little pods, Robo cargo system and supernodes
- Manufacture driverless vehicles in NZ for job and wealth creation

One participant suggested following the AVs road map as being implemented in Australia. Another participant stressed the need to implement US federal rules as it would take a long time to implement Australia's road map. Regarding the use of AVs interfaces and technology improvement measures, the participants remarked the following:

- AVs user interfaces are being modernized where a single camera is used and from the facial images and body weight sensors installed in the car seat to monitor the physical health of young and older adults.
- Shortly, one can summon the car for going to the doctor and calling an ambulance etc.
- Monitor detailed performance about the categories of road user, install commentary drive (sort of an advanced police driver) or a channel on the radio for AVs
- Improve consumer education about the performance of AVs.
- Doing R&D on how much does the driver know about the functionality of AVs? And how much manufacturing company is sharing data about what that technology can do?

- Need to study S curve where once the first interested people have approved the technology, the AV fleet volume can be increased together with a cost decrease, hence validating the study – 3 significance.
- Carry out realistic situations simulation with statistically sound parameters derived from the real world by real drivers.
- Carry out user studies to determine what kind of signals behave differently, easy language for AVs and how it communicates with drivers, how AV initiates a zip manoeuvre and driver's awareness of the system thinking in fall back routine. For example, behaviour on the yellow and red light, staying in a lane and interacting with larger vehicles.
- Audio commentary just before 20 seconds of fallback routine informing the user to take over through blinking system, loud noises and some shaking. Whereas in robust fallback, the car should drive on the side of the road and stop before handing over to a human.

Regarding implementation timelines of AVs, the participants' general remarks are as under:

- Deployment of AV3 is not far away; however, its sensing technology and legal readiness are still questionable from the safety point of view.
- Deployment of AV4 and AV5 is likely to be introduced in 10 to 15 years

Table 5.49

Future Directions and AV Implementation Timelines Theme 4

ID / Transcript	Datum/Quotation	Comment	Sub Code	Main Code/Theme	Ref
AC1 Transcript-3	We need to define measurement performance criteria within the operation design domain of these AVs and how these interact with our spaces, city centres, less parking spaces and how	Smart City Development and AVs Infrastructure, Need of AVs Performance Measurement criterion	Future Direction	AVs Challenges and Future Directions	1/2

ID / Transcript	Datum/Quotation	Comment	Sub Code	Main Code/Theme	Ref
	the cities will be built in that way.				
CO1 Transcript-8	I think the challenge is that governments tend to focus on infrastructure. We can do a better job by utilizing AV 'Robo taxis', transforming to electric vehicles (EVs) and in-service safety systems.	Significance of EVs, Robo taxis and in-service safety systems	-Do-	-Do-	1/8
CO1 Transcript-8	We need to utilize a shuttle of Robo taxis in place of or in conjunction with public transport in Auckland and Canterbury within a geofenced area satisfying last-mile operations. Besides doing fleet operation of AVs commercially, use in retirement communities or planned communities, especially north of Christchurch in the area called Pegasus, incentivising the use of EVs for poor, and the real-time monitoring of AVs software and hardware.	Use of AV and CAVs in various areas	-Do-	-Do-	2/8
CO1 Transcript-8	Future AVs won't be shuttles, but there'll be little pods, Robo cargo system and supernodes	Future AVs	-Do-	-Do-	3/8
CO2 Transcript-7	NZ can be involved in developing driverless vehicles to provide the jobs in the industries in the wealth that will create.	Manufacturing CAVs	-Do-	-Do-	1/2
CO2 Transcript-7	We need to have dedicated driverless vehicle lanes.	Infrastructure readiness	-Do-	-Do-	2/2
CO5 Transcript-8	We need to monitor detailed performance in relation to road user categories, install a commentary drive (sort	Measure to the successful deployment of AVs	-Do-	-Do-	1/1

ID / Transcript	Datum/Quotation	Comment	Sub Code	Main Code/Theme	Ref
	of an advanced police driver) or a channel on the radio for AVs. Works needs to be done in terms of consumer education about the performance of AVs. NZ need to follow US AVs regulations.				
GO Transcript-9	What we have to work out is the Australian approach, a similar one that we think we should be applying in NZ.	Legal and Infrastructure Readiness	-Do-	-Do-	1/2
GO Transcript-9	We need to do R&D on how much does the driver know about the functionality? And how much is the company sharing about what that technology can do? Are they explaining carefully what the limits and constraints of it? Are they really upfront about the fact that the driver needs to be really aware of what's happening and able to take control back.	Future research directions	-Do-	-Do-	2/2
IM Transcript-9	NZ need to come up with an agreed road code for AVs. How are we going to implement them and introduce them to the network? If something goes wrong, we go and fix the road code and not the manufacturers.	Need of Road code	-Do-	-Do-	1/2
IM Transcript-9	Let's create a tram. This is the first step. That tram doesn't need to have steel on the ground. It can go everywhere you want. You can change that tracks anytime that you like.	Create a Tram in NZ	-Do-	-Do-	2/2

ID / Transcript	Datum/Quotation	Comment	Sub Code	Main Code/Theme	Ref
IP1 Transcript-13	We are planning to launch new projects in 2025 or 2030, where we hope that the first step would be towards Robo taxi. Today our approach is not to attach anything with the body. It is just from a single camera and from the facial images and also from body weight. When you sit in the car, you have a body and different sensors you can put in the seat.	Future timelines for Robo taxis, AV interfaces	Future Timelines	-Do-	1/2
IP1 Transcipt-13	In the near future, you will see that you can summon your car, call your doctor, summon your ambulance, and summon different kinds of facilities from the comfort of the seat of your vehicle.	Future AVs uses	Future Direction	-Do-	2/2
IP3 Transcript-6	There is a need for smaller public transport that can run on more separate lanes prepared for autonomous cars.	Future AC public transport	-Do-	-Do-	1/2
IP3 Transcript-6	Then you have the S curve where once the first interested people have tested and kind of approved the technology, you will have a volume increase together with a cost decrease, like electrification.	Technology versus cost S curve, necessary of SD Modelling	-Do-	-Do-	2/2
IP5 Transcript-2	Do simulation. You can simulate in a way that you will have a realistic situation with statistically sound parameters derived from what you have really seen in the real world by real drivers.	Simulation studies	-Do-	-Do-	1/5

ID / Transcript	Datum/Quotation	Comment	Sub Code	Main Code/Theme	Ref
IP5 Transcript-2	In real-time user studies, we need to find out what kind of signals behave differently, what is an easy language for AVs and how it communicates with drivers, how AV initiates a zip manoeuvre, and driver's awareness of the system thinking in fall back routines. It may be in the shape of some environmental displays to inform the driver before handing over to build trust, such as 20 seconds as a safety period.	How to conduct user studies and using AV interfaces	-Do-	-Do-	1/4
IP5 Transcript-2	The audio commentary might help just to get him into the scene again. However, before the fallback routine, the system should inform the user to take over through the blinking system, loud noises, and some shaking. Whereas in the case of a strong fallback, the car should drive on the side of the road and stop before handing over to a human is much more plausible to me. Also, vehicle behaviour on yellow and red light.	Future AVs interfaces, especially during fallback routine procedures	-Do-	-Do-	2/4
IP5 Transcript-2	We should focus on sharing accident data is shared across, for example, different companies in general.	Crash data sharing	-Do-	-Do-	3/4
IP5 Transcript-2	Do we really want to have another Amazon like a US company controlling the whole market or Tesla or somebody else? Which I think would be a shame.	No monopoly of a single AV company in the market	-Do-	-Do-	4/4

ID / Transcript	Datum/Quotation	Comment	Sub Code	Main Code/Theme	Ref
AC1 Transcript-3	Human-level five AV is likely to be in 10 years to 15 years' time.	AV5 intro Future timeline	Future timelines	-Do-	1/1
GO Transcipt-1	None of the companies like Tesla, Bosh, and Holden is even considering deploying those vehicles in New Zealand in the next ten years.	Companies not considering deploying AVs in NZ	-Do-	-Do-	1/2
IP5 Transcript-2	Level three autonomy is not that far away in the sense that you almost have the system already for the highway. However, I think it's far away from the sensing technology and the safety point of view, especially in the backdrop of the legal liability point of view.	AV3 deployment timeline	-Do-	-Do-	2/2

5.5.6 Theme – 5: Trust and Governance Framework

The participants had varying views on deploying an AV framework that can work for humanity's betterment. However, all were found unanimous in agreeing to this study's contours of the proposed integrated trust and governance framework for deployment of AVs in NZ. The experts stressed the need for constituting a framework that increases trust and acceptance of people. And looks after their safety, thus minimizing crashes and congestion. , However, few participants highlighted various KPIs for utilization of framework, including; (1) safety, (2) security, (3) data and (4) cyber security, (5) privacy, (6) situation awareness, (7) education and training of users, (8) reliability, (9) transparency, (10) user-friendliness, (9) cost and (10) need for appropriate legislation. The main remarks of the participants are illustrated in Table 5.50. To get more insights into experts' views, the suggested framework of two participants can be seen in Figure 5.45 and Figure 5.46 below.

Figure 5.45

CO5 AVs Deployment Framework

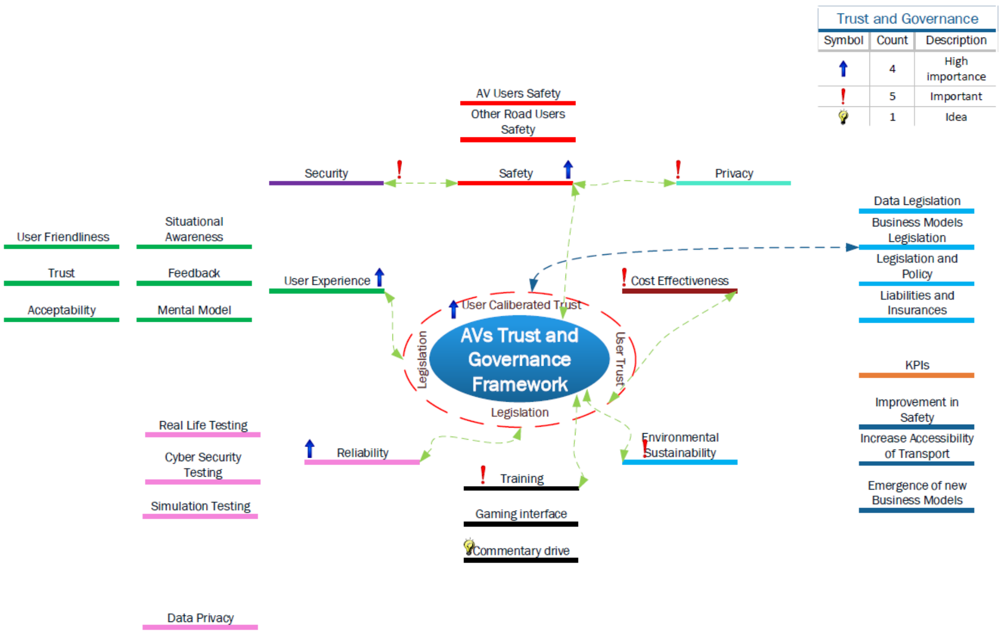


Figure 5.46

CO4 AVs Deployment Framework

One of the participants stressed the need for continuous testing throughout AVs life spans, and a few other suggested improvements in transport infrastructure such as (1) control centres, (2) hubs, (3) redesigning of roads, (4) use of sensors, (5) creation of compliance taskforce and (6) real time warrant of fitness (WOF). Generally, all the participants supported and validated the Trust and Governance Framework as suggested and researched in this study.

Table 5.50

Trust and Governance Framework for AVs Deployment Theme 5

ID / Transcript	Datum/Quotation	Comment	Sub Code	Main Code/Theme	Ref
AC1 Transcript-3	An AV framework needs to be based on the fundamental needs of humans. I think the study is definitely on the right lines.	Need of a Framework	KPIs	Trust and Governance Framework	1/2
AC1 Transcript-3	The goal should be to minimize the number of cars on the roads.	Significance of Framework for safety and lesser congestion	-Do-	-Do-	2/2
CO1 Transcript-8	One, there should be no accidents and second, how many of these edge cases have been navigated successfully?	Significance of Framework for safety	-Do-	-Do-	1/1
CO4 Transcript-4	The main pillar is safety, user-focused research, redesigning of infrastructure, reliability, rules and regulations, user friendliness, situation awareness, feedback, cyber security, and privacy. How do these affect the trust and acceptability of users?	Main contours of Framework to establish trust among the public	-Do-	-Do-	1/5
CO4 Transcript-4	For the implementation of AVs, the road design with many lanes on a highway, embedding sensors in the roads and redesigning the public spaces is required. I'm a big fan of control centres with tele operations-basically transport hops and hubs outside the city, making sure that everything is safe running smoothly.	Improving Infrastructure	-Do-	-Do-	2/5

ID / Transcript	Datum/Quotation	Comment	Sub Code	Main Code/Theme	Ref
CO4 Transcript-4	Continuous testing, I suppose, or very long duration testing. So, simulation testing, real-life testing, specimen testing, testing cybersecurity and testing backup systems.	Utilization of Framework	-Do-	-Do-	3/5
CO4 Transcript-4	Ensuring data is legislated from the safety-critical point of view and commercial point of view and creating different standards for various goals in ODD.	Data Legislation and preparing standards	-Do-	-Do-	4/5
CO4 Transcript-4	Creation of making a task force to monitor and establish basically guilt on automated legal questions.	Taskforce monitoring legal compliance	-Do-	-Do-	5/5
CO5 Transcript-11	Definitely like to have one of the pillars as cost-effectiveness, and other safety third is security for this pleasant experience as users. Then fifth, sustainability and then the rules for laws and regulations.	Framework Metrics	-Do-	-Do-	1/1
IM Transcript-9	Invest in AV ecosystem with 40% in the structure of the vehicle, 40% of the infrastructure and 20% for the overall system. If you fail to introduce that, then you are never going to have a complete ecosystem.	Investment directions	-Do-	-Do-	1/1
IP5 Transcript-2	One pillar can be safety, then transparency and third may be legislation	Framework Metrics	-Do-	-Do-	1/1
CO2 Transcript-8	Making a real-time WOF for AV is a necessity. All I'm really talking about is that OEM then sends a healthy signal to the regulator. So the regulator knows in real-time and then the	Real-time WOF	Testing and Deployment of Framework	-DO-	1/1

ID / Transcript	Datum/Quotation	Comment	Sub Code	Main Code/Theme	Ref
	consumer can know in real-time and then the insurer can know in real-time that everything's regarding AV is working smoothly.				

5.6 The Chapter Summary

This chapter presented the result and analysis of Study 1 to 4 to support the research aim and objectives. Study – 1 findings are based on the user study with BMW AV level2/3 vehicle on Auckland roads in live traffic conditions. This complementary user study assisted in confirming the significance of key influencing factors within the context of literature in different usage phases and classifying them into two groups. After formulating the HMI AD Event Relationship Identification Framework, the first cluster of key determinants were grouped into HFs and trust domain and the other cluster into Governance/Legal readiness and trust domain. The results of Study – 1 were confirmed and validated in Study – 2 through SEM. The main focus in this Study – 2 is descriptive statistics and statistical analysis using SPSS and Amos version 26, besides confirming Study - 1. Study – 2 ventures into validating the most significant determinants based on key parameters influencing AD in NZ as suggested by Study - 1. This study has gone a step further and found that Trust is a fundamental factor that mediates all other AD factors towards AVs implementation. Study – 3, based on SD Modelling, practically tested the theoretical output of the proposed framework. It has successfully tested the design framework's applicability and brought in significant predictions for AVs market maturity, people preferences to dispose of old AV technologies in favour of the newest AVs technologies and switching to the car-sharing regime. These insights can also be significant for pursuing strategic policies for AVs diffusion in NZ. All the studies interpretations and the suggested integrated trust and governance framework was validated by experts' interviews in Study – 4 through thematic analysis in NVivo 11. Thus, this chapter effectively tested and validated the Trust and Governance Framework for the successful deployment of AVs in NZ. The next chapter will present a detailed discussion of the results and findings of the current Chapter.

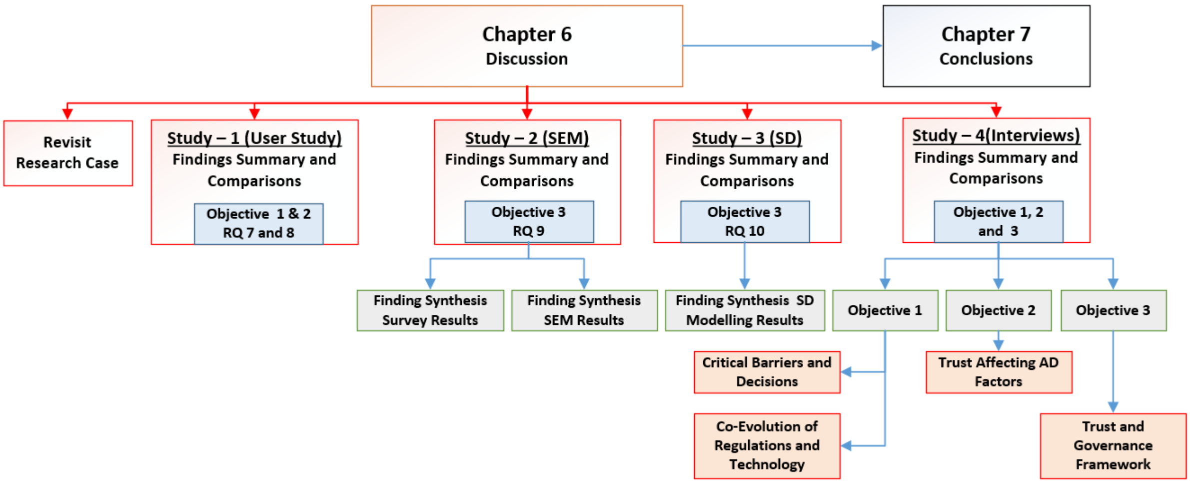
Chapter 6 - Discussion

6.1 Introduction

The research was designed to propose a trust and governance framework for the successful deployment of AVs in NZ. The validity of the proposal was evaluated employing four studies described in Chapter 5. The development of an integrated trust framework was one feature of this challenge. Another concern was measuring, testing, and evaluating the result for pragmatic decision-making realizing societal benefits in NZ. This Chapter synthesizes the findings accrued from Study – 1 to Study – 4 and deliberates on the research case in the backdrop of the research aims and objectives within the context of literature. It carries out a detailed synopsis of research insights and delineates the uniqueness of this innovative research. It carries out relevant comparisons highlighting agreements and disagreements from the previous research studies. As a guide, Figure 6.1 illustrates the layout and contours of this Chapter.

Figure 6.1

The Discussion Chapter Layout



6.2 Revisit the Research Case

The global market in self-driving cars is estimated to reach \$7.03 billion by 2021 and \$21 billion by 2035 (Du et al., 2021). AVs are a harbinger of significant evolution in human history and a game-changer in harnessing smart and sustainable technologies towards overall societal benefits (Chehri & Mouftah, 2019; Georg Doll, 2020). These driverless technologies will serve as a catalyst in transforming the cascade of our built environment digital and physical infrastructure, transport and mobility paradigms. AVs are likely to reduce road trauma and serve as an essential part of cyber-physical systems (CPS) in smart cities context (D. J. Fagnant & K. Kockelman, 2015; Mouftah et al., 2020; Pieroni et al., 2018; Sell et al., 2019; Um, 2019; Yan et al., 2020). COVID – 19 crisis has further proved and exacerbated the success of these technologies ensuring safety in the Mobility-as-a-Service (MaaS) value chain (Boll, 2020; MSCI, 2020; Wiseman, 2020a, 2020b).

However, their intended objectives and market penetration are unknown due to the lack of data about the magnitude of specific AD factors in this eco-system since AVs are in the early stage of the product life cycle (Nieuwenhuijsen et al., 2018). Moreover, recent research studies primarily focus on optimistic orientation, projecting AVs as a commercially viable and safe technological enterprise. These studies in the literature explored various topics concerning AVs. These relate to the public expectations, the effect of congestion on travel behaviour, more tripping, last-mile/first-mile impact, and decrease in the number of accidents (Correia & van Arem, 2016; Gruel & Stanford, 2016; Hoogendoorn et al., 2014; Milakis et al., 2017b; Scheltes & de Almeida Correia, 2017; Stasinopoulos et al., 2021; Yap et al., 2016). Whereas, existing literature lacks a broader view on the impacts (both positive and negatives) of AVs on social, behavioural (Cavoli et al., 2017; Cohen & Hopkins, 2019), legal arrangements, public acceptability and accessibility (Fitt, Curl, et al., 2018). None of the studies ventured into the true complexity of exploring holistic AD human-machine interaction factors globally or in NZ

The NZ being the testbed of innovative technologies, is set to gain long-lasting benefits in the testing and deployment of AVs. However, presently it is marred with significant challenges of growing and ageing population, traffic congestions, accidental deaths, rise in immigration, ill-equipped transport and road infrastructure, lagging government legal strategies and limited funding (Fitt, Frame, et al., 2018; Geoscience, 2020; KPMG, 2020; MOT, 2020; S. NZ, 2020). There are two distinct stages of adopting driverless technologies in NZ: testing and public acceptability towards its introduction and deployment. Generally, if societal and behavioural intentions align with technical innovations, it will lead to users' acceptance (Kraetsch et al., 2021). In an earlier survey of knowing the public readiness for AVs among various countries, namely China, India, Japan, US, UK and Australia / NZ, the topmost concern among NZ people is about 'Trust in technology' (85.3%)' (Starkey & Charlton, 2020).

Trust mediates micro and macro interactions regarding people's reliability and acceptability towards new forms of transport (Fisher et al., 2020). Trust in automation is a significant mediator (though not the only one) of using automation (Wintersberger, 2020). Two facets materially affect the trust dynamics. It includes the extent of human interaction with the automation technology tasks within the domain of human-machine collaboration so-called internal environment (Craig Morrisona, 2020). And how the external “world view” environment set in by governance/legal readiness structure as seen by user and technology alike affects trust. System trust rest on the functioning of the bureaucratic legal system that leads to social order addressing the complexities of social order.

In contrast, Interpersonal trust in the context of automated systems is an effort to manage the interpersonal relationship between humans and machines. Hoff and Bashir (2015) and other researchers explored various technology acceptance models (Ghazizadeh et al., 2012; Lee & Moray, 1992; Venkatesh & Davis, 2000) and stressed the need to investigate trust impacting factors in real-world environments. They explore situational and dispositional factors to study how dynamic trust evolves from initially learned trust through experience and interaction with the technology. However, all these models in the literature neither addressed the driverless domain nor were based on empirical observations.

These developments call for investigations into new methodologies to capture these complexities and identify user trust and acceptance requirements addressing internal and external AD environment factors in AVs. It further highlights the need for interdisciplinary research to establish the theoretical and methodological foundations for trust in AVs with experimental testing. And in doing so, determine a rationale and practical trust and governance framework for AVs in NZ.

This frame of reference relates to exploring the various dimension of driverless technology in AVs and identifying key AD factors affecting trust in NZ. The challenge was to articulate a conceptual trust framework that juxtaposes the driverless technology potential (Gleeson et al., 2018) and the public policy engagement. In this background and the highlighted research void and its linkages with users’ trust dynamics within human factor engineering and socio-technical domain in NZ, the following key objectives were purported in this study:

- **Objective 1:** To examine the critical perspectives of driverless technologies in the backdrop of the deployment of AVs.
- **Objective 2:** To analyze the role of key AD factors affecting trust based on significant HMI and governance determinants for the implementation of AVs in NZ.
- **Objective 3:** To develop and assess an integrated trust and governance framework for the successful adoption of AVs in NZ.

This study explored ten research questions to realize the objectives. The study identified barriers in AVs' adoption, trust and technology acceptance theories and human-machine AD interaction factors. The study observed that primarily there is a web of trust where vehicle automation and users acceptance reside. The study then examined this web of trust (WoT). It explored its mediation linkages at the micro-level with human-machine interaction constructs and an overall government regulatory structure at the macro level. Finally, the study examined the linkages of interpersonal trust with institutional trust in a more extensive interconnected network.

The applicability of this innovative research was explored using mixed methods to address the research questions. The research case phenomenon is investigated utilizing reliable evidence from the lens of the Pragmatic paradigm, the theoretical perspective of the Design Science Research approach employing Multi-phase Research Design. In Multi-phase Design, the study is justified, evaluated and validated considering a case study of AVs deployments in NZ using four studies in two phases. In Phase 1, Concurrent Embedded Design Correlational Model comprising study – 1 (AV user study) and 2 (SEM) was carried out. In Phase 2, Convergent Parallel Design Model comprising study – 3 (SD) and 4 (Experts' interviews) was pursued.

Study – 1 based on literature review and user study with Level 2 BMW X5 xDrive40i SUV Vehicle with most of the functions of Level 3 was done. The research study provided solid foundations for observing and grouping the key AD driving factors in live traffic conditions. Study – 2 using an exploratory survey and SEM, tested various hypotheses and validated trust and governance framework. During the process, Study – 2 confirmed the aspirations of the NZ general public towards AVs, challenges towards implementation and perceptions on trust and governance mechanisms. Study – 3 simulated the conceptual trust and governance framework utilizing the SD Modelling process and examined the future market penetration of AVs in the next 100 years. It also projected the theoretical output of the trust and governance framework in real-time and gave future policy insights for shaping future transportation governance regimes for AVs in NZ. Study – 4 employed experts' interviews and validated the findings from Study 1, 2 and 3 and the trust framework. In the following paras, the research will highlight the results and contributions of these studies to meet the research aim and objectives successfully.

6.3 Study – 1: Summary of Findings and Comparison

The summary of the findings relates to the fulfilment of research aim, objectives 1 and 2 and research questions 7 and 8. The research question addressed are namely: **RQ 7.** *What are the key AD factors affecting interpersonal and institutional trust during human-machine interaction (HMI) for AVs deployment in NZ?* And **RQ 8**. *What HMI AD events are affected by key trust affecting factors during human–AV interaction?*

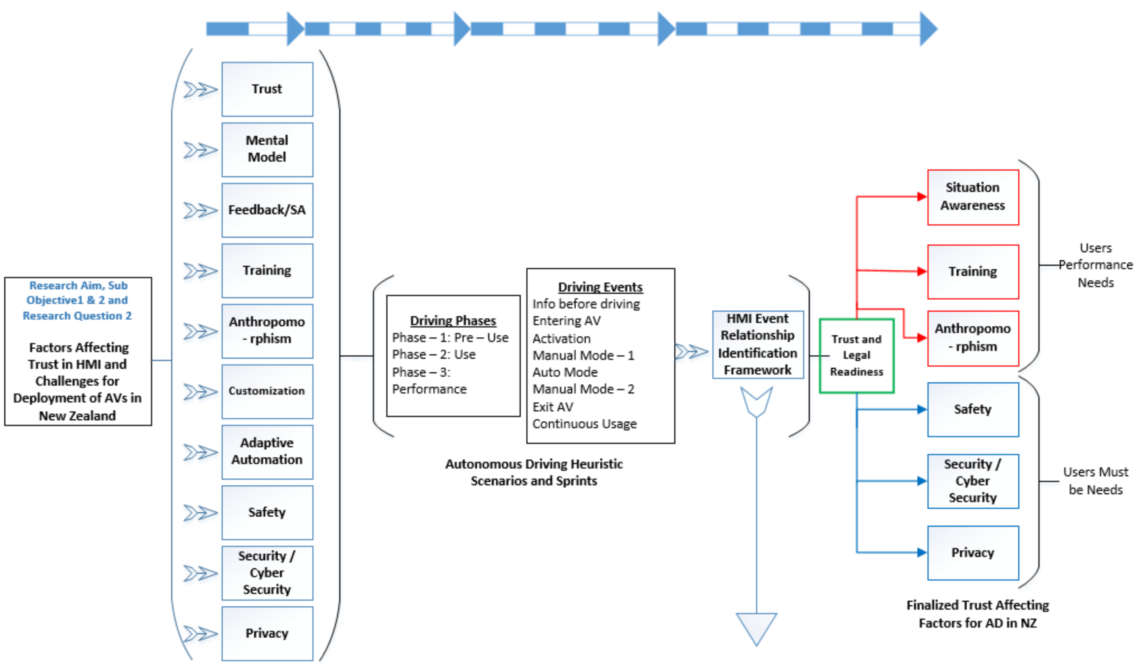
This study used a Level 2 BMW X5 xDrive40i SUV Vehicle with most of the functions of Level 3. These include forward-collision warning, automated emergency braking, lane change warning system, parking assistant, driving assistance with adaptive cruise control, autopilot (ranging from few seconds to 1 ½ minute). The BMW AV was used in autonomous and manual modes in live traffic and uncontrolled environments scenarios on free highways/ motorways in Auckland. The study used six subjects on three different driving routes. It was observed that the urgent requirement during HMI interaction is the driver's ability to take back control from AV in emergency and legal readiness structure based on users' safety, privacy and security in NZ. An appropriate and calibrated trust is needed towards these critical scenarios for the successful adoption of AVs. It was identified that in edge cases, where drivers need to resume control of the AV urgently to avoid any collision, vehicle automation negatively affects the mental model of the driver, situation awareness, and perception-reaction time.

6.3.1 Findings Synthesis: AV User Study.

The study found key determinants affecting AV's trust and acceptability while performing various heuristic scenarios and interviews. These include situation awareness, mental model and training of the driver, anthropomorphism, customization and adaptive Automation (classified as HFs internal determinants) from an interpersonal trust point of view. And safety, security/cyber security and privacy (classified as external determinants related to Governance/Legal Readiness domain). It was identified that all the determinants had linkages with institutional and interpersonal trust. These determinants were presented in the HMI AD Event Relationship Identification framework Matrix (HMI – ADERIF) based on the synthesized findings. The matrix was formulated in the light of real-time interaction of various driving scenarios and collaborative workshops during user study in Auckland. For example, a mental model of the driver influences the pre-use phase significantly. In contrast, driver training affects all phases and events marked with a star in Figure 6.2, consequently shaping the driver's trust.

