Framework for the integration of an advanced manufacturing paradigm and methodologies in New Zealand manufacture-to-order SMEs

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Abstract

In the early 1990's the Toyota Production System has revolutionised the thinking of manufacturing. Methodologies like Kanban and Single Minute Exchange of Dies are promising cost reductions and productivity increases but so far only a few New Zealand (NZ) companies have successfully implemented some of these methodologies. Further research revealed that not only Toyota's production system but also its whole management system, its product development and its culture contribute to the success of the company being today the largest car manufacturer of the world. Without a doubt, this holistic approach also known as Lean Production coins the current understanding and paradigm within the context of manufacturing and operations. The adaptation and implementation of these Lean principles have successfully found its way into other areas like the health sector and administration processes. However there is still a lack of research regarding manufacture-to-order environments and the adaptation to the requirements of small and medium enterprises (SME). Besides there is hardly any research known, which analyses the influence and role of the national culture during such a Lean transformation.

The main objective of the thesis is the development of a Lean transformation framework for manufacture-to-order companies under consideration of their national and organisational context. The focus lies on NZ SMEs that operate in a manufacture-to-order environment characterised by a high degree of variability and by low volumes.

In order to assure the practicality of the framework for NZ based industry, the research project followed a case study approach. Five cases are explored. In two of the case studies the researcher was actively involved during the implementation and therefore could verify by iterative interaction with the industry partners the practicality of the developed Lean transformation framework. Data about the leadership profiles, the degree of variability, the level of the integration of Lean methodologies and techniques, the sequence of implementation, and of the actual performance development was collected and analysed by triangulation.

For NZ companies who intend to integrate Lean principles and methodologies, the Lean transformation framework can provide valuable guidance on their way to a learning and continuously improving organisation.

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.

Markus L. Stamm

Research ethics:

The ethics application for this research project was approved by the Auckland University of Technology Ethics Committee, AUTEC Reference number 09/218.

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I dedicate this work to my parents.

Auckland, September 2011 Markus L. Stamm

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Abbreviations

AR	Action Research
ACM	Automotive Components Manufacturer
BIC	Best in Class
CLD	Causal Loop Diagram
CNC	Computer Numerical Control
CI	Continuous improvement
CSF	Critical success factor
DMAIC	Define Measure Analyse Improve Control
ETO	Engineer-to-order
EFQM	European Foundation for Quality Management
GDP	Gross Domestic Product
GNI	Gross National Income per capita
IDV	Individualism
IMVP	International Motor Vehicle Program
JIT	Just in Time
LEI	Lean Enterprise Institute
LTO	long-term orientation
MTS	Manufacture-to-stock
MAS	Masculinity
MRP	Material Resource Planning
NFWO	New Forms of Work Organisation
NZ	New Zealand
NZTE	New Zealand Trade and Enterprise
OPF	One Piece Flow
OM	Operations Management
OECD	Organisation for Economic Cooperation and Development
OEE	Overall Equipment Effectiveness
POLCA	Paired-cell Overlapping Loops of Cards with Authorization
PDI	Power distance
QC	Quality Control
SMED	Single Minute Exchange of Dies
SME	Small and Medium Enterprise
SPC	Statistical Process Control
SD	System Dynamics
SPK	System of Profound Knowledge
TOC	Theory of Constraints
TPM	Total Productive Maintenance
TQC	Total Quality Control
TQM	Total Quality Management
TMC	Toyota Motor Corporation
TPS	Toyota Production System
UAI	Uncertainty avoidance
VSM	Value Stream Mapping
WIP	Work in Process
WW	World War

1 Introduction

1.1 Problem statement

"Over long periods of time, small differences in rates of productivity growth compound, like interest in a bank account, and can make an enormous difference to a society's prosperity. Nothing contributes more to reduction of poverty, to increases in leisure, and to the country's ability to finance education, public health, environment and the arts." (Blinder & Baumol, 2000)

New Zealand ranked in the latest OECD study regarding annual growth in Gross Domestic Product (GDP) per hour worked as fourth last of the 30 OECD countries. This widely used measure represents an established indicator for a nation's productivity being considered to be a key source for economic growth, competitiveness and hence sustainable wealth (Organisation for economic cooperation and development (OECD), 2008). The New Zealand Government has previously set policies and strategies with the specific aim of achieving a place in the top quartile of OECD productivity rankings (see the Growth and Innovation Framework, Ministry of Economic Development, June 2005). Projects like the Workplace Productivity Working Group (WPWG) (Workplace Productivity Working Group (WPWG), 2004), the 'Manufacturing+ Report' (The Vision Group & M. Pratt (Chairperson), 2006) and the Aichi project initiated by New Zealand Trade and Enterprise (NZTE) (Edmond, 2007) focus on productivity improvements within the New Zealand context. There is only little research which impact New Zealand's characteristics regarding its size, culture, economic structure and geography have on the nation-wide productivity efforts. Additionally mainly because of its size, New Zealand has a conspicuous high percentage of small and medium companies (SME) that account for about 60% of employment (Massey, 2007) and build as suppliers also the outsourced 'backbone' for larger companies. Researchers have concluded over the last two decades that SMEs require individual and customised approaches to achieve business excellence and productivity improvements ((Massey et al., 2005), (Jonas Hansson, 2001), (Hill & McGowan, 1999), (Ghobadian & Gallear, 1996), and others). Particular factors of SMEs like for example informal processes (Zink, Koetter, Longmuss, & Thul, 2008), an 'organic' corporate structure

(Ghobadian & Gallear, 1997), lack of enterprise data, and dynamic business results exacerbate consistent and coherent research activities.

In the area of specialised manufacturing, which includes industries like automotive, heavy and light engineering, plastics, aviation, marine, and others, NZTE has been assisting to achieve sustainable global competitive advantages. One of the initiatives funded by NZTE has been the already mentioned Aichi project, which guides businesses through the lean manufacturing process (Edmond, 2007). This project started with eight companies in 2005 in collaboration with a consultant who was co-funded by NZTE. However four companies dropped off after a short while. The obvious initial success in the remaining four companies led to wider Lean implementation efforts in other companies and industries. Today, there are more than 20 companies in the 'Aichi' network. As the benefits in terms of productivity and social contribution of a Lean transformation have been revealed to be obvious (M. Wilson, Heyl, & Smallman, 2008), the next challenge lies in finding the more systematic, efficient and sustainable ways for future companies, who are willing to start their 'Lean journey'. Hereby it is important to take into account the specific requirements of organisational changes within New Zealand's geographical circumstances, its cultural aspects and economic, industrial, and corporate structures. Flynn and Saladin concluded in a study examining the correlation of scores of the Baldrige award, as one example for a productivity improvement initiative, between different nations that "national culture plays a strong role in the effectiveness of the Baldrige construct" and that "there is not a universal model for performance excellence and that practices and approaches should be adapted to the local culture" (Flynn & Saladin, 2006, p.599). Besides there could not be found many research studies regarding the sustainability of Lean transformations over a period longer than two years. Therefore the lessons learned of the first companies of the Aichi project need to be determined.

Generally Lean Production evolved in the automotive industry in Japan (Toyota) and has been successfully adopted in many other areas (healthcare, hospitals, administration, etc.). Though there is still a lack of research in the area of low volume and high variability and project environments (Lander & Liker, 2007) (Srinivasan, Jones, & Miller, 2004), where many SMEs as manufacture-to-order companies operate.

“Productivity isn’t everything, but in the long run it is almost everything. A country’s ability to improve its standard of living over time depends almost entirely on its ability to raise its output per worker.” (Krugman, 1994)

1.2 Research objectives and definitions

1.2.1 Main research objective

The WPWG, which was established to determine ways of improved workplace productivity, stated in its report (Workplace Productivity Working Group (WPWG), 2004) four types of actions:

1. Raising awareness: to create the awareness of the importance of workplace productivity and the basic knowledge for improvements
2. Diagnostic tools: to assess current business performance and derive concrete measures to improve the practices
3. Implementation – assistance and support for firms to decide what specific actions to take and the best way to put these in place
4. Research and Evaluation – collecting and developing the knowledge base about workplace productivity and which business practices are successful.

These four actions build the basis for the seven drivers of workplace productivity: building leadership, creating productive workplace cultures, encouraging innovation and the use of technology, investing in people and skills, organising work, networking and collaboration, and finally measuring what matters.

This thesis aims at contributing in the actions 3 and 4 with a special focus on New Zealand’s manufacturing SMEs.

The main objective of this thesis is the development of a customised transformation framework to sustainably implement advanced manufacturing paradigms and methodologies in NZ SMEs in order to increase their value creation and productivity. The main focus lies on SMEs in the manufacture-to-order and one-of-a-kind environment.

Hence, advanced manufacturing paradigms[1] need to be determined. Further leverage points respectively constraints for higher productivity that are outside the manufacturing system are to be explored within case studies.

1.2.2 Definition of the term framework

Before elaborating on the elements and interconnections of the framework, the term itself needs further explanation. According to Popper a framework represents a set of basic assumptions or fundamental principles in which discussion and actions can proceed (Popper, 1994). A further function of a framework is to provide "a clear picture of the leadership goal for the organisation and should present key characteristics of the to-be style of business operations" (Aalbregtse, Heijka, & McNeley, 1991). A conceptual framework is seen by Botha as a model "to provide a perspective or focus in order to interpret phenomena" relevant to the research object (Botha, 1989). Therefore a conceptualisation including a logical structure may support management in their Lean transformation by giving guidelines which decisions and activities need to be carried out. Further, Struebing and Klaus stress that a structured implementation plan for a TQM transformation might be even more important in small companies than in large ones because of the limited personnel and time resources (Struebing & Klaus, 1997).

Further, more general requirements with regards to the framework itself are determined by Yusof and Aspinwall who developed a framework for the implementation of TQM for SMEs. A simple framework will be better for a small business because of the lack of resources (S. M. Yusof & E. Aspinwall, 2000). Yusof proposes characteristics that need to be considered for the development of an implementation framework:

- systematic and easily understood
- simple structure
- clear links between elements which are presented
- general enough to suit different contexts
- represent a road map and a planning tool for implementation
- answers 'how to implement?', and not 'what is' TQM?
- implementable

[1] The definition of manufacturing paradigm is described in chapter 1.2.4.

As an example of existing frameworks, Figure 1 shows Zayko's Lean operating system design framework. The framework gives a sequential guidance starting at a concept level which is subdivided into the scope and design phase and then leading over to a configuration level that contains the phases of engineering the actual value stream and of reflection and continuous improvement (Zayko, 2006). Hence it provides a sequence from a rough conceptual level to a more detailed configurational level, but it lacks in the opinion of the author details how to approach the individual phases and which techniques to consider. The framework implies by the sequence that the more essential leverage points to reduce variability and therefore to improve the manufacturing system lie within the rationalisation of the product landscape and the streamlined design of the supply chain.

Figure 1: Lean Operating System Design Framework (Zayko, 2006)

1.2.3 Objectives of the transformation framework

The developed transformation framework should provide guidance on which elements and functions need to be considered in order to implement advanced manufacturing paradigms and methodologies out of a managerial perspective (owner and CEO level). Hence it should incorporate the main principles of advanced production methodologies taking into account the specific prevailing contextual factors that are discussed in chapter 3.2. Further in a more detailed version, the framework makes suggestions which techniques might support the main elements of the framework. However it will not directly give advice about the sequence of the transformation process. First of all, as the analysis of existing transformation processes and also the transformation history of the case studies will show, there is not only one way to implement Lean principles and methodologies. Secondly the framework aims at illustrating the systemic and holistic character of a Lean manufacturing system and therefore indicating a sequence within the framework might give the wrong impression that the elements can be implemented separately and independently. But in order to assist SMEs in this matter, a general transformation process is developed in chapter 5.4 based on a comprehensive literature review of existing transformation processes and on the experiences gained out of the case studies.

1.2.4 Definition of paradigms, methodologies, techniques and tools

In order to analyse and understand the evolution of manufacturing theory the author utilises the categorisation of Mingers and Brocklesby which originally was developed to structure research itself. In the opinion of the author this categorisation can be transferred into the context of manufacturing and operations management to assist with the understanding of current best practices.

Mingers and Brocklesby suggest that the world of research is separated into four levels, (1) paradigms, (2) methodologies, (3) techniques, and (4) tools (John Mingers & Brocklesby, 1997). Kuhn defines a paradigm as “an entire constellation of beliefs, values and techniques, and so on, shared by the members of a given community” (Kuhn, 1996). According to Mingers and Brocklesby a research paradigm can be understood as “a very general set of philosophical assumptions that define the nature of possible research and intervention” (John Mingers & Brocklesby, 1997).