Figure 6.2

Study – 1: Summary Findings and HMI Event Relationship Framework



HMI Event Relationship Framework

Phases	Pre - Use	Use						Performance
Events ⇨ Factors ⇩	Info before Driving	Entering AV	Activation	Manual Mode - 1	Auto Mode	Manual Mode - 2	Exit AV	Continuous Usage
Mental Model	☆							
Training	☆		☆		☆			☆
Feedback			☆	☆	☆	☆		☆
Anthropomorphism			☆	☆	☆	☆		☆
Safety		☆	☆	☆	☆	☆	☆	☆
Privacy			☆	☆	☆	☆		☆
Security		☆	☆	☆	☆	☆		☆
Customization				☆	☆	☆		☆
Adaptive Automation				☆	☆	☆		☆

The HMI Framework is intentionally left loose as a general guide to make it easier to understand the chain of events and how the relationship with trust affecting factors occurs during a single or continuous AD scenario. Later, to prioritise the user preferences keeping in view their significance within the context of literature, a Kano model was employed to classify these AD influencing factors. The finalized classification of these determinants was based on User *"Excitement needs," "Performance needs,"* and *"Must – need"* (see Figure 5.4 Chapter 5). Due to the dual role of few determinants, it was concluded to include users' mental model and feedback in situation awareness and customization and adaptive Automation in Anthropomorphism. Hence, the critical AD trust affecting determinants were reduced from 9 to 6, i.e., situation awareness, training, anthropomorphism, safety, security / cyber security, and privacy (see Figure 6.2 above).

Trust is generally defined as one's willingness to place in a vulnerable position, to technology, with a positive expectation of an outcome or a positive nature of future behaviour (Mayer et al., 1995). Though an abstract notion in automation, trust is a leading concept in HMI (Ekman et al., 2018) paradigm, which binds user acceptance and correct use with technologies and thrives on many dimensions (Fisher et al., 2020; Wintersberger, 2020). It has been observed that technological change leads to social change (Chen et al., 2020; Mohd et al., 2011). Most of the earlier studies on the subject are based on technology acceptance models and theories developed by Mayor, Hoff, and Lee (Hoff & Bashir, 2015; Lee & Moray, 1992; Lee & See, 2004). The researchers applied the Technology acceptance model (TAM), Unified Theory of Acceptance and Use of Technology (UTAUT), and Theory of Planned Behaviour (TPB) to find the role of user trust and task technology compatibility (Rahman et al., 2018). These theories provide a foundation to model user acceptance of driver support functions. The TAM Model highlights perceived ease of use (PEOU) and perceived usefulness (PU) embedded in the theory of reasoned action (TRA) and the theory of planned behaviour (TRB). The UTAUT model observes effort expectancy (EE), Social Influence (SI) performance expectancy (PE), and facilitating condition (FC) as the core variables. It considers gender, age, experience, and voluntariness of use (VOU) having pronounced moderating effects on these core variables. These theories suggest that behavioural intention is necessary for the use of a technological system and measures the users' acceptance with the behavioural intention and use of technology.

However, these theories were originated within the context of information technology and did not specifically address driverless or semi driverless systems in automation. These scientific endeavours explored a few HMI endogenous trust influencing factors individually (Aremyr et al., 2018; Ekman et al., 2018; Kaur & Rampersad, 2018). These theories do not capture holistic trust corroborating AD factors in the external and internal environment for the successful proliferation of driverless technologies. The behavioural intention investigations were based on the actual use of technology relating to the internal environment only. There have been few attempts to examine a unified user's acceptance model for driverless technologies. Ghazizadeh et al. (2012) proposed Automation Acceptance Model (AAM) augmenting TAM with trust and compatibility, and Vlassenroot et al. (2010) suggested in-vehicle automation using intelligent speed adaptation. However, these models have not been supported by empirical evidence despite the solid theoretical background (Rahman et al., 2018).

Hoff and Bashir (Hoff & Bashir, 2015) stressed the need to investigate trust impacting factors in real-world environments and explore situational and dispositional factors. They argued about the significance of multidimensional construct to study how dynamic trust evolves through experience and interaction with a system and technology from initially learned to trust. Moreover, it has been lately noticed that influencing factors for acceptance of technology need to include trust, perceived risk (PR) based on safety requirements, personality traits, social influence and external environment (Chen et al., 2020), extending UTAT and TAM.

This study is the first-ever AV user study in NZ and elsewhere in live traffic conditions that explored the critical AD trust influencing variables in human factors and legal readiness domains. This novel research took a holistic view of all exogenous and endogenous factors impacting user acceptance and deployment of AVs. This study followed a practical approach to creating a calibrated trust framework for AD systems based on crucial determinants within an HMI design process. The user study followed a slightly similar approach to studies pursued by Ekman and Aremyr recently (Aremyr et al., 2018; Ekman et al., 2018) regarding the HMI design process integrating trust factors. However, it widely differs as it is performed on high and medium density roads in live traffic conditions. Secondly, user interviews and brainstorming sessions integrate and confirm these factors and their relationship in the proposed framework. Thirdly, it omits unnecessary events, including ‘control transition,’ ‘change of context,’ ‘incident and implicit/explicit information,’ as highlighted by Ekman study. During interaction with actual AD scenarios in real-time, the user study concludes that the control transition process does not take place and cannot be measured.

Additionally, the ‘change of context’ and the ‘incident’ occur in one continuous event/usage; hence, there is no need to deal with these events and make the framework complex explicitly. This study is in line with recent studies of Raats and Jian (Chen et al., 2020; Raats et al., 2020) that explored public acceptance in AVs and identified a requirement to extend the integrated technology acceptance model. The study also proposed incorporating new variables as depicted in key determinants (Figure 6.2 above). Increased users’ acceptance of AVs is likely to assist in the realization of associated perceived benefits, as discussed in chapter 2, leading to positive social implications.

The study contributes to driverless technology in general and AVs in particular, addressing the users’ interpersonal and institutional trust within the HMI domain for acceptance. It illustrates that user trust mediates not only in the human factors domain but also in the governance domain. Previous literature addressed trust from an interpersonal trust point of view only. The developed framework can be used in the design process of AVs to get insights into AVs' performance and map the scenarios against the suggested framework to ensure appropriate trust. Since there are multiple interactions and interpretations of the trust determinants and the design solutions, further research can validate individual factors vis-a-vis the corresponding autonomous events/phases highlighted in the framework. Nevertheless, this study is unique in identifying critical AD determinants affecting the adoption of AVs in NZ, bridging the socio-technical gap and leading to futuristic research insights.

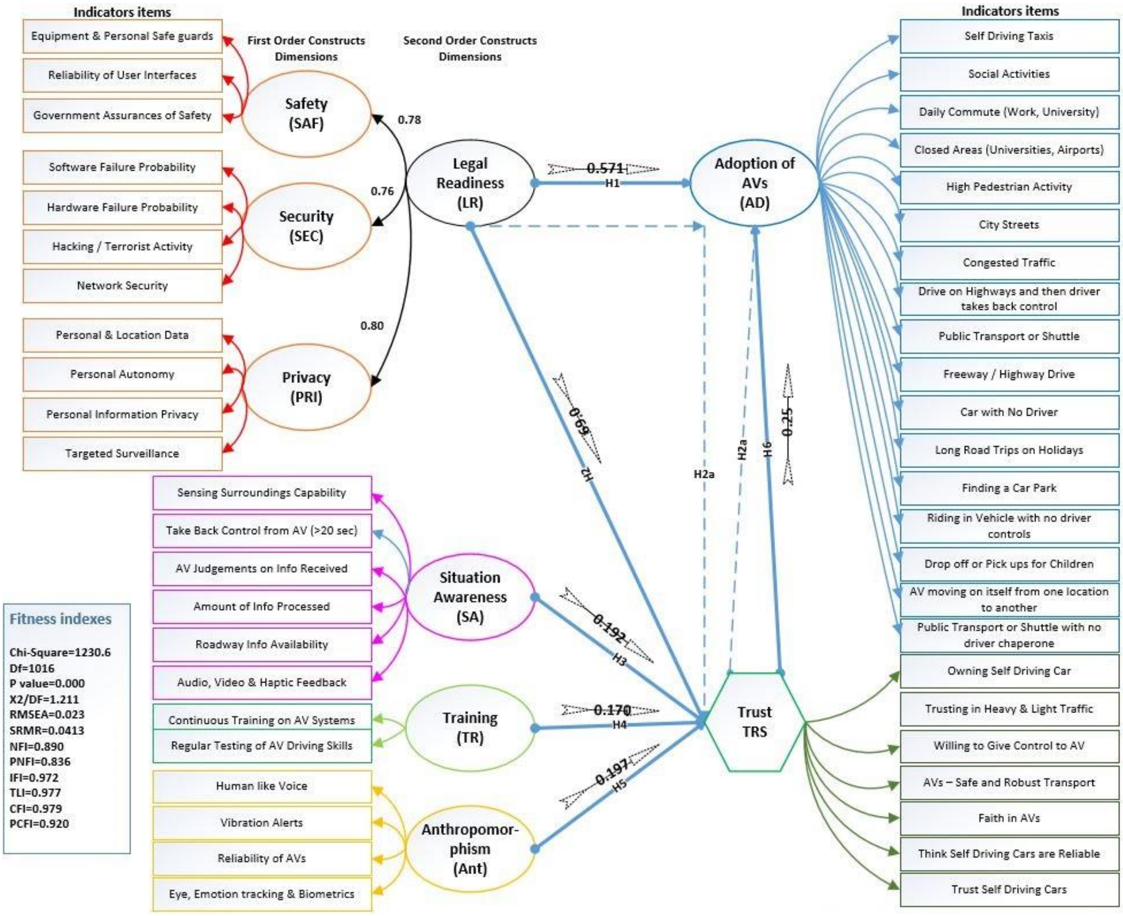
6.4 Study – 2: Summary of Findings and Comparison

The summary of the findings relates to the fulfilment of the research aim, objective 3 and investigating research question 9. The research question addressed are namely: **RQ 9.** *How to articulate a relationship between key corroborating trust affecting factors for developing an integrated trust and governance framework for the adoption of AVs in NZ?*

Study – 2 developed an integrated model between Trust and adoption of AVs in NZ to observe the relationship between situation Awareness, anthropomorphism and training in trust – HFs HMI domain and safety, security/cyber security and privacy in trust – governance/legal readiness domain. The study provided a good explanation of the proposed integrated model by positively supporting the seven suggested hypotheses. Figure 6.3 depicts the suggested holistic Trust and Governance Model, including 46 indicator items, three first-order constructs and six second-order constructs, beta values and fitness indexes.

Figure 6.3

The integrated Trust and Governance Framework Model



6.4.1 Findings Synthesis: Study – 2 Survey Results.

The research systematically examined the interaction between various trust affecting factors after getting key inputs from Study – 1 and confirming the challenges towards successful AVs adoption in NZ through a survey. It was found that the people in NZ people consider 'Trust' (26.5%) as a fundamental challenge followed by a legal readiness regime (17.7%) towards full implementation of AVs. The public concerns for key trust affecting factors include situation Awareness (17.7%), anthropomorphism (8.7%), and training (10.8%) in the human factors domain. At the same time, safety (31.9%), security/cybersecurity (13.9%) and Privacy (12.1%) concerns were identified in trust affecting the legal readiness domain.

Regarding adoption preferences, males were more inclined towards AD in NZ than females. The public wants to use AVs not only in closed areas (84%) but also in congested traffic (70%), highways/freeways (80.6%), public transport with driver chaperone (86.7%), Daily commute (57.9%), taxis (57.1%), long road trips on holidays (85.7%), and social activities (35.7%). The findings explored in Study – 1 and 2 regarding barriers and key AD trust influencing factors agree with the conclusions drawn in the literature (in Chapter 3).

Various studies concluded that trust is a precondition for the use of automated systems (Muir & Moray, 1996; Parasuraman & Riley, 1997) as it is essential for user acceptance (Ghazizadeh et al., 2012) as well as for a good user experience (Waytz et al., 2014). Typically, the significance of trust is essential in the successful deployment of AVs (Ekman, 2020a; Lee & Moray, 1992; Wintersberger, 2020). Similarly, the requirement of adequate legal regulations and governance regimes is mandatory (Lee & Hess, 2020; Taeihagh et al., 2021).

Moreover, the need for situation awareness (M. Endsley, 1995; Fisher et al., 2020; Stanton et al., 2006), anthropomorphism (Aremyr et al., 2018; Epley et al., 2007), and training (Lajunen & Summala, 1995; McDonald et al., 2018; McDonald et al., 2017) is highlighted in earlier studies. Also, the role of safety (Board, 2019; Commission, 2019a; Huntington, 2018; Venkatesh et al., 2003; Ward, 2011), security/cyber security (Kaur & Rampersad, 2018; Williams, 2020) and privacy (Cavoukian, 2009; Glancy, 2012; MOJ, 2020; Schoonmaker, 2016) is recognized by various authors. Generally, the results of this study survey are consistent with the results of empirical findings of the previous studies in different countries and existing theories.

This study is also in line with an earlier survey done in NZ, where people highlighted significant barriers of trust, safety, and lack of control in the implementation of AVs (Starkey & Charlton, 2020). The study is justified and supports what has been suggested in the literature, and lays the foundation for the research results' generalisability. The study highlights the critical barriers and concludes that co-evolution of regulation and technology is quintessential for the successful deployment of AVs. The study lays down the parameters regarding crucial trust influencing AD factors in technology and governance for designing a practical roadmap for AVs' deployment in NZ. The findings would be helpful in the understanding of critical factors of interpersonal and institutional trust for the deployment of AVs.

6.4.2 Findings Synthesis: Study – 2 SEM Results.

The main research aim was to develop a holistic trust and governance framework for optimum acceptability and adoption of Autonomous Vehicles (AVs) in NZ. The aim was achieved through testing seven hypotheses (H1, H2, H3, H4, H5, H6, H2a) after employing SEM and CFA techniques, as highlighted in Chapter 4. All statistical results regarding second and first-order constructs obtained through factor analysis were found within the recommended thresholds. The Cronbach's alpha (α) values for legal readiness, adoption, trust, situational awareness, anthropomorphism, and training were found within recommended thresholds. It indicated that the retained survey items were compelling, and the internal structure was consistent with their respective constructs. The theoretical predictive relationship in terms of standardized factor loadings (regression coefficients) from the constructs to the corresponding survey items (measurable variables) was also found statistically significant at the probability level of (***) $p < 0.001$. Hence, it was concluded that all the observed variables significantly measure the latent variables (constructs).

Moreover, the causal-effect links confirmed that the constructs in the model influence one another. All goodness of fit measures associated with the selected indexes for both the measurement and structural model was found sufficient, confirming the theoretical model fit well with the observed data. It can be acknowledged that the conceptual model framed for this study is powerful in explaining the reality of the existing situation of the topic under investigation. The seven hypotheses suggested by the model for validating the holistic trust and governance framework in NZ were fully supported through hypothesis testing of the researched constructs.

The study generally agrees with Yuen, Wong, et al. (2020) remarks that perceived AV technology is a giant leap from traditional vehicle technologies, influencing public opinion because of various concerns. These include safety, lack of control (situational awareness), steep learning curve (training), cyber security, trust and non-readiness of legal and liability rules. However, there has been very little research in the literature regarding the role and relevance of AVs' regulation in a smart urban transport system (Ljungholm, 2020).

User attitude towards technology is governed by the belief in the convenience of its performance and social influence, including governance structure (Davis, 1989; Ljungholm, 2020). It means that user interactions with the efficacy of the governance systems and utilization of technology need to be well expressed to create a positive effect on the user. Perceived usefulness is related to several trust factors, including legal readiness comprising enhanced safety, cyber security and privacy of the driver and the direct HMI factors with AVs. Earlier studies explored these challenging factors in anthropomorphism, situation awareness, training, safety, security, privacy and policy partly or individually (Aremyr et al., 2018; Ekman, 2020b; Endsley, 2016; Kim & Shrestha, 2020). Unlike other studies, this study measured the driver's trust addressing these crucial challenges in a holistic trust framework. The components of this integrated framework were found individually and collectively predicting adoption of AVs based on users' trust.

The effects of users' trust are supported in the findings of previous studies highlighted above; however, there has been no empirical evidence to support these components' effects collectively. In addition to the direct impact, this study also examined the mediating effect of trust in legal readiness and adoption. Results confirmed Hypothesis 2a (see Table 5.31 Chapter 5) that the trust mediates legal readiness/governance based on safety, security and privacy towards the adoption of AVs. The conclusive factors and their effects identified in this framework goes beyond the impact of perceived usefulness (PU) and perceived ease of use (PEOU) is posited in the TAM (Davis, 1989). Therefore for driverless and semi driverless systems, this study confirms the inclusiveness of these determinants towards their adoption.

Earlier research examined the applicability of institutional trust in AI technologies (Spadaro et al., 2020). However, none of the studies or the technologies acceptance models available in the literature ever ventured into the net effects of institutional and interpersonal trust. This innovative study explored individual key dimensions of trust affecting interpersonal and institutional trust. It provided evidence that institutional trust promotes interpersonal trust (as seen by the mediation results) for the successful implementation of AVs. The study also confirmed the importance and application of the SEM and CFA techniques in studying various determinants in driverless technology. This study explored the relevance of AV regulations through the validated framework in detail. The research question and objectives anticipated in this study are fully realized.

Trust needs treatment more than just a precondition of acceptance (Wintersberger, 2020). Trust is a multidimensional cognitive construct that has been examined by several disciplines, including anthropology, psychology, economics, political science, and sociology (Bhattacharya et al., 1998). Lewicki and Bunker (1995) suggested that trust should be studied from an institutional and interpersonal perspective. System trust is the "trust in the functioning of bureaucratic sanctions and safeguards, the so-called legal system" (Lewis & Weigert, 1985). Institutional trust ultimately promotes interpersonal trust, increasing the feeling of security (Spadaro et al., 2020). In human-automation joint performance, cognitive engineering (CE) and information system (IS) studies explored automaton acceptance (Ghazizadeh et al., 2012). CE studies observed task technology compatibility needs and identified trust as a significant attitude towards automation reliance and acceptance (Lee & See, 2004; Muir, 1987). Inappropriate trust leads to misuse and disuse of automation (Parasuraman & Riley, 1997). Understanding the interactions between trust and use, disuse, and misuse are necessary for the formulation of predictive human-machine models (Tenhundfeld et al., 2021). IS researchers developed TAM (Davis, 1989), identifying PU and PEOU as the main attitude determinants predicting behavioural intention to accept the automation system.

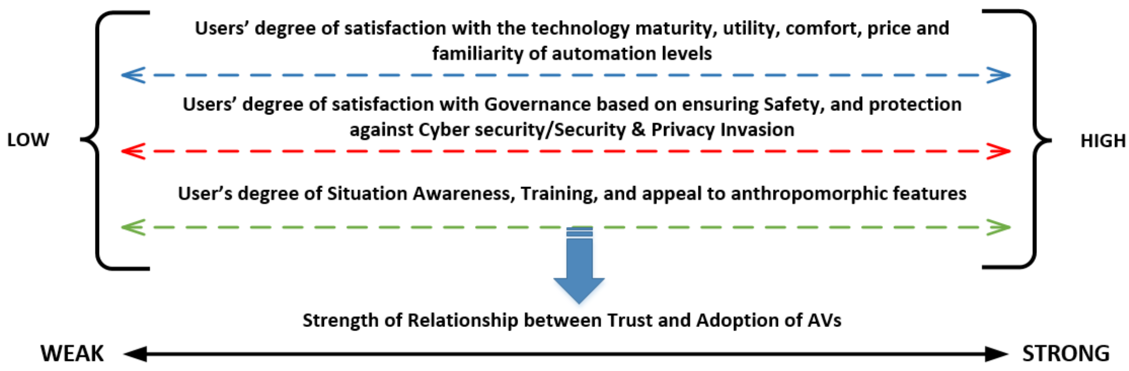
This research study observes that trust assessment is underutilized in Human Factor Engineering (Tenhundfeld et al., 2021). Also, the AVs would be based on artificial intelligence (AI) and a new generation of technologies to simulate human intelligence (Glikson & Woolley, 2020) and interact with the environment requiring complex risk mitigation decisions (Cunneen et al., 2019b). Present research does not address AD trust holistically from interpersonal and institutional perspectives to address this challenge. The cognitive underpinning of trust theories and models in the literature provides a partial solution and does not answer the realities of the semi-autonomous and autonomous systems.

In recent literature, the prominent user acceptance models regarding automation and trust are TAM, extended TAM, AAM, Hoff and Bashir, Muir and several other scholars (Davis, 1989; Ghazizadeh et al., 2012; Hoff & Bashir, 2015; Lee & See, 2004; Muir, 1987).

These models are generally based on the Theory of Reasoned Action (TRA), Theory of Planned Behaviour (TPB) and Unified Theory of Acceptance and Use of Technology (UTAUT) (Fishbein & Ajzen, 1975; Venkatesh et al., 2003) highlighted above and in Chapter 3 (3.2.3 and 3.2.4). These models bear similar components, e.g., there are similarities between PU (perceived use) in TAM and PE (performance expectancy) in UTAUT; between PEOU (perceived ease of use) in TAM and EE (effort efficiency) in UTAUT; and between social norms in TPB and social influence in UTAUT (Rahman et al., 2018). The proposed integrated trust model validates and integrates the essentials of these theories and models and extends these to yet another level as identified in Figure 3.12 Chapter 3 and three layers of influence AD trust Figure 3.13 Chapter 3 (3.2.5) (see Figure 6.4 below).

Figure 6.4

AD Trust Layers of Influence



Muir (1987) proposed that trust formation depended on three human expectations: persistence, technical competence, and fiduciary responsibility. The persistence relates to the natural and moral social orders, technical competence depends on automation performance, and fiduciary responsibility denotes how much other agent is morally obligated to prioritise the other's interest before their own. In this study, interpersonal trust HFs determinants based on situation awareness, training, and anthropomorphism define technical competence, and institutional trust LR determinants comprising safety, cyber security, and privacy denoting the natural and moral social orders.

Extended TAM is developed on TRA. The user's behavioural intention to use a system is directly influenced by trust, and task technology compatibility indirectly affects behavioural intention through PU and PEOU (Davis, 1989). The compatibility refers to how well the automated system performs vis-à-vis user needs and requirements in a specific context. Similarly, Ghazizadeh et al. (2012) produced a conceptually similar AAM model, which was more explicitly based on the Technology Acceptance Model. In this study, the task technology capability is explored using HFs / HMI trust determinants identified in AV user trials (Study – 1) having similar trajectories to TRA, extended TAM and AAM towards reliance and ultimately adoption of AVs in NZ.

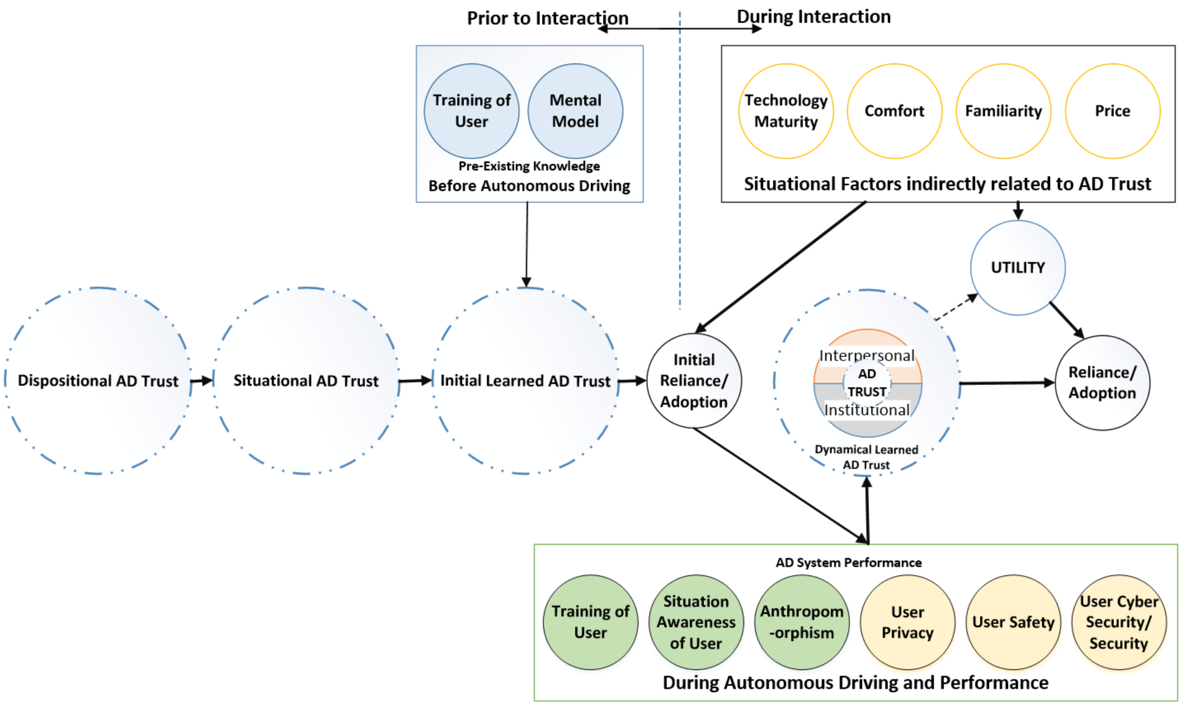
Lee and See (2004) identified that the foundation of trust refers to the social order that allows trust to arise. Performance, process and purpose are purely related to technical domains of automation. This study supports Lee and See (2004) assimilation model, which depicts that trust is essentially an effective response though partially influenced by analogical and analytical processes in the context of human-machine trust (see Figure 3.10 Chapter 3). The analogical is based on societal norms, rules, and regulations defined by others, and affective refers to the emotional response to the expectancies. In this study, the social order and analogic process is denoted by the institutional trust based on safety, security/cyber security and privacy regulations in the backdrop of structure theory (Jones & Karsten, 2008). The performance, process and purpose are related to the dynamically learned trust (Hoff & Bashir, 2015) during actual interaction with the AV.

Hoff and Bashir (2015) advocated examining trust impacting factors in real-world environments. Moreover, their model identified that learned trust is based on initially and dynamically learned trust. The initially learned trust is acquired through brand/reputation of system, understanding and experience with similar systems, and expectations from the system. The dynamically learned trust is a result of direct system interaction and features. These factors cumulate to shape the user reliance behaviour and performance of the system. This study is carried out utilizing inputs from the AV user trials in live traffic real-time environmental conditions. The initially learned trust is denoted and explored through users' pre-existing knowledge based on their mental model and initial training to use the AD system as identified in Study – 1.

Similarly, user’s familiarity with AV, AV technology maturity, its price and comfort affects utility along with dynamic trust developed during AD interaction (Abbass, 2019; Nieuwenhuijsen et al., 2018; Wang & Zhao, 2019) and ultimately the reliance/adoption as examined in Study – 3. Initially learned trust improves with the changes in the pre-existing knowledge, mental model, and training and transforms into dynamically learned trust during actual interaction with the AV systems and design features. The dynamic learned AD trust is based on interpersonal and institutional AD trust corroborating factors during HMI observed in Study – 1, examined and validated in Study – 2. The performance, process and purpose dimensions of the Lee and See (2004) model are related to the dynamically learned trust dimension of Hoff and Bashir (2015) model during actual interaction with the AV. The suggested AD Trust Model components and their interactions towards adoption of AVs augmenting Hoff and Bashir (2013); Hoff and Bashir (2015) is illustrated in Figure 6.5.

Figure 6.5

Suggested AD Trust Model and Components



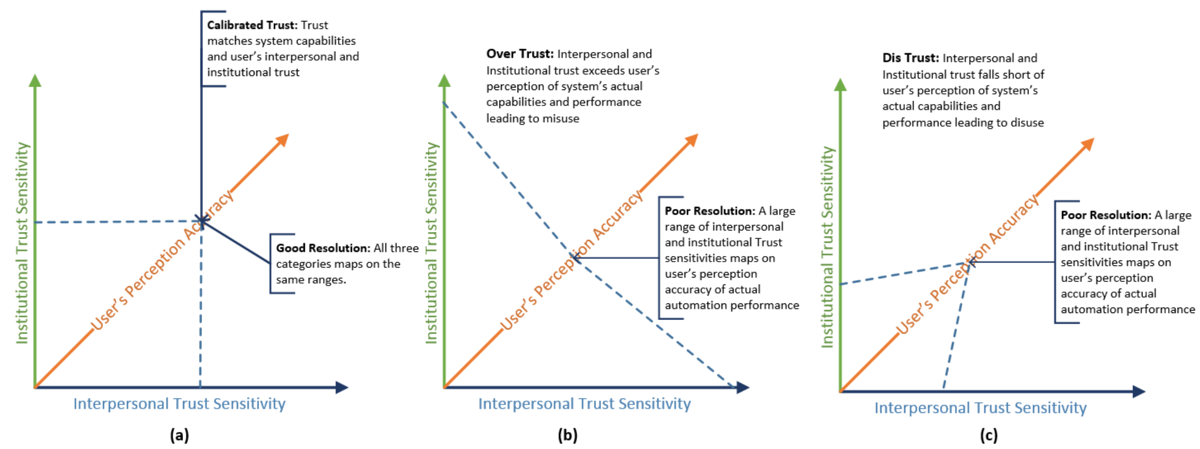
AVs need to interact not just with passengers but with pedestrians, fellow drivers, other road users; hence their acceptability depends on the people trust in the entire eco system in which AVs thrive. Lately, the theoretical underpinning of trust in automation and AVs within HMI emphasizes an interdisciplinary approach to study beyond usability and perceived ease of use to factors external to HMI impact towards social and other domains (Raats et al., 2020). Therefore, this study examined the critical human-machine interaction factors in the socio-technical realm and the crucial legal readiness determinants to form holistic trust in the entire system for the acceptability of driverless technology. These AD adoption factors would likely form the cornerstone of a hybrid human-machine mental model and a new socio-technical framework bounded by psychological, technical and legal realities.