Hence a paradigm in the context of research can be seen as a view of reality embedded in the three philosophical dimensions:

1. Ontology, which are the types of entities assumed to exist and the nature of that existence;
2. Epistemology, which are the possibilities of, and limitations on our knowledge of the world; and
3. Praxeology, which is how we should act in an informed and reflective manner;

A fourth dimension is mentioned by Mingers as axiology which is what is valued or considered good (J. Mingers, 2003). This is incorporated in what the purposes of the model are, and who (facilitator, analyst, participant) develops and uses the model.

Each distinct set of these three dimensions defines a paradigm. These elements of a paradigm which are usually explained in a paradigmatic discussion about research are in the opinion of the author also applicable in the context of operations management in order to analyse the current understanding of best practices in manufacturing. A complementary broader definition that incorporates areas outside of research can be added from Gummesson who defines a paradigm as a world view representing people's value judgements, norms, standards, frames of reference, perspectives, ideologies, myths, theories, and so forth. Anything in fact that governs their thinking and action (Gummesson, 1991).

For the purpose of this thesis a manufacturing paradigm can be understood as the (maybe hidden) business assumptions that led to the characteristics and nature of current known manufacturing methodologies. Those assumptions have – like in the world of research – an ontological and epistemological foundation.

If we go down a level in perspective, within a certain paradigm a specific set of methodologies can develop. A methodology is a structured set of guidelines or activities to assist people in undertaking research or intervention (John Mingers & Brocklesby, 1997). A methodology is also viewed as the principles of method (Checkland, 1999). An important point to note is that a methodology may develop from within a certain paradigm, and will therefore embody the philosophical assumptions and principles of that paradigm. Just as a paradigm can have a set of methodologies, each methodology in turn can be decomposed down to a set of techniques. Therefore Total Quality Control (TQC), Total Quality Management (TQM), Theory of Constraints (TOC), Six Sigma and Lean Production are defined in this work as methodologies.

A technique is a specific activity with a clear and well-defined purpose (John Mingers & Brocklesby, 1997). Examples of techniques include control charts (TQC), the five focusing steps (TOC), or Single Minute Exchange of Dies (SMED) (Lean Production). Techniques can also be decomposed into lower level tools that are used within it. At the 'lower' sub-level a tool is an artefact that can be used to perform a certain technique. For example, statistical analysis software used when performing statistics, or a SD software package used when performing SD modelling are artefacts that may be appropriate for a specific technique.

It needs to be emphasised that the relation between the different levels of categorisation is multidirectional and self-influential. For example within the Toyota Production System specific techniques like Kanban or SMED developed. By further advancing these techniques, the overall effect of low inventory on flow and the coherence with short setup times became more obvious and a more integral part of the deducted management strategies.

1.3 Structure of thesis

The first chapter of the thesis introduces the problem and presents the research objectives. Further it gives an overview of the research framework.

Chapter 2 explains the research design and the research methodology. The research questions and hypotheses are presented. Afterwards the dominant methodology of case study research is specified and the followed research process is outlined. Concluding, the research limitations are discussed.

In chapter 3 the theoretical background is determined. Firstly the contextual factors of New Zealand and of SMEs are explored. Chapter 3.3 analyses the existing manufacturing and operations theory. After describing the relationship to flow systems, the role of variability, the differences between push and pull systems and after classifying the term 'manufacture-to-order', the prevailing methodologies of Total Quality Management, Theory of Constraints, Six Sigma and Lean Production are analysed and the essential principles and methodologies are extracted. This compilation outlines the current understanding of best practices in the context of manufacturing methodologies and hence sketches the current prevailing manufacturing paradigm.

Chapter 4 systematically presents data that resulted of the five case studies. The background of each case study is described and a detailed overview of the Lean transformation history is presented. In addition the development of the performance of each case study over the period of their Lean transformation is highlighted. In chapter 4.8 in a triangulation of the qualitative and quantitative data, the relationship between the leadership profile, the degree of variability, the development of performance, and the level of integration of Lean methodologies is analysed.

The insights of the theoretical chapter 3 and the practically oriented chapter 4 lead to the development of the Lean transformation framework and correspondent transformation process which are elaborated in chapter 5.

Chapter 6 specifies the discussion about the presented transformation framework by its practical validation within the case studies. Further the research questions are revisited and discussed.

In chapter 0 the most important results of the thesis are summarised and relevant conclusions are drawn. Hereby major recommendations are formulated and the specific contributions to the research area are presented. The thesis concludes with an outlook of future research that is related to this work.

1.4 Overview of the research

Field of research	The main field of research is the NZ specialised manufacturing industry with a special focus on two longitudinal case studies. Based on three further observational case studies a broader field of research covers manufacture-to-order companies.
Object of research	The main object of research is the process and methodology how NZ SMEs in a manufacture-to-order environment embrace and implement advanced manufacturing paradigms, respectively principles, and its derived methodologies.
Motivation for the research	Motivation for the research is on the one side the very high pressure of international competition the NZ specialised manufacturing industry is facing and on the other side the perception that the mentioned advanced manufacturing paradigms and methodologies have not been widely used in NZ averaged-sized manufacturing companies.
Crucial influencing factors of the investigation	The research outcome is mainly determined by the interdependence on how the main case study companies as representatives of a NZ manufacture-to-order SMEs perceive the current manufacturing paradigm and how they consequently adopt it within their given context. Hence the result of this research might be influenced by the general openness of NZ companies to adopt new management paradigms and methodologies.
Objective of the research	The main objective of this thesis is the development of a customised transformation framework to sustainably implement advanced manufacturing paradigms and methodologies in NZ SMEs in order to increase their value creation and productivity. The main focus lies on SMEs in the manufacture-to-order and one-of-a-kind environment.

2 Research design and methodology

This chapter presents the methodological framework that has been used to study advanced manufacturing paradigms in the context of New Zealand small and medium enterprises, and provides justification for the selected research design.

Firstly, prevailing research paradigms are discussed in the context of the research problem and research questions of this study. Secondly, the philosophical position of the research is elaborated to clarify the justification for the multi-methodological research approach that was developed.

The term research methodology is to be understood as "the combination of techniques used to enquire into a specific situation" (Easterby-Smith, Thorpe, & Lowe, 2002). Hence, research methodology refers to the overall approach to the research process from the theoretical groundwork to the collection and analysis of data. The research methodology in this study is mainly a combination of the theory-building case study approach by Eisenhardt (Eisenhardt, 1989) and the action research approach (Kurt Lewin, 1946) (Coughlan & Coghlan, 2002). The selected research methodology can be categorised under contingency research which enables to pay specific attention to the contextual factors that might influence the use and performance outcome of operations management (OM) practices (Sousa & Voss, 2008). Sousa and Voss further argue that contingency research can provide guidelines for the selection of the set of OM practices that is most appropriate for a given organisational context and hence, it might also provide valuable insights for practitioners.

A theoretical model for the integration of advanced manufacturing paradigms (Lean transformation model) is developed by continuous interaction with the action research partners (see Figure 2). The action research methodology is explained more in detail in chapter 2.3.1. Besides, the development of the Lean transformation model will be supported by three additional observational case studies with very low involvement (see chapter 2.3.3) and insights resulting out of discussions with international Lean practitioners in internet forums, the discussion and observation of Lean practitioners of the Aichi network, and discussions with academic Lean experts. The applied data collection methods are mainly historical data analysis (e.g. performance data), participant observations, and interviews in combination with questionnaires.

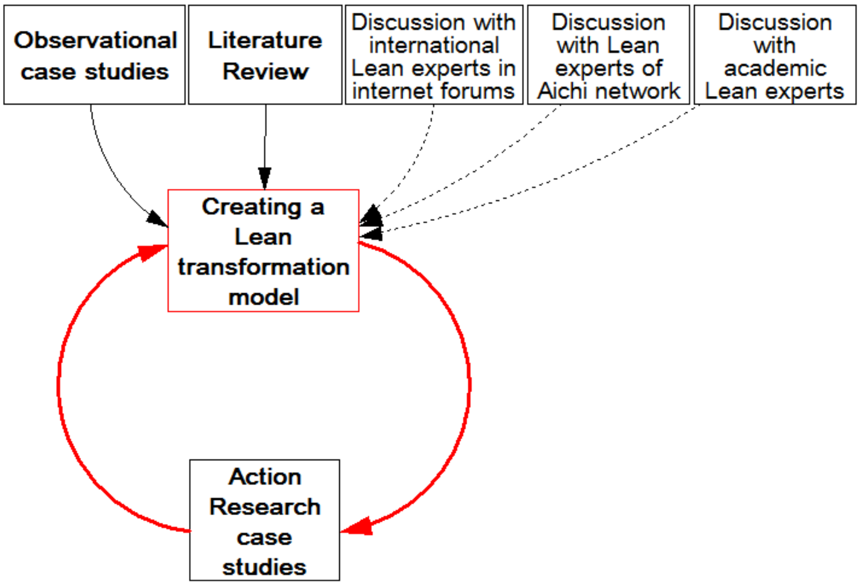

Figure 2: Concept of research design

2.1 Research questions and hypotheses

Figure 3 illustrates the relationship between the three main research questions and the two qualitative hypotheses of this thesis. In between there are also shown sub-questions that serve as additional guidance for the research.

Research question A addresses the contextual factors of New Zealand and of SMEs and how those factors are expected to influence the implementation of advanced manufacturing paradigms and methodologies. Therefore New Zealand's economy with a special focus on the manufacturing industry, the geography and especially New Zealand's culture is to be analysed and potential influential factors for the adaptation to advanced manufacturing methodologies are to be determined.

Question B is the central research question of this thesis. By asking how manufacturing paradigms and methodologies can be integrated, the practical and industry-oriented purpose of this research is emphasised. The focus is on the exploration, analysis and development of a methodological approach that assists NZ SMEs in the integration and adaptation of advanced manufacturing paradigms and methodologies. Hence an inductive exploratory research approach based on several case studies is chosen and is explained in the following chapter. The focus on manufacture-to-order companies that generally operate in a high variability low volume environment is addressed in research question C which needs to be seen as an extension of question B.

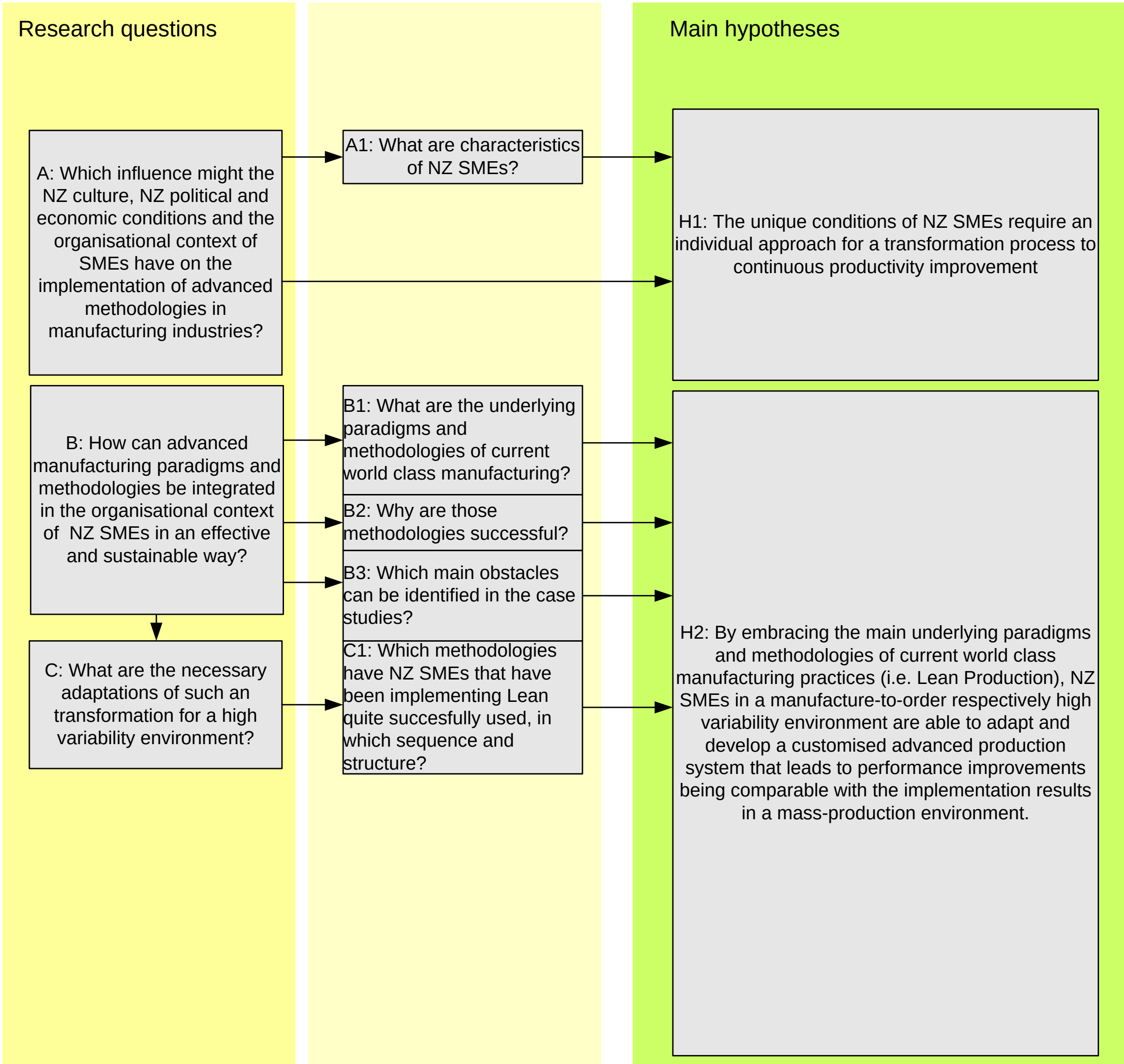

Figure 3: Research questions and hypotheses

In addition two research hypotheses are formulated which are qualitatively evaluated by a discussion of the research questions and of the major insights of the case studies in the chapters 6 and 0.

The following chapter addresses the theoretical perspectives on the research project and defines the research's philosophical position.

2.2 Theoretical perspectives on research

In order to enable the creation and further development of scientific knowledge, the philosophy of science examines the theories that are available to the research community (Gray, 2004). The philosophy of science ultimately addresses the question of how scientists should conduct research based on the understanding of the nature of knowledge. Differences within theoretical perspectives are mainly in the diverse ways how reality can be perceived and how knowledge can be derived based on that perception. These dissimilarities also affect the role of the researcher and the research methods (Gray, 2004). The boundaries between existing research paradigms can cause confusion and might become bewildering due to the inconsistent or even contradictory terminology applied to them (Bryman & Bell, 2007). However in the opinion of the author, any researcher has to be aware of the main theoretical perspectives of the existing research paradigms under which scientific knowledge has been developed and created through centuries. In general positivism and interpretivism are the main paradigms that have developed and coined the Western scientific community (Silverman, 1998) (Gray, 2004). It needs to be mentioned that interpretivism is considered by many authors as synonymous to the phenomenological approach confirming the existence of an ambiguous and not clear terminology (Solem, 2003) (Collis & Hussey, 2003). Within this study the author adopts Gray's categorisation of research paradigms (Gray, 2004). Gray lists phenomenology as well as realism, symbolic interactionism, hermeneutics and naturalistic inquiry as examples for interpretivism. The following two sections present the two prevailing research paradigms and the implications to knowledge development and creation.

2.2.1 Positivism

The essential component of positivism lies within the perception of reality as external and objective. Hence, positivists argue that knowledge can be constructed by applying the methods of the natural sciences to the study of social reality (Lee & Baskerville, 2003) (Bryman & Bell, 2007). This argument conditions that reality is available objectively and externally and therefore can be and has to be measured through objective methods rather than being inferred subjectively through sensation, reflection or intuition (Easterby-Smith et al., 2002). Further for positivists, reliable knowledge is created from the observation of phenomena and should be utilised in order to demonstrate the truth or falsity of hypotheses (Easterby-Smith et al., 2002). Knowledge is considered as valid and reliable when it is genuinely based on observations which are used to test theories or provide material for the development of laws (Silverman, 1998) (Bryman & Bell, 2007).

The positivistic approach represents almost a dichotomy to the views of interpretivism which states that social research should differentiate between the study of human behaviour and the natural order.

2.2.2 Interpretivism

Davidson defines interpretisvism as "accepting as valid knowledge well justified different interpretations of the same social phenomenon" (Davidson, 1992). In other words, a certain phenomenon can be reasoned in more than one way and the explanations depend on different interpreters. Indeed, some authors argue that interpretivism emphasises the phenomenon in its context. Hence, the researcher's individual experiences and context might generate different understandings and results. In this case however, there is a strong chance of researcher bias and thus concerns with regards to reliability are to be diligently addressed (Babbie, 2009) (Easterby-Smith et al., 2002). Easterby-Smith terms the recognition of the contribution of the individual and consequently the inherent subjectivity in the interpretation of social phenomena as social constructionism.

Phenomenology as a subcategory of interpretivism is the study of phenomena in their natural environment, together with the acknowledgement that scientists cannot avoid affecting those phenomena studied. Proponents for phenomenology argue that social and management sciences are socially constructed and therefore subjective. In such a social construct, it is difficult for the researcher to remain objective during the research (Easterby-Smith et al., 2002). Further, phenomenologists contend that the phenomenon at hand can only be fully understood through the subjective interpretation of and intervention in reality. This is in strong contrast to positivism where hypotheses and theories are tested whereas as phenomenology has more a hypothesis and theory forming character.

2.2.3 The research's philosophical position: combination of both approaches

In the following chapter the author summarizes the differences and commonalities of the prevailing research paradigms and sees the need to combine both approaches in the field of production and operations management. Production and operations management is to be understood as a combination of complex technical and social systems. The interaction between the technical system and the social system within operations management is often dynamic and hence cause-effect dependencies can be difficult to be determined. Consequently the author agrees in this context with Näslund who questions the usefulness of applying only one single approach in order to advance an academic discipline. Näslund argues that if everyone in a research community conducts research with very similar research methods within one research paradigm, the discipline very likely will not evolve and results might not be useful in the eyes of the practitioner (Näslund, 2002).

Neumann elaborates within Table 1 the positivist and interpretive research paradigm and elaborates on the main differences (Neuman, 2003).

Table 1: Differences between Positivism and Interpretivism

	Positivism	**Interpretivism**
Reason for research	To discover natural laws so people can predict and control events	To understand and describe meaningful social action
Nature of social reality	Stable pre-existing patterns or order that can be discovered	Fluid definitions of a situation created by human interaction
Nature of human beings	Self-interested and rational individuals who are shaped by external forces	Social beings who create meaning and who constantly make sense of their words
Role of common sense	Clear distinct from and less valid than science	Powerful everyday theories used by ordinary people
Theory looks like	A logical, deductive system of interconnected definitions, axioms, and laws	A description of how a group's meaning system is generated and sustained
An explanation that is true	Is logically connected to laws and based on facts	Resonates or feels right to those who are being studied
Good evidence	Is based on precise observations that others can repeat	Is embedded in the context of fluid social interactions
Places for value	Science is value free, and values have no place except when choosing a topic	Values are an integral part of social life: no group's values are wrong, only different

In general theory building and testing can be approached from two directions. Some research problems and research questions require to start with abstract thinking and to connect theoretical concepts and ideas to concrete evidence found within the research object. The theoretical concepts are then evaluated and tested against the evidence at hand (deductive research approach). The second approach (inductive) begins with observations of concrete phenomena found in e.g. empirical data. Based on this evidence, the researcher tries to derive patterns and generalisations and to develop abstract and more commonly valid concepts, ideas and even laws. In research of socio-technical systems, researchers are flexible and use both approaches at various points in their studies (Easterby-Smith et al., 2002). The research project has got both deductive and inductive elements. The deductive approach is appropriate to define current manufacturing best practices, to implement them in the context of New Zealand SMEs and finally to test their effectiveness. On the other hand an inductive approach is required exploring whether within the unique NZ context an individual framework for the implementation of best practices is necessary. This explorative aspect of the research emphasizing the potential influence of the context of the research object let the author decide to follow a case study approach combining action research case studies enriched with observational case studies. The reasoning and discussion of the case study approach is explained in chapter 2.3 in more detail.

The main objective of this study is to develop a framework for the integration of an advanced manufacturing paradigm and methodologies in NZ manufacture-to-order SMEs. Hence, the development of the framework is highly dependant on the current understanding of the researcher of best practices in the context of manufacturing and how this constructed manufacturing paradigm and its methodologies and theories are perceived and recognised by the targeted industry. Thus, the conceptualisation depends on the researcher's and involved organisations' perception on the prevailing manufacturing paradigm. It is essential to investigate within the study the application of manufacturing methodologies in the context of the research object over a longer period of time in order to provide an improved understanding of the manufacturing paradigm. This view is most pertinent with the ontological assumptions of social constructionism and the epistemology of interpretivism. However the validation of the effectiveness of the framework has to be achieved by finding clear evidence for the improvement of performance parameters within the studied organisations. The performance measurement and assessment should not be influenced by the researcher's interpretation. Hence empirical evidence is collected to evaluate the relationship between the application of manufacturing methodologies and its influence on the performance of the manufacturing system. This approach keeps with the logical positivism.

Further the study also aims at finding evidence for the influence of the national and organisational culture on the implementation of the framework. Here the researcher tries to triangulate existing studies and data with the observations and objective data within his own study. With this perspective in mind the research certainly also contains a positivistic ontological component and an objectivistic stance.

As the researcher sees usefulness and relevance in both approaches for this study and research questions at hand, he agrees with a growing number of authors that argue for the combination of both research paradigms and research methods (Näslund, 2002).

The combination of research paradigms or the use of mixed methods in order to accommodate the needs of the research is called triangulation. The term is borrowed from navigation and surveying where a minimum of three reference points are taken to check an object's location (Easterby-Smith et al., 2002). Neumann lists four distinct types of triangulation (Neuman, 2003):

- Data triangulation – data is collected from different sources and/or at different times.
- Investigator triangulation – the phenomenon is researched by several researchers independently.
- Methodological triangulation – qualitative and quantitative methods of data collection are applied.
- Theory triangulation – theory is transferred from one field of research and used to explain a phenomenon in another discipline.

By using triangulation shortcomings of individual methodologies and approaches can be overcome by the appropriate combination of the divergent elements of the alternative research paradigms. Triangulation assists with identifying the most suitable methodological propositions independent of their research paradigm in order to address the research problem in the most appropriate way. Näslund mentions that the opportunity to combine both qualitative and quantitative methods provides one of the main advantages of case-based research (Näslund, Kale, & Paulraj, 2010). Seaker et al. write that the goal of this approach is to minimise method-related variance while maximising trait-related variance (Seaker, Waller, & Dunn, 1993).

As previously mentioned the following chapter discusses the suitability of case study research taking into account the exploratory and partly inductive character of the research project.

2.3 Case study research

Yin generally defines a case study as an empirical inquiry that investigates a "contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2003, p. 13). This inherently postulates that contextual conditions might have a significant influence on the phenomenon of study. Besides Yin adds to his definition that a case study addresses the research need of having multiple variables of interest by relying on several sources of evidence. Therefore the case study needs to be seen as a research strategy that comprises a holistic method covering the logic of design, data collection techniques, and specific approaches to data analysis (Yin, 2003).

Case studies are thought better suited than surveys for investigating organisational context (Yin, 1994). Yin also states that with special regards to small organisations long-term casework would seem more conducive to researching e.g. human resource development than surveys. Additionally Yin notes that case studies are the preferred strategy when the researcher cannot oversee the whole complexity of the research object and therefore has little control over events and when 'how' or 'why' questions are posed (Yin, 2003). This is in alignment with Humphrey and Scapens who argue that case study research can be used to gain a better understanding of dynamic business practices in their social contexts in a way that is not dominated by the managerial perspective (Humphrey & Scapens, 1996). The validity of case study research in operations management has been advocated by a number of researchers (McCutcheon & Meredith, 1993), (Meredith, 1998), (Voss, Tsikriktsis, & Frohlich, 2002). On the other hand critics often claim that case research is not 'rigorous' because many of the variables may not be mathematically quantified. Meredith argues that the scientific method is not necessarily dependent on such elements as laboratory controls, statistical controls, mathematical propositions, or replicable observations. In order to achieve rigorous research results, Meredith lists as the four requisites controlled observations, controlled deductions, repeatability, and generalisation and elaborates that those requisites are simply differently realised in case study research (Meredith, 1998). Yin argues in this context that the more functionalist approach of statistical generalisation is replaced by a more theoretical generalisation driven by logic rather than probability (Yin, 2003).

In summary by allowing to investigate "holistic and meaningful characteristics of real-life events" (Yin, 2003, p. 2), such as organisational and managerial processes or the maturation of management philosophies, the methodology of case study research was selected as the main method for this research project. Therefore this research project follows a multiple-case study approach combining two long-term action research case studies with three observational case studies. Based on the case study work this research project aims on the one hand to illustrate in a practice-oriented approach (Dul & Hak, 2008, referred to chapter 2) the usefulness of Lean Manufacturing methodologies by describing the design, implementation and evaluation of exemplary intervention in the longitudinal case studies and on the other hand at developing broader generalisations and to derive major strategies for implementing current manufacturing paradigms and Lean Manufacturing methodologies in New Zealand SMEs.