Out of the large body reviewed literature, there is no research towards the calibration/appropriateness of trust vis-à-vis system performance and establishing a relationship between trust and legal readiness framework. A significant study on developing appropriate calibration is carried out by Lee and See (2004) (see Figure 3.7 Chapter 3) and Parasuraman and Riley (1997). Lee and See (2004) described a relationship between calibration, resolution, and automation capability to define appropriate trust in automation. They stated that the appropriate reliance depends on how well trust matches the actual performance of automation. This phenomenon of user's trust in automation and actual automation capabilities is denoted as 'calibration' (Muir, 1987). Poorly calibrated trust gives rise to 'over trust' and 'misuse of automation' as user overestimates the capabilities of the automation. 'Under trust' leads to the 'disuse of automation' where the user underestimates the true automation capabilities. Therefore, poorly calibrated trust due to misuse and disuse of automation leads to catastrophic, life-threatening consequences. Lee and See (2004) suggested additional factors to explore the appropriate level of trust based on resolution and specificity. Lately, another study examined trust calibration based on perceptual accuracy, perceptual sensitivity and trust sensitivity (Merritt et al., 2015).

Based on the findings, this research study suggests linking resolution and specificity with appropriate trust calibration by examining the behaviour of calibration in three categories. These are interpersonal trust sensitivity, institutional trust sensitivity and user's perceptual accuracy. The institutional and interpersonal trust sensitivities relate to the user's adjustment over time to the institutional and interpersonal antecedents observed in this study for reliability and attitude towards AVs adoption. The user's perceptual accuracy denotes the extent of the user's perception of their performance that matches the actual automation performance. The significance of this calibration is supported in Study – 2 (H2a) by the trust mediation of interpersonal and institutional trust via legal readiness and HFs determinants towards adoption. However, trust calibration warrants further investigations. Figure 6.6 below; (a) displays a good resolution of all three categories maps on similar ranges, ensuring a calibrated trust, (b) illustrates poor resolution and over trust where interpersonal and institutional trust sensitivities exceed user's perception of systems' actual capabilities and performance leading to over trust and misuse of automation, and (c) highlights poor resolution and over trust where interpersonal and institutional trust sensitivities fall short of user's perception of systems' actual capabilities and performance leading to distrust and disuse of automation. Calibrating user's trust appropriately assists in designing and efficient working of an intelligent AV system (Liu, 2010). The AD Acceptance Model would provide a theoretical scaffolding to earlier technology acceptance theories ensuring successful adoption of AVs.

Figure 6.6

Suggested AD Trust Calibration



The proposed integrated model validates and integrates the various essentials of previous theories and models on the subject and extends these theories to yet another level. The study observes the co-evolution of regulations and technology through the lens of people's trust and confirms that interpersonal trust is promoted through institutional trust.

This study carries great significance for the end-users with practical and managerial implications. Moreover, it is noteworthy that the study bears a strong impact as it is established on existing theories and models, ample data size, and the use of an advanced multivariate statistical approach with a recommended software package. In terms of insights into describing the model outputs, this study contributes to the body of knowledge by validating the trust-legal readiness construct as a second-order construct. The study has successfully developed an integrated Trust and Governance framework for the adoption of AVs. It provides better assimilation of the interplay of various trust affecting determinants for making AVs as attractive as possible for the prospective users.

6.5 Study – 3: Summary of Findings and Comparison

The summary of the findings relates to the fulfilment of research aim, objective 3, Research Question 10, i.e., **RQ 10**. *How to visualize a futuristic roadmap for AVs' adoption and planning appropriate policy and guidance strategy for their successful deployment in NZ?*

System Dynamics (SD) modelling process was employed using Vensim PLE 1.8.2. The study identified the diffusion of AVs in NZ, capturing beta values of trust and governance framework factors from Study – 2 and other variables within the context of the literature quantitatively. This Study – 3 validates and practically manifests the theoretical output of the framework. It provides significant predictions and milestones for AVs market penetration, technology maturity, and people preferences. It has also observed the utility behaviour to dispose of old AV technologies in favour of the newest AVs technologies and switching to the car-sharing regime, fleet sizes and adoption rates in the society.

The study is based on a quantitative model and two casual loop diagrams (Chapter 5) to observe this complexity. This research study thrives on feedback loops of (1) trust, (2) word of mouth, (3) limits on exogenous growth rate and (4) learning by doing and searching. These loops form a dynamic behaviour among model components that influences the diffusion of AVs through a functional pathway approach. Each level of automation from AV0 to AV5 has its technology maturity, adoption rate, market penetration and works on limits of success archetype.

Study – 3 is pursued in the backdrop of Technology Specific Innovation System (TSIS) (Hekkert et al., 2007), the Innovation Diffusion Theory (Rogers, 2010), Trust theory (Lee & See, 2004) (see Table 3.3 Chapter 3), and the Abernathy and Utterback (1978) Model. Six important system components were identified using these theories and employed in this SD study. These include (1) trust from Study -2 (2) AVs technology maturity, (3) the perceived economic utility based on comfort, familiarity, price, trust, (4) AVs fleet size and adoption rate, and (5) Car Sharing. Newes et al. (2011) and Vimmerstedt et al. (2016)

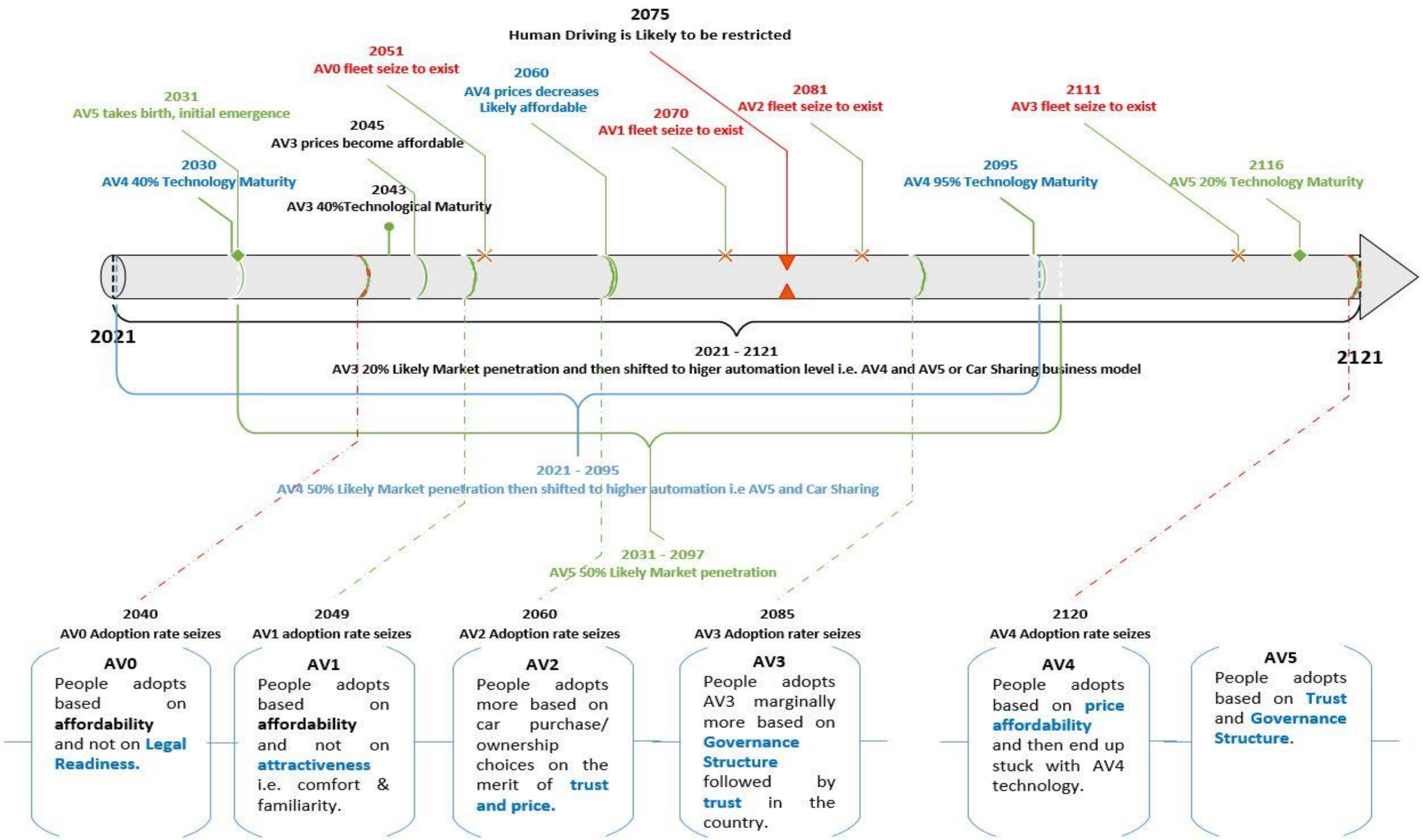
identified technology maturity as the state of technology readiness. Rogers (2010) remarked that positive familiarity occurs if more users have continuous interaction of novel technology in a particular period. Moreover, if technology is less complex and easier to use, it is easier to learn and offers more comfort. The users select a product that provides maximum utility (Lancaster, 1971). However, since AVs have not diffused in society, Rogers (2010) proposed few methods. These include examining the adoption rate and utility of the similar past innovations, asking users' opinion on the subject, and exploring the acceptability of the innovation in a pre-diffusion stage (Nieuwenhuijsen et al., 2018).

Earlier research studies have already explored the notions of comfort, utility, technology maturity, and trust towards the adoption of self-driving technologies (Das et al., 2020; Hollström, 2019; Lajunen & Sullman, 2021; Menon, 2015; Nieuwenhuijsen et al., 2018; Wu et al., 2020). This study has previously highlighted trust influence layers (Figure 6.4 above) to explore the AVs proliferation phenomenon based on the trust framework (see Figure 3.13 and Table 3.3 Chapter 3). The first two influence lines were examined in Study – 1 and 2 to formulate an integrated framework. The impact of the third influence line based on familiarity, comfort, technology maturity and economic utility was explored in this SD study to augment additional variables and identify the output of the proposed integrated trust framework in real-time.

The dynamics of AVs adoption were studied to articulate how policy and technological developments assist in adoption rates and address the direction and speed of this innovation. The insights of this novel study provide AV deployment timelines and a Road Map for 100 years till 2121 (see Figure 6.7) for the policymakers and other stakeholders alike in NZ to restructure the overall AV governance regime in the country and prepare the AV infrastructure accordingly.

Figure 6.7

AVs Deployment Timeline and Key Milestones Next 100 Years in NZ



Note: The utilities for AV3 to AV5 are the highest for societies that adopt AVs based on Trust and Governance / LR. These societies that make choices become relatively happier overtime with the AV technologies than do the societies that rely on price and attractiveness (comfort and familiarity). Adoption of AVs can be increased by giving subsidy or resorting to tax reduction to lower the cost of a specific technology, secondly people can be encouraged to replace their old cars with new ones. Increase in technology development can happen through knowledge accumulation and transfer by doing research and field tests, validation user studies and devising AVs implementation strategies by universities, research institutions and private R& D consultancy firms.

The model simulates that the AVs' utility increases with the appropriate trust, legal readiness structure, and attractiveness. With the growth of the fleet size of a certain AV level, the probability of end users' familiarity with this particular AV type increases and the people are more likely to adopt. Similarly, with the rise in awareness and maturity of AV technology, the AVs sales would grow and fleet size increase. The end-users will gain more trust in the performance and reliability of this specific level of AV technology, and it will speed up adoption.

6.5.1 Findings Synthesis

The model is applied in NZ enabling environment considering three scenarios. These include baseline, high automation, trust and governance, and low automation, trust and governance scenarios. The baseline scenario is mainly based on beta values of trust and governance framework adopted from Study – 2 and other parameters. The High Automation and High Trust and Governance scenarios displayed a greater trust of NZ people and a progressive AV regulating regime in NZ. The Low Automation and Low Trust and Governance scenarios are based on a generally lower trust of NZ people and a conservative AV regulating control.

It is evident from the results that if NZ people have greater trust in AV technologies, with a progressive governance regime, then the proliferation of driverless technologies are likely to be at a greater speed accruing maximum benefits to society. In this scenario, people are most likely to adopt AV1 in 2025, AV2 in 2030, AV3 in 2035, AV4 in 2036 and AV5 will continue even after 2045. The NZ people will stop using non AV cars in 2041, AV1 in 2049, AV2 in 2060, AV3 in 2085, and AV4 cars in 2120 and will be using AV5 mainly after that (see Figure 6.7 above). The number of car-sharing people who do not own a car in NZ has increased over 100 years. The maturity of AV5 technology will influence the growth of car sharing in the population. The most valuable insights are achieved in the deployment and market penetration of AV3, AV4, and special attention to AV level 5 technology.

According to this study, the high trust and high governance scenario in NZ has predicted that the AV3 market achieves under 20% diffusion in the year 2045 – 2055 and then seizes to exist in 2085. This phenomenon will happen as people have already transferred to AV4 and AV5 and car-sharing business models. AV3 market penetration never reaches above 20%. In the case of AV4, the market maturity achieved 43% around the year 2061, and the adoption rate seizes in the year 2120. AV0, AV1, and AV2 adoption rates seize in the year 2041, 2049 and 2060. The most useful AV5 technology achieves 90% market penetration in 2121, and the adoption rate continues after that in a high trust and governance scenario (see Table 5.39 Chapter 6). It is suggested that with the provision of external funds to AV4 vehicles, there will be an increase in the diffusion of this technology that reaches the maximum in the year 2030. A faster move towards car sharing growth results in the adoption of higher-level AV5 by AV4 users, and AV4 cars will travel more km/cars than without external funds.

Similarly, in the augmented model, it can be concluded that people adopt cars based on affordability at the lower level of automation, i.e., AV0 to AV1. In contrast, in higher automaton levels, people initially adopt based on other preferences. This includes the adoption of AV2, due to trust and price, AV3 due to Legal readiness, AV4 due to price affordability and AV5 due to attractiveness. And later, with the passage of time and proliferation of technology ostensibly, people adopted a higher level of automation based on the overall utility behaviour of technology. Thus, people want to own AV3 and AV4 people based on price affordability and not attractiveness, and AV5 based on Legal readiness and Trust. Therefore the AV5 level can only be successful over time if there is trust in people supported with progressive governance and legal readiness structure. It can also be concluded that 40% technology maturity of AV3 is likely to happen in 2043, AV4 in 2030 (earlier than AV3), AV5 in 2116. Moreover, 95 – 100% maturity is expected for AV3 in 2110, AV4 in 2080 and AV5 kept growing. AV3 is likely to achieve a maximum adoption rate in 2050, AV4 in 2048, whereas AV5 remains steady after 2121.

In any innovation process, the knowledge is gathered via the R&D process during the initial innovation cycle of the technology through research organisations and universities to develop the technology (Kamp, 2002). During this cycle, purchase prices remain high (Abernathy & Utterback, 1978). However, by gaining more knowledge using R&D over time, price reduction occurs through learning by searching effects. Perceived gains of the technology drive amount of R&D expenditure and the market size. The technology maturity range (1- 100%) indicates the state of readiness for technology (Newes et al., 2011; Vimmerstedt et al., 2016). As highlighted earlier, when the fleet size of a particular level of automation increases, it results in additional experience and lowering the purchase price. With the reduction in price, the utility increases and fleet size is increased. The fleet size of any AV level grows through sales. Sales depend upon the utility and the maturity of a specific level of automation, illustrating a flow of AVs from lower to a higher level. As technology gets more mature, it gives trust and confidence to the user, which positively affects sales.

The literature informs that the technology maturity takes an S-shaped curve and is a trade-off between reliability and performance (Mahajan & Peterson, 1985; Sterman, 2000). S-shaped curve depicts the increase in marginal costs with maturity in technology. Several studies were studied to investigate the phenomenon and the implementation path for AVs in NZ (Bierstedt et al., 2014; Kyriakidis et al., 2015; Litman, 2020, 2021; Milakis et al., 2017a; Milakis et al., 2017b; Nieuwenhuijsen et al., 2018; Shladover, 2015; Underwood, 2014). A number of earlier studies has already carried out an analysis on the effect of congestion on travel behaviour, more tripping, last-mile/first-mile impact, and decrease in the number of accidents due to the use of AVs (Correia & van Arem, 2016; Gruel & Stanford, 2016; Hoogendoorn et al., 2014; Milakis et al., 2017b; Scheltes & de Almeida Correia, 2017; Stasinopoulos et al., 2021; Yap et al., 2016). Some other studies examined through historical analogies, focussed panel discussions, and scenario development techniques to estimate and predict the market penetration of AVs (Bierstedt et al., 2014; Kek et al., 2009; Milakis et al., 2017a; Nieuwenhuijsen et al., 2018; Shladover, 2015; Sterman, 2010; Zhang et al., 2020). However, none of the studies quantitatively explored the true complexity of various holistic interacting human and other factors on AV market penetration.

Nieuwenhuijsen et al. (2018) presented a technology evolution model of AV, showing progression in phases of adoption between stages/levels of AV technology considering variables of fleet size/sales, safety, attractiveness and convenience to use. There is an element of knowledge sharing assumed in the R&D process. The Nieuwenhuijsen et al. (2018) model was built on the understanding that an enabling policy and infrastructure environment is necessary for AV adoption and focuses on the cost economics of phasing in new technologies. Gruel and Stanford (2016) and Stanford (2015) theorized a wide range of factors for adopting AVs, emphasizing the ability of new technology to change human behaviour. The overarching system is modelled to comprise three components: transport system, stakeholder systems, user systems, and their interactions. C. Liu et al.

(2019) modelled trust and situation awareness as a function of word of mouth and advertising. Insurance premiums and risk of a crash is modelled as a factor driving adoption. Safety (AI safer than human) is modelled as a factor driving adoption. Zhang and Qin (2014) explored electric vehicles and conventional vehicles and looked at the adoption considering the growing trend of vehicle ownership and use. Its decision structure was based on economic considerations.

These earlier studies primarily focus on the effects on the traffic and not significantly on other impacts regarding ownership. Table 6.1 displays a bird's eye view of the market penetration estimates found in earlier studies until now. Generally, there is no consistency on market penetration rates of AV3 to AV5, nor do these levels (AV3 to AV5) seems close to reality in 2021. Moreover, these estimates were based on people's expectations from the overall transportation system and not from the underpinnings of future car fleets levels independently.

Therefore, in this study, an effort has been made to include the people's expectations and the estimation of the future car fleet behaviour independently on the adoption and penetrations of AVs. The end-users gain more trust in the performance and reliability of this specific level of AV technology, and it will speed up adoption due to an increase in observability (Rogers, 2010).

Table 6.1

AVs Market Penetrations Estimations Found in the Literature

Market Penetrations of AVs	**Range**	**References**
Market Penetration AV1	0-10% in 2000	Kyriakidis et al. (2015); Shladover (2015)
	10 – 20% in 2015	
	3 – 21% in 2025	Nieuwenhuijsen et al. (2018)
Market Penetration AV2	0-15% in 2015	Kyriakidis et al. (2015)
	10 – 51% in 2025, 0 – 34%in 2050, 0-8% in 2075, 0 – 2% in 2100	Nieuwenhuijsen et al. (2018)
Market Penetration AV3	Intro in 2017 - 2020	Underwood (2014)
	70% in 2020	
	14 – 49% in 2025, 1 – 62% in 2050, 0 – 75% in 2075, 0 – 64% in 2100	Nieuwenhuijsen et al. (2018)
Market Penetration AV4	Introduction in 2018 - 2021	Shladover (2015); Underwood (2014)
	Highways and Urban Streets Before 2030	

Market Penetrations of AVs	Range	References
	0 – 23% in 2025, 2 – 29% in 2050, 4 – 22% in 2075, 1 – 17% in 2100	Nieuwenhuijsen et al. (2018)
Market Penetration AV5	Introduction between 2025 - 2045	Bierstedt et al. (2014); Litman (2020, 2021); Milakis et al. (2017a); Underwood (2014)
	25% in 2035	
	50% in 2035 - 2050	
	75% in 2045 - 2060	
	90% in 2055	
	0 – 35% in 2025, 2 – 86% in 2050, 8– 96% in 2075, 17 – 99% in 2100	Nieuwenhuijsen et al. (2018)

Note: The table is adopted and then updated (Nieuwenhuijsen et al., 2018).

In this study, the AVs deployment eco-system in NZ remains considerably uncertain, where market penetration varies with the scenarios adopted and policies pursued by the authorities. With a 'High Automation and High Trust and Governance Scenario,' there is likely to be a proliferation of AV technologies, especially at a higher level of automation. With the suitable policy instruments adopted for knowledge accumulation, creating awareness, and provision of funds and subsidies, an early realization of the benefits can be harnessed. Adjusting the lifetime of any vehicle seems much more plausible than using policy instruments for adjusting price (Nieuwenhuijsen et al., 2018). It will be challenging for the authorities to change the adoption rate, depending on the technology maturity influencing situation awareness and anthropomorphism attributes controlled by OEMs.

The novel model developed in this study can be used for objective learning about the influencing factors for the diffusion of AVs and more assimilation of the interaction of multifaceted strategies and their perceived effects on the deployment of AVs. This innovative research observed the integration of the key latent human factors with technological development determinants to getting insights into shaping the future eco-system for the diffusion of autonomous technologies

6.6 Study – 4: Summary of Findings and Comparison

The summary of the findings relates to the fulfilment of research aim, objective 3, Research Question 11, i.e., RQ 11. *Develop an integrated trust and governance framework and examine its feasibility and validation for AVs deployment in NZ*.

Study – 4 presents the findings from thematic analysis of semi-structured interviews of 13 experts around the globe from NZ, UK, Germany, Sweden and Australia. These experts comprise AV industry professionals, manufacturers, CEOs, academicians, policymakers, and human factor experts. The summary of the findings relates to the fulfilment of aim and objectives 1, 2 and 3 to validate results and interpretations of the Study – 1, 2 and 3.

6.6.1 Objective 1.

Objective 1 was to examine the critical perspectives of AVs implementation. The primary focus was on critical barriers and co-evolution of regulations and technology in their deployment in NZ and globally, addressing RQ 3 and 4. These were explored and verified using Themes 1 and 2 of this study (see 5.5.2 and 5.5.3 Chapter 5).

6.6.1.1 Critical Barriers and Decisions for AVs Implementation

Study – 4 identified and verified significant challenges towards AVs' deployment. These include people's trust (85%), pragmatic governance structure (77%), improvement in technology (75%), the requirements of realistic user and simulation studies (74%), the study of human and market penetration of AVs (72%). Few experts believed in technical challenges including HMI, data privacy (56%), security and safety of people (98%), situation awareness (71%), anthropomorphism (56%), IT and physical infrastructure (68%), and over projection of media (35%). Study – 4 also highlighted the significance of co-evolution of regulation and technology for the proliferation of driverless technologies.

Numerous studies have investigated these barriers earlier (Becker & Axhausen, 2017; Bezai et al., 2021; Chen et al., 2020; D. J. Fagnant & K. Kockelman, 2015; Johansson, 2019; Nastjuk et al., 2020; Schoettle & Sivak, 2014b; Yuen, Wong, et al., 2020) and grouped in various domains (Table 6 Chapter 2). It has been argued that these enablers/barriers mainly stem from end-users psycho-social behaviours and how AVs' adoption will be influenced by public opinion (Yuen, Wong, et al., 2020) and government actions (Bezai et al., 2021). Chen et al. (2020) recently measured public acceptance of driverless busses in China and found that people are more concerned about safety performance, riding time, cost, and personal safety. Bezai et al. (2021) explored and distributed into the categories of (1) User/Government perspectives that include (i)

Users' acceptance and behaviour, (ii) Safety, and (iii) Legislation, (2) Information and Communication Technologies (ICT) which include (i) Computer software and hardware, (ii) Communication systems V2X, and (iii) accurate positioning and mapping. Na Liu Liu et al. (2020) examined the challenges in the privacy and cyber security domains. Taeihagh et al. (2021) discussed regulatory challenges. Schoettle and Sivak (2014a) found that almost 88% of participants are somewhat worried about riding in AV due to safety consequences of equipment or system failure (96.2%), legal liability of drivers (92.8%), and confusion due to unexpected situations (94.7%). Kyriakidis et al. (2015) observed that participants are concerned regarding software hacking and misuse, legal responsibility, safety, and data privacy.

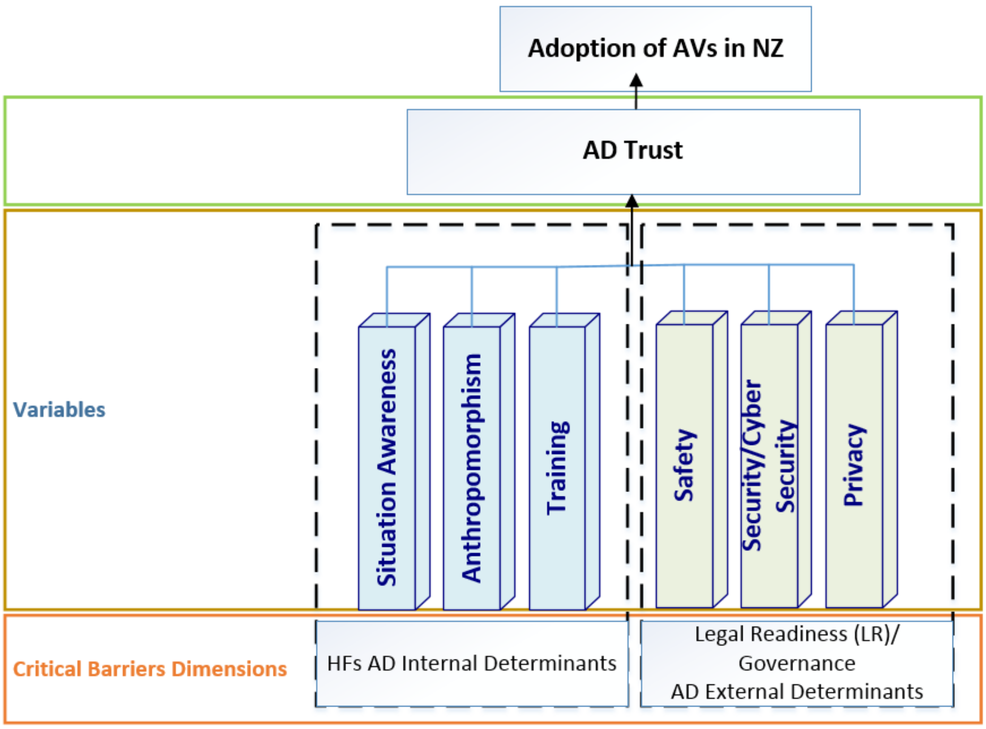
This research identified these critical barriers after carrying out a comprehensive literature review. The study explored user acceptance challenges in the backdrop of three behavioural theories, namely; (1) Innovation diffusion theory, (2) Perceived value theory, and (3) Trust theory (Castelfranchi & Falcone, 2010; Kotler & Armstrong, 2010; Rogers, 2010). It was found that people's mindsets and attitudes serve as the key to adopting new technology and affect the realization of perceived benefits (Liljamo et al., 2018; Yuen, Wong, et al., 2020). The study explored these barriers distinctly into (1) safety, (2) user acceptance, (3) governance/legal readiness, and infrastructure categories in a comprehensive literature review in Chapter 2 (2.6.2 and Figure 2.13 and Table 2.3). After exploring global barriers, the study investigated the public perceptions vis-à-vis critical AVs barriers in NZ. It was found that NZ public considers the significant challenges include (1) trust, (2) safety, (3) lack of control, (4) higher cost (Starkey & Charlton, 2020), (5) legal readiness structure (KPMG, 2018), civil liability, cyber security (Jain, 2020), and privacy (Hing, 2019). It was observed that primarily AVs implementation challenges are driven by trust theory. It is also noteworthy that similar trajectories were found regarding barriers and trust influencing AD factors in AV user study. These barriers were again re-examined and grouped into most critical determinants in the light of AV user trials for AD in NZ and public survey study (see Figure 5.5 Chapter 5).

In the NZ context, the experts identified few additional challenges in the proliferation of AVs. These comprised issues concerning laws amendments in criminal and civil liability, road safety, property damages, and regulations dealing with human-driven cars and cars without humans. The experts recommended that the infrastructure readiness and preparation of road code is essential. These observations were also found in Study – 1 and Study – 2.

The finalized barriers within the NZ context due to user study trials, interviews and brainstorming workshops comprised situation awareness, anthropomorphism, training, safety, security/cyber security and data privacy. These had already been further analysed and positively correlated in Study – 2 using SEM. Some challenges regarding cost, attractiveness, technology and infrastructure development pointed in Study – 4 was also explored in Study – 3 and milestones were provided on the timeline. These finalized critical trust influencing barriers in AD are illustrated in Figure 6.8 below.

Figure 6.8

Critical AD Trust Influencing Barriers



6.6.1.2 Law Changes and Co-Evolution of Regulation and Technology

The experts' interviews supported Study – 1. They remarked that the NZ small market and low manufacturing base is not well prepared in the regulatory domain for the complete diffusion of AVs. However, it was highlighted that to remain competitive, NZ must take significant steps towards successfully deploying AV3 to AV5 to realize the benefits. The participants stressed the need for the co-evolution of regulations and technology. They opined that it could be done by pursuing a pragmatic governance structure incorporating safety, security/cyber security and, data privacy protection measures. The experts were not exactly sure about higher automation level deployment on roads shortly. Still, they all agreed that there is a need to improve the legal readiness structure, AV user interfaces for better sensing and fallback routine procedures, drafting a performance measure criterion for AVs, and defining ODDs for different AVs.

NZ is a signatory of the 1949 Convention of Road Traffic Art. 8(1), "every vehicle… shall have a driver" (UN, 1949), which is in contrast to the NZ legislation regime that does not require a driver (Gingrich & Moe, 2019; MOT, 2021). This doesn't have any legal effect in NZ; however, there is a likely risk that the courts may like to interpret domestic legislation to be consistent with international law (Cameron, 2018). The law changes are needed to update the building code and clarify liability in offences involving AVs, including speeding and illegal parking (Cameron, 2018). NZ need to adopt US Federal Government Policy to encourage manufacturers to produce safety assessments of their AVs under NZ conditions. Besides specific amendment is required in Land Transport Act to create a new liability regime (Cameron, 2018). In present shape, the NZ Accident compensation scheme (ACC) is a no-fault scheme, where an injured person may claim compensation paid out of petrol taxes and motor vehicle licence fees but cannot bring a civil action. This means they will be having no recourse against AV manufacturers (Cameron, 2018; Hing, 2019). Manufacturers do not contribute to motor vehicle funds under ACC since they do not suffer financial impacts due to personal injuries associated with their products (NZ, 2020b).

Few experts from NZ pointed towards formulating a real-time digital warrant of fitness for AVs, changes in building code, addressing understaffing in the Ministry of Transport and, focusing on smart driverless public transport in the shape of small shuttles/trams, pods and supernodes. The participants were of the view that NZ is not doing enough. They pointed out that the NZ authorities had laid back on policies relating to AVs in recent years. The legal expert said that there is no driver requirement in the car in NZ, and the law is currently adequate to deal with the situation of cars that require human supervision. However, he remarked that it is not sufficient, and there is a risk that the NZ court would object to this rule. The majority of the participants agreed that there should be only two laws in the regulations domain, one for AVs requiring human input and the other dealing with AVs with no human involvement.

6.6.2 Objective 2.

Objective 2 is mainly related to identifying and analysing the role of crucial AD factors affecting trust in AVs. Objective 2 was examined and validated in theme 2 (see 5.5.3 Chapter 5) of the experts' interview. Few participants argued several different factors for the successful implementation of AVs. However, they unanimously believed that users' acceptance and trust is the lynchpin among other HMI factors.

6.6.2.1 Trust Affecting Factors for Autonomous Driving (AD) in NZ.

The participants laid stress on various trust affecting AD factors. These include safety, situation awareness, training of users, security/cyber security, privacy and the need for having a regulatory framework comprising these factors. Some participants also highlighted customization, adaptive automation, transparency, liability, ownership, and cost to achieve users' trust in AVs. They stressed the need for real-time user studies and public demonstration of key AVs technologies. These views expressed in Study – 4 validated the trust affecting factors within the context of literature as observed in Study – 1 and Study – 2. Study 1 also assisted in the categorization of these trust affecting determinants in two domains, i.e., internal HMI domain and external legal readiness domain having interconnected linkages through trust.

Trust in automation is a significant mediator (though not the only one) of using automation (Wintersberger, 2020). The interaction between humans and automation is mediated by trust (Ghazizadeh et al., 2012), and it has a positive influence on a user's intention to adopt new technology (Kaur & Rampersad, 2018). Trust in automation affect acceptance, utilization, reliance (Lee & Moray, 1992; Lee & See, 2004; Parasuraman & Riley, 1997). A direct association was also found between compatibility, trust and intention to use (Rahman et al., 2018). It was identified that the trust in AV regulations partially mediated the privacy/security risks (Waung et al., 2021). Trust mediates the relationship between factors that influence technology acceptance and behavioural intention (BI) (Chan & Lee, 2021). In few other studies, though not in the driverless technologies domain, mediating effects of trust was found in information sharing, integration, data vulnerability and negative word of mouth (WOM) (Cai et al., 2010; Martin et al., 2017). Trust positively relates to perceived safety (Xu et al., 2018), privacy and security ((Kaur & Rampersad, 2018)

The participants highlighted the role of trust as a mediator towards variables affecting user's intention and reliance on AVs. They opined that trust positively relates to safety, privacy, security, and data sharing.

6.6.3 Objective 3.

Objective 3 was to develop and assess an integrated trust and governance framework for the successful adoption of AVs in NZ, addressing RQ 9, 10 and 11. The findings were analysed and validated using Themes 4 and 5 of Study - 4 (see 5.5.5 and 5.5.6 Chapter 5). The results were in line with the conclusions of Study – 1 and 2.

6.6.3.1 Trust and Governance Framework.

All the participants unanimously supported and validated this study's proposed trust and governance framework, though some of them also highlighted few additional parameters. Most experts' views were related to constituting a framework that increases trust and acceptance of people and looks after their safety to minimize injuries, crashes, and congestion. Findings relate to various KPIs for utilization of framework. These include (1) safety, (2) security and cyber security, (3) data privacy, (4) situation awareness, (5) education and training of users, (6) reliability, (7) transparency, (8) user-friendliness, (9) and cost.

NZ transport technology company HMI technologies manufactured and ran AV shuttle trials in Christchurch, Melbourne, and Sydney and tested the first 5G network-connected vehicle test in Auckland (Harry, 2019; HMI, 2018). NZ environment has two likely AVs deployment pathways in the foreseeable future. The first is to create fleets of AVs in contained urban spaces. Second, gradually increasing the number of vehicles with autonomous features on NZ roads (MOT, 2021). Private AV can offer flexibility in use, whereas commercial AV could be operated as bus, shuttle, tram, taxi and freight services or as a shared AV (SAV - a combination of traditional car-sharing and taxi services) due to the advantage of multitasking and relatively inexpensive (Fagnant & Kockelman, 2014; Krueger et al., 2016; Milakis et al., 2017).

The future urban landscape is likely to witness the advance of emerging transportation technologies like 'SkyTran' for private compact carriages (people pods) and platoons of private autonomous cars with very few people (Wiseman, 2017, 2020a). Fitt, Frame, et al. (2018) highlighted a plausible future scenario for NZ where AVs co-exist with driver-controlled vehicles and private car ownership in a multifaceted economic model.

It has been identified that the societal benefits can be realized through the 'use of trackless autonomous trams' as public transport is likely to dominate driverless vehicle technology. Trackless Trams / Autonomous rail transit (ART) projects are being launched in Australia, Germany, Qatar, China, and Singapore (Chamberlain, 2020; Newman et al., 2019). In another Public Transport 2045 study, the NZ Ministry of Transport identified that the likely transport scenario in future would be based on personalized pods and connected corridors (Enoch et al., 2020; MOT, 2015).

Participants also pointed out that in NZ enabling environment, the first step towards AVs development can be the production of driverless trams due to the emergence and manufacturing of AV4 shuttles by HMI technologies. The experts agreed that a road map could be designed where creating additional lanes as per ODDs, AVs can co-exist with driver-controlled vehicles. They believed that AVs' deployment path could be visualized by pursuing private car ownership and collaborative driverless car-sharing mechanism complementing each other in a multifaceted economic model. This can be later transformed into driverless pods and supernodes controlled by transport hubs as transport systems evolve. Participants stressed the need for continuous testing throughout AVs' life spans. Few suggested improvements in transport infrastructure, including control centres, hubs, roads redesign, sensors' use, and compliance task force creation (Lyon et al., 2017; P. Lytrivis et al., 2018).

Theme 4 regarding future directions and timelines (see 5.5.5 Chapter 5) also validated the interpretations of Study - 1 and Study – 3 for exploring the future implementation direction and diffusion timelines of AVs. The experts had varying views and were unsure about higher automation level deployment on roads shortly. However, their general statements regarding the deployment of AV3 to AV5 were found in line with Study – 3. The experts' interviews had a close resemblance to the AVs timelines in Figure 6.7 above, and Road map Figure 7.3 Chapter 7 but overall fall short of the milestones due to uncertainty of maturity and penetration of autonomous technologies in the future, mainly level 3 to level 5.

Earlier studies identified numerous trust-based frameworks. Wintersberger (2020) investigated distrust, over trust and multi-tasking theoretical considerations. He highlighted the significance of multimodal and attentive user interfaces to deal with these issues. Häuslschmid et al. (2017b) compared various visualisation overlaid on a driving scene of a chauffeur avatar, a world in miniature and car indicators. They observed that these result in an increase in trust. Basu and Singhal (2016) suggested a framework based on user trust and agent trust to harness multimodal sensor data from the vehicle and user's wearable or handheld device. The study observed the data access from the cloud and used features like gaze, facial expression. Ekman et al. (2018) identified a trust-based framework based on usage phases, automated driving (AD) events, factors and levels. Chien et al. (2018) explored a validated cross-cultural trust measure in the US, Taiwan and China for measuring trust in automation. They considered Honour, Face and Dignity cultures based on Leung and Cohen's theory of Cultural Syndromes and Hofstede's Cultural Dimensions. Cho and Hansman (2018) defined a framework showing complete architecture involving driver, automation systems and the environment.

However, none of the studies explored trust-based governance and HFs' role in the proliferation of driverless technologies. There has been very little research in the literature regarding the role and relevance of AVs regulation in a smart urban transport system (Ljungholm, 2020). NZ Government has a vital role in maximising social welfare goals of cybersecurity regulating safety, security and privacy already highlighted above in this study. Hence public trust from an institutional trust point of view having interaction with interpersonal trust employing a pragmatic governance regime is mandatory for a successful transition to driverless technology. Therefore the same is explored in Study – 1, 2 and 3 and then validated in Study – 4. These governance goals need to be translated into technical standards in collaboration with relevant industry stakeholders and international bodies. In the context of AVs, the security and privacy aspects need to be embedded into the holistic safety domain in the impending transport regulation paradigm (Anderson et al., 2018).

Study – 4 validated the earlier studies (see Figure 6.9) and suggested integrated trust and governance framework for deployment of AVs in NZ. These will be discussed in recommendations sections of this study.

Figure 6.9

Overview of Main Constructs and Concepts Validation Process

Main Constructs and Concepts	Explored in Study – 1 Literature Review	Explored and Validated in Study – 1 User Study	Explored and Validated in Study - 2	Explored and Validated in Study - 3	Validated in Study - 4
Mental Model	☑	☑			☑
Training	☑	☑	☑	☑	☑
Feedback / Situation Awareness	☑	☑	☑	☑	☑
Anthropomorphism	☑	☑	☑	☑	☑
Safety	☑	☑	☑	☑	☑
Privacy	☑	☑	☑	☑	☑
Security / Cyber security	☑	☑	☑	☑	☑
Customization	☑	☑			☑
Adaptive Automation	☑	☑			☑
Transparency	☑	☑			☑
Cost	☑			☑	☑
Attractiveness	☑			☑	☑
User Studies	☑	☑			☑
Interpersonal and Institutional Trust	☑	☑	☑	☑	☑
Governance / Legal Readiness Structure	☑	☑	☑	☑	☑
Co-Evolution of Regulations and Tech	☑	☑	☑	☑	☑
Infrastructure Readiness	☑			☑	☑
Future Time lines	☑			☑	☑
Trust and Governance Framework	☑		☑	☑	☑

6.9 Chapter Summary.

This Chapter has provided a detailed discussion utilizing research findings within the literature and research objectives. The research case is revisited, and the synthesized results of the four studies are presented. The outcomes were compared with the earlier research followed by the explanations. The uniqueness of the study supported with pragmatic interpretation was highlighted. The next Chapter 7, concludes the research study.

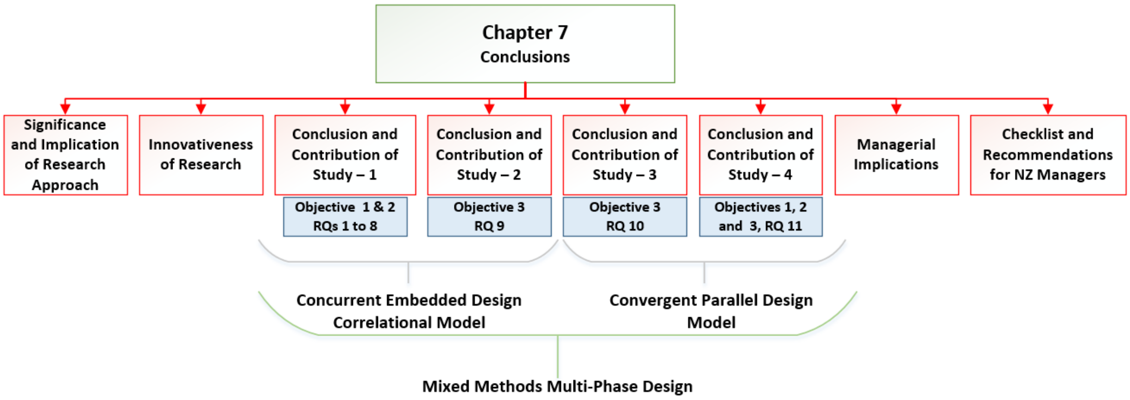
Chapter 7 – Conclusions and Recommendations

7.1 Introduction

The Chapter concludes the research and delineates its distinct contribution to the immediate discipline and wide body of knowledge covering a broad range of disciplines. It provides final comments on the significance, innovativeness and contributions of four studies. The Chapter presents significant implications for private and public sectors in NZ besides articulating concrete measures for restructuring the policy and pragmatic decision making in the country for successful deployment of AVs. Late, the Chapter unfolds a detailed step by step implementation checklist and recommendations for NZ driverless technology managers to realize societal benefits. In the end, it highlights the research limitations and future research directions, followed by a concluding statement. Figure 6.1 illustrates the layout of this Chapter.

Figure 7.1

The Conclusion Chapter Layout and Content



7.2 Research Conclusions, Contribution and Implications to Theory & Practice

This innovative research study carries significant theoretical and practical contributions in the immediate discipline of users' trust, interaction with AVs, and HMI factors for their successful adoption in NZ. Moreover, this unique study holds far-reaching implications for a wide body of knowledge within the folds of driverless technology in a smart city context. The significant contributions include; (1) AD Trust Acceptance Model for Driverless Technology (DT)(see Figure 7.4 below), (2) constructs and measures employed in this study (see Table 4.1 Chapter 4), (3) selection and application of research methodology in NZ enabling environment (see 4.2.1 Chapter 4), (4) significant research implication and knowledge contribution for the rest of the world in driverless technology domain, (5) HMI-AD Event Relationship Identification framework (see 5.2.3 Chapter 5), (6) Integrated trust and governance model for NZ (see 5.3.5.2 Chapter 5), and (7) a unique quantitative SD Model for insights into the diffusion timelines and roadmap for AVs in NZ (see Figure 5.15 and Figure 5.33 Chapter 5, Figure 6.7Chapter 6, and Figure 7.3 below). Some other valuable contributions include; (8) recent updates, development and futuristic directions for AVs deployment from senior experts around the world (Study – 4), (9) Provision of a comprehensive checklist for managers (see 7.2.8 below).

Since AVs are in the early product life cycle, these insights would provide implementation pathways towards effective decision making in NZ and elsewhere. The underlying conceptual framework proposed by the study is in line with the recent NZ Ministry of Transport AVs Work Programme and Regulation 2025 Project, NZTA policy on testing AVs in NZ (MOT, 2021; NZTA, 2021) and International approaches to regulate driverless technology.

7.2.1 Significance and Implication of Research Approach.

The author endeavoured to approach this social and design phenomenon from a pragmatic paradigm employing mixed research methodologies in a design science research settings to access the 'truth.' This approach is warranted to justify, interpret and validate the design variables and the artefact concurrently in different stages of the research process. Therefore, four studies were conducted mainly in two phases in a Multi-Phase Design setting (McBride et al., 2019). Multiphase Design aimed to address the incremental research questions and provide an overarching methodological trust and governance framework for AVs adoption in NZ.

The first phase comprising Concurrent Embedded Design Correlational Model employed study – 1 (AV user study) and 2 (SEM) to seek solutions regarding two different research questions, i.e., RQ 8 and 9 in objectives 2 and 3 concurrently (Creswell & Clark, 2017; Fonner et al., 2021). The qualitative data of the AV user study was embedded in study – 2 (SEM) to shape and develop the intervention and use correlations to identify relationships between trust affecting variables. It assisted in explaining the predictive relationships and the trust and governance phenomenon in the implementation of AVs in NZ. The interpretations were drawn from the convergence of findings and analysis from qualitative and quantitative data.

In Phase 2, Convergent Parallel Design Model comprising study – 3 and 4 was pursued (Castro et al., 2010). It incorporated simultaneously prioritizing qualitative and quantitative phases (Harrison, 2013; McBride et al., 2019). The integrated results were triangulated during interpretation (Tashakkori & Creswell, 2007). The interpretations provided a complete understanding of the realized benefits, challenges, co-evolution of regulation and technology, diffusion timelines and likely proliferation road map for AVs in NZ. In this design phase, study – 3 incorporated quantitative System Dynamics (SD) modelling technique, and study – 4 used semi-structured interviews to capture follow-up data from study – 1 and study – 2. The data and results from study – 3 and study – 4 are collected simultaneously and merged in the research implications assisting in inclusive research analysis.

This research approach and methodology are employed in NZ and elsewhere for the first time to study the phenomenon and critical interactions of trust, governance, and HMI for the deployment of AVs. The Activity theory helped to know these dynamic interactions between driver, AV and trust (Cao et al., 2013; Kaptelinin & Nardi, 2007; Nardi, 1996). An effort is made to observe the critical trust corroborating determinants for AD in NZ and their real-time impact in the future. Hence, HMI Event Relationship Identification Framework and holistic Trust and Governance Framework were developed to assist in a greater understanding of all stakeholders in NZ and elsewhere.

7.2.2 Innovativeness of the Research Study.

This is the pioneering study in NZ and elsewhere to observe various dimensions of trust in AVs, combining interpersonal and institutional trust. The innovative user study gauged the human factors using BMW AV in real-time in live traffic conditions. The study identified the mediating effect of trust in governance and human factors towards the adoption of AVs and captured fundamental trust corroborating factors both in HMI and legal readiness domain for AVs in NZ. The study observed and simulated the co-evolution of regulation and technology to fetch futuristic insights for shaping pragmatic policy for the successful diffusion of AVs in NZ.

Moreover, it examines the HMI design processes to provide guidelines for AV developers and designers to observe and incorporate users' trust while designing various AV users' interfaces and technologies. The study questioned the technology acceptance models and their applications in the driverless domain. It filled the gap of Hoff and Lee's Models incorporating new variables. The study endeavoured to provide preliminary insights in early test environments of AVs while articulating appropriate governance readiness measures and technology advancement through knowledge transfer, subsidies, tax reduction and R & D processes.

7.2.3 Conclusion and Contribution of Study – 1.

Study – 1, based on a comprehensive literature review, provided a detailed account of various perspectives of driverless technologies in the backdrop of AVs. These include the evolution of AVs and their significance during the recent pandemic COVID – 19 crisis. The study articulated updated research on crucial HMI factors, followed by thorough deliberations on AVs benefits and barriers and the role of users' trust technology acceptance theories and models. Moreover, it discussed people's perceptions of AV technologies worldwide in general and NZ in particular. It has also identified the role of AV user interfaces and appropriate legislation and infrastructure.

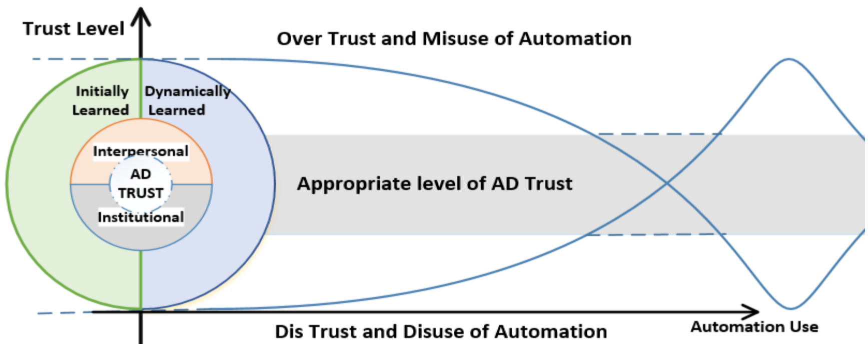
User Study uniquely identifies and confirms key determinants affecting user acceptance and trust employing BMW AV, giving insights to early test case environments. The naturalistic and longitudinal user study observed driver behaviour and formulation of calibrated dynamic trust in live traffic conditions. At a practical level, the study identified holistic trust influencing factors based on exogenous and endogenous determinants. These include training, situational awareness, and anthropomorphism as internal HFs AD determinants. And safety, security/cyber security, and privacy relating to the external environment based on legal readiness/governance.

At a theoretical level, the study extended the TAM to include new variables that characterize driverless technology's operation design domain in a complex setting. The study had tried to bridge Hoff and Lee's models as these models do not address the driverless or semi driverless system in Automation in the backdrop of ADAS, especially from the point of view of trust affecting factors. The study attempted to fill the knowledge gap by utilizing a practical approach in creating an appropriate AD trust for

AV systems within an HMI design process. The study provided an HMI Event Relationship identification framework for AV designers based on the interaction of the nine trust-affecting factors, eight mental model, training, feedback, anthropomorphism, safety, privacy, security, customization and adaptive Automation. The eight HMI AD events comprised information before driving, entering vehicle, Activation, Manual Mode 1, Auto Mode, Manual Mode 2, Exit Vehicle and Continuous Usage. The three phases relate to pre-use, use and performance. Later, mapping AD trust influencing factors on the 'Kano Model' and input from brainstorming ideations sessions (see 5.2.3 Chapter 5), holistic trust and governance needs were finalized into two categories. Due to their linkages and user effects, customization and adaptive automation were grouped into anthropomorphism and feedback into situation awareness.

Figure 7.2

HMI Event Identification Relationship Framework and AD Trust Graph



Phases	Pre - Use	Use						Performance
Events / Factors	Info before Driving	Entering AV	Activation	Manual Mode - 1	Auto Mode	Manual Mode - 2	Exit AV	Continuous Usage
Mental Model	☆							
Training	☆		☆		☆			☆
Situation Awareness			☆	☆	☆	☆		☆
Anthropomorphism			☆	☆	☆	☆		☆
Safety		☆	☆	☆	☆	☆	☆	☆
Privacy			☆	☆	☆	☆		☆
Security/Cyber Security		☆	☆	☆	☆	☆		☆

Note: Appropriate Level of AD Trust (Grey portion) based on user's calibration of Interpersonal and institutional trust with the actual automation use is required to avoid safety risks during AD.

The finalized determinants related to HFs HMI user needs on situation awareness, training, anthropomorphism. The legal readiness needs were based on safety, security/cyber security and privacy challenges. To illustrate the phenomenon of over and under trust vis-à-vis misuse and disuse of automation during the initial and dynamic learned trust phase was integrated into the framework (see Figure 7.2 above).The study has provided an understanding of various trust affecting factors in designing HMI solutions rather than individual factors to ensure appropriate trust in the system. It means that trust is a dynamic process. Secondly, AV manufacturers need to portray the autonomous technologies to the general public via media campaigns and improve user's mental model through training before actual interaction with AV. This process needs to continue throughout automation use, ensuring an appropriate level of trust for the adoption of AVs in the backdrop of various phases and events highlighted in the HMI Event Relationship Identification framework. More attention needs to be paid to the use phase. Thus, this user study is unique in identifying key determinants affecting the adoption of AVs in NZ, bridging the socio-technical gap in AVs and other stakeholders and paving the way towards further research.

7.2.4 Conclusion and Contribution of Study – 2.

Study – 2 based on SEM and CFA techniques proposed integrated Trust and Governance Framework. This is the first-ever study that validated and integrated the various essential contours of previous theories and models on the subject and extends these theories to yet another level. It observed the co-evolution of regulations and technology through the lens of trust of the people and concluded that interpersonal trust is promoted through institutional trust perspective as well. This quantitative study based its findings on a realistic user study in active traffic conditions instead literature review only. This innovative study explored individual key dimensions of trust affecting interpersonal and institutional trust. It provided evidence that institutional trust promotes interpersonal trust (as seen by the mediation results) towards the successful implementation of AVs. The study also confirmed the importance and application of the SEM and CFA techniques in studying various determinants in driverless technology.

Moreover, it is noteworthy that the study is established on existing theories, comprehensive data, advanced multivariate statistical approach with a recommended software package, and confirms the empirical results within the context of literature. For describing the model outputs, this study contributed to the body of knowledge by validating the trust-legal readiness constructs as a second-order. The legal readiness construct contains three second-order constructs (safety, security/cyber security and privacy) and study had total 46 indicator items (see Figure 6.3 Chapter 6). The suggested conceptual model provides a holistic picture and better assimilation of the interplay of various trust affecting determinants for making AVs as attractive as possible for the prospective users. It ensures their acceptability for sustainable implementation in a Smart City context. By interpreting and validating the concepts and findings of Study – 1, this study highlighted the multifaceted and multidimensional interaction of various trust influencing factors for the successful adoption of AVs in NZ.

7.2.5 Conclusion and Contribution of Study – 3.

This study provides AV deployment timelines and a Road Map for the next 100 years till 2021 for the policymakers and other stakeholders alike in NZ to restructure the overall AV governance and infrastructure edifice in the country. Study – 3 validated the Trust and Governance framework further (after Study – 2). It has quantitatively measured the real-time theoretical output of the framework to identify milestones for the diffusion of AVs in NZ. It has provided significant insights into (1) AVs market penetration, (2) technology maturity, (3) people preferences and (4) utility behaviour to dispose of old AV technologies in favour of newest AVs technologies, (5) switch to car sharing regime, and (6) likely behaviour of the fleet sizes and (7) adoption rates in the society.

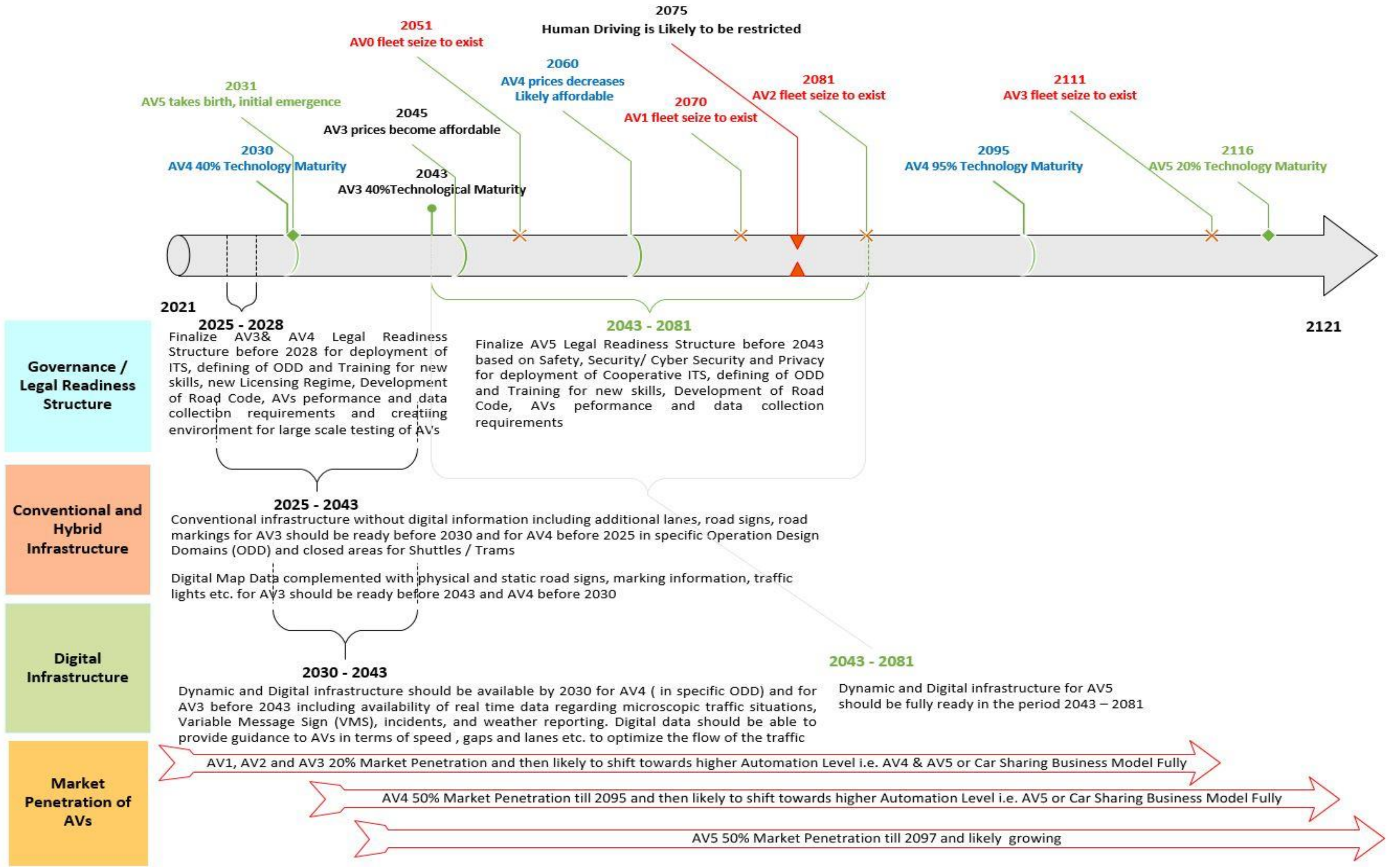
The main contribution is developing a detailed SD Model for NZ enabling environment. Several scenarios and simulations can be generated to observe the futuristic implementation pathways for self-driving cars in NZ. The study model employed three scenarios using beta values of an integrated model developed in Study – 2 and capturing other significant parameters within the context of literature. The scenarios comprised 'baseline,' 'high automation, trust and governance,' and 'low automation, trust and governance.' The baseline scenario is mainly based on beta values of trust and governance framework and other parameters. The High Automation and High Trust and Governance scenarios displayed a greater trust of NZ people and a progressive AV regulating regime in NZ. The Low Automation and Low Trust and Governance scenarios are based on a generally lower trust of NZ people and a conservative AV regulating control. The model included the people's expectations and the estimation of the future car fleet behaviour independently on the adoption and penetrations of specific levels of AVs. With a 'High Automation and High Trust and Governance Scenario,' the study highlighted the likely proliferation of AV technologies, especially at a higher level of

Automation. With the adoption of suitable policy instruments for knowledge accumulation and transition via universities, public and private organizations, creating awareness, providing subsidies and external funds, societal benefits can be realized. The model formulated in this study can be used for objective learning about the influencing factors for the diffusion of AVs and more assimilation of the interaction of multifaceted strategies and their perceived effects on the deployment of AVs. Hence, in a nutshell, this novel research study observed the integration of the key latent human factors with technological development determinants to getting insights into shaping the future eco-system for the diffusion of autonomous technologies. None of the earlier studies had ventured into the true complexity of various holistic interacting human and other factors on AV market penetration quantitatively.