2.3.1 Action research case study

Action research (AR) is based on the active participation by those who have to carry out the work in the exploration of problems (formulated as the hypothesis) that they identify and anticipate. After investigation of these problems the researcher(s) define and implement strategies and continuously monitor their progress. Hence the researcher does not take a role as an objective observer, instead she/he actively participates in the research object which can be often according to Checkland a change process in an organisation (Checkland, 1999). The researcher elicits to which extent the implemented strategies had been exhausted and fulfilled and whether the hypothesis could be confirmed. Besides newly perceived problems can be brought to discussions resulting in further research questions (Adelman, 1993). Therefore action researchers embark on a role as external facilitators who enable change in an organisation and provide in a scientific and objective manner the opportunity of reflection. It becomes clear that AR requires an extensive understanding of the context of the research object and of the involved cases (Coughlan & Coghlan, 2002). Näslund elaborates on the intimate connection of AR to systems thinking which according to Senge can help organisations to better understand interdependency and organisational change (Näslund, 2002) (P. Senge, 1990). Greenwood and Levin link the presentations of General Systems Theory and pragmatism directly to AR. AR specifically "engages in systems-informed, pragmatic social science" (Greenwood & Levin, 1998). It is argued that AR is an appropriate research approach to deal with managerial and organisational problems which are often perceived as unstructured and difficult to define. These real-world problems are to be included in research, however "must not be forced into a traditional, structured form of research" (Näslund, 2002). Hence, the approach intends to contribute both to academic theory and knowledge and to practical action and offers by its nature a high potential of relevance to the business community. Susman and Evered conclude that as a procedure for generating knowledge, AR has a greater potential than positivist science for understanding and managing the affairs of organisations (Susman & Evered, 1978). According to Gummesson there is not always a big difference between the roles of academic research and management consultant (Gummesson, 2000). Though, Gummesson argues that researchers require more theoretical justifications, while consultants require more empirical justifications. Further consultants work under tighter time and budget constraints and the consultancy work is generally more linear – engage, analyse, act and disengage whereas AR is cyclical (see Figure 4). Action research is suitable when the research question(s) are related to describing a sequence of actions that are taking place over time in a group or organisation (Coughlan & Coghlan, 2002). It also seems to be appropriate in cases where the understanding of the process of change, development or improvement of a problem that is related to the research question (Eriksson & Kovalainen, 2008) is essential. Another mentioned limitation of AR is the lack of generalizing results, as in many AR studies only one case is analysed (Argyris & Schon, 1989). This point of critique can be weakened by having multiple cases and by applying triangulation of data collection methods to improve the overall rigor. As the researcher is by nature directly involved in her/his research, the researcher's bias and influence on the data collections, the actions, analysis and critical review is seen as one further argument opposing AR (Baskerville & Wood-Harper, 1996). However, the author elaborated in chapter 2.2.3 his paradigmatic stance that individuals will influence the system and hence he accepts the fact that the research process as well as the research outcome might be affected. In order to reduce bias of the researcher, the author decided to use methods of triangulation, exploring three further observational case studies with a low involvement and to be actively involved in two AR case studies. Members of those AR organisations actively contributed to the process of information collection, reflection and conceptualisation of new ideas and constructs.

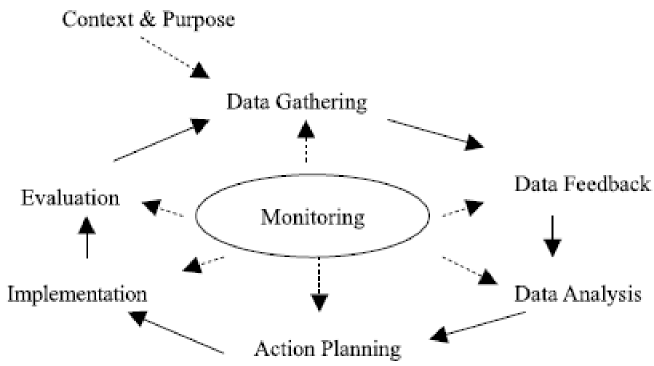

Figure 4: Action Research cycle (Coughlan & Coghlan, 2002)

Coughlan and Coghlan (see also Figure 4) present an action research cycle consisting of one pre-step in order to understand the context and the purpose of the research object, of six main steps to collect and analyse data and to plan and implement action and finally of a meta-step to monitor the progress and effects of the research (Coughlan & Coghlan, 2002). The researcher is involved in the actual organisational change process and then in order to critically review and analyse, she/he steps aside. This can be followed by further action. By following this cyclic research process together with the studied organisations, authenticity and trustworthiness will be increased due to the collaborative character of parts of the research.

Greenwood and Levin argue that General Systems Theory (GST) and Dewey's philosophical standpoint of pragmatism greatly contributes to the epistemological foundation for action research (Greenwood & Levin, 1998). They present the following core characteristics of AR:

1. AR is interwoven in its context and addresses real-life problems.

2. AR is inquiry where participants and researchers generate in collaboration knowledge by shared communication.
3. AR sees in the diversity of experience and capacities within the social setting an opportunity for the enrichment of the research-action process.
4. The meanings constructed in the inquiry process lead to social action, or these reflections on action lead to the construction of new meanings.
5. The credibility-validity of AR knowledge is evaluated based on whether taken actions solve problems (workability) and increase participants' control over their own situation.

Susman lists further six characteristics of AR that overcome deficiencies of the positivistic paradigm (Susman & Evered, 1978). Firstly AR is future oriented by generally dealing with practical problems and creating a more desirable state. Further, as there is an interdependence between the researcher and the research object or client system, the direction and the outcome of the research process is influenced by the needs and competencies of the two parties. Thirdly AR implies system development by aiming at the development of appropriate structures, a necessary system and competencies. Susman states that the focus is on generating the required communication and problem-solving procedures. The generated theory by AR is grounded in action which itself was guided by theory and the evaluation of their consequences. The action researcher needs to be aware that the developed theories for action are the product of previously taken action and hence are subject to re-examination and reformulation when entering any new research situation. It is essential that the action researcher recognizes that the process itself should ideally generate the objectives, the problem definition and the research methodology and that the implications and consequences of interventions cannot be fully anticipated ahead of time. Another characteristic of AR is that it is situational which means that observed or generated relationships between people, events and things are not free of their context and can change as the definition of the situation changes.

2.3.2 System Dynamics as an action research technique

The System Dynamics (SD) methodology and its technique causal loop diagrams (CLD) are not only one of the methodologies of the research object (advanced manufacturing paradigms and methodologies), they also serve as a research technique itself by describing the complex and dynamic interdependencies that take place in an organisational change. Lane & Oliva confirm this view by illustrating how SD modelling enables to maintain dynamic coherency in complex situations and illustrates its ability to represent causal structures (D. Lane & Oliva, 1998). Non-linear root-cause networks (mainly as CLDs and simple simulations) could be developed together with the research partners and proved to be a precious technique in the communication process with senior management to create a shared understanding of the meaning and effects of current situations (see example in Figure 5). These systemic causal loop diagrams provided the involved with a structured and visual basis for debate and reflection about the possibility of a certain intervention. Besides SD proved to be valuable in other areas of operations management, e.g. Thun et al. relate 'quality' of the process of manufacturing strategy to the behaviour of the manufacturing performance (Thun, Dekkers, & Anselmann, 2008).

A more detailed explanation of SD as a methodology and its relation to System Thinking is presented in chapter 3.3.4.

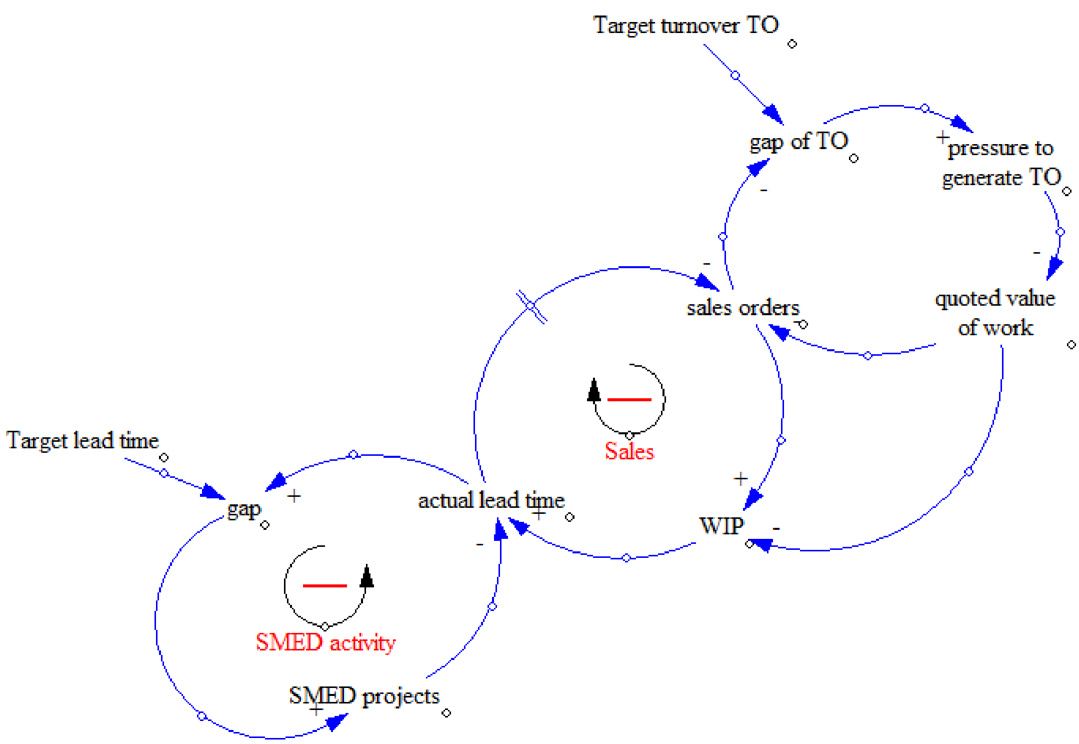

Figure 5: Example of causal loop diagram

2.3.3 Observational case studies

The observational research itself follows an open approach to exhaust the flexibility provided by this research methodology. Three case study companies were visited to collect empirical data. This allows the researcher to "…observe and monitor all aspects that seem relevant to the problem at hand." "The more unstructured the observation, the greater the potential for observer bias, but also the more flexible data collection can be with less danger of potentially significant data being missed" (Lancaster, 2005). The main focus of company visits was to explore the 'Lean transformation' history out of the owner's or manager's perspective and to collect previous results regarding performance.

2.3.4 Quality and rigor criteria

The overall research approach of this project is classified as action research which has implications on the evaluation of the quality of the research. In positivistic research there are in general four criteria evaluating the quality of the research: these four criteria are the three traditional validity aspects (constructs, internal, external) and reliability tests derived from the natural sciences. In general case study research shows based on those criteria a tendency for construct error, insufficient validation and disputable generalizability (Näslund et al., 2010). As the research project does not follow a purely positivistic paradigmatic approach, the author refers to a number of authors who advocate that a new definition of rigor might be required and hence the results of AR should not be exclusively judged by the same validity criteria with which positivistic research is judged (Herr & Anderson, 2005) (Lincoln & Guba, 1985). Hirschman advocates for example evaluative criteria such as credibility (the truthfulness of research findings) and transferability (the research findings can be applied to another situation or organisation) (Hirschman, 1986). Lincoln and Guba present further criteria, such as dependability (how consistent research outcomes can be reproduced) and confirmability (the results are reflective of the inquiry) (Lincoln & Guba, 1985). The outcomes of an AR project should be judged in terms of workability of the solutions that were developed. This connects directly to the pragmatic philosophy of AR. Workability means whether the initial problem is or is not solved by the developed actions and concepts and hence is to be seen as the first credibility challenge (Greenwood & Levin, 1998).

In order to improve the rigor of the research study, especially as the researcher is actively involved, the research process and sequence including all methods and procedures is to be clearly described. Another mean to enhance validity is the use of triangulation (Näslund et al., 2010). To overcome the researcher's influence and bias on the findings, it is important to describe her/his role and the status within the case. Additionally findings should be critically reviewed over the whole research duration in a democratic and collaborative process with members of the case organisations.

Table 2 displays a list of quality and rigor criteria including helpful questions for the evaluation of case based research in general (Miles & Huberman, 1994, pp. 277-280).

Table 2: Quality and rigor criteria and questions

Criteria	Questions
Objectivity / Confirmability	Are the study's general methods and procedures described in detail? Can we follow the actual sequence of how data were collected, processed, condensed/transformed and displayed for specific conclusion drawing? Are the conclusions explicitly linked with exhibits of displayed data? Were rival conclusions truly considered? Are the study data retained and available for reanalysis by others?
Reliability / Dependability / Auditability	Are the research questions clear, and are the features of the research design congruent with them? Is the researcher's role and status within the site explicitly described? Are the basic paradigms and analytic constructs clearly specified? Were data collected across the full range of appropriate settings suggested by the research questions?
Internal validity / Credibility / Authenticity	How content rich and meaningful are the descriptions? Was triangulation used, and did triangulation produce generally converging conclusions? Are the findings internally coherent, and are concepts systematically related? Are areas of uncertainty identified?
External Validity / Transferability / Fittingness	Are the characteristics of the original case fully described to enable adequate comparisons with other cases? Does the report examine possible threats to generalizability? Have limiting effects been described? Are the processes and outcomes described generic enough to be applicable in other settings?
Utilization / Application / Action orientation	Are the findings intellectually accessible to potential users? What is the level of usable knowledge offered? Do the actions taken actually help solve the problem? Have users of findings learned, or developed new capabilities?