In the backdrop of this study (see Figure 7.3 below), NZ should be ready for AV3 and AV4 from 2025 to 2028 and AV5 between the years 2043 to 2085. Governance Structure comprises the deployment of intelligent transport systems (ITS), regulations on safety, security/cyber security and data privacy, defining operation design domains (ODD), and training managers and other stakeholders in new skills. It must also include a new Driver Licensing Regime, development of Road Code, AVs performance and data collection requirements and environment to support a large scale testing of AVs. Due to the 40% market maturity of AV3 by 2043, there is a need for conventional infrastructure without digital information, including additional lanes for AVs. Road signs and markings for AV3 should be ready before 2030. Digital map data complemented with static road signs and traffic lights must be installed before 2043. AV4 hybrid infrastructure should be ready by 2025 in specific ODDs and closed areas for shuttles and trams. The remaining infrastructure should be completed before 2030 since AV4's 40% technology maturity is likely to be achieved by 2030. Dynamic and Digital infrastructure should be available for AV 4 by 2030 (in specific ODD), AV3 by 2043 and AV5 by 2085. It must include the availability of real-time data regarding microscopic traffic situations, Variable Message Signs (VMS) and incidents and weather reporting. Digital data should guide AVs in terms of speed, gaps and lanes movements etc., to optimize the flow of the traffic.

Figure 7.3

Suggested AVs Deployment Road Map Next 100 Years in NZ

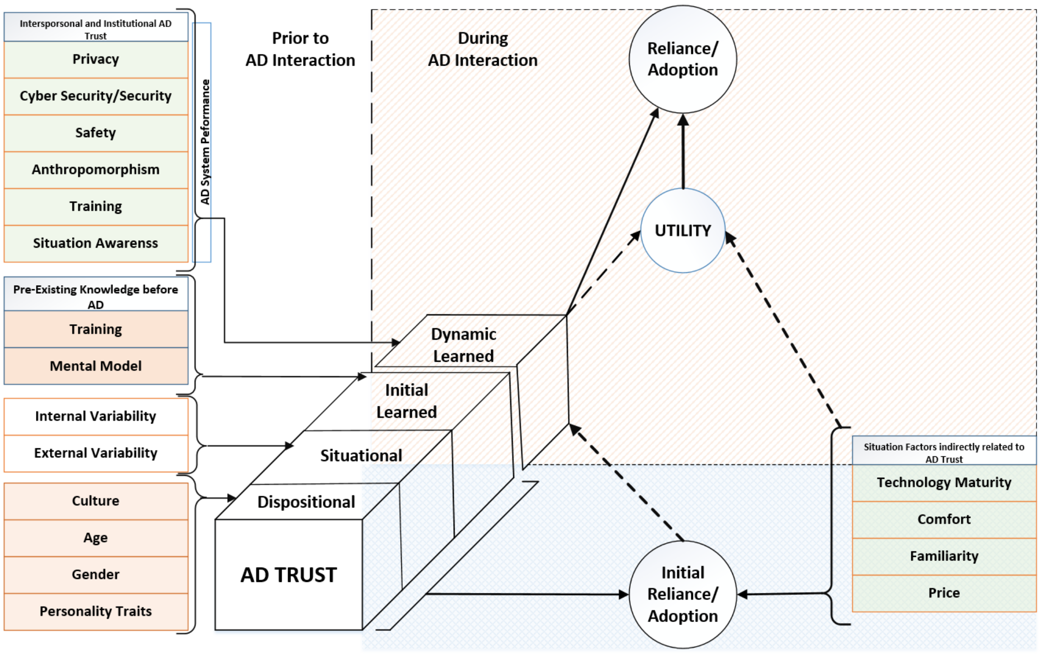


7.2.6 Conclusion and Contribution of Study – 4.

This study has carried out validation exercise of the objectives accrued in previous studies and approved the suggested integrated trust and governance framework in study- 2 for AVs deployment in NZ. It gave a detailed AVs current status around the globe, advancement and regulations trajectories in NZ and the rest of the world and future implementation pathways. The study is based on the thought-provoking views of high-level experts in the autonomous driving domain. Study – 4 identified and validated the benefits and challenges for AVs deployment, conceptual holistic trust and governance framework and significance of the real-time user studies for successful deployment of AVs. Moreover, this study provided numerous other aspects and dimensions of self-driving technologies and HFs for future research and development. In the light of four studies and Finding Synthesis (see 6.4.2 and Figure 6.5 Chapter 6), the study proposes an AD Trust Acceptance Model for driverless and semi-driverless systems (Figure 7.4).

Figure 7.4

AD Trust Acceptance Model for Driverless Technologies



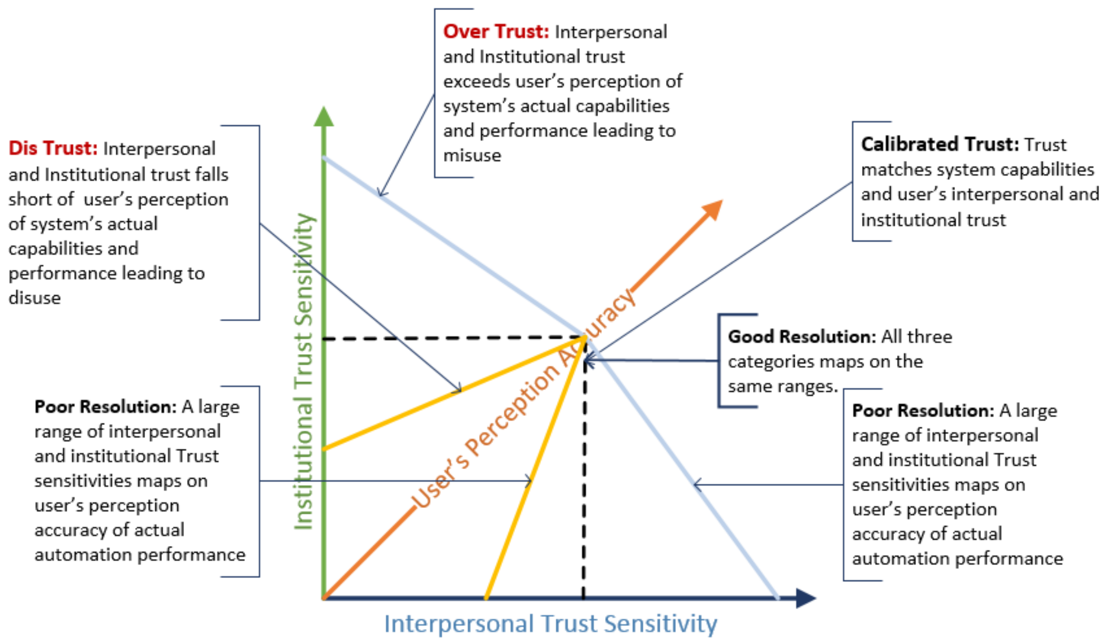
Note: How initial and dynamic learned AD trust interacts with other situation factors increasing the utility and initial and reliance on AVs. This diagram builds on theorized concepts of Trust Theory (Lee & See, 2004), Hoff and Bashir (2015) model, the Innovation Diffusion Theory (Rogers, 2010) and Technology Specific Innovation System (TSIS) (Hekkert et al., 2007).

In Figure 4, depositional and situation factors for AD trust are the same as discussed in Hoff and Bashir (2015) model. However, initial learned is influence by the pre-existing knowledge of the user based on their mental model, training and other situation factors resulting in initial reliance. The dynamic learned trust is based on critical HFs and LR HMI Determinants identified in HMI-ADERIF and validated in Study – 2. The situation factors explored in Study – 3 and dynamic leaned AD trust factors interact to improve the utility of AVs and ultimately result in their successful adoption. The initial, dynamic learned trust and situation factors and initial/final reliance was under-theorized by Hoff and Bashir (2015). The AD Acceptance Model would provide a theoretical scaffolding to earlier technology acceptance theories ensuring successful adoption of AVs.

In the backdrop of the AD Acceptance Trust Model for DT, appropriate AD trust is mandatory for mitigating life-threatening safety risks and pragmatic decision making in these situations. Figure 7.5 highlights the interpersonal and institutional AD trust sensitivity and user's perceptual accuracy. A good resolution of all three categories needs to maps on similar ranges, ensuring a calibrated trust assists in designing and efficiently working an intelligent AV system.

Figure 7.5

AD Acceptance Trust Calibration



7.2.7 Managerial implications.

This study provided a detailed account of establishing a calibrated trust between humans and AVs in New Zealand, identified the essential corroborating trust affecting factors, and presented a way for successful diffusion of driverless technology. Hence, this study has significant implications for the deployment of AVs and enforce strategies to increase these technologies for the overall benefit of society successfully. In addition, the study assists project managers, manufacturers, lawmakers, transport authorities, researchers, consultancies, other public and private organizations and the general public in several ways.

Study – 1 provides a holistic picture to the OEMs and project managers in realizing the key factors and how these interact with the user mental model, situational awareness, understanding and confidence during AD in real case driving scenarios under live conditions of traffic. The HMI AD Event Relation Framework (HMI – ADERIF) framework developed in the study provides greater assimilation of how trust evolves and then transforms during various usage phases and the related events. The framework holds the key to optimum user acceptance in the driverless domain. HMI OEMs can use this framework as a design tool to shape human trust holistically in an AV and the overall driverless eco-system. Future researchers can also take the lead from the design space and variables of the framework to further validate these individual factors during a single or in several AD events to increase the trust level while developing self-driving cars.

It is also noteworthy for the AV developers and transport authorities that the operational design domain (ODD) and enabling traffic environment during dynamic driving tasks (DDTs) affects users' trust and designing and operational use of the specific level of AV. Therefore, future testing and evaluation comprising realistic user studies in live traffic with novice users are essential in prioritizing AVs' deployment, establishing secure communication and feedback to the user, and preparing hybrid road infrastructure. This first-time study looked into the linkages of interpersonal and institutional trust from a driverless technology point of view; it has provided a way for the researchers to fundamentally re-assess and augment the various trust models and theories present in the literature today.

Study – 2 provides a greater understanding to R & D managers to assimilate sentiments of the general public towards AVs implementation and validates the significance of trust and its mediation from an interpersonal and institutional perspective. It has emphasized the need for co-evolution regulation and technology and informed research organizations, government authorities and other stakeholders in NZ and elsewhere that trust is the key to user acceptance. Moreover, trust mediates people's micro intentions on automation reliance and macro interactions towards a comprehensive legal readiness regime for overall public acceptability for AVs. The study provided valuable insights to the transport planners to understand the consequences of driverless disruption and pursue effective risk mitigation strategies to address data privacy, cyber security, and safety challenges. This study also gives insights into the likely adoption scenarios of the general public in NZ. NZ has a well-known supportive environment for testbed of emerging technologies. The proposed study integrated model can serve as a stepping stone for the public and private sector to implement and promote AVs deployment. The general public can be also be made more aware of the latest cutting edge driverless technologies and how to harness their use successfully. This leading study can open up new vistas of research in the driverless domain, especially in the backdrops of AVs, HMI and relevance of trust. The study will also speed up the government efforts to grapple the autonomous technologies to realize their benefits for society. It will pay the way towards developing physical, hybrid and digital infrastructure for AVs and remain competitive with the world.

Study – 3 provided insights into the futuristic timelines of AVs diffusion in society to the NZ planners and the general public alike and provided a road map for successful adoption of AVs. This innovative study is beneficial to the transport and infrastructure development authorities in NZ to restructure the overall AV governance and infrastructure edifice in the country. Study – 4 compares NZ's standing with the rest of the world in the driverless domain and gives pragmatic insights to all stakeholders regarding measures to successfully address various challenges. It stipulates concrete steps to restructure governance, rules and regulations, and the driverless eco-system to absorb these technologies.

Overall, the research study outcomes facilitate the usage and deployment of AVs in NZ and provide valuable insights to the rest of the world. In addition, this innovative study offers an initial take-off point for the early test case for pursuing AVs implementation strategies and roadmap for various regions and demographics.

7.2.8 Checklist and Recommendations for NZ Managers.

The proposed integrated trust and governance framework developed in Study -2 is recommended to be adopted for deployment of driverless and semi-driverless systems in NZ.

This research study has provided insights into the challenges towards the successful proliferation of AVs technologies for driverless and semi driverless systems in NZ. The study has developed a detailed integrated trust framework based on crucial determinants to address these challenges. Later, the study scientifically endeavoured to manifest the output of this framework on a timeline of 100 years based on likely scenarios. In the light of the empirically accrued findings, the study delineates a comprehensive checklist and recommendations for NZ driverless technology managers. It will assist in pragmatically addressing the AVs' deployment challenges and realization of societal benefits. A detailed checklist is as below:

- The realistic user studies in live traffic conditions in various regions of NZ be pursued based on formulated HMI AD Event Relationship Framework of Study – 1.
- The finalized integrated Trust Model in Study – 2, including corroborating determinants, be included in policy instruments to ensure people's attractiveness, trust and advancement of driverless technologies.
- There should be only two laws in the regulations domain, one for AVs requiring human input and the other dealing with AVs with no human involvement. The challenges in the NZ enabling environment are primarily in criminal and civil liability, safety, property damage, and infrastructure. In the backdrop of the NZ accident compensation scheme ACC scheme, users cannot bring a civil action, which means they will have no recourse against AV manufacturers. Privacy torts in NZ need to be broadened in case information is collected by AVs. It is suggested to follow US SELF Drive Act 2020, where OEMs must furnish an AVs privacy plan before deployment. Moreover, property damage schemes must be enforced on lines of ACC duly funded by OEMs, users and the government.

- NZ lawmakers need to make few amendments to criminal law. Currently, it does not make it clear who is liable when a driverless vehicle has an accident and similar changes in the civil liability. The liability should be with OEM, operator or licensor of the vehicle but not with the driver or people in the vehicle. Liability needs to rest with corporate and criminal liability should only be from a symbolic point of view. The law changes are required for liability clarification in offences involving AVs, including speeding and illegal parking.
- The capacity development within the responsible organizations overseeing the driverless technology paradigm requires developing relevant standards and regulations. These should include (1) safety, (2) cyber security, (3) liability, (4) updating road code and, (5) building code, (6) defining ODD, (7) training of manager in new skills, (8) new driving licensing regime, (9) AVs' performance data collection requirements and (10) real-time digit warrant of fitness. Additionally, the cyber security risks and terrorism towards vehicle automation must be addressed as a priority. There is a need to constitute a collaborative platform for public and regulatory authorities to find an appropriate course of action.
- NZ needs to adopt US Federal Government Policy to encourage manufacturers to produce safety assessments of their AVs under NZ conditions. A specific amendment is required in the Land Transport Act to create a new liability regime. In AV 4 levels deployment, the German recent promulgated law can be followed where AV4 vans are allowed in specific ODDs cameras controlled by staff in distant operational rooms.
- Realistic awareness regarding AVs technologies through media campaigns and public demonstrations be resorted to educating the masses. Overly optimistic expectations about self-driving cars need to be avoided.
- NZ enabling environment has two likely AVs deployment pathways in the foreseeable future; creating fleets of AVs in contained urban spaces and incrementally increasing the number of vehicles with autonomous features on NZ roads. The First Step towards AVs development can be deploying the driverless tram (AV4) in specific ODDs. People showed preferences in Study 2 that they are likely to adopt AVs in closed areas, public transport with driver chaperone, Long road trips, and freeways. A plausible scenario can be deploying

AV 'Robo taxis' in conjunction with public transport in Auckland and Canterbury within a geofenced area / ODD. Another case may include deploying AVs in retirement communities or planned communities, especially in places like the north of Christchurch called Pegasus and incentivising using electric vehicles (EVs) for the poor.

- A road map can be designed to create additional lanes as per ODDs. AVs can co-exist with driver-controlled vehicles, besides pursuing private car ownership and collaborative driverless car-sharing mechanism complementing each other in a multifaceted economic model. This can be later transformed into driverless pods and supernodes controlled by transport hubs as transport systems evolve.
- For AV level 3, the conventional road infrastructure without digital information, including additional lanes for AVs, road signs, and road markings, should be ready before 2030. However, Digital map data complemented with static road signs and marking information and traffic lights etc., must be installed before 2043.
- For AV4, hybrid infrastructure should be ready by 2025 in specific ODDs and closed areas for shuttles and trams and rest to be completed before 2030.
- Dynamic and Digital infrastructure should be available for AV4 by 2030 (in specific ODD), AV3 by 2043 and AV5 by 2085. It must include the availability of real-time data regarding microscopic traffic situations, Variable Message Signs (VMS) and incidents and weather reporting. Digital data should guide AVs in speed, gaps and lanes movements to optimize the traffic flow.
- To increase the speed of adoption and technology development, subsidy or tax reduction measures must be resorted to lowering the cost of the technology. People can be encouraged to rapidly replace their old cars with new ones through media campaigns, programs, and tax benefits. Using these tactics, the average lifetime of vehicles can be reduced. Adjusting the lifetime of any car seems much more plausible than using policy instruments for adjusting the price. However, it is challenging for the authorities to change the adoption rate, depending on the technology maturity influencing situation awareness and anthropomorphism attributes controlled by OEMs.
- Driverless technology advancement depends on the effectiveness of knowledge transfer to create an enabling environment for propagating field tests, validation

user studies and AVs implementation strategies. This knowledge is developed by the private and public sector joint efforts, including universities, research institutions, and private R & D departments in consultancy firms. This knowledge accumulation and sharing process must be harnessed through a network as other stakeholders will not share information. In a collaborative environment, the government must ensure academia-industry linkages on various research topics, so knowledge depreciation does not occur. It is understandable that NZ is a small market and generally absorbs these technologies from abroad. However, it is noteworthy that NZ people and industry support innovation. To remain on pace with the rest of the world, NZ needs to harness driverless technologies sooner or later. An R& D fund can be created utilizing the private and public sectors locally and regionally to support driverless technology enabling environment, thus encouraging new entrepreneurs to take up this challenge.

- We need to address understaffing in the Ministry of Transport and focus on intelligent driverless public transport in the shape of small shuttles, trams, pods and supernodes.
- There is a need for continuous testing throughout AVs life spans and improvement in transport infrastructure such as control centres, transport hubs, redesigning of roads, use of sensors, and creation of compliance task force.
- All companies involved in manufacturing, testing, and deploying AVs technologies must be brought under an overarching organization to create open data platforms and share accident data, knowledge, and processes.
- Driver mental model needs to be trained over time once they are made to undergo various simulations, driving licensing exams, and other such training measures to assess the AV maturity and decision-making paradigm. In addition, lawyers need to be trained on soft insurance and liability in case of software or hardware failure on camera accidents.
- NZ can be involved in developing driverless vehicles to provide jobs in the related driverless technologies industries.
- The provision of detailed data reporting for test vehicles is another facet of safety for collecting information on potential safety risks. NZ is suggested to follow Victoria's regulations that demand real-time monitoring and recording of

performance, location and compliance with permit requirements during the test (appropriate training, driver and vehicle safety assessment). And in case of any damage, the legal entity responsible for testing should be made liable.

- There is a need draft guideline for a privacy architecture framework on UK Dft and CPNI outlined in ISO 29101 for the AV manufacturers. Moreover, in data protection and cyber security, NZ must draft regulations similar to EU GDPR, WP 25 / WP 29 standards and 'euroncap.'
- It is suggested to publish a safety code of practice regarding AVs, including (1) presence of human safety driver during on-road testing, (2) a separate license with additional provisions if the remote monitor is used during the test, (3) safety driver and remote monitor capable enough to deactivate the system at any time, (4) A training program for the safety drivers and remote monitors, (5) A comprehensive safety management plan as developed by Australia, (6) Substantial fines and penalties for non-compliance with safety rules, (7) submission of disengagement reports as in California state whose format should be standardized across all manufacturers, (8) testing permit accompanied with substantial insurances, and (9) the requirement to record the trials in real-time.
- There is a need to urgently develop a new generation of road infrastructure comprising rapid repair and prefab modular solutions. The construction may involve low carbon, recycled material, development of wearing courses based on 3 D printing and use of sensor mats in the pavements. Moreover, the road infrastructure and power equipment must have an embedded system to recharge electric vehicles and use renewable energy.
- Taking the lead from other countries, adopting a proactive strategy, and following framework guidelines are needed. Investing in governance and infrastructure to shape our eco-systems in the driverless domain is an absolute necessity.

7.3 Research Limitations and Future Directions

The research process in this study accrued main results and findings from literature review, NZ public survey, user study and experts' interviews in the backdrop of COVID – 19 pandemic conditions. The study is just a first step and may not be considered as final as it is possible to alter some determinants and the policy interventions based on further research. The objective was to find out the theoretical output and reflect on the trust and governance framework quantitatively besides finding measures to speed up the technology.

The study carries several limitations and opportunities for later research. First of all, the availability of BMW AV was affected by the pandemic as the Company fell below the stock and could not provide the vehicle as often as it should be made available. Resultantly it affected the frequency of the user study driving sprints and scenarios. Moreover, COVID – 19 tracing and other requirements also limited the availability of novice users to increase the frequency of their participation.

Besides, the study was carried out in specific areas within Auckland. The study was limited due to the non-availability of full AV3 as AV2 could only switch to autopilot function from few seconds to 1 ½ minute depending upon the speed and traffic conditions. Hence in the future, there is a requirement to utilize AV3 and gather more observations from different users and user studies. These experimental testing should not be restricted to one particular area or region. It should be carried out in various rural and urban areas to assess the appropriate trust needs, future mobility and accessibility scenarios, and the AVs' deployment pathways.

Moreover, hybrid and digital infrastructure demands, evaluation of user interfaces, and promulgation of pragmatic rules and regulations can be analyzed. Since NZ is producing AV4 shuttles, future research may involve using shuttles besides employing autonomous electric vehicles and other connected autonomous transport. Similarly, in future research efforts, the deployment of AV4 vehicles in open and closed areas such as airports associated with key situational factors including safety, reliability, monitoring, cybersecurity, and terrorism can be studied for more in-depth analysis.

The research was also affected by the non-availability of AVs OEMs and other professional and academic experts in NZ. The study needed to recruit experts from other developed countries. Therefore, their views pertain to those specific regions and set of enabling conditions. Moreover, pandemic crisis and wide geographical zone forced the use of zoom technology instead of one-on-one interviews. These conditions also precluded the author from moving abroad to meet various experts and companies in person or attending world conferences. Hence, in the future, it is essential to carry out capacity development in our universities, research organizations, consultancies and other public and private setups to remain competitive.

The sample size for NZ public survey was though adequate. However, in the future, a larger sample size could provide further insights into various dimensions, challenges and future implementation directions of driverless technology. Besides, as highlighted above, future research needs more realistic naturalistic and longitudinal studies to understand edge cases. These user studies need to find out about the behaviour of AVs concerning different traffic signals, their communication with driver and external environment, and initiating a zip manoeuvre. Moreover, the research is need for driver's awareness of the system thinking in fallback routine, the behaviour of AV on the yellow and red light, staying in a lane and interacting with larger vehicles. There is a need to research how much the driver knows about the functionality of AVs? And how much manufacturing company is sharing data about what that technology can do.

The HMI AD Event Relationship Framework developed in Study – 2 needs further validation and testing against a single or numerous trust affecting factors and their interactions with AD events to understand HMI scenarios and develop design guidelines. Further research can assist in the assimilation and validation of user interfaces for the disabled, sick, and people who cannot drive. The collaborative approach of HMI designers, OEMs, and researchers is necessary to examine the chain of AD events and interactions. It will help in realistic gauging the dynamic trust formulation and evaluation of HCI concepts in driverless technology.

The integrated Model based on the trust and governance framework developed in Study – 2 captures key trust determinants. However, since the literature observed several other factors in light of available technology acceptance theories and models (TAM), this study might have missed few factors in global settings. This study observed the mediating effect of trust, whereas further researchers may investigate the moderating behaviours of the driver, age, gender, income, and driving experience.

Moreover, the study observed a research void regarding technology acceptance theories and models. Trust and acceptance models and theories widely used in the literature bear their emergence from human-robot interaction (HRI) or information technology (IT) paradigms. No model addresses the driverless technology domain holistically. These models gradually introduced trust, perceived risk (PR) based on safety requirements, personality traits, social influence and external environment parameters. Lately, Automation Acceptance Model (AAM) identified trust and compatibility integrating information systems and cognitive engineering. However, empirical observations do not support both TAM and AAM despite having solid theoretical background. Theoretical underpinnings of these models seemed to lag far behind the pace of technological developments, semi-autonomous vehicles, and performance implications of advanced driving assistance systems (ADAS).

There is still a lack of clarity and understanding regarding the effects of Automation on human behaviour in the context of highly automated vehicles (HAVs), particularly when users are confronted with a lower level of Automation where vehicles require human input for full control. The unfolding of the phenomenon of trust and driver acceptance, especially in ADAS and HAVs, is profoundly complex, multifaceted and multidimensional compared to its application in drones, aviation, and similar other industries. These theories and models need a fresh look in the backdrop of a unique split-second myriad of safety risks. Moreover, no modelling theory in the present literature describes AVs' acceptance domain holistically considering interpersonal and institutional trust.

In Study - 3, the author has confidence in the model's robustness and reliability and has carefully chosen the structure and input values in light of already held studies and real-time data. However, there are several aspects of mobility that may not be fully captured in this model. This system dynamics (SD) study does not incorporate impacts of political, economic and cultural factors that influence the adoption of AVs. Moreover, there is a lack of data about the magnitude of some specific aspects of this eco-system since driverless technology is early in the product life cycle. Impacts on congestions, emissions and traffic safety are also not considered as these determinants are more relevant to the non-geographical nature of an SD Model.It should also be taken into account that the model may contain some limitations in terms of full data availability to simulate. Also, specific initial values of various stocks were needed to be set in SD Model by the author to start the simulation, which may not be the exact representation of real-world systems as AV3, AV4, and AV5 are still not available in the market. However, all these values were kept within the context of literature, taking the lead from the earlier studies to acquire tangible results. In the modelling analysis and simulation of the extended model, it is found that the system seems uncertain with market penetration by varying utility weights, including the trust and governance variables. Similarly, the value of accumulation of knowledge by searching and doing towards technology maturity may not have a replica in the real world to simulate its actual behaviours.

Moreover, the SD Modelling examined the diffusion of AVs in the next 100 years till 2121, which may be a long time horizon. There may be several corroborating factors and conditions for AD and the emergence of new players and possibilities during this time. Besides, the likely emergence of AV level 5 will be a transformative and radical change, consequently disrupting more than one sector. Hence it may be fruitful and exciting to study the Mobility-as-a-Service (MaaS) pathway or level 5 as a private extravagance intermittently in a limited time framework in the model.

7.4 Concluding Statement.

This research study explored pragmatic solutions to realize the trust dynamics and governance for humanizing driverless technology for AVs in NZ. The research proposed an AD Trust Acceptance Model, an integrated trust and governance model and a HMI event relationship identification framework for adoption in NZ. It provided insights into the likely AVs diffusion pathways and a roadmap utilizing four studies. The framework developed during the user study was intentionally left loose to fit future research directions for further examination. It is hoped that the findings of this research study have provided initial insights into AV technologies and intrigued future scholars in extending the knowledge base in more detail. This study has made an effort to further the evidence in establishing trust during HMI in AVs in early test environments. It has provided interesting facts to government institutions and other stakeholders to carry out cost and benefit analysis while carrying out transport investment decisions. The study has also provided a detailed summary for articulating and restructuring the legal readiness structure in NZ to address the technologies and societal challenges. Overall, the study endeavoured to contribute knowledge by juxtaposing experimental user testing and quantitative methodologies to successfully explore trust's theoretical and practical contours towards the positive deployment of AVs in NZ.

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Appendices

Appendix A: Ethics Approval Letters (User Study, Experts Interviews and Survey)

21 May 2020
Ali GhaffarianHoseini
Faculty of Design and Creative Technologies

Dear Ali

Re Ethics Application: **19/282 Realizing trust dynamics and governance for humanizing driverless technology**

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

Your ethics application has been approved in stages for three years until 21 May 2023.

This approval is for the user study and expert focus groups and/or interviews only. An application for additional stages needs to be submitted to AUTEC before recruitment and data collection for those stages commences.

Standard Conditions of Approval

1. The research is to be undertaken in accordance with the Auckland University of Technology Code of Conduct for Research and as approved by AUTEC in this application.
2. A progress report is due annually on the anniversary of the approval date, using the EA2 form.
3. A final report is due at the expiration of the approval period, or, upon completion of project, using the EA3 form.
4. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form.
5. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
6. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.
7. It is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard and that all the dates on the documents are updated.

AUTEC grants ethical approval only. You are responsible for obtaining management approval for access for your research from any institution or organisation at which your research is being conducted and you need to meet all ethical, legal, public health, and locality obligations or requirements for the jurisdictions in which the research is being undertaken.
Please quote the application number and title on all future correspondence related to this project.
For any enquiries please contact ethics@aut.ac.nz. The forms mentioned above are available online through http://www.aut.ac.nz/research/researchethics

(This is a computer-generated letter for which no signature is required)
The AUTEC Secretariat
Auckland University of Technology Ethics Committee
Cc: attiq.urrehman@aut.ac.nz; Nicola Naismith; John Tookey

Ethics Approval (Letterfor Survey)

29 June 2020
Ali GhaffarianHoseini
Faculty of Design and Creative Technologies

Dear Ali

Re Ethics Application: **19/282 Realizing trust dynamics and governance for humanizing driverless technology**

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

Your ethics application for the online survey for the public has been approved for three years until 21 May 2023.

Standard Conditions of Approval

8. The research is to be undertaken in accordance with the Auckland University of Technology Code of Conduct for Research and as approved by AUTEC in this application.
9. A progress report is due annually on the anniversary of the approval date, using the EA2 form.
10. A final report is due at the expiration of the approval period, or, upon completion of project, using the EA3 form.
11. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form.
12. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
13. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.
14. It is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard and that all the dates on the documents are updated.

AUTEC grants ethical approval only. You are responsible for obtaining management approval for access for your research from any institution or organisation at which your research is being conducted and you need to meet all ethical, legal, public health, and locality obligations or requirements for the jurisdictions in which the research is being undertaken.

Please quote the application number and title on all future correspondence related to this project.

For any enquiries please contact ethics@aut.ac.nz. The forms mentioned above are available online through http://www.aut.ac.nz/research/researchethics

(This is a computer-generated letter for which no signature is required)

The AUTEC Secretariat

Auckland University of Technology Ethics Committee

Cc: attiq.urrehman@aut.ac.nz; Nicola Naismith; John Tookey

Appendix B: Consent and Participation Information, Protocols and Questionnaires

<u>Consent Form - when user study field testing is involved.</u>

Project title: ***Realizing Trust Dynamics and Governance for Humanizing Driverless Technology***

Project Supervisor: ***Dr Ali GhaffarianHoseini, Dr Nicola Naismith, and Prof John Tookey***

Researcher: ***Attiq Ur Rehman***

○ I have read and understood the information provided about this research project in the Information Sheet dated dd mmmm yyyy.

○ I have had an opportunity to ask questions and to have them answered.

○ I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time without being disadvantaged in any way.

○ I understand that if I withdraw from the study then I will be offered the choice between having any data that is identifiable as belonging to me removed or allowing it to continue to be used. However, once the findings have been produced, removal of my data may not be possible.

○ I have read and satisfied with the risk assessment, mitigation and safety management plan and I am not suffering from heart disease, high blood pressure, any respiratory condition (mild asthma excluded), any illness or injury that impairs my physical performance, or any infection

○ I agree to take part in this research.

○ I wish to receive a summary of the research findings (please tick one): Yes○ No○

Participant's signature:

....

Participant's name:

....

Participant's Contact Details (if appropriate):

………………………………………………………………………………………..

Date:

Approved by the Auckland University of Technology Ethics Committee on ***type the date on which the final approval was granted*** ***AUTEC Reference number*** ***type the AUTEC reference number***

Note: The Participant should retain a copy of this form.

<u>Consent Form - For use when Survey is involved</u>

Project title: ***Realizing Trust Dynamics and Governance for Humanizing Driverless Technology***

Project Supervisor: ***Dr Ali GhaffarianHoseini, Dr Nicola Naismith, and Prof John Tookey***

Researcher: ***Attiq Ur Rehman***

- ○ I have read and understood the information provided about this research project in the Information Sheet dated dd mmmm yyyy.
- ○ I have had an opportunity to ask questions and to have them answered.
- ○ I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time without being disadvantaged in any way.
- ○ I understand that if I withdraw from the study then, while it may not be possible to destroy all record. I will be offered the choice between having any data that is identifiable as belonging to me removed or allowing it to continue to be used. However, once the findings have been produced, removal of my data may not be possible.
- ○ I agree to take part in this research.
- ○ I wish to receive a summary of the research findings (please tick one): Yes○ No○

Participant's signature:

....

Participant's name:

....

Participant's Contact Details (if appropriate):

……………………………………………………………………………………..

Date:

***Approved by the Auckland University of Technology Ethics Committee on** type the date on which the final approval was granted **AUTEC Reference number** type the AUTEC reference number*

Note: The Participant should retain a copy of this form.

<u>Consent Form - For use when online interviews are involved</u>

Project title: ***Realizing Trust Dynamics and Governance for Humanizing Driverless Technology***

Project Supervisor: ***Dr Ali GhaffarianHoseini, Dr Nicola Naismith, and Prof John Tookey***

Researcher: ***Attiq Ur Rehman***

- ○ I have read and understood the information provided about this research project in the Information Sheet dated 26-08-2020.
- ○ I have had an opportunity to ask questions and to have them answered.
- ○ I understand that notes will be taken during the interviews and that they will also be audio-taped and transcribed.
- ○ I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time without being disadvantaged in any way.
- ○ I understand that if I withdraw from the study then I will be offered the choice between having any data that is identifiable as belonging to me removed or allowing it to continue to be used. However, once the findings have been produced, removal of my data may not be possible.
- ○ I agree to take part in this research.
- ○ I wish to receive a summary of the research findings (please tick one): Yes○ No○

Note : Please sign the Consent Form, then kindly scan or photograph and return back the form to the researcher.

Participant's signature:

....

Participant's name:

....

Participant's Contact Details (if appropriate):

……………………………………………………………………………………..

Date:

Approved by the Auckland University of Technology Ethics Committee on** type the date on which the final approval was granted* **AUTEC Reference number** ***type the AUTEC reference number

Note: The Participant should retain a copy of this form.

Participant Information Sheet
<u>For Industry Experts Interview</u>
Date Information Sheet Produced:

04/03/2020

Project Title

Realizing Trust Dynamics and Governance for Humanizing Driverless Technology

An Invitation

Dear [insert name]

You received this document [email] as I would like to invite you to participate in interview.
I currently work as a Ph.D. researcher at School of Engineering, Computer and Mathematical Sciences, Built Environment Engineering Department, Auckland University of Technology. My supervisors are Dr Ali GhaffarianHoseini, Dr Nicola Naismith, and Prof John Tookey.
Autonomous Vehicles (AVs) will emerge as a powerful catalyst, thus forming a potentially disruptive technology opening doors to a large variety of technological, design-related, socio - cultural and legal changes. AVs have the potential to address several transportation challenges, including improving road safety, reducing congestion, optimizing traffic flow and providing additional comfort for drivers and passengers. Present day research is mostly focused on optimistic technological orientation of AVs, thus lacking the predominant social linkages and identification of appropriate trust factors in Human Machine Interface design especially in the background of AVs operating in closed environments for their acceptability by the society. This research study aims to investigate the appropriate human machine interaction (HMI) scenarios for humanizing driver-less technology thorough an appropriate users' interfaces, autonomous driving scenarios and regulations for realization of trust between Human and Machine. The study will also suggest a holistic trust-based framework ensuring appropriate planning policy and guidance strategy for designing trust between Human Machine Interaction (HMI) systems.
You will be asked to participate in field testing of autonomous vehicle level 2 or level 3 in various driving scenarios and events. You should be mentally and physically fit and in possession of full driving license. During various stages of driving operations, you will subjected to few snap questions and latter a workshop session to get you impression about the service, user interfaces and how it can be further improved. I would highly value your contribution but please do not oblige to participate. Your identity includes name, position, and affiliation will not be exposed on my publications as well as Ph.D. thesis. Please note that this is voluntary and may withdraw at any time before completing the data collection. If there is any conflict of interest at any point of time, you are able to choose whether to proceed with the research or not, your decision will neither advantage you nor disadvantage you. I look forward to your response.

Best regards,
Attiq Ur Rehman
Ph.D. research candidate

What is the purpose of this research?

The research aim is to investigate the conditions, factors and Autonomous Driving events for ensuring appropriate trust for optimum acceptability and implementation of Autonomous Vehicles (AVs) / Shuttles. Primary research objective is 'How to humanize driverless technology for prospective users realizing appropriate governance structure and trust dynamics in Human –Autonomous Vehicles Interaction'. The sub objectives are (1) To ascertain the challenges of implementation of autonomous vehicles in the New Zealand and global context affecting the urban development and the existing traffic situation, (2) To identify the factors affecting trust between the human and the machine and evaluate new and emerging AVs interface technologies facilitating positive user perception and (3) To formulate a holistic trust and governance based framework for an appropriate planning policy and guidance strategy for designing trust between Human Machine Interaction (HMI) systems seeking to promote well-being.

How was I identified and why am I being invited to participate in this research?

You will have responded to the email sent by AUT University or through one of colleagues in your professional network were identified through interest or experience in the autonomous vehicles. You have been identified as you fit the criteria of the research in autonmous vehicle domain.

How do I agree to participate in this research?

If you choose to participate in the study, then you would need to sign a consent form stating that you have accepted to participate. You will be sent a consent form at the same time as I send you this information sheet. You will have the opportunity to ask any further questions before you sign the consent form and commence the interview.

Your participation in this research is voluntary and whether or not you choose to participate will neither advantage nor disadvantage you. You are able to withdraw from the study at any time before data collection is completed. If you choose to withdraw from the study, then you will be offered the choice between having any data that is identifiable as belonging to you removed or allowing it to continue to be used. However, once the findings have been produced, removal of your data may not be possible.

You are also supposed to agree in principle not to disclose any confidential or organisationally sensitive information received during focus groups interviews. Moreover the confidentiality of information obtained incidentally during research must also be respected accordingly.

What will happen in this research?

This project involves experts' focus group interview sessions / workshop. However, if it is a focus group interview session, it will take 240 – 300 minutes in 4 – 5 phased stages of 60 minutes each but final timings will depend upon the your availability. This will be recorded and transcribed. In case we are unable to proceed with focus group interviews then you will be requested for individual interview which interview will take approx. 60 minutes depending upon your availability again.

What are the discomforts and risks?

It's very unlikely that you will experience any discomfort. If you do not feel comfortable answering a question you are not obliged to answer it.

How will these discomforts and risks be alleviated?

You have the right to refuse to answer any question you feel that you are not comfortable answering. You also have the option of withdrawing from the interview at any time within the data collection process.

What are the benefits?

For the participants: The results from the research could assist the participants in increasing their knowledge in optimizing trust between human and machine, successful implementation of autonomous vehicles technology, paving way towards new business model and promoting health and wellbeing of general people. The summary of the research results could be sent to the participants.

For the researcher: The study will be a qualification for his Ph.D. degree.

For the wider community: The study provides empirical data to encourage successful implementation of driverless technology, establishing appropriate trust between human and machine, paving way towards new business models and promoting health and well-being of the people.

Future Policy Planning and Guidance Strategy for Manufactures as well as Regulators in NZ: Since this framework is based on underlying NZ Technology Action Plan, NZ ITS Strategy and NZTA regulations for testing and deployment of AVs, it will prove to be a stepping stone to facilitate understanding of what is needed so that the future driver as well as general public will have an appropriate level of trust for AD systems, thus promoting the correct usage.

Streamlines Complexity between Optimum Resource Usage, Environment Degradation and Human wellbeing: It will address the problems of rising immigration, wellbeing of ageing population, reduction of transport congestions and optimum use of resources in NZ. The study will acknowledge the complex interactions between autonomous systems, safety, accessibility, health and privacy.

The researchers will benefit from the project through completion of a Doctor thesis and academic journal article publications. You are able to get a chance to be able to contribute to the body of knowledge with your experience and expertise.

How will my privacy be protected?

In the final report, there will not be any identification of name, company, and their roles. The participants will not be identified individually but they will be acknowledged as a social group of experts in an autonomous vehicle company. A consent form will be signed by the participants before the interview. All information which is not hereby known to others and is sensitive either commercially or technically is considered confidential and will only be used for academic purposes. The participants may withdraw themselves or any information/documentation that they have provided for this research project at any given time before the completion of the collection of data without being a disadvantage in any way. Data received will be treated as confidential in terms of storage and analysis.

Specific Questions Relating to Zoom Focus Groups Session. The researcher will attempt to conduct focus groups via Zoom technology, gathering multiple people to be interviewed at the same time in the AUT virtual room. Participants will be connected to the meeting via their computer, smart phone or tablet. During the one-hour session, all participants will be in the same on-screen room seeing each other live and responding instantaneously. Details will be as under:-

1. **What will be involved?** An online focus group interview using ZOOM – a web-based video conferencing app. The researcher will offer you registration via an online scheduling tool, Doodle. Moreover, to cater for various geographical locations World Clock Meeting Planner will be use i.e. https://www.timeanddate.com/worldclock/meeting.html. After you agree to participate, you will be requested to join 4 or 5 others online in a semi-structured group interview for about 60 minutes' sessions. The sessions would be in 4-5 phased stages of 60 minutes totalling 240 to 300 minutes. I will moderate the group by prompting

discussion using questions. I will also ask your permission to record the session. After the session, I will debrief the key points heard, and will immediately write a summary.

2. **Technology information**. I will send instructions on how to use ZOOM, and offer you an opportunity to trial it with me prior to the focus group session. The session will be video recorded (via ZOOM) and will be audio recorded. I will then transcribe the data based on the permission obtained.

3. **Data storage:** At the end of the focus group session, I will download all files to a secure hard drive on a password-protected AUT computer and delete all original files. On completion of the study, all data will be kept in a secure facility at the SECMS Department AUT. Everything will be password protected and held for six years, and then permanently deleted.

4. **Privacy and Confidentiality**. Since the participants will in a group with others, including me, your responses will not be confidential during the session. However, beyond that and once the focus group session has ended, your identity will remain confidential. Your name and identifying information will be removed from your responses (a pseudonym will be used from then on), and stored separately. Prior to the focus group session, I will email you requesting demographic information. It will be used to compose the groups, and for analysis of the study data. However, all care will be taken to present it in a way that that doesn't personally identify you.

5. **Benefits of Participating.** You will be provided unique opportunity to share ideas, experiences and views on the state of the art research in autonomous vehicle domain around the world, and to contribute their voice to this field of study.

6. **Potential Risks**. Since it is not an anonymous study, your names will be used during the focus group session. In order to protect privacy and maintain confidentiality, you are requested to agree to not name or discuss other group members or their responses outside of the focus group session. You will also be requested to agree in principle not to disclose any confidential or organisationally sensitive information received during focus groups interviews. Moreover the confidentiality of information obtained incidentally during research will also be respected accordingly.

7. **Withdrawing from the study**. Participation in the study is voluntary. You will be able to withdraw from the study at any time without giving a reason, by emailing the researcher. If you decide to withdraw during the focus group session, you can simply exit or stop answering questions. Once video recording of the focus group has commenced withdrawal of their data will not be possible.

What are the costs of participating in this research?

You will contribute your time and your experience in this research.

What opportunity do I have to consider this invitation?

You will be given one to two weeks to consider this invitation.

Will I receive feedback on the results of this research?

You are able to receive feedback on the results of this research, and this will be obtained in the journal article upon your request of this document to which you can get an electronic copy of the journal article.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the

Project Supervisor: *Dr Ali GhaffarianHoseini, alighh@aut.ac.nz, 09 921 9999 ext 7968*

Thesis supervisor: *Attiq UR Rehman,* attiq.urrehman@aut.ac.nz*, AttiqUr.Rehman@wintec.ac.nz +64 21 02944010, skype:attiq_1971*

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Kate O'Connor, *ethics@aut.ac.nz*, 921 9999 ext 6038.

Whom do I contact for further information about this research?

Please keep this Information Sheet and a copy of the Consent Form for your future reference. You are also able to contact the research team as follows:

Researcher Contact Details:

Attiq Ur Rehman, attiq.urrehman@aut.ac.nz, AttiqUr.Rehman@wintec.ac.nz +64 21 02944010, skype:attiq_1971

Project Supervisor Contact Details:

Dr Ali GhaffarianHoseini – aliqhh@aut.ac.nz - 09 921 9999 ext 7968

Approved by the Auckland University of Technology Ethics Committee on *type the date final ethics approval was granted*, AUTEC Reference number *type the reference number*.

Participant Information Sheet

<u>For User Study Field Testing Workshop/ Interview Sessions</u>
Date Information Sheet Produced:

04/03/2020

Project Title

Realizing Trust Dynamics and Governance for Humanizing Driverless Technology

An Invitation

Dear ------

You received this document [email] as I would like to invite you to participate in autonomous vehicles user study (field testing) and workshop sessions/ interviews.
I currently work as a Ph.D. researcher at School of Engineering, Computer and Mathematical Sciences, Built Environment Engineering Department, Auckland University of Technology. My supervisors are Dr Ali GhaffarianHoseini, Dr Nicola Naismith, and Prof John Tookey.
Autonomous Vehicles (AVs) will emerge as a powerful catalyst, thus forming a potentially disruptive technology opening doors to a large variety of technological, design-related, socio - cultural and legal changes. AVs have the potential to address several transportation challenges, including improving road safety, reducing congestion, and optimizing traffic flow and providing additional comfort for drivers and passengers. Present day research is mostly focused on optimistic technological orientation of AVs, thus lacking the predominant social linkages and identification of appropriate trust factors in Human Machine Interface design especially in the background of AVs operating in closed environments for their acceptability by the society. This research study aims to investigate the appropriate human machine interaction (HMI) scenarios for humanizing driver-less technology thorough an appropriate users' interfaces, autonomous driving scenarios and regulations for realization of trust between Human and Machine. The study will also suggest a holistic trust-based framework ensuring appropriate planning policy and guidance strategy for designing trust between Human Machine Interaction (HMI) systems.
You will be asked to participate in field testing of autonomous vehicle level 2 or level 3 in various driving scenarios and events. You should be mentally and physically fit and in possession of full driving license. During various stages of driving operations, you will subjected to few snap questions and latter a workshop session to get you impression about the service, user interfaces and how it can be further improved. I would highly value your contribution but please do not oblige to participate. Your identity includes name, position, and affiliation will not be exposed on my publications as well as Ph.D. thesis. Please note that this is voluntary and may withdraw at any time before completing the data collection. If there is any conflict of interest at any point of time, you are able to choose whether to proceed with the research or not, your decision will neither advantage you nor disadvantage you.
I look forward to your response.
Best regards,
Attiq Ur Rehman
Ph.D. research candidate

What is the purpose of this research?

The research aim is to investigate the conditions, factors and Autonomous Driving events for ensuring appropriate trust for optimum acceptability and implementation of Autonomous Vehicles (AVs) / Shuttles. Primary research objective is 'How to humanize driverless technology for prospective users realizing appropriate governance structure and trust dynamics in Human –Autonomous Vehicles Interaction'. The sub objectives are (1) To ascertain the challenges of implementation of autonomous vehicles in the New Zealand and global context affecting the urban development and the existing traffic situation, (2) To identify the factors affecting trust between the human and the machine and evaluate new and emerging AVs interface technologies facilitating positive user perception and (3) To formulate a holistic trust and governance based framework for an appropriate planning policy and guidance strategy for designing trust between Human Machine Interaction (HMI) systems seeking to promote well-being.

How was I identified and why am I being invited to participate in this research?

You will have responded to the email sent by AUT University or through one of the colleagues in your professional network were identified through your interest / experience in autonomous indurstry . You have been identified as you fit the criteria of the research in autonmous vehicle domain.

How do I agree to participate in this research?

If you choose to participate in the study, then you would need to sign a consent form stating that you have accepted to participate. You will be sent a consent form at the same time as I send you this information sheet. You will have the opportunity to ask any further questions before you sign the consent form and commence the interview.

Your participation in this research is voluntary and whether or not you choose to participate will neither advantage nor disadvantage you. You are able to withdraw from the study at any time before data collection is completed. If you choose to withdraw from the study, then you will be offered the choice between having any data that is identifiable as belonging to you removed or allowing it to continue to be used. However, once the findings have been produced, removal of your data may not be possible.

What will happen in this research?

This project involves a user study of autonomous vehicles. You will be asked to participate in field testing of autonomous vehicle level 2 or level 3 in various driving scenarios and events for a duration of 30 minutes first on an isolated track and then on a road. The likely routes used for two driving scenarios i.e. mixed roads and motorway only i.e., will be (1) BMW NZ Group Headquarters – Pacific rise road – Southern motorway – Princess Street Otahuhu – South eastern highway – Southern motorway – BMW NZ Goup Headquarters. (2) BMW NZ Group Headquarters – Southern Motorway – Point Chevalier – Onehunga – BMW NZ Group. Before driving the level 2 vehicle, you will be given proper training and while driving I will be sitting as second seater with you. You should be mentally and physically fit and in possession of full driving license. During various stages of driving operations, you will be asked questions and latter a workshop session to get you impression about the service, user interfaces and how it can be further improved. A proper risk mitigation and safety management plan will be in place during the entire driving event to safeguard against all likely or impromptu risks. You will be asked prepared questions during the three different phases while driving including peruse, learning and performance during interaction with AV. The peruse phase will involve what happens before your first physical interaction with the AD system, the learning phase will last until the you have learned how the AD system works and the performance phase will take a long term perspective not only during learning phase but also performance phase. The questions will cover the whole test drive but focussing on certain critical events including manually driving the vehicle, system activation, deactivation and usage, as well as their thoughts of the system after the test drive. The questions will be constructed in a manner to receive your as much feedback as possible regarding thoughts and feelings about the system in terms of trust and usability. The user study interview and ideation workshops will take 180 – 240 minutes after 3 driving scenarios. Ideation workshops will be held to mature the concept creation and conclusions.

What are the discomforts and risks?

It's very unlikely that you will experience any discomfort. If you do not feel comfortable answering a question you are not obliged to answer it. There will be no discomfort during driving as I will be sitting next to you besides you will be given full training on the vehicle before driving. Additionally a detailed Risk Mitigation Plan would be in place to ensure fail safe safety mechanisms.

How will these discomforts and risks be alleviated?

You have the right to refuse to answer any question you feel that you are not comfortable answering. You also have the option of withdrawing from the interview at any time within the data collection process.

What are the benefits?

For the participants: The results from the research could assist the participants in increasing their knowledge in optimizing trust between human and machine, successful implementation of autonomous vehicles technology, paving way towards new business model and promoting health and wellbeing of general people. The summary of the research results could be sent to the participants.

For the researcher: The study will be a qualification for his Ph.D.degree.

For the wider community: The study provides empirical data to encourage successful implementation of driverless technology, establishing appropriate trust between human and machine, paving way towards new business models and promoting health and well-being of the people.

Future Policy Planning and Guidance Strategy for Manufactures as well as Regulators in NZ: Since this framework is based on underlying NZ Technology Action Plan, NZ ITS Strategy and NZTA regulations for testing and deployment of AVs, it will prove to be a stepping stone to facilitate understanding of what is needed so that the future driver as well as general public will have an appropriate level of trust for AD systems, thus promoting the correct usage.

Streamlines Complexity between Optimum Resource Usage, Environment Degradation and Human wellbeing: It will address the problems of rising immigration, wellbeing of ageing population, reduction of transport congestions and optimum use of resources in NZ. The study will acknowledge the complex interactions between autonomous systems, safety, accessibility, health and privacy.

The researchers will benefit from the project through completion of a Doctor thesis and academic journal article publications. You are able to get a chance to be able to contribute to the body of knowledge with your experience and expertise.

How will my privacy be protected?

In the final report, there will not be any identification of name, company, and their roles. The participants will not be identified individually but they will be acknowledged as a social group of experts in a particular autonomous vehicle company. A consent form will be signed by the participants before the interview. This consent form will describe what information will be exposed or protected. All information which is not hereby known to others and is sensitive either commercially or technically is considered confidential and will only be used for academic purposes. The participants may withdraw themselves or any information/documentation that they have provided for this research project at any given time before the completion of the collection of data without being a disadvantage in any way.

What are the costs of participating in this research?

You will contribute your time and your experience in this research.

What opportunity do I have to consider this invitation?

You will be given one to two weeks to consider this invitation.

Will I receive feedback on the results of this research?

You are able to receive feedback on the results of this research, and this will be obtained in the journal article upon your request of this document to which you can get an electronic copy of the journal article.

What do I do if I have concerns about this research?

Any concerns regarding the nature of this project should be notified in the first instance to the

Project Supervisor: *Dr Ali GhaffarianHoseini, alighh@aut.ac.nz, 09 921 9999 ext 7968*

Thesis supervisor: *Attiq UR Rehman,* attiq.urrehman@aut.ac.nz, *AttiqUr.Rehman@wintec.ac.nz +64 21 02944010, skype:attiq_1971*

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Kate O'Connor, *ethics@aut.ac.nz*, 921 9999 ext 6038.

Whom do I contact for further information about this research?

Please keep this Information Sheet and a copy of the Consent Form for your future reference. You are also able to contact the research team as follows:

Researcher Contact Details:

Attiq Ur Rehman, attiq.urrehman@aut.ac.nz, AttiqUr.Rehman@wintec.ac.nz +64 21 02944010, skype:attiq_1971

Project Supervisor Contact Details:

Dr Ali GhaffarianHoseini – alighh@aut.ac.nz - 09 921 9999 ext 7968

Approved by the Auckland University of Technology Ethics Committee on *type the date final ethics approval was granted*, AUTEC Reference number *type the reference number*.

PROTOCOLS FOR USER STUDY IN AUTONOMOUS DRIVING SESSIONS

RISK ASSESSMENT, MITIGATION AND SAFETY MANAGMENT PLAN

Purpose. To carryout risk assessment during User study testing of Autonomous Vehicles in a research study and mitigate the risks to participants by ensuring a sound safety protocols in place.

User Study. As laid down in Research Approach Stage 2, the user study will consist of a sample population (5 -10) that will test drove a course in a level 2/3 AV with adaptive cruise control and lane keeping assistance. The participant will be asked various driving event / scenario based question affecting their trust level before, during and after operation.

Identification of Hazards and Risks to Participants. Hazard mainly perceived to be during the operation stage

Task	Hazard	Risk	Priority	Control
Driving on a small stretch of vacant constricted course (1-2km)	Participant driving alone	May be unable to call for help if something goes wrong	**III**	1. Arrange of another helper vehicle near site. 2. Ensure communication with the help vehicle and with the base Headquarter i.e. BMW Group Office Headquarters 3. Ensuring adequate training of the driver on both modes i.e., autonomous and manual before mounting the vehicle. 4. Ensure First class driver license 5. Ensure adequate training course for the second person
		Accidently hit the surrounding benchmarks while driving on a turn in autonomous mode	**I**	
	Driver Tired	Suffers Anxiety	**IV**	
Driving on a University Campus Road (1 – 2 km)	Driver driving alone, surrounding Pedestrians, walkways, signals etc.	Accidently hit kerbs, pedestrians	**I**	
		Suffers Depression and Anxiety	**IV**	
Driving on a congested road (3-4 km in various driving modes)	Driver along with the second person, Nearby traffic, Pedestrians	Accident to nearby pedestrians or traffic	**I**	
		Taking with another person	**III**	

		Fault with Vehicle	**IV**	6. Ensure Vehicle Warrant of Fitness before the operation. 7. Ensure Vehicle is full insured. 8. Ensure adequate communication and warning to nearby medical services (if required) 9. Ensure sign off of ethical wilful document by all participants. 10. Call off any driving operation in any untoward weather condition
		Suffer Anxiety	**IV**	
	Inclement Weather		**II**	

SAFETY MANAGEMENT PLAN. It will incorporate all control measures indicated in above table. All safety protocols will be based on risk priorities identified above. The Safety Management Plan would be as follows.

1. First of all, priority one risks will be mitigated and managed. Participants will be selected only if they are in possession of full driving license and they are in good health. All participants will undergo mandatory training by BMW Group Training officer about the driving scenarios, hazard management / health and safety plan before mounting the vehicle. A support vehicle will be standby during the operation stage and will also accompany the main vehicle. Nearby medical and emergency services will be kept in loop and fool proof communication arrangement be ensured with the participants and the base headquarter.

2. The operating vehicle will be checked against updated warrant of fitness and insurance requirements.

3. The operating speed of the vehicle will be as per laid down NZTA rules.

4. In case of inclement weather the driving operation will be cancelled.

5. All participants will be requested to sign off the willingness ethical document before entering into the user study.

6. **Consideration in case of Car Crash**. Please read this para in conjunction with the table reflected above regarding Identification of Hazards and Risks to Participants. In case of car crash would be avoided at all cost with all precautionary measures in place as reflected in para 1 above. In order to pay the damages, a detailed procedure has already been worked out with BMW NZ Group where in case of fault of first or third party, detailed insurances has been coordinated. In case of fault of the driver, an access of NZD 5500 will be required from the driver. The accident will be immediately reported by the support vehicle and nearby emergency services will be alerted. All injured persons will be immediately evacuated to hospital and next of kin will be informed.

EXPERTS INTERVIEW QUESTIONS

INTERVIEW SHEET ONE

Q No 1. Can you please tell about yourself, background and industry associations?

Q No 2. In your expert opinion, what are the challenges of implementation of autonomous vehicles (AVs)? Also kindly tell about how AVs emergence would affect the urban development and existing traffic situation?

Q No 3. Do you see any barriers towards AVs implementation in our traffic system?

Q No 4. In your opinion, what must be configured / changed in the legislation to allow autonomous driving at level 4 and level 5?

Q No 5. Can you please highlight any factors which affect towards establishing trust between human and autonomous technology adoption?

Q No 6. Kindly tell how anthropomorphism factors influences such trust? Can training / skill on AVs influences trust?

Q No 7. How and which new and emerging AVs interface technologies facilitate trust between human and machine besides ensuring positive user perception?

Q No 8. How can a trust contribute towards humanizing driverless technology, confidence in service, passenger comfort and ease of use especially through optimally designed user interfaces in AVs?

Q No 9. Please highlight the present and latest industrial or academic research and development done in terms of these user interfaces in AVs?

Q No 10. What privacy, safety, security factors/parameters incorporating in governance structure to make AVs a success story?

Q No 10. In your opinion, what matter the most for people perception of risk and benefit related to AVs?

Q No 11. Does the prospect of in-car entertainment or increased efficiency and productivity for passengers affect their attitude towards autonomous vehicles?

Q No 12. How we can ensure optimum trust level between human and machine in terms of legislation, government sponsored policy & guidance strategy, insurance/liability mechanism, Anthropomorphism (human like features) and user interfaces?

Q No 13. Can you please suggest any other appropriate measure to increase the trust level between human and machine like training, passenger mind tuning, interactive feedback/output from the AV system, adaptive automation, customization and error information?