2.4 Research process

This study has adopted Eisenhardt's 8-step theory building-method as it offers a systematic process and clear structure to the inductive, case-oriented approach. The process itself involves constant iteration backward and forward between steps, which can also be conducted simultaneously (Eisenhardt, 1989).

Besides this methodology is chosen because the research project is situated at the interface of business studies, industrial engineering, and social sciences and requires a new perspective on the actual understanding of Lean methodologies taking the contextual factors of a manufacture-to-order environment and the particular characteristics of NZ SMEs into account. Additionally Van de Ven and Poole (Van de Ven & Poole, 1990) confirm the practicability of this inductive theory-building case study approach especially for longitudinal change processes. According to Womack, a Lean transformation generally takes around 5 years (J.P. Womack & Jones, 2003), which certainly can already be seen as a longitudinal change process.

In the following the eight steps of the research approach are described more in detail:

I) Specifying research questions

The researcher is required to understand the background of the field and to design a research concept of iterative activities and to identify the research questions. Therefore both theoretical and practical knowledge of the field are needed (see also Figure 3 in chapter 2.1).

The design of the study concentrates on the following research questions, based on the presented research framework:

A) Which influence might the NZ culture, NZ political and economic conditions and the organisational context of SMEs have on the implementation of advanced methodologies in manufacturing industries?

B) How can advanced manufacturing paradigms and methodologies be implemented in NZ SMEs in an effective and sustainable way?

C) What are the necessary adaptations of such an implementation and its tools for a manufacture-to-order environment with a special focus on one-of-a-kind environment?

II) Selecting cases

Two types of cases being used during this research are differentiated by the level of involvement with the firm and by the methodology used. Three ‘observational’ case studies are going to include firms that are in the process of implementing Lean practices within the Aichi program. These are low involvement cases where the focus is on observing the organisation about the Lean methodologies they use and how they are adapting them. Two ‘participatory action research’ case studies are being conducted which require active and intensive involvement by the author. As this research is more related to the organisational features of industrial organisations, it is also named ‘industrial action research’ (Eriksson & Kovalainen, 2008). Work was done with a highly customised tool making company over a period of almost three years to develop the correspondent adaptations to the particular needs of a manufacture-to-order environment. The other industrial action research partner is a manufacturer of highly customised luxury motor yachts which provides the ideal case study in a one-of-a-kind environment.

All five case studies are ‘New Zealand owned and operated’ companies and therefore represent one national culture. In terms of company size (medium-sized) and product mix (high variability, low volume) all companies have comparable characteristics, which narrows down the number of rival explanations (Yin, 2003) for the understanding of the role of cultural factors.

III) Crafting research instruments and protocols

The following research instruments were used for the data gathering process in the case studies:

a. Direct regular observation in the action research (AR) case studies

b. Active involvement in continuous improvement (CI) activities in the AR case studies

c. Informal discussions with management members of the AR case studies

d. Review of internal and external documents and production data of the AR case studies and if available of the observational case studies.

e. Direct observation of Aichi meetings and informal exchange of experiences

f. Visits of observational case study sites with semi-structured interviews

g. Structured surveys addressed to the Aichi members (one survey about the impediments of a Lean implementation and one leadership survey)

h. Dynamic and complex facts of the cases are clarified with SD techniques.

The instruments of data collection are summarised in Table 3.

Table 3: Research instruments within the case studies

Type of case study	Used research instruments
Participatory action research	• Direct observation of meetings • Active involvement in CI activities • Informal discussions with management members • Review of internal and external documents and production data • Survey questionnaire exploring the leadership profile as one main indicator for organisational culture
Observational	• Direct observation during company tours • Review of internal and external documents and production data • Semi structured interviews • Survey questionnaire exploring the leadership profile as one main indicator for organisational culture

IV + V) Collecting and analysing data

The data collection and analysis regarding the AR case studies is continuously carried out, as the researcher is partly involved in the day-to-day business of the companies and has access to relevant corporate data. This allows the researcher to become an 'organisational insider' thus gaining a deep understanding of the organisation's culture and practices.

Minutes of the AICHI meetings and conferences as well as notes about the visits of the observational case studies are taken and analysed for cross-case similarities and differences.

VI) Shaping hypotheses

Out of the research questions and first analytic reflection on the gathered data main hypotheses have been developed. Qualitative and quantitative data are triangulated to provide support for these hypotheses. A replication logic (Yin, 2003) between cases with otherwise similar characteristics allows inferences about the role of culture. If stark differences are identified in socio-cultural elements of the Lean transformation between the cases, the unique culture of the organisations, among others, can serve as an explanatory variable. On the other hand, if clear communalities between cases are identified, this may be indicative of the influence of the NZ national culture.

It is important to note, however, that it is not the aim of this study to statistically test these hypotheses.

The following two main hypotheses have been developed:

1. By embracing the main underlying principles and thinking of current world class manufacturing practices (i.e. Lean Production), NZ SMEs in a manufacture-to-order respectively high variability environment are able to adapt and develop a customised Lean Production system that leads to performance improvements being comparable with the implementation results in a mass-production environment.
2. The unique conditions of NZ SMEs (see chapter 3.2) require an individual approach for a transformation process to continuous productivity improvement

VII) Reviewing theoretical literature and body of knowledge of practitioners

The review of the literature is simultaneously conducted during the whole research project.

The first part of the research consists of a literature review and interviews with Lean practitioners and experts (if required) in order to define and develop a clear understanding of the evolution and nature of current advanced manufacturing paradigms and their methodologies. This is used as the basis for the field research performed by visiting and/or working directly with the industry partners (action research).

Additionally the literature review focuses on the national and organisational characteristics or even specific cultural phenomena that could be relevant within the context of the case studies. In the context of New Zealand, there are for example studies found that explore the so-called ‘Tall-Poppy syndrome’ being characteristic for New Zealand. Hence the researcher searched for evidence of this phenomenon in the case studies and analysed if and how it affects the continuous improvement initiatives.

VIII) Reaching closure

Out of the literature review, the field research based on the observational case studies offered by the AICHI programme and two action research case studies, a theoretical model of the main underlying principles embedded in a correspondent Lean transformation framework customised for companies in a manufacture-to-order environment will be developed. This theoretical concept and the experiences within the case studies will lead to a high level transformation process intending to support and to guide owners and managers of NZ SMEs during a Lean transformation.

2.5 Research limitations

Due to the unique and complex conditions (actual legal, political and economic situation, corporate culture, leadership characteristics, etc.) of those case studies, some conclusions and developed strategies may not be transferred to another case in a copy-exactly procedure. Nevertheless the conclusions can serve as directions and as a ‘pool of potential actions’ and will provide a high level framework to embrace advanced manufacturing paradigms. Besides, during the data collection process, there are some practical limitations regarding the access to corporate data and the availability of contact persons.

Bartunek et al. present a case of a manufacturing company where the development of an integrated manufacturing system through action research did involve major changes in how the firm operated its business (Bartunek, Costa, Dame, & LeLacheur, 2000). They mention that the role of the researcher can be limited and hence difficult when suggesting potential improvement changes but not having the power to monitor and control the outcomes of the changes. As the researcher is not a part of the involved companies Bartunek’s concerns might be relevant in this case as well.

One further limitation of this research was to find enough organisations that fulfilled the selection criteria of company size (SME), type of manufacturing work (high variability low volume environment), and being in an early phase of a Lean transformation and that were willing to participate. Five companies could be found participating either as action research or observational case studies. Figure 6 illustrates that based on the small sample size of participating companies there is a limited applicability of statistical methods in order to correlate and compare collected data, for example data of the leadership survey that led to the development of the leadership profile of the case studies.

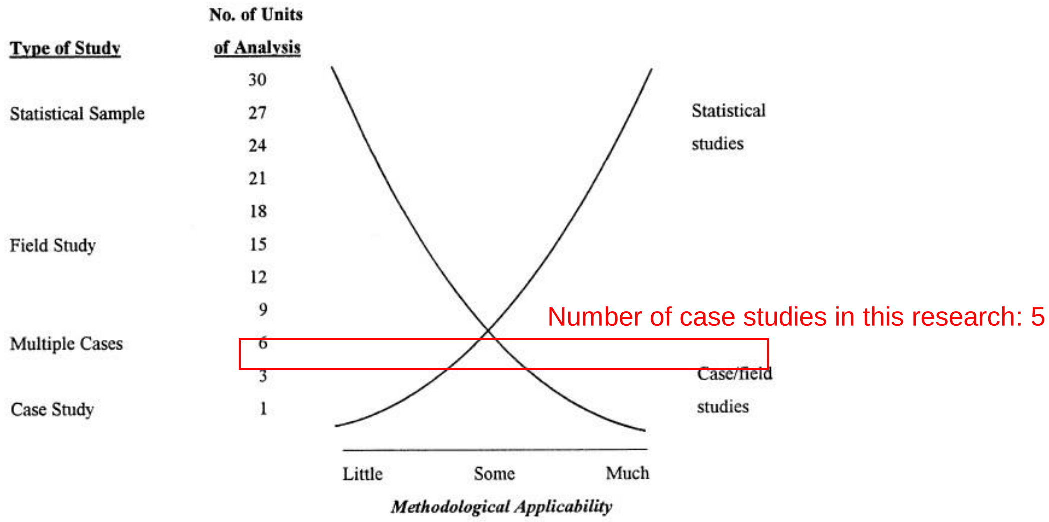

Figure 6: Methodological applicability relative to number of units (Meredith, 1998)

3 Theoretical background

3.1 Introduction

This chapter discusses the theoretical background of the research object and its underlying context. As the research mainly is based on one AR case study, it is essential to describe the researcher’s understanding of the contextual factors of the research object. Therefore the chapter reviews based on a multi-dimensional framework New Zealand’s economy and culture, the New Zealand manufacturing sector and the characteristics of small and medium enterprises (SMEs) before it analyses the literature of current manufacturing theory to outline current advanced manufacturing paradigms and methodologies. As the research object addresses the transformation of manufacturing organisations towards advanced manufacturing systems and methodologies, best practices of changing organisational systems are presented. In the opinion of the researcher, it is beneficial in AR to receive as a reader a detailed introduction to the researcher’s understanding of the theoretical background of the research object. This might assist in interpreting actions and outcomes within the AR case studies.

In the literature review and within the AR case study it became obvious that the leadership type has a crucial role in an organisational change. Therefore the role of leadership in general and within the NZ context is explored.

3.2 Context

3.2.1 New Zealand’s background

3.2.1.1 New Zealand’s economy

New Zealand has a mixed economy which operates on free market principles. Over the last two decades, the New Zealand economy has changed from being one of the most regulated in the Organisation for Economic Cooperation and Development (OECD) to one of the least regulated. A recent free trade agreement (2008) with China facilitates 37 per cent of Chinese exports to New Zealand to be tariff free (New Zealand Ministry of Foreign Affairs and Trade, 2008) which leads to an intensified competition with low-price imports. It has sizable manufacturing and service sectors complementing a highly efficient agricultural sector. Exports of goods and services account for around one third of real expenditure gross domestic product (GDP) (The Treasury of New

Zealand, 2008). Export markets are equally diversified with a rapidly growing importance of Asian countries such as South Korea, Taiwan, Malaysia, Hong Kong, Singapore, Indonesia, China and Thailand. This contrasts with over 50% of exports going to the United Kingdom in 1960 (John & Fargher, 2004). New Zealand had in 2008 a GDP of US $ 128.492 billion (International Monetory Fund, 2009).

Net international investment income flows are large and negative, because New Zealand investment abroad is small compared with foreign investment in New Zealand (John & Fargher, 2004).

3.2.1.2 New Zealand's geography and population density

New Zealand's geography in combination with its population density needs to be mentioned as an influential contextual factor for its manufacturing industry.

The country stretches over 268000 square kilometres and has a population density of 15 habitants per square kilometre (Statistics New Zealand, 2006) which is only one third of the world's average. This already implies logistic challenges regarding the supply of raw materials and the exchange of industrial and consumer goods within the industry which mainly concentrates on the three main urban areas Auckland-Hamilton, Wellington, and Christchurch.

Another influential factor is represented by the geographical isolation of the country itself. The distance to international markets complicates not only the export of goods but also the import of raw material and industrial goods. The cost of transport which is mainly a function of weight, distance, and volume strongly affects the make-or-buy decisions and consequently influences the price of exported goods. An additional factor influencing the managerial decisions in the manufacturing industry with regards to international competitiveness is the challenge of lead time of purchased goods and also the delivery time.

These challenges are elaborated further within the case studies (refer to chapter 4.3 and following).

3.2.1.3 New Zealand's society and culture

In this chapter specific characteristics of New Zealand's society and culture that might have an influence on a manufacturing system are explored and discussed. Therefore Hofstede's culture model is used to point out the unique

NZ characteristics and possible implications within the research context. Additionally the so-called ‘tall poppy syndrome’ and ‘no. 8 fencing wire’ mentality, both said to be specific social respectively cultural phenomena of New Zealand are briefly explained.

In the 2006 census, roughly 10% of the NZ population claimed identification with two or more ethnic groups. Almost 68% of the population are of European descent, and almost 15% are Maori. Pacific Islanders and Asian groups comprise 14.7% and 9.1% (Statistics New Zealand, 2006). Although these figures might imply a very diversified and manifold culture that makes it difficult to talk about one culture for New Zealand, Kennedy notes, that New Zealanders (“Kiwis”) will argue strongly for the existence of a unique identity, for the existence of something that differentiates them from others, a “Kiwi” culture (J. C. Kennedy, 2007).

In order to evaluate New Zealand’s cultural characteristics, Hofstede’s model of cultural dimensions is consulted more in detail (see Figure 7). Hofstede developed a quantitative model to compare national cultures based on five dimensions (Hofstede & Hofstede, 2004) (see Figure 7): power distance (PDI), individualism (IDV), masculinity (MAS), uncertainty avoidance (UAI), and later added long-term orientation (LTO).

There is a number or researchers who concluded based on Hofstede’s database that differences in national cultures also affect management practices in terms of strategy (Schneider & DeMeyer, 1991), style of leadership (Dorfman & Howell, 1988) and human resource management. Therefore the objective is to take cultural specifics of New Zealanders for the development of the transformation framework into account. Additionally New Zealand’s results are compared with Japan as the country of origin of the Toyota Production System (TPS), with the United States as a country with many transplants of the TPS, and with Mexico and Sweden where similar research projects with a focus on SMEs could be found during the literature review. Further New Zealand’s score is compared with United Kingdom as a very often used reference point. In fact, Figure 7 shows that New Zealand and UK resemble the most.

Kennedy conducted a qualitative and quantitative analysis based on the GLOBE study that refers to Hofstede’s cultural model to evaluate the characteristics of the culture and leadership in New Zealand. New Zealand ranked in the highest 20% of countries on the dimensions of Performance

Orientation and Institutional Collectivism. In an international comparison, New Zealand stands out as being a society that places importance on high standards of performance, while supporting practices that encourage collective distribution of resources and collective action. In contrast, it ranked at the low end of the sample in regard to Power Distance, Future Orientation, In-Group Collectivism, and Assertiveness. Hence New Zealanders seem to value egalitarianism more highly than most other countries.

The comparatively low rating of Future Orientation in the GLOBE study could be confirmed by a survey pointing out that NZ companies are not paying sufficient attention to long-term planning (Knuckey, Leung-Wai, & Meskill, 1999). In a subsequent study Knuckey et al. note that more than 75% of the businesses of the sample plan within a horizon of one year or less. Slightly less than one half of the asked companies are not defining broader goals and visions for a long term guidance for the organisation. According to the study this can be related to the scale of most enterprises and to the reliance on one or a few people who lead and manage the business (Knuckey, Johnston, & Campbell-Hunt, 2002). Knuckey also mentions that leadership appears to be the key driver of best practice in the manufacturing sector (Knuckey et al., 1999). The role of leadership in the context of this study is discussed more in general in chapter 3.4.3.

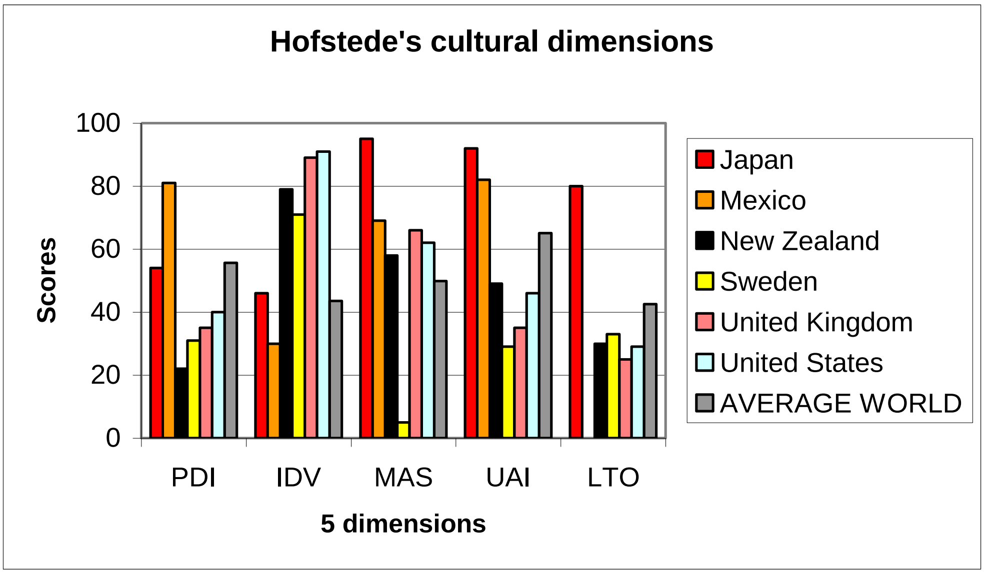

Figure 7: Hofstede's cultural dimensions: A selected comparison with New Zealand (adapted from (Hofstede, 2003))

The diagram of Figure 7 containing the direct data of Hofstede supports Kennedy's findings. New Zealand ranks in international comparison low regarding power distance, long term orientation and uncertainty avoidance and scores very high regarding individualism.

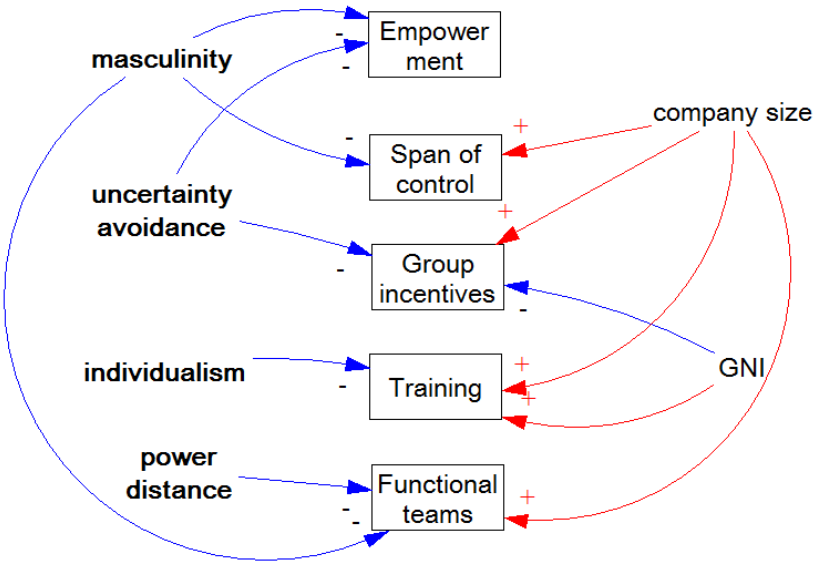

Figure 8: Relationship between Hofstede's cultural dimensions and the elements of new forms of work organisations (NFWO) (Cagliano, Caniato, Golini, & Micelotta, 2009)

Cagliano et al. analysed the impact of national culture on the adoption of new forms of work organisation (NFWO) by correlating Hofstede's first four cultural dimensions with data from the fourth edition of the International Manufacturing Strategy Survey (IMSS 4) focusing on the integration level of so-called new forms of work organisation. In order to assess NFWO adoption, Cagliano et al. determined the five elements of NFWO: empowerment, span of control, group incentives, training, and functional teams. Empowerment contains characteristics like the degree of job rotation, multi-skilling and autonomy using 1-5 Likert-like scale on the extent to which the workforce is autonomous in performing tasks. Span of control is measured by the number of employees under the responsibility of one of the line supervisors. Again in order to assess the dimension of group incentives a 1-5 Likert-like scale on the usage of group incentives is used. The level of training is simply measured by hours of training. The usage of functional teams is measured by the percentage of total workforce working in functional teams. Additionally the variables of company size and gross national income per capita (GNI) are considered. The main outcomes of this study are visualised in Figure 8 based on the logic of causal loop diagrams (CLD). The blue arrows (marked with a '-' at the tip) indicate a negative relationship, e.g. there is a statistical tendency that the higher the degree of masculinity of a nation is, the lower seem to be its scores of measures for the dimension empowerment. The red arrows (marked with a '+' at the tip) indicate a positive relationship, the larger a company is, the higher is the level of span of control, which seems to be a logic consequence.

Looking at the specific scores of New Zealand for Hofstede's cultural dimensions (see Figure 7), Table 4 summarises the author's interpretation of Cagliano's findings with regards to New Zealand.

Table 4: Implications of New Zealand's cultural characteristics on NFWO (based on results of (Cagliano et al., 2009))

Hofstede's cultural dimensions NZ compared to the world average		**Implications based on New Zealand's cultural characteristics**
↗	Masculinity	Slight tendency of negative acceptance of means of empowerment
↓	Uncertainty avoidance	Tendency of positive acceptance of group incentives Tendency of positive acceptance of means of empowerment (multi-skilling, job rotation, and autonomy)
↑	Individualism	Tendency of a lower usage of training
↓	Power distance	Tendency to work well in functional teams

Nevertheless the strongly growing diversity of cultures in New Zealand needs to be emphasised with recent immigration 'waves' from China, East Asia, India, and Middle East and according to Newburn, the 'face' of New Zealand is recently changing (Newburn, 2009). Without a doubt this fact needs to be considered in this research, as cultural differences and language barriers may influence the workplace environment.

Regarding the educational level, the number of full-time students have multiplied over the last two decades, though, the proportion of New Zealanders continuing their education is low by international standards (Chatterjee & Birks, 2001). Having a closer look at graduated engineers Figure 9 shows that the percentage of tertiary graduates is lower compared with international standards.

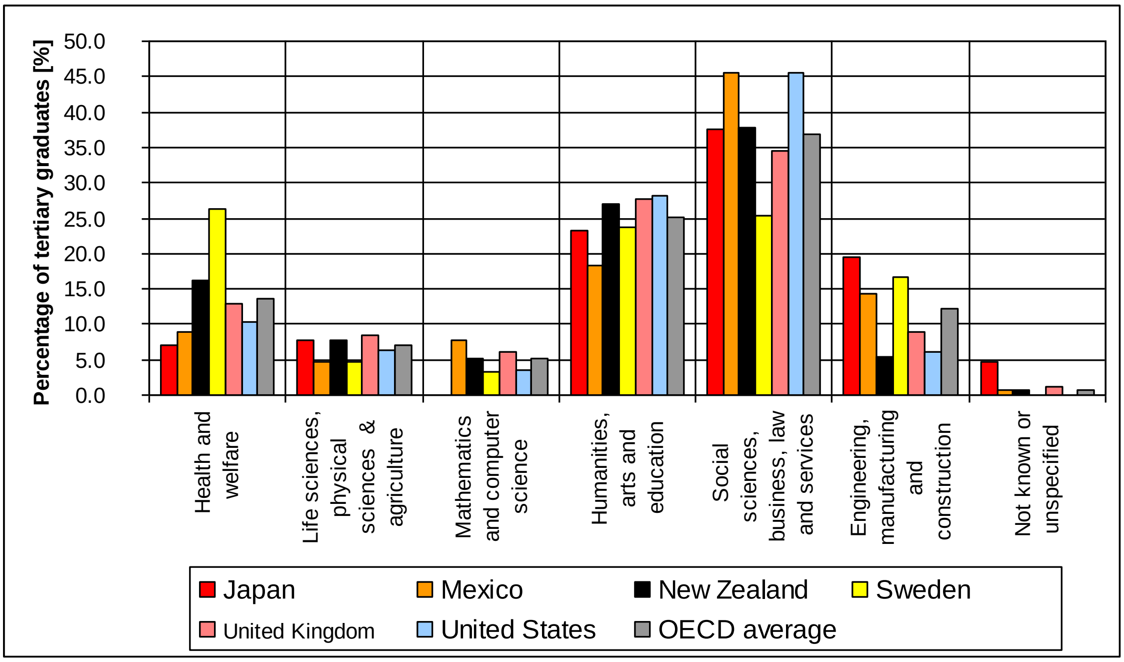

Figure 9: Percentage of tertiary graduates, by field of education (2007) (OECD, 2009)

In the context of New Zealand's social and business behaviour the so-called tall poppy syndrome needs to have further explanation as its usage seems to be quite peculiar to Australasia (Mouly & Sankaran, 2001). A tall poppy, according to the 1997 edition of Oxford Dictionary of New Zealand English, is a "conspicuously successful person". The Australian National Dictionary adds to this definition that a tall poppy is a person "whose distinction, rank or wealth attracts envious notice or hostility" (Ramson, 1988). Therefore, staying within the picture of the syndrome's name, a too tall poppy is to cut down to size. Feather investigated the attitudes of several target groups towards tall poppies and found that the respondents' reactions to tall poppies are highly correlated with their own sense of self-esteem, and that jealousy and envy are important factors contributing to this phenomenon (Feather, 1991). In the context of 'professional jealousy' Thome mentions measures like "diplomatically downplaying any personal successes when they do occur" for high-achievers (Thome, 1993). As in organisational transformations the role of outstanding leaders as initiators is quite substantial (see chapter 3.4), the phenomenon of tall poppy syndrome can have an impact in the New Zealand context on an organisational change itself, the involvement of staff e.g. stepping forward to initiate improvement projects, and any human-resource activities enabling the enhancement of the manufacturing system (e.g. peer evaluation procedures, definition of responsibilities, performance reviews, selecting 'change facilitators',…). In this context Inkson et al. list as a main barrier for NZ organisations to be excellent the 'mediocrity' mentality. They elaborate that in NZ, excellence does not seem to be especially admired or rewarded resulting out of the basic attitude of egalitarianism. Further it is argued that there is a tendency of New Zealanders to avoid failures, because competence is more admired in NZ society. Further Inkson et al. itemise as barriers for NZ excellence the tendency of over control and of low work ethics (Inkson, Henshall, Marsh, & Ellis, 1986).