Q No 14. Do you think that a self-driving car may be vulnerable to security / cyber security & privacy invasion in terms of software related security laws, virus, malwares, traffic incidents/interruptions etc and how to overcome these?

Q No 15. In your opinion, how can government ensure safety features, standards around manufacturing, vehicle design and infrastructure communication?

Q No 16. How can we ensure co-evolution of regulation and AV technology for successful implementation of self-driving vehicle?

Q No 17. In your opinion how harnessing immersive technologies comprising Virtual, Augmented and Mixed Reality (VAMR) and electroencephalography (EEG), Artificial Intelligence (AI), Machine Learning (ML), BCI (Brain Computer Interface) etc can ensure realization of trust dynamics in AVs?

Q No 18. Can you please put some light on following technical parameters (if possible)?

a. How can we increase situational awareness (SA)?
b. How can we minimize stress in passengers and drivers in autonomous mode?
c. What type of information and feedback is critical to be reviewed by the users in self-driving vehicle and how to ensure?
d. How can we make HMI (human machine interaction) system more adaptable and user friendly?
e. How to ensure successful two way communication between human and machine?

INTERVIEW SHEET TWO

Reserve Questions (Depending upon the situation and Expert professional knowledge level). These questions will be asked in case of individual interviews in addition to above questions in interview sheet 1.

1. **What is the present state of the transport system in NZ and the barriers AVs implementation in our traffic system?**

(a) What are the potential issues generated on NZ road by AV's? if there is a lack in privacy, security, safety in AV technology? (Examples)

(b) Does NZ incorporate effective infrastructure and management system to handle AV data? If yes what are they?

(c) Do you see a future where automated vehicle technology is integrated into public transportation, especially in suburb to suburb commutes?

2. **What must be changed in the legislation to allow autonomous driving, at levels 4 and 5?**

(a) Do you think current NZ policy environment is suited for AV technology? If not mention the drawbacks and remedies

(b) How AT will protect consumer privacy rights if data exchange becomes standard practice in NZ environment?

(c) What are safety and security legalisation that need to install to ensure better AV experience?

(d) Is it possible to establish continuous improvement in AV safety? if yes, what are the policy option?

(e) List out the potential risk associate with legal alteration in NZ environment according to Auckland transport perspective?

3. **How to design a co-evolution of regulation and technology, so that regulation does not hamper the development of the technology and associated services to society, but also does not allow the technology before it is safe enough?**

(a) What are the challenges associated with AV algorithms design and explain algorithm standard to establish safe and secure AVs in NZ road?

(b) What are the challenges posed by AV data collection and exchange on individual and Auckland transport?

(c) Is it necessary to review vehicle approval system to examine the operation and efficiency of AVs in NZ built environment? if yes what may be the brand-new safety assessment for AVs?

(d) Name the vital legal concerns regarding AV technology influencing AV adoption?

Research Topic 2. What are the factors affecting the Human-Machine Interaction Paradigm and how it can be enhanced?

4. **What events and factors affect in human-machine interaction in autonomous vehicles and how public acceptability can be ensured?**

(a) List out the potential risk associated AV technology in NZ environment according to Auckland transport perspective?

(b) What is the current plan to encounter people concern related to AV technology by Auckland transport?

(c) List out the advantages and disadvantages to Auckland transport after AV adoption?

(d) What are positive and negative effect in NZ lifestyle after AV introduction anticipated by Auckland transport?

5. **How can a trust contribute towards humanizing driverless technology and confidence in service through optimally designed user interfaces in AVs?**

(a) Do you think trust is important in operating AVs? If yes, what are the parameters affecting trust and methods to advance public trust over AV?

(b) What are the factors that influences people belief over AV technology and confidence in their belief about AV?

(c) How should the success of automated vehicles be measured? How do we know whether it is benefiting society?

(d) Do you think we should be concerned with the potential for automated vehicles to work against public transportation?

(e) How should the transportation/engineering planning professions prepare for a future with vehicle automation?

Legislation

1. What is the probability of technical error comprising vehicle safety? and identify the range of factors to achieve socially beneficial regulation to ensure safety?

2. Define the legitimate methods of determining the safety of AVs?

3. What type of AV governing strategy will be adopted by NZ authority?

No response prevention-oriented control-oriented toleration-oriented adaptation oriented

4. Please answer the following:

(a) Name the type and permissible duration of information storage from AVs.

(b) Who controls and access the AV information and how it’s used?

Survey Online Questionnaire

STATEMENT BY THE PERSON AGREEING TO PARTICIPATE IN THE STUDY

By entering the survey, I indicate that I have read the information provided and agree to participate. Clicking on the " Yes I Consent" below indicates that you have read the above information, you voluntarily agree to participate, and you are atleast 18 years of age.

Yes I Consent
No I donot Consent

What gender do you identify as?

Male
Female
Gender diverse, please state below:

Please indicate your ethnicity?

European
Moari
Pacific People
Asian
Middle Eastern/Latin American / African
Others

What is your age?

18-24 years
4-35 years
36-45 years
46 - 65 years
> 65 years

What is your highest level of education?

Less than Bachelor degree
Bachelor Degree
Master Degree
Doctoral Degree

How long have you been driving?

1-3 years
4-5 years
6-7 years
>7 years

Concerns and Adoption Scenarios

The following questions ask about your concerns and your preferences for adoptions of self driving vehicles. Please respond to each question using the scale below (for each question, select that best reflects your response). Please answer open and honestly, there are no right or wrong answers.

How concerned are you about the following issues associated with autonomous vehicles?

	Not all Concerned	Slightly Concerned	Somewhat Concerned	Moderately Concerned	Extremely Concerned
Consumer lack of Trust and Beliefs on self driving Cars	○	○	○	○	○
Legal responsibility of driver or owner in case of accident	○	○	○	○	○
Legal Responsibility of ownership in case of any accident	○	○	○	○	○
Interaction with pedestrians and other non self driving vehicles	○	○	○	○	○
High Cost of autonomous Vehicle	○	○	○	○	○
Inadequate rules and regulations	○	○	○	○	○
Inadequate traffic infrastructure	○	○	○	○	○

Propensity to Adopt and Trust Self Driving Cars

	Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
I usually trust and want to adopt autonomous car until there is reason not to.	○	○	○	○	○

	Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
For the most part, I do not want to adopt and distrust autonomous cars	○	○	○	○	○
I general, I would rely on self driving car to assist me.	○	○	○	○	○
My tendency to trust and adopt new and latest autonomous and user interface technologies is high.	○	○	○	○	○
It is easy for me to adopt self driving car to do its job.	○	○	○	○	○
I am likely to trust and adopt autonomous car even when I have a little knowledge	○	○	○	○	○

What situations you will like to adopt self driving vehicles?

Taxi that are fully self driving	City Streets
Social Activities (dinner, events, social gatherings etc)	Drive Control on Highways
Daily Commute (to work, university etc)	Public Transport
Closed areas like university, airports and others	Freeway / High way
High Pedestrian Activity	Car with No driver
Congested Traffic	Long Road Trips (holidays) on country roads

Factors to Influence Adoption

Anthropomorphism (Human like feature)_ Adaptive Automation

	Most Unlikely	Unlikely	Neutral	Likely	Most Likely
I would like to drive the autonomous vehicles if it carries human like voice to interact	○	○	○	○	○

	Most Unlikely	Unlikely	Neutral	Likely	Most Likely
I would put faith in autonomous car if during transfer of control I get visual, auditory and haptic cues like vibration alerts	○	○	○	○	○
I think the autonomous vehicles are reliable	○	○	○	○	○
I like a self driving car having use interface with eye tracking, emotion detection, gesture and biometrics	○	○	○	○	○

Situational Awareness and Feedback

	Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
The car's capability of "sensing" it's surroundings would influence my trust in it (accuracy of the sensors)	○	○	○	○	○
The ability to take back control from the vehicle in less than 20 seconds would influence my trust in it.	○	○	○	○	○
Effectiveness of the car's learning curve (making judgments on the information received) would influence my trust in it.	○	○	○	○	○
Amount of information that the car can access would influence my trust in it	○	○	○	○	○

	Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
Amount of roadway information available to the car (weather, traffic, constructions, etc.) would influence my trust in it.	○	○	○	○	○
Feedback (audio, visual, haptic or combined) would influence my trust in it.	○	○	○	○	○

Training

	Strongly Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Strongly Agree
I think continuous training on the autonomous car systems can make me more proficient in handling unexpected situations	○	○	○	○	○
I think regular testing of my driving skills would assist me in taking control back from the car	○	○	○	○	○

Trust

	Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
I feel safe if I own a self driving car?	○	○	○	○	○
I will trust the self driving car in heavy and light traffic conditions?	○	○	○	○	○
I am willing to give up control to an autonomous car?	○	○	○	○	○

	Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
Driverless cars can provide a robust and safe mode of transport.	○	○	○	○	○
I put faith in autonomous cars.	○	○	○	○	○
I think autonomous cars are reliable.	○	○	○	○	○
I trust self driving cars.	○	○	○	○	○

Governance Structure

Privacy - How concerned are you about the following issues in autonomous cars?

	Not at all Concerned	Slightly Concerned	Somewhat Concerned	Moderately Concerned	Extremely Concerned
Data Privacy (Personal and location information)	○	○	○	○	○
Personal autonomy (Making your choices instead of car)	○	○	○	○	○
Personal information Privacy	○	○	○	○	○
Targeted Surveillance	○	○	○	○	○

Safety- How concerned are you about the following issues in autonomous cars?

	Not at all Concerned	Slightly Concerned	Somewhat Concerned	Moderately Concerned	Extremely Concerned
Enough Safety safeguards (Equipment and personal) to make me feel comfortable while using driveler less cars	○	○	○	○	○

	Not at all Concerned	Slightly Concerned	Somewhat Concerned	Moderately Concerned	Extremely Concerned
Reliability of underlying technologies and user interfaces in autonomous cars	○	○	○	○	○
Assurance from Government to protect me from problems associated with autonomous cars	○	○	○	○	○

Security - How concerned are you about the following issues in autonomous cars?

	Not at all Concerned	Slightly Concerned	Somewhat Concerned	Moderately Concerned	Extremely Concerned
Probability of Software failure during operation of autonomous cars	○	○	○	○	○
Probability of hardware failure	○	○	○	○	○
Vehicle and System Security (hacking/terrorist activity)	○	○	○	○	○
Network security with transport infrastructure and other cars	○	○	○	○	○

Ranking of Adoption Factors

Of the following factors related to Autonomous Vehicles, which you consider are more important ? Please Rank them

	1	2	3	4	5	6	7
Trust of the People on self driving cars	○	○	○	○	○	○	○
Well developed Rules and Regulation for using autonomous cars	○	○	○	○	○	○	○
Increased Situation Awareness of Vehicle	○	○	○	○	○	○	○
Better User Interaction with Vehicle (Mental Modal)	○	○	○	○	○	○	○
Feedback from Car to the User	○	○	○	○	○	○	○

	1	2	3	4	5	6	7
Human like features of Autonomous Cars	O	O	O	O	O	O	O
More Training and Driving skills of users	O	O	O	O	O	O	O

Please grade the most important factors and scenarios of use that would influence your decision to adopt autonomous cars.

	1	2	3	4	5	6	7	8	9	10
Software hardware and network security	O	O	O	O	O	O	O	O	O	O
safety Safe guards (Equipment and Personal)	O	O	O	O	O	O	O	O	O	O
Personal and Data Privacy	O	O	O	O	O	O	O	O	O	O
Ability to take back control from Vehicle	O	O	O	O	O	O	O	O	O	O
Sensing (accuracy of sensors) and situational awareness of the vehicle	O	O	O	O	O	O	O	O	O	O
Feedback to User based on Audio interface	O	O	O	O	O	O	O	O	O	O
Feed back to User based on Visual interface	O	O	O	O	O	O	O	O	O	O
Multi-modal Feed back System based on Audio and Visual interface	O	O	O	O	O	O	O	O	O	O
Emotion Tracking of User Mental state (anxiety, anger, sadness, fatigue etc)	O	O	O	O	O	O	O	O	O	O
Central Monitoring Station for Vehicles (Network Control Centre)	O	O	O	O	O	O	O	O	O	O

AV User Study Questionnaire

Humanizing Driver-less Technology

Autonomous Vehicles (AVs) have the potential to address several transportation challenges, including improving road safety, reducing congestion, optimizing traffic flow and providing additional comfort for drivers and passengers. Present day research is mostly focused on optimistic technological orientation of AVs, thus lacking the predominant social linkages and identification of appropriate trust factors in Human Machine Interface design especially in the background of AVs operating in closed environments for their acceptability by the society.

This research study aims to investigate the appropriate human machine interaction (HMI) scenarios for humanizing driver-less technology thorough an appropriate users' interfaces, autonomous driving scenarios and regulations for realization of trust between Human and Machine. The research aim is to investigate the conditions, factors and Autonomous Driving events for ensuring appropriate trust for optimum acceptability and implementation of Autonomous Vehicles (AVs). Primary research objective is 'How to humanize driver less technology for prospective users realizing appropriate governance structure and trust dynamics in Human –Autonomous Vehicles Interaction'.

There are three sets of Questions in this online survey form. First set of Questions deal before you have any driving experience with autonomous cars, Second set of uestions deal while you have activated the engine of an autonomous car and third set of Questions pertains to after assisted driving operation with an AV car

1. Email address *

Form 0 : Personal data

2. Have you studied Personal information Sheet and do you give your consent for this user study? *

Mark only one oval.

- ◯ Agree
- ◯ Not agree

3. Gender *

Mark only one oval.

- Male
- Female
- Prefer not to say
- Other: ______________________

4. What is your age? *

Mark only one oval.

- 18 - 24 years
- 25 - 35 years
- 35 - 45 years
- 45 - 65 years
- > 65 years

5. How many years have you been driving? *

Mark only one oval.

- 1- 3 years
- 3 - 5 years
- 5 - 7 years
- > 7 years

6. What car-make do you have experience to drive *

Mark only one oval.

- BMW
- Audi
- Toyota
- VW
- Honda
- Others

Form 1 : Questions Before Driving BMW X5 Autonomous Level 2 Vehicle

7. How often do you drive? (days per month on average) *

Mark only one oval.

- ◯ 1- 7 days
- ◯ 7 - 14 days
- ◯ 5 - 7 days
- ◯ > 7 days

1 A. Questions Before Activation of Engine

8. Qs before activation - What did you feel? Rate from 1 -5 , 1 - Not Good, 2 - Somewhat Satisfied, 3- Okay, 4 - Almost Good, 5 - Good *

Mark only one oval.

	1	2	3	4	5	
Not Good	◯	◯	◯	◯	◯	Good

9. Question before activation - Rate from 1 least probability to 5 Most probability *

Check all that apply.

	1	2	3	4	5
I am suspicious about the systems intent, action or outputs?	☐	☐	☐	☐	☐
The systems actions will have a harmful or injurious outcome?	☐	☐	☐	☐	☐
I am confident in the system?	☐	☐	☐	☐	☐
The system provides security?	☐	☐	☐	☐	☐
The system is dependable?	☐	☐	☐	☐	☐
I can trust the system?	☐	☐	☐	☐	☐
I am familiar with the system?	☐	☐	☐	☐	☐
Do you feel stressed because of the system?	☐	☐	☐	☐	☐

10. Question before Activation - What do you expect?

11. Question before Activation - Any other information you would like to have at this point?

1B. Question before driving - Technology Adoption

Question before driving - Knowledge

12. Qs before driving - How much do you know about self-driving cars? From 1 (no knowledge) to 5 (a greater deal of knowledge)? *

Mark only one oval.

	1	2	3	4	5	
No knowledge	◯	◯	◯	◯	◯	Greater deal of knowledge

13. Qs before driving (Experience) - Please indicate how much experience you have with each vehicle technology. From 1 (very little experience) to 5 (a great deal of experience) *

Check all that apply.

	1	2	3	4	5
Cruise control	☐	☐	☐	☐	☐
Adaptive cruise control	☐	☐	☐	☐	☐
Adaptive/smart headlights	☐	☐	☐	☐	☐
Automatic emergency braking	☐	☐	☐	☐	☐
Autopilot	☐	☐	☐	☐	☐
Blind spot detection	☐	☐	☐	☐	☐
Forward collision warning	☐	☐	☐	☐	☐
Lane centering/lane keeping assist	☐	☐	☐	☐	☐
Lane departure warning	☐	☐	☐	☐	☐
Parking assist	☐	☐	☐	☐	☐
Pilot assist	☐	☐	☐	☐	☐

14. Qs before driving (Perception and Trust) - From 1 (not at all) to 5 (very much) *

Check all that apply.

	1	2	3	4	5
How risky do you think it is to use a self-driving car?	☐	☐	☐	☐	☐
How beneficial do you think it is to use a self driving car?	☐	☐	☐	☐	☐
How much would you trust self-driving cars to do work in poor weather conditions?	☐	☐	☐	☐	☐

15. Exploring Fear Factors before driving-Below some of the thoughts which may pass through your mind while driving driverless cars. Please indicate severity 0 – 4, 0 – Never occurs, 1 – rarely occours , 2 – half of the time driving occurs, 3 – usually occurs, 4 – always occurs *

Check all that apply.

	Never Occurs	Rarely Occurs	Half of the time driving occurs	Usually Occurs	Always Occurs
I will be unable to catch my breath	☐	☐	☐	☐	☐
I cannot control whether other cars hit me	☐	☐	☐	☐	☐
I will be injured	☐	☐	☐	☐	☐
I will injure someone	☐	☐	☐	☐	☐
I will not be able to think clearly	☐	☐	☐	☐	☐
I will die	☐	☐	☐	☐	☐
People riding with me will hurt	☐	☐	☐	☐	☐

Exploring Anthropomorphism factors - Before Driving

These questions you will answer after you have done driving on the AV Car

16. Self Reported Trust -Before Driving Rate from 1 – 5, 1- least to 5 – Most *

Check all that apply.

	1	2	3	4	5
How safe would you feel if you own a car like this one?	☐	☐	☐	☐	☐
How much do you trust the car if you drive it in heavy and light traffic conditions?	☐	☐	☐	☐	☐
How confident you are about the car driving the next course safely?	☐	☐	☐	☐	☐
Rate you willingness to give up control to the car?	☐	☐	☐	☐	☐
Did you feel you could rely on the autonomous Car what it was supposed to do?	☐	☐	☐	☐	☐

Exploring Safety factors -Before Driving

These questions you will answer after you have done driving on the AV Car

Check all that apply.

	No answer	Not safe at all	Not too safe	Somewhat safe	Very safe
How safe would you feel sharing the road with a driverless Car?	☐	☐	☐	☐	☐
If these cars became widespread, do you think number of people killed in accidents will increase?	☐	☐	☐	☐	☐
How safe would you feel regarding privacy of this car software data?	☐	☐	☐	☐	☐
How satisfied you feel regarding the security mechanism of this car?	☐	☐	☐	☐	☐

System Activation

These questions you will answer after you have done driving on the AV Car

18. Question during activation - What did you feel? Rate from 1 -5 , 1 - Not Good, 2 - Somewhat Satisfied, 3- Okay, 4 - Almost Good, 5 - Good *

Mark only one oval.

	1	2	3	4	5	
Not Good	◯	◯	◯	◯	◯	Good

19. 1C. Question after Activation -Do you understand how to activate the system?

Mark only one oval.

◯ Yes

◯ No

◯ Maybe

20. Question after activation - Rate from 1 least probability to 5 Most probability *

Check all that apply.

	1	2	3	4	5
I am suspicious about the systems intent, action or outputs?	☐	☐	☐	☐	☐
The systems actions will have a harmful or injurious outcome?	☐	☐	☐	☐	☐
I am confident in the system?	☐	☐	☐	☐	☐
The system provides security?	☐	☐	☐	☐	☐
The system is dependable?	☐	☐	☐	☐	☐
I can trust the system?	☐	☐	☐	☐	☐
I am familiar with the system?	☐	☐	☐	☐	☐
Do you feel stressed because of the system?	☐	☐	☐	☐	☐

21. After activation of the engine, *

Check all that apply.

	0	25%	50%	75%	100%
% situations where Car and its autonmousfunctions did work as expected?	☐	☐	☐	☐	☐

22. Optional Question - What type of input did you get?

23. Optional Question - Which information helped you to activate the system?

24. Optional Question - What information did you like to have more?

25. Optional Question - What information did you have less?

26. After Assisted Driving *

Check all that apply.

	0	25%	50%	75%	100%
How much in % understand when/when not the system will assist?	☐	☐	☐	☐	☐

27. Qs after assisted Driving - What did you feel? Rate from 1 -5 , 1 Not Good 2 - Somewhat Satisfied 3- Okay 4 - Almost Good 5 Good *

Mark only one oval.

	1	2	3	4	5	
Not Good	◯	◯	◯	◯	◯	Good

28. Question after assisted driving - Rate from 1 least probability to 5 Most probability *

Check all that apply.

	1	2	3	4	5
I am suspicious about the systems intent, action or outputs?	☐	☐	☐	☐	☐
The systems actions will have a harmful or injurious outcome?	☐	☐	☐	☐	☐
I am confident in the system?	☐	☐	☐	☐	☐
The system provides security?	☐	☐	☐	☐	☐
The system is dependable?	☐	☐	☐	☐	☐
I can trust the system?	☐	☐	☐	☐	☐
I am familiar with the system?	☐	☐	☐	☐	☐
Do you feel stressed because of the system?	☐	☐	☐	☐	☐

29. What would give you more trust for the system? *

30. Where do you think your focus lies, on the system itself or on the road? *

31. Is there any information you are missing or is there information that could have been presented in any other way? *

32. What do you do while the system is activated/or think you would do?

33. After Deactivation

Check all that apply.

	0%	25%	50%	75%	100%
how sure you were when you are in full control again?	☐	☐	☐	☐	☐
Did the system work as you expected?	☐	☐	☐	☐	☐

34. How did you know?

35. What situations did you "doubt" the system?

Form 2 - Questions After Driving BMW X 5 Autonomous Level 2 Vehicle

36. After one time driving experience, Did you get enough how much information from the systems itself in order to understand what to do? *

Check all that apply.

	0	25%	50%	75%	100%
Did you get enough how much information from the systems itself in order to understand what to do?	☐	☐	☐	☐	☐

37. Q After driving (Perception and Trust) - From 1 (not at all) to 5 (very much) *

Check all that apply.

	1	2	3	4	5
How risky do you think it is to use a self-driving car?	☐	☐	☐	☐	☐
How beneficial do you think it is to use a self driving car?	☐	☐	☐	☐	☐
How much would you trust self-driving cars to do work in poor weather conditions?	☐	☐	☐	☐	☐

38. Q After driving (Training) - From 1 (5%) to 5 (100%) *

Check all that apply.

	5%	25%	50%	75%	100%
Can we increase the trust level in autonomous cars by increase the training and skills of the drivers?	☐	☐	☐	☐	☐

39. Exploring Fear Factors after driving-Below some of the thoughts which may pass through your mind while driving driverless cars. Please indicate severity 0 – 4, 0 – Never occurs, 1 – rarely occours , 2 – half of the time driving occurs, 3 – usually occurs, 4 – always occurs *

Check all that apply.

	Never Occurs	Rarely Occurs	Half of the time driving occurs	Usually Occurs	Always Occurs
I will be unable to catch my breath	☐	☐	☐	☐	☐
I cannot control whether other cars hit me	☐	☐	☐	☐	☐
I will be injured	☐	☐	☐	☐	☐
I will injure someone	☐	☐	☐	☐	☐
I will not be able to think clearly	☐	☐	☐	☐	☐
I will die	☐	☐	☐	☐	☐
People riding with me will hurt	☐	☐	☐	☐	☐

Questions After Driving - Anthropomorphism Factors - Rate from 1 – 5, 1- least to 5 – Most

40. Perceived Anthropomorphism *

Check all that apply.

	1	2	3	4	5
How smart the AV Car is?	☐	☐	☐	☐	☐
How well it could feel what is happening?	☐	☐	☐	☐	☐
How well it could anticipate what was about to happen?	☐	☐	☐	☐	☐
How well it could plan a route?	☐	☐	☐	☐	☐
How did you perceive the Car as Human-like actions?	☐	☐	☐	☐	☐
Do you perceive the Car moving smoothly?	☐	☐	☐	☐	☐

41. Likely / Perceived Enjoyment *

Check all that apply.

	1	2	3	4	5
How enjoyable the driving was?	☐	☐	☐	☐	☐
How comfortable you felt while driving?	☐	☐	☐	☐	☐
Do you want to own a car like this one?	☐	☐	☐	☐	☐
Did interaction with the car made you feel annoyed?	☐	☐	☐	☐	☐
Did interaction with the car made you feel bored?	☐	☐	☐	☐	☐
Did interaction with the car made you feel relaxed?	☐	☐	☐	☐	☐

42. Self-Reported Trust *

Check all that apply.

	1	2	3	4	5
How safe would you feel if you own a car like this one?	☐	☐	☐	☐	☐
How much do you trust the car if you drive it in heavy and light traffic conditions?	☐	☐	☐	☐	☐
How confident you are about the car driving the next course safely?	☐	☐	☐	☐	☐
Rate you willingness to give up control to the car?	☐	☐	☐	☐	☐
Did you feel you could rely on the CAR what it was supposed to do?	☐	☐	☐	☐	☐

43. Safety - Rate 1 -5, 1 – No answer, 2 – Not safe at all, 3 – Not too safe, 4-somewhat safe, 5 – very safe *

Check all that apply.

	No Answer	Not Safe at all	Not too safe	Somewhat safe	Very safe
How safe would you feel sharing the road with a driverless Car?	☐	☐	☐	☐	☐
If these cars became widespread, do you think number of people killed in accidents will increase?	☐	☐	☐	☐	☐
How safe would you feel regarding privacy of this car software data?	☐	☐	☐	☐	☐
How satisfied you feel regarding the security mechanism of this car?	☐	☐	☐	☐	☐

44. Legality - Rate 1 -5, 1 – No answer, 2 – Strongly Oppose, 3 – Oppose, 4- Favour, 5 – Strongly Favour *

Check all that apply.

	No Answer	Strongly Oppose	Oppose	Favour	Strongly Favour
Requiring these Cars to travel in dedicated lanes	☐	☐	☐	☐	☐
Restricting them in travelling in certain areas like schools	☐	☐	☐	☐	☐
Requiring to have a person in driving seat to control in emergency situations	☐	☐	☐	☐	☐

Form 3: other information about BMW HMI related question

What additional features or user interfaces do you think would increase your level of trust in a vehicle? Give a short answer based on different scenarios as under.

45. a. While you approach towards a driverless vehicle and opens a door

46. b. When you sits in the AV

47. c. when you starts an AV

48. d. When it is in operation

49. e. While on traffic lights

50. f. In case of emergency stops

51. g. When vehicle stops at the destination

52. Of the following, which are more important to you? Rank them in order from 1 (most important) to 3 (least important). *

Check all that apply.