Another NZ peculiarity that has its origin in the agricultural sector is known in vernacular under the term 'Kiwi ingenuity' and the versatility of the so-called 'no. 8 fencing wire' underlining the natural blent for invention (Catley, 1997). It alludes to a hands-on mentality of fixing almost any problem in a pragmatic and quick way by just using a 'no. 8 fencing wire'. Kennedy describes it as a "problem-solving attitude to life" involving a willingness "to tackle problems and take on responsibilities outside one's normal role" (J. C. Kennedy, 2007, p. 400). Iconic figures that are associated with the 'Kiwi ingenuity' are for example Sir Edmund Hillary who drove as the first person a motorised vehicle overland to the South Pole by using converted farm tractors or John Britten who created the world's fastest twin-engine four-stroke superbike (Bridges & Downs, 2000). This hands-on mentality can be in favour of experimenting with new methodologies and techniques and therefore might facilitate a Lean adaptation. On the other hand there could be the tendency of favouring 'quick fixes' rather than a structured problem solving approach.

Having shown that New Zealand possesses in fact a culture that has certainly a unique pattern regarding its national culture and society, it is necessary to point out that there is evidence in literature that the organisational culture has more influence on a successful Lean transformation than the national culture. Firstly there are case studies of the NUMMI plant providing evidence of successful transfer of Lean methodologies and the philosophy of continuous improvement which indicates that it can be transferred to a country with cultural differences (Pil & MacDuffie, 1999) (Russ, 1996). Recht and Wilderom indicated that the transfer of kaizen-oriented suggestion systems relies more on organisational culture than on the national culture (Recht & Wilderom, 1998). Also Aoki found the higher influence of the organisational setting rather than of national cultural factors (Aoki, 2008) while exploring the transfer of Japanese kaizen activities to Chinese transplants.

3.2.2 New Zealand's manufacturing sector

In early postwar times the New Zealand manufacturing sector evolved within an import protection provided by government and experienced a radical shift of economic policy with the economic reform of 1984 introducing a consequent liberalisation of the economy (John & Fargher, 2004). Before 1984, the fear of monopoly behaviour in combination with the tendency to support new 'infant industries' through their early founding phases, resulted in a common acceptance of public sector involvement in the marketplace (Chatterjee & Birks, 2001).

Nowadays, there are more than 20,000 manufacturers in New Zealand (The Vision Group & M. Pratt (Chairperson), 2006). There is a general trend towards concentration of industry in the Auckland area (Chatterjee & Birks, 2001). Taking only into account the specialised manufacturing sector which includes the automotive, aviation, electronics, engineering, marine and plastics sectors, there are 15,000 companies. Together they contribute around 14% of GDP and over 44% of export receipts and therefore contribute as the second largest industry group (see Figure 10). Companies within the sector are critical to the performance of the economy's primary industry and, with 37% of private sector investment in research and development, they contribute significantly to innovation in wider sectors of the economy (NZTE (New Zealand Trade and Enterprise), 2006). In an international comparison, New Zealand's specialised manufacturing sector is particular, because it is mainly made up of small and medium enterprises and only around 2100 companies employ more than 100 people (Ministry of Economic Development, 2008). Including the meat and dairy products, manufactured products are around 63% of exports and are NZ$ 69.5 billion worth of sales (by end of June 2005) (The Vision Group & M. Pratt (Chairperson), 2006).

A constantly and rapidly changing international environment and the emergence of large developing economies, such as China and India, are intensifying competition in the global marketplace. Despite these changes, and the challenges they pose, a growing number of New Zealand specialised manufacturing companies have found opportunities and considerable success in niche export markets. For example regarding automotive components manufacturer (ACM) most SMEs focus on the Australian market and only a few larger ACM companies are exporting to 30-50 different markets. However a diversification of their products and markets took place. They successfully leveraged their core competencies into product lines for automotive, marine, hardware, military, aviation and other markets (Miller & Whitcher, 2003).

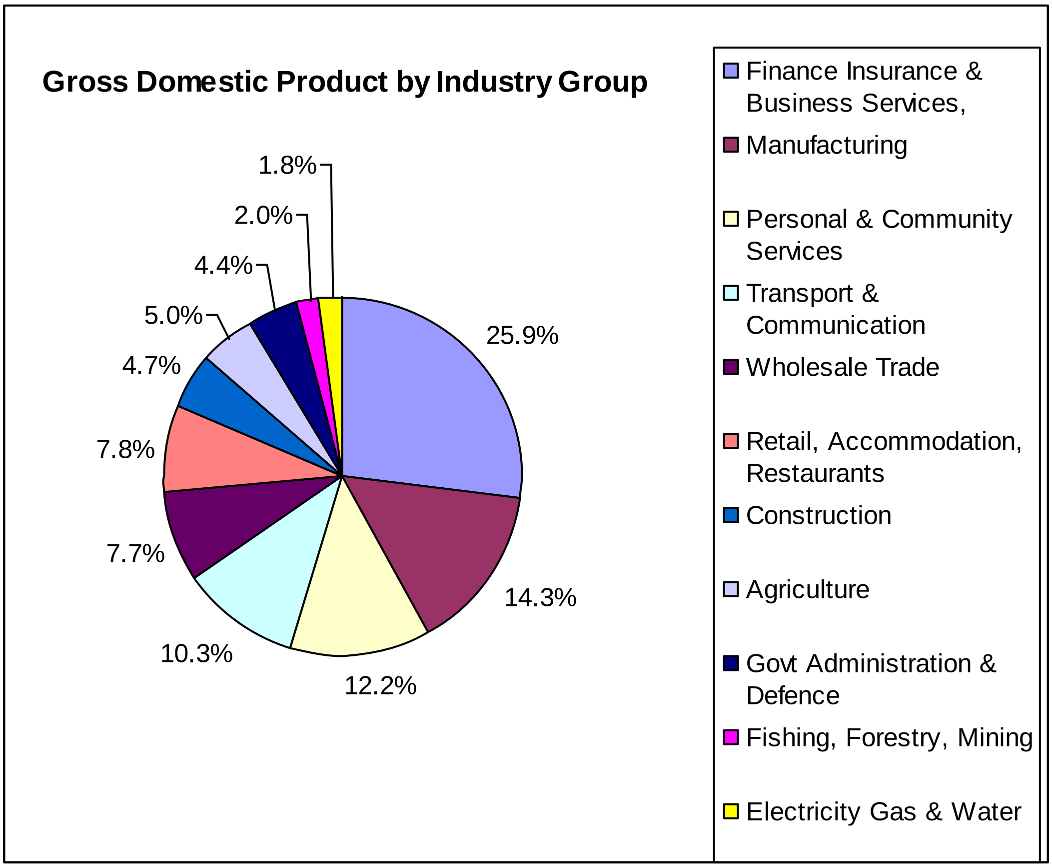

Figure 10: Contribution to GDP by industry groups (The Treasury of New Zealand, 2008)

In order to compare NZ's industry in regard to their international competitiveness, the database of the Global Competitiveness Report is a very valuable source (The World Economic Forum, 2008).

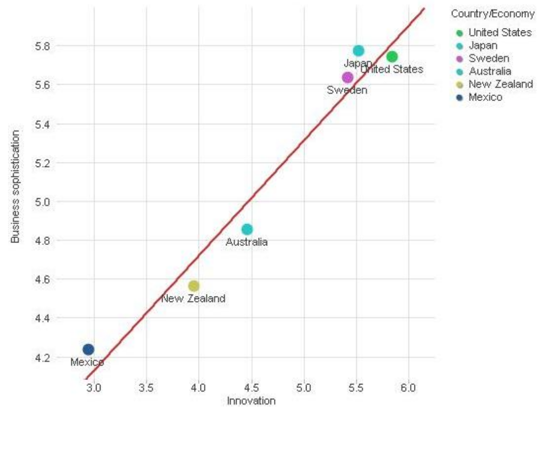

Figure 11: Business sophistication versus Innovation (The World Economic Forum, 2008)

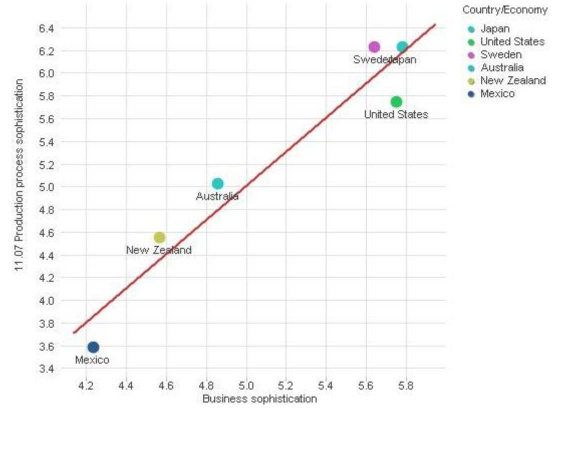

Figure 12: Production process synchronisation versus Business sophistication (The World Economic Forum, 2008)

Figure 11 and Figure 12 are referring to New Zealand's performance regarding the dimensions business sophistication, innovation and sophistication of production processes compared with the nations of Mexico, Australia, Sweden, Japan and United States (The World Economic Forum, 2008). These results align with the low scores regarding productivity of the OECD study. It is noticeable that the low scores are consistently passed through from the side of innovation to the degree of business sophistication and finally to the production processes where innovations based on a solid business model are supposed to be efficiently transformed into physical products or services. The underlying parameters for business sophistication and innovation are shown in Table 5. The numbers describe the ranking in comparison with all participating countries (n=134) from the best to the worst performing country. According to the report, New Zealand has for the green marked parameters in an international comparison a competitive advantage, whereas the red marked parameters symbolise a competitive disadvantage.

A NZ study led by Knuckey provides a comparison of NZ manufacturing firms with a sample of Swedish firms (Knuckey et al., 2002). This comparison is mainly of interest as the economies are comparable in size and they also share some geographic and demographic characteristics. Across most operational practices and performance outcomes analysed in this study, Swedish manufacturers outperformed New Zealand manufacturers, particularly in the elements of leadership and planning and quality and supplier focus. The exception is in the area of information management, where New Zealand manufacturers invest more efforts.

Table 5: NZ Business sophistication and Innovation (The World Economic Forum, 2008)

Business sophistication	37	
A. Networks and supporting industries	51	
11.01 Local supplier quantity	78	D
11.02 Local supplier quality	20	A
11.03 State of cluster development	71	D
B. Sophistication of firms' operations and strategy	28	
11.04 Nature of competitive advantage	43	D
11.05 Value chain breadth	71	D
11.06 Control of international distribution	44	D
11.07 Production process sophistication	30	D
11.08 Extent of marketing	25	D
11.09 Willingness to delegate authority	11	A
Innovation	26	
12.01 Capacity for innovation	28	D
12.02 Quality of scientific research institutions	19	A
12.03 Company spending on R&D	36	D
12.04 University-industry research collaboration	24	D
12.05 Gov't procurement of advanced tech products	64	D
12.06 Availability of scientists and engineers	76	D
12.07 Utility patents*	24	D

3.2.3 Small and medium enterprises

3.2.3.1 Definition of small and medium enterprises

As this research mainly focuses on the Lean transformation in small and medium sized enterprises (SME), this term is briefly discussed and a commonly accepted definition for NZ SMEs is presented.