	1. Least Important	2. Important	3. Most Important
Well-developed laws for the development	☐	☐	☐
Sale and use of autonomous cars	☐	☐	☐
Affordable cost for an autonomous car	☐	☐	☐
Personal safety and the safety of those around you while operating an autonomous car	☐	☐	☐

Appendix C: Sample AV Expert's Code Book in NVivo 11 for Thematic Analysis

24/05/2021 2:05 PM

AV Experts' Interview Code Book _24 May 2021

Name	Description	Hierarchical Name	Number Of Children	Number Of Sources Coded	Number Of Coding References
AVs Deployment Challenges and Benefits	Barriers and Benefits of AVs Diffusion in Society	Nodes\\AVs Deployment Challenges and Benefits	7	13	582
AVs Challenges and Future Directions	Concerns of the Society, Barriers and Challenges towards deployment of AVs as well as future implementation	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions	29	13	400
Ability to take back Control	Driver Ability in taking back control from AV especially in Level 2 and level 3 i.e. Switching to human control from	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Ability to take back Control	0	6	16
Accessibility of Public and Private transport	Public and private transport not enough to serve communities, besides special concerns of their	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Accessibility of Public and Private transport	0	5	7
Better User Experience	How to ensure better user experience travelling in AVs, also include significance of user study, simulation, comfort in travel. and use of various interfaces	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Better User Experience	0	4	13
Co Evolution of Regulation and Technology	How Regulation and AV Technology can go hand in hand.	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Co Evolution of Regulation and Technology	0	5	6
Concept of Smart City and Stakeholder Engagement	Role of stakeholder in establishment of Smart City	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Concept of Smart City and Stakeholder Engagement	0	1	1
Congestion	Can this problem be solved or not?	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Congestion	0	6	10
Cost of AVs	Significance of AVs being expensive initially	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Cost of AVs	0	4	4

Name	Description	Hierarchical Name	Number Of Children	Number Of Sources Coded	Number Of Coding References
Data Sharing	Need of Data Sharing Among Manufacturing Companies	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Data Sharing	0	5	8

Name	Description	Hierarchical Name	Number Of Children	Number Of Sources Coded	Number Of Coding References
Electrification of AVs	Significance of EVs in the backdrop of reducing carbon footprint	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Electrification of AVs	0	1	2
Environment Friendly Concerns	pollution free environment applications	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Environment Friendly Concerns	0	1	1
Especially to COVID 19 pendemic	AVs significance in pandemic environment	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Especially to COVID 19 pendemic	0	3	6
False Picture _Green Washing	Media and Some of Companies are painting needlessly false picture of AVs to sell those to potential buyers	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\False Picture _Green Washing	0	4	11
HD Mapping and 5G	Deployment of these advance technologies to facilitate deployment of AVs	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\HD Mapping and 5G	0	2	5
Infrastructure and IT Infrastructure	Need of Infrastructure related to AVs	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Infrastructure and IT Infrastructure	0	8	18
Mental Model	significance of Driver appropriate mental model while using AVs	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Mental Model	0	5	11
Modelling and Simulation Environment	Req of Simulation Environment for edge case scenarios and real time conditions for testing AVs	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Modelling and Simulation Environment	0	2	2
Need of User Studies	Significance of Natualistic and Real time studies using AVs	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Need of User Studies	0	3	13

Network Control Center	Importance of Network Control Data Center for controlling the movement of AVs in real time.	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Network Control Center	0	3	4

Name	Description	Hierarchical Name	Number Of Children	Number Of Sources Coded	Number Of Coding References
NZ AVs Enabling Environment for AVs	Overall Environment in NZ for AVs Market	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\NZ AVs Enabling Environment for AVs	0	4	38
NZ Law Related to AVs and Driverless Technology	Government need to make laws in this domain	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\NZ Law Related to AVs and Driverless Technology	0	4	51
Potential Risks	Risk associated with AVs Technology	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Potential Risks	0	10	28
Rules Regulations Legislation	Significance of Rules and Regulations towards AVs Adoption	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Rules Regulations Legislation	2	10	36
Criminal Liability	Against offenders	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Rules Regulations Legislation\Criminal Liability	0	4	12
Insurance	Potential insurance mechanism for deployment of AVs	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Rules Regulations Legislation\Insurance	0	2	2
Safety	Signifiance of Safety and Security of Users in AVs	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Safety	0	8	14
SEA Levels Interpretation	Various Automation levels given by NHTSA globally and problems identified in human factors domain regarding these levels.	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\SEA Levels Interpretation	0	8	21

Security and Cybersecurity	Security issues surrounding AVs Deployment	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Security and Cybersecurity	0	5	8

Name	Description	Hierarchical Name	Number Of Children	Number Of Sources Coded	Number Of Coding References
Situational Awareness	Situation Awareness of User	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Situational Awareness	0	4	5
Technology	Drawbacks, Challenges towards AV Technology implementation	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Technology	1	7	29
AVs Companies Comparative Analysis	What various AVs Manufacturers are doing?	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Technology\AVs Companies Comparative Analysis	0	5	30
Training and New Skills	Requirement of necessary skills for AVs users	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Training and New Skills	0	5	13
Trust on AV Technology	How to reach towards an appropriate and caliberated user trust on AVs without going towards over and under trust?	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Trust on AV Technology	2	10	19
Higher or Under Trust	Requirement for a appropriate caliberated trust while using AVs	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Trust on AV Technology\Higher or Under Trust	0	7	11
User Understanding of AVs	Consumer understanding and appreciation of the vehicles	Nodes\\AVs Deployment Challenges and Benefits\AVs Challenges and Future Directions\Trust on AV Technology\User Understanding of AVs	0	2	3
AVs Companies Recent Development	Recent Developments by AV manufacturing companies	Nodes\\AVs Deployment Challenges and Benefits\AVs Companies Recent Development	0	2	3
Country wise status on AVs	What is the current sate of AV technological work in specific	Nodes\\AVs Deployment Challenges and Benefits\Country wise status on AVs	0	8	24

Future Directions	Future Research Paradigms including Driverless Technology, Maas	Nodes\\AVs Deployment Challenges and Benefits\Future Directions	0	12	74
Future Timeline	Future Time line for AVs deployment on Roads	Nodes\\AVs Deployment Challenges and Benefits\Future Timeline	0	4	5

Name	Description	Hierarchical Name	Number Of Children	Number Of Sources Coded	Number Of Coding References
Potential Benefits of AVs Interfaces	Use of AVs interfaces, Social Robots for Wellfare of Elderly and use of emotion ware HMI interface	Nodes\\AVs Deployment Challenges and Benefits\Potential Benefits of AVs Interfaces	4	12	62
Drawbacks of present day traffic	Present Traffic System and its challenges	Nodes\\AVs Deployment Challenges and Benefits\Potential Benefits of AVs Interfaces\Drawbacks of present day traffic	0	2	6
Emotion Aware - Elderly People	Emotional behaviour Tracking for Elderly or Sick people in AVs, People subject to	Nodes\\AVs Deployment Challenges and Benefits\Potential Benefits of AVs Interfaces\Emotion Aware - Elderly People	0	2	8
Social Benefits	AVs social benefits to society	Nodes\\AVs Deployment Challenges and Benefits\Potential Benefits of AVs Interfaces\Social Benefits	0	11	47
Use of Social Robots	How use of social robots help elderly people for their health and well being? and use of emotion aware HMI interface.	Nodes\\AVs Deployment Challenges and Benefits\Potential Benefits of AVs Interfaces\Use of Social Robots	0	1	1
Publc Expectations Towards AVs	Public Attitude towards AVs adoption	Nodes\\AVs Deployment Challenges and Benefits\Publc Expectations Towards AVs	0	8	14
Great quote	It includes various memorable quotes in primary and secondary literature	Nodes\\Great quote	0	8	31
HFE - Psychology - Cognition	Identifying, Analyizing and Exploring Human Factors Engineering Concepts, their significance within	Nodes\\HFE - Psychology - Cognition	0	2	5

Human Machine Interaction Paradigm	Explore various HMI Scenarios in case of AVs and Various Trust Models given by researches in the field	Nodes\\Human Machine Interaction Paradigm	7	9	69
ADAS	Advance Driving Assistance Systems	Nodes\\Human Machine Interaction Paradigm\ADAS	0	1	1
Emotion Tracking	It relates to tracking the emotional behaviour of users/drivers in AVs	Nodes\\Human Machine Interaction Paradigm\Emotion Tracking	0	1	5
Multi Modal interactions	significance of user interface, their effect on user situational awareness and mental model	Nodes\\Human Machine Interaction Paradigm\Multi Modal interactions	0	6	16

Name	Description	Hierarchical Name	Number Of Children	Number Of Sources Coded	Number Of Coding References
Two way communication	How communication between Human and Machine interactions. Also explores the	Nodes\\Human Machine Interaction Paradigm\Two way communication	2	6	11
Human Side	How human agent best communicate with AV system	Nodes\\Human Machine Interaction Paradigm\Two way communication\Human Side	0	2	2
Machine Side	How best AV system interact with human	Nodes\\Human Machine Interaction Paradigm\Two way communication\Machine Side	0	3	4
User Interfaces	User Interfaces in AVs	Nodes\\Human Machine Interaction Paradigm\User Interfaces	0	6	22
VAMR	Virtual Augmented Reality Applications	Nodes\\Human Machine Interaction Paradigm\VAMR	0	3	8
Various Models	Significance and overview of various Trust Models	Nodes\\Human Machine Interaction Paradigm\Various Models	0	1	3
Importance of Trust in AVs	Exploring the significance of Users Trust in AVs and how trust mediates between technology and	Nodes\\Importance of Trust in AVs	1	6	10
Trust Mediation	How Trust Mediation Takes place between AVs and Adoption through Legislation	Nodes\\Importance of Trust in AVs\Trust Mediation	0	1	2

Influencing Factors Affecting AD Adoption	Key Factors, Parmeters and Determinants that affect Autonomous Driving Adoption Options. It includes factors related to Trust and HMI Domain and factors related to Trust and Legal Readiness /Governance/	Nodes\\Influencing Factors Affecting AD Adoption	2	10	184
User Trust and Governance Structure_Rules_Legal Readiness - Key Determinants	It includes exogeneous factors relating to Legal Readiness and Governance Mechanism of Governement and how these affect trust of the people	Nodes\\Influencing Factors Affecting AD Adoption\User Trust and Governance Structure_Rules_Legal Readiness - Key Determinants	7	8	89

Name	Description	Hierarchical Name	Number Of Children	Number Of Sources Coded	Number Of Coding References
Cyber Security	A self-driving car may be vulnerable to traffic incidents and interruptions, software related security flaws, virus and malwares	Nodes\\Influencing Factors Affecting AD Adoption\User Trust and Governance Structure_Rules_Legal Readiness - Key Determinants\Cyber Security	0	3	4
Liability	Who should liability in case of AV untoward incident?	Nodes\\Influencing Factors Affecting AD Adoption\User Trust and Governance Structure_Rules_Legal Readiness - Key Determinants\Liability	0	5	10
Ownership	How user will forgo their desire to own a vehicle, once we will be having Costly AVs.	Nodes\\Influencing Factors Affecting AD Adoption\User Trust and Governance Structure_Rules_Legal Readiness - Key Determinants\Ownership	0	3	5
Privacy	Personal and Data Privacy of AV Users	Nodes\\Influencing Factors Affecting AD Adoption\User Trust and Governance Structure_Rules_Legal Readiness - Key Determinants\Privacy	0	6	9
Rules Regulations Policy	Legal Readiness Structure addressing safety, security and privacy	Nodes\\Influencing Factors Affecting AD Adoption\User Trust and Governance Structure_Rules_Legal Readiness - Key Determinants\Rules Regulations Policy	0	6	42

Safety	The Government need to make safety standards around manufacturing, vehicle design, infrastructure and	Nodes\\Influencing Factors Affecting AD Adoption\User Trust and Governance Structure_Rules_Legal Readiness - Key Determinants\Safety	0	6	13
Security	Security of AV users	Nodes\\Influencing Factors Affecting AD Adoption\User Trust and Governance Structure_Rules_Legal Readiness - Key Determinants\Security	0	5	6
User Trust and HMI Fators _ Key Determinants	It includes endogeneous factors of Anthropomorphism, Customization, Erogonomics,	Nodes\\Influencing Factors Affecting AD Adoption\User Trust and HMI Fators _ Key Determinants	9	10	94
Anthropomorphism	A system which acts more like human in terms of voice, gender and name	Nodes\\Influencing Factors Affecting AD Adoption\User Trust and HMI Fators _ Key Determinants\Anthropomorphism	0	5	11

Name	Description	Hierarchical Name	Number Of Children	Number Of Sources Coded	Number Of Coding References
Customization and Adaptive Automation	A system which can adapt to user's likings	Nodes\\Influencing Factors Affecting AD Adoption\User Trust and HMI Fators _ Key Determinants\Customization and Adaptive Automation	0	2	2
Ergonomics and Neuro Ergonomics	Significance of Ergonomics and Neuro Ergonomics for smooth and speedy diffusion of AVs	Nodes\\Influencing Factors Affecting AD Adoption\User Trust and HMI Fators _ Key Determinants\Ergonomics and Neuro Ergonomics	0	3	4
Feedback	Significance of AV feedback system to the AV Driver	Nodes\\Influencing Factors Affecting AD Adoption\User Trust and HMI Fators _ Key Determinants\Feedback	0	4	7
Human and AI Mental Model	In order to rightly use the system, the user mind need to figure out the system functions and competencies for assimilation. Similary AV need to tune its Artificial	Nodes\\Influencing Factors Affecting AD Adoption\User Trust and HMI Fators _ Key Determinants\Human and AI Mental Model	0	6	18
Situational Awareness	A system agent continuously providing output and behaving like senses. The SA is	Nodes\\Influencing Factors Affecting AD Adoption\User Trust and HMI Fators _ Key Determinants\Situational Awareness	0	5	8

	the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future				
Training	To improve the user's knowledge, system training is conducted before and after first usage	Nodes\\Influencing Factors Affecting AD Adoption\User Trust and HMI Fators _ Key Determinants\Training	0	5	19
Transparency and Info to User	Portrayal of clear and transparent information to AV User via AV interfaces	Nodes\\Influencing Factors Affecting AD Adoption\User Trust and HMI Fators _ Key Determinants\Transparency and Info to User	0	4	5
Trust	Trust mediates relations not only between human but human and automation and is a key challenge in adoption of AVs	Nodes\\Influencing Factors Affecting AD Adoption\User Trust and HMI Fators _ Key Determinants\Trust	0	8	19

Name	Description	Hierarchical Name	Number Of Children	Number Of Sources Coded	Number Of Coding References
Key Forces Shaping Travel Behavior	In Future what will be key forces that affect and shape user choices and travel behavior relevant to driverless technology	Nodes\\Key Forces Shaping Travel Behavior	0	8	17
Participant Background	Professional and academic background of participants	Nodes\\Participant Background	0	12	12
privacy		Nodes\\privacy	0	1	1
Regulations in Interviews	Significance of Rules and Regulations for implementation of AVs	Nodes\\Regulations in Interviews	0	9	29
Smart City Concept and Wellfare of Humanity	How Driveless Technology and AVs will affect Smart City , Urban development pattersn and work	Nodes\\Smart City Concept and Wellfare of Humanity	0	4	7

Transportation System Reaction to intial AV Deployment	How we will carryout initial deployment of AVs in our Transport System and how the Transport System will react?	Nodes\\Transportation System Reaction to intial AV Deployment	0	3	3
Trust and Governance Framework	Captures Concepts Regarding Trust and Governance Framework Structure, KPIs and How to arrive at	Nodes\\Trust and Governance Framework	6	9	164
Common Definitions Taxonomies User Trust Models and Standards	Requirement of laying down universal definition of autonomy levels from human factor point of view , regulations point of vies , setting correct trust models and universal standards for testing and deployment of AVs	Nodes\\Trust and Governance Framework\Common Definitions Taxonomies User Trust Models and Standards	0	2	6
KPIs	Key Performance Indicators to measure successful deployment of AVs	Nodes\\Trust and Governance Framework\KPIs	0	9	77
Operational Design Domain ODD	ODD for AVs	Nodes\\Trust and Governance Framework\Operational Design Domain ODD	0	3	10
Testing and Deployment Framework for AVs		Nodes\\Trust and Governance Framework\Testing and Deployment Framework for AVs	0	5	30

Name	Description	Hierarchical Name	Number Of Children	Number Of Sources Coded	Number Of Coding References
Training of Drivers_Users	How training , simulations and user study affects Users driving skills in AVs? Are simulations can be an alternative to User study? How to organize training of Users theoretically and practically for their licensing as AV Driver?	Nodes\\Trust and Governance Framework\Training of Drivers_Users	1	4	9
Simulations	Significance of AVs simulation studies	Nodes\\Trust and Governance Framework\Training of Drivers_Users\Simulations	0	4	9

Two Levels from Regulations or Tech View		Nodes\\Trust and Governance Framework\Two Levels from Regulations or Tech View	0	3	5
Trust in Interviews	Significance of people trust in AVs for their successful deployment	Nodes\\Trust in Interviews	0	13	166
User Center Perspective on AD_ Significance of Real time studes	Significance of User needs and Preferences in Driverless Technology	Nodes\\User Center Perspective on AD_ Significance of Real time studes	2	6	21
Simulation Vs Naturalistic and Longitudinal Studies	Compartive Analysis of Simulated Training for Users versus Naturalitistic and Longitudinal user studies.	Nodes\\User Center Perspective on AD_ Significance of Real time studes\Simulation Vs Naturalistic and Longitudinal Studies	0	4	11
Technology Vs User Perspective and Human Factors	Which is more significant, Human Factors or Technology advancement efforts related to	Nodes\\User Center Perspective on AD_ Significance of Real time studes\Technology Vs User Perspective and Human Factors	0	5	10

Appendix D: Equations of SD Model Study - 3

(001) A= Ac+Aw Units: People
(002) a0=C0*Comfort Weight+F0*Familiarity Weight Units: 1
(003) a1=C1*Comfort Weight+F1*Familiarity Weight Units: 1
(004) a2= C2*Comfort Weight+F2*Familiarity Weight Units: 1
(005) a3=C3*Comfort Weight+F3*Familiarity Weight Units: 1
(006) a4=C4*Comfort Weight+F4*Familiarity Weight Units: 1
(007) a5=C5*Comfort Weight+F5*Familiarity Weight Units: 1
(008) abr= sr*Ac Units: People/Year abandonment
(009) Ac= INTEG (inc Ac, 2e+006) Units: People Car sharing users with a car
(010) alpha=10.4 Units: Year
(011) ant1= M1+Calibrate Trust variable Units: Dmnl
(012) ant2= M2+Calibrate Trust variable Units: Dmnl
(013) ant3= M3+Calibrate Trust variable Units: Dmnl
(014) ant4=M4+Calibrate Trust variable Units: Dmnl
(015) ant5=M5+Calibrate Trust variable Units: Dmnl
(016) ar0= Ci0/Vtot Units: 1/Year
(017) ar1=ci1/Vtotf Units: 1/Year
(018) ar2= ci2/Vtot Units: 1/Year
(019) ar3= ci3/Vtot Units: 1/Year
(020) ar4= ci4/Vtot Units: 1/Year
(021) ar5= ci5/Vtot Units: 1/Year
(022) arcs= g*PA/N*A Units: People/Year
(023) Attractiveness weight= 0.25 Units: 1 [0,1]
(024) AV0= INTEG (Ci0-cj0,4.4e+006) Units: Cars
(025) AV1= INTEG (ci1-cj1,3000) Units: Cars
(026) AV2= INTEG (ci2-cj2,300) Units: Cars
(027) AV3= INTEG (ci3-cj3, 0) Units: Cars
(028) AV4= INTEG (ci4-cj4,12) Units: Cars
(029) AV5= INTEG (ci5-cj5,0) Units: Cars
(030) Aw= INTEG (inc Aw,initial car users sharing) Units: People Car sharing users without a car
(031) Beta Ant= 0.2 Units: 1
(032) Beta LR= 0.69 Units: 1
(033) Beta SA= 0.19 Units: Dmnl
(034) Beta tr= 0.17 Units: 1
(035) birthrate deathrate=0.016 Units: Dmnl/Year
(036) C0= 0 Units: 1
(037) c01= (M1*(U1/(U1+U0))*1/alpha*AV0) Units: Cars/Year
(038) c02=AV0*1/alpha*M2*(U2/(U2+U0)) Units: Cars/Year
(039) c03=AV0*1/alpha*M3*(U3/(U3 +U0)) Units: Cars/Year
(040) c04=AV0*1/alpha*M4*(U4/(U4+U0)) Units: Cars/Year
(041) c05=AV0*1/alpha*M5*(U5/(U5+U0)) Units: Cars/Year
(042) C1=0.1 Units: 1
(043) c12=1/alpha*M2*(U2/(U1+U2))*AV1 Units: Cars/Year
(044) c13=1/alpha*M3*(U3/(U1+U3))*AV1 Units: Cars/Year
(045) c14=1/alpha*M4*(U4/(U1+U4))*AV1 Units: Cars/Year
(046) c15=1/alpha*M5*(U5/(U1+U5))*AV1 Units: Cars/Year
(047) C2=0.2 Units: 1

(048) c23=1/alpha*M3*(U1/(U1+U2))*AV2 Units: Cars/Year
(049) c24=1/alpha*M4*(U2/(U2+U4))*AV2 Units: Cars/Year
(050) c25=1/alpha*M5*(U2/(U2+U5))*AV2 Units: Cars/Year
(051) C3=0.5 Units: 1
(052) c34=1/alpha*M4*(U3/(U3+U4))*AV3 Units: Cars/Year
(053) c35=1/alpha*M5*(U3/(U3+U5))*AV3 Units: Cars/Year
(054) C4=0.8 Units: 1
(055) c45=1/alpha*M5*(U1/(U1+U5))*AV4 Units: Cars/Year
(056) C5=1 Units: 1
(057) Calibrate Trust variable=-0.3 Units: 1
(058) chh=Vtot/(N/shh) Units: Cars/household
(059) Ci0=IF THEN ELSE(new AV0>0, new AV0, 0) Units: Cars/Year
(060) ci1=c01+IF THEN ELSE(new AV1>0, new AV1, 0) Units: Cars/Year
(061) ci2=c02+c12+IF THEN ELSE(new AV2>0, new AV2, 0) Units: Cars/Year
(062) ci3=c23+c13+c03+IF THEN ELSE(new AV3>0, new AV3, 0) Units: Cars/Year
(063) ci4=c04+c14+c24+c34+IF THEN ELSE(new AV4>0, new AV4, 0)Units: Cars/Year
(064) ci5=c05+c15+c25+c35+IF THEN ELSE(new AV5>0, new AV5, 0)Units: Cars/Year
(065) cj0=c01+c02+c03+c04+c05+egr0 Units: Cars/Year
(066) cj1=c15+c13+c12+c14++erg1 Units: Cars/Year
(067) cj2=c23+c24+c25+erg2 Units: Cars/Year
(068) cj3=c34+c35+erg3 Units: Cars/Year
(069) cj4=c45+erg4 Units: Cars/Year
(070) cj5=erg5 Units: Cars/Year
(071) Comfort Weight=0.5 Units: 1
(072) cpp=Vtot/N Units: Cars/People cars per person
(073) Cv=fc*abr/Vtot Units: Dmnl/Year
(074) d0=AV0/Vtot Units: 1
(075) d1=AV1/Vtot Units: 1
(076) d2=AV2/Vtot Units: 1
(077) d3=AV3/Vtot Units: 1
(078) d4=AV4/Vtot Units: 1
(079) d5=AV5/Vtot Units: 1
(080) egr0=Vtot*Cv*AV0/Vtot Units: Cars/Year
(081) erg1= Vtot*Cv*AV1/Vtot Units: Cars/Year
(082) erg2= Vtot*Cv*AV2/Vtot Units: Cars/Year
(083) erg3=Vtot*Cv*AV3/Vtot Units: Cars/Year
(084) erg4= Vtot*Cv*AV4/Vtot Units: Cars/Year
(085) erg5= Vtot*Cv*AV5/Vtot Units: Cars/Year
(086) F0=AV0/Vtot Units: Dmnl
(087) F1=AV1/Vtot Units: Dmnl
(088) F2=AV2/Vtot Units: Dmnl
(089) F3=AV3/Vtot Units: Dmnl
(090) F4=max(0,AV4/Vtot) Units: Dmnl
(091) F5=AV5/Vtot Units: 1
(092) Familiarity Weight=0.5 Units: 1
(093) fc=Vtot/N Units: Cars/People fraction of car sharing users with car
(094) FINAL TIME = 2120 Units: Year The final time for the simulation.
(095) g=IF THEN ELSE(M5>0.4, tm, 0)+gm Units: Dmnl/Year
(096) gm=0.02 Units: 1/Year [0,1]

(097) Growth Legal readiness=0.05 Units: 1 [0,?]
(098) Growth Training=0.05 Units: 1
(099) hh=N/shh Units: household 2.2
(100) "Impact of AV1-5 sales on LR"= INTEG (ZIDZ((ci1+ci2+ci3+ci4+ci5),Vtot),0)
Units: 1
(101) inc Ac=fc*arcs-abr Units: People/Year
(102) inc Aw= abr+arcs*(fc) Units: People/Year
(103) initial car users=N*(1-initial fraction of people car sharing) Units: People
(104) initial car users sharing=N*initial fraction of people car sharing Units: People
(105) initial fraction of people car sharing=0.25 Units: 1

This takes into consideration the proportion of the population that are under the age of 18 and are not allowed to drive (won't own a vehicle). There are (2021) 1.1 million people estimated to be under the age of 18 in New Zealand. For the model, we do not model changes in the structure of the population (age), so we assume that for the 100 year simulation, the proportion of children (under the age of 18) will remain one quarter.

(106) initial legal readiness=0.69 Units: 1
(107) Initial N=5.1e+006 Units: People
(108) INITIAL TIME = 2021 Units: Year The initial time for the simulation.
(109) initial training=0.17 Units: 1
(110) Initial vehicles=4.4e+006 Units: Cars
(111) ip0=18315 Units: NZD
(112) ip1=23808.4 Units: NZD
(113) ip2=36630.2 Units: NZD
(114) ip3=109891 Units: NZD
(115) ip4=366302 Units: NZD
(116) ip5=915758 Units: NZD
(117) irp0=1 Units: NZD
(118) irp0 0=1 Units: NZD
(119) irp1=914.53 Units: NZD
(120) irp2=4578.77 Units: NZD
(121) irp4=183151 Units: NZD
(122) irp5=457879 Units: NZD
(123) legal readiness beta=0.571 Units: 1
(124) LR=(1/(1+EXP(-Growth Legal readiness*(Time-start year)/TIME STEP)))^(1/initial legal readiness)*"Impact of AV1-5 sales on LR"Units: Dmnl [0,?] safety security and privacy and comfort(1/(1+exp(-kx))^a
(125) LR weight=0.25 Units: 1 [0,1]
(126) M1=(1/(1+EXP(-Technology growth factor*(Time-start year)/TIME STEP)))^(0.69) Units: Dmnl
(127) M2=(1/(1+EXP(-Technology growth factor*(Time-start year)/TIME STEP)))^(0.87) Units: Dmnl
(128) M3=(1/(1+EXP(-Technology growth factor*(Time-start year)/TIME STEP)))^(5.5) Units: Dmnl
(129) M4=(1/(1+EXP(-Tech growth factor for AV4*(Time-start year)/TIME STEP)))^(3.2)Units: Dmnl
(130) M5=(1/(1+EXP(-Technology growth factor*(Time-start year)/TIME STEP)))^(6) Units: Dmnl
(1.51)
(131) N= INTEG (Net change N,Initial N) Units: People

(132) nd=N-Aw Units: People
(133) ndt=DELAY FIXED(N-Aw, 1, 6.375e+006) Units: People
(134) Net change N=N*(birthrate deathrate) Units: People/Year
(135) new AV0=IF THEN ELSE(Vtot<(N-Aw)*fc, (nd-ndt)*fc, 0)*AV0/Vtot/TIME STEP Units: Cars/Year
(136) new AV1=IF THEN ELSE(Vtot<(N-Aw)*fc, (nd-ndt)*fc*AV1/Vtot/TIME STEP, 0) Units: Cars/Year
(137) new AV2=IF THEN ELSE(Vtot<(N-Aw)*fc, (nd-ndt)*fc, 0)*AV2/Vtot/TIME STEP Units: Cars/Year
(138) new AV3=IF THEN ELSE(Vtot<(N-Aw)*fc, (nd-ndt)*fc, 0)*AV3/Vtot/TIME STEP Units: Cars/Year
(139) new AV4=IF THEN ELSE(Vtot<(N-Aw)*fc, (nd-ndt)*fc, 0)*AV4/Vtot/TIME STEP Units: Cars/Year
(140) new AV5=IF THEN ELSE(Vtot<(N-Aw)*fc, (nd-ndt)*fc, 0)*AV5/Vtot/TIME STEP Units: Cars/Year
(141) np2=(p2/(ip2+irp2)) Units: 1
(142) np3=(p3/(ip3+rp3)) Units: 1
(143) np4=(p4/(ip4+irp4)) Units: 1
(144) np5=(p5/(ip5+irp5)) Units: 1
(145) npo=(p0/(ip0+irp0)) Units: 1
(146) p0=ip0*(1-(1/(1+EXP(-0.02*(Time-start year)/TIME STEP)))^(5)) Units: NZD
(147) p1=ip1*(1-M1) Units: NZD
(148) p2=ip2*(1-M2) Units: NZD
(149) p3=ip3*(1-M3) Units: NZD
(150) p4=(ip4-Subsidy effect on AV4 price)*max((1-M4),0) Units: NZD
(151) p5=ip5*(1-M5) Units: NZD
(152) PA=N-A Units: People
(153) PAd=N-A Units: People
(154) pn1=(p1/(ip1+irp1)) Units: 1
(155) Price weight=0.25 Units: 1 [0,1]
(156) ptd=10000 Units: km/People 10000km per year
(157) rp3=64102.8 Units: NZD
(158) SA1=M1+Calibrate Trust variable Units: Dmnl
(159) SA2=M2+Calibrate Trust variable Units: Dmnl
(160) SA3=M3+Calibrate Trust variable Units: Dmnl
(161) SA4=M4+Calibrate Trust variable Units: Dmnl
(162) SA5=M5+Calibrate Trust variable Units: Dmnl
(163) SAVEPER = TIME STEP Units: Year [0,?]The frequency with which output is stored.
(164) shh=2.2 Units: People/household
(165) sr=0.05 Units: Dmnl/Year [0,1]
(166) start year=2020 Units: Year
(167) Subsidy effect on AV4 price=0 Units: NZD [1,10]% of price of AV4 subsidised?
(168) T1=(SA1*Beta SA+ant1*Beta Ant+Beta LR*LR+Beta tr*tr) Units: Dmnl
(169) T2=(SA2*Beta SA+ant2*Beta Ant+Beta LR*LR+Beta tr*tr) Units: Dmnl
(170) T3=max(SA3*Beta SA+ant3*Beta Ant+Beta LR*LR+Beta tr*tr,0) Units: Dmnl
(171) T4=max(0,SA4*Beta SA+ant4*Beta Ant+Beta LR*LR+Beta tr*tr) Units: Dmnl

(172) T5=max(0,SA5*Beta SA+ant5*Beta Ant+Beta LR*LR+Beta tr*tr) Units: Dmnl
(173) tc=td/Vtot Units: km/Cars
(174) td=ptd*N Units: km
(175) Tech growth factor for AV4=0.1 Units: 1
(176) Technology growth factor=0.05 Units: 1 [0,?]
(177) TIME STEP = 1 Units: Year [0,?] The time step for the simulation.
(178) tm=0.1 Units: 1/Year
(179) tr=(1/(1+EXP(-Growth Training*(Time-start year)/TIME STEP)))^(1/initial training)Units: Dmnl
(180) Trust beta=0.25 Units: 1
(181) Trust weight=0.25 Units: 1 [0,1]
(182) U0=npo*0.5+a0*0.5 Units: Dmnl
(183) U1=pn1*Price weight+a1*Attractiveness weight+LR*legal readiness beta*LR weight+T1*Trust beta*Trust weight Units: Dmnl
(184) U2=np2*Price weight+a2*Attractiveness weight+Trust beta*T2*Trust weight+LR*legal readiness beta*LR weight Units: Dmnl
(185) U3=np3*Price weight+a3*Attractiveness weight+Trust beta*T3*Trust weight+LR*legal readiness beta*LR weight Units: Dmnl
(186) U4=np4*Price weight+a4*Attractiveness weight+Trust weight*T4*Trust beta+legal readiness beta*LR*LR weight Units: Dmnl
(187) U5=np5*Price weight+a5*Attractiveness weight+T5*Trust beta*Trust weight+LR*legal readiness beta*LR weight Units: Dmnl
(188) Vtot=AV0+AV1+AV2+AV3+AV4+AV5 Units: Cars