According to Massey there is no universally accepted definition (Massey, 2005), because small companies can be found across almost the entire spectrum of business activity which exacerbates the definition by industry sector, such as manufacturing, retail or service. Besides, the legal format, such as sole trader, partnership or company, can vary. However, the Bolton Committee developed a definition of a small firm that has provided the basis for definitions throughout the world (Great Britain Committee of Inquiry on Small Firms, 1971). It pointed out three particular aspects:

- The small firm has not a formal, specialised management structure. It is mostly owner-managed in a personalised way.
- The small firm is independent, in the sense that it is not a subsidiary of a larger enterprise and the owner is free of outside control in making decisions.
- The small firm has a relatively small market share, serving a local or regional rather than a national market.

Massey emphasises some practical difficulties in the application of this definition especially experienced by statistical agencies that were in charge of counting the number of small firms within an economy (Massey, 2005). As a consequence most countries have taken a very pragmatic way to defining a small firm: the number of people employed within the firm (mostly in terms of the total number of full-time equivalent staff (FTEs) is considered as the main criterion to distinguish between large and small firms.

This approach was also taken by Cameron (Cameron, 1999) who mainly divides New Zealand SMEs into three categories:

- Micro business: 5 or fewer employees
- Small business: 6 to 49 employees
- Medium business: 50 to 99 employees

Everything above 99 employees belongs according to this definition to the category of large companies. Cameron's definition of SMEs as enterprises with fewer than 100 employees is at the lower end of the range in international terms. The most common definition of a SME in OECD countries is a firm with fewer than 500 employees (OECD, 1997). This research project will lean on Cameron's definition.

Generally, in New Zealand, the proportion of SMEs in comparison with large businesses is similar to several of other Organisation for Economic Cooperation and Development (OECD) countries, although SMEs account for a higher proportion of employment relative to other countries (Small Business Advisory Group, 2004) (see Figure 13).

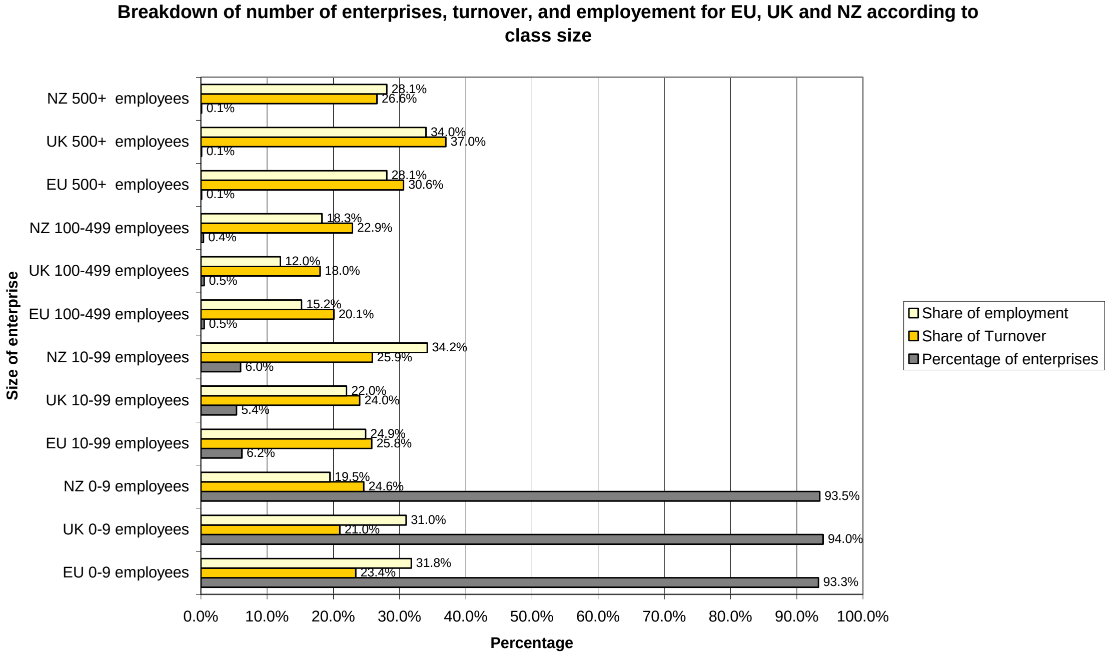

Figure 13: Statistics of NZ SMEs in comparison with EU and UK (data of EU and UK from (Ghobadian & Gallear, 1997), data for NZ from (Ministry of Economic Development, 2008))

Having a closer look at the statistics, 98.74% of all companies in New Zealand have less than 50 employees (Ministry of Economic Development, 2006). SMEs (less than 50 employees) accounted for 43.64% of total employment in February 2005. The NZ average number of employees per enterprise as at February 2005 is 5.2. In comparison with that the EU average number of employees per enterprise as at May 2004 is 7.2. Most of New Zealand's SMEs are located in the major centres including Auckland, Christchurch and Wellington. In summary these figures make clear that SMEs contribute a substantial proportion to New Zealand's economy.

In the 1980s the NZ government defined criteria established by the Small Business Agency to determine small businesses. Small businesses were defined as exhibiting any of the following features (Ministry of Economic Development, 2008):

• it is personally owned and managed

• the owner/operator makes most management decisions

• there is generally no specialist staff at management level

• it is not part of a larger business or group of companies with access to managerial expertise (Devlin, 1984).

These criteria are also taken into account for the selection of appropriate case studies.

3.2.3.2 Research in SMEs

As shown in the precedent chapter, the economic importance of SMEs in New Zealand is substantial. Hence the number of researchers and of governmental institutions has constantly increased trying to understand and to support the activities of these enterprises.

Generally it is important to acknowledge that research in SMEs can vary to the research methodology in large firms (Hill & McGowan, 1999). The reasons for this variation will be mainly discussed in the following chapter 3.2.3.3. Hill and McGowan generally divide research in the area of management in the more conventional positivist/quantitative methodologies and the qualitative methodologies which operate in their opinion in another paradigm of research.

Lewis et al. note that small firms have an inherent complexity as they present 'the lived experience' of an owner-manager or entrepreneur. The role of the 'person' and the 'firm' is interwoven and therefore boundaries between those two entities are permeable. Hence Lewis et al. state that the researcher needs to understand the nuances of a person as well as a firm, and to deal with subtlety and diversity (Lewis, Massey, & Harris, 2007). Another challenge lies within the fact that the research is usually designed to satisfy a concrete need of a client which can be the SME itself and very often other stakeholder groups, e.g. policy makers and agencies who are supporting SMEs (in New Zealand one example is certainly NZTE). This often results in the researcher's dilemma of creating an academically robust research design and the usefulness for the practitioners (Curran & Blackburn, 2001). Hence, Curran even argues that research in smaller enterprises is actually more difficult, as measurement, because of a lack of paper- and computer-based corporate data, can be more difficult. This lack of consistent corporate data could be confirmed within the case studies.

Lewis et al. arrive at six dimensions of complexity that they faced during a NZ-based research project in SMEs: the attitudes of SME owner-managers to participating in research, the access to SMEs, the attitudes of the 'purchasers' of research, the isolation as a research community, the lack of an SME paradigm, and finally working in teams (Lewis et al., 2007).

3.2.3.3 Characteristics of SMEs

In this chapter the specific characteristics of SMEs found in literature are identified. In this context the attitude and behaviour of SMEs with regards to improvement initiatives are explored.

Most of the improvement initiatives (e.g. TQM and Lean Production) have their origin in large organisations in order to achieve a uniform and consistent approach for the corporate development. The therefore necessary systems and methodologies have been consequently tailored to the characteristics of larger companies. Hence, it is necessary to analyse the characteristics of SMEs whether they impede or facilitate improvement efforts and organisational transformations. A study in the New Zealand context for example comes to the conclusion that large firms tend to have better practices than medium firms, especially in relation to leadership and planning, operations and quality, and employee practices (Knuckey et al., 1999). Cocca summarised the main characteristics of SMEs based on an extensive literature review (Cocca & Alberti, 2009). Table 6 and Table 7 present Cocca's analysis and are extended by the results of Yusof (S. M. Yusof & E. Aspinwall, 2000). Yusof et al. added to their review of characteristics two additional columns discussing the advantages and disadvantages with special regards to a TQM implementation. Besides, the categorisation of Yusof into external and internal aspects is integrated in Cocca's work.

Table 6: Characteristics of SMEs: external environment

External environment		
Markets		
• Lack of market influence • Narrow span of market activities, normally smaller customer base • Mostly local and national markets, few international • Highly competitive, turbulent, uncertain environment	Advantages: Potential of high profitability if in niche market. Strategically easier to develop core compe-tencies according to target markets.	Disadvantages: Difficulties to achieve economies of scale. Difficulties of demand forecasting and therefore of effective material and capacity planning.
Customers		
• Demands made by stronger customers • Closer contact to customers, many known personally • Lack of power to leverage payments of debts	Advantages: Customer needs can be identified by direct immediate information and communication.	Disadvantages: Danger of too many individualised customer wishes can make standardisation difficult.

Table 6 summarises the externally influenced characteristics of SMEs. Out of the perspective of the development of the manufacturing system, the uncertainty of demand forecasting and its effects on capacity planning and the higher tendency of high variability of products in order to satisfy all individual customer wishes need to be considered.

Table 7 discusses the internal aspects of SMEs. On the one hand the more organic structure and more informal communication channels and procedures in combination with the high integration level of all employees' creativity is clearly in favour of improvement initiatives in the manufacturing system. On the other hand the personalities and their attitude towards change of management and owners can limit a potential transformation. Additionally short-term thinking can paralyse a transformation process which is considered to take more than three to five years (J.P. Womack & Jones, 2003). Therefore it needs a correspondent emphasis on a long-term vision and goals. One further influential factor is the lack of resources in terms of expertise, time, and financial support (e.g. for training).

Massey et al. found in a study in the context of business excellence that small enterprises find it generally difficult to allocate their improvement efforts. Apart from more marketing and staffing, there was no clear understanding or apparent need for best practices. Nevertheless the respondents acknowledged the benefits of formalisations and standardisation towards best practices (Massey et al., 2005). This can be supported by a Canadian study of Scott et al. that revealed that continuous improvement is less used in small enterprises than in large ones (Scott, Wilcock, & Kanetkar, 2009).

Further research shows the tendency of SMEs of having barriers to the implementation of performance management systems (Hudson, Smart, & Bourne, 2001). One of the reasons for that is seen as the lack of resources (Ghobadian & Gallear, 1997).

One further characteristic of SMEs is that many employees feel responsible for the same tasks and duties (Zink et al., 2008). This causes an overlap of responsibilities and therefore can lead to misunderstandings and duplication of work. The formal division of work and responsibilities are often influenced by the personal relationships of managing employers or the owners themselves. Hill emphasises in this context the significant role of the initial entrepreneur (founder) who driven by a strong commitment and vision influences the organisation's behaviour and culture (Hill & McGowan, 1999).

Table 7: Characteristics of SMEs: internal environment

Internal environment		
Resources, structure and operational procedures		
• Flat with very few hierarchical layers • Lack of bureaucracy, low degree of standardisation and formalisation of activities and procedures • Simple planning and control system • Informal evaluation, control, and reporting procedure • Flexible, adaptable, and innovative processes • Limited resources: time, human, financial • High degree of tacit knowledge • Low degree of specialisation • Skills shortage	Advantages: Flexible and quick communication line. Informal implementation of new procedures. Simple system allows fast response to customer needs.	Disadvantages: Lack of expertise in change initiatives because of low specialisation and general skills shortage. Therefore it often needs external support (financially and regarding knowledge transfer). Potentially the owner controls too much and therefore lacks delegation which can limit growth and change. Lack of proper system structure exacerbates efficiency of work and monitoring of it; high variability of work outcome.
Management practice		
• Poor strategic planning • Short term vision and orientation • Control and decision making rest primarily with one or a few people, less delegation • Intuition-based decision making • Reactive, fire-fighting strategy • Lack of management expertise •	Advantages: Short and informal decision line can facilitate change.	Disadvantages: Intuitive decision-process may result in wrong decisions. Uncommitted or dictatorial owner/manager ethos and behaviour may damage new initiatives.
Culture and behaviour		
• Result-oriented • Organic, not strong departmental mind-set • Operations and behaviour of employees strongly influenced by owners'/managers' ethos and outlook • Focus on technical aspects and production	Advantages: Unified culture can be a good starting point for improvement initiatives. Organic structure is in favour of team empowerment.	Disadvantages: Culture is strongly dependent on owner and it can be difficult to change the culture if the owner does not change correspondently. Result-driven culture can exacerbate a culture of experimentation and can repress the openness to mistakes.
Human resources		
• Informal training • Individuals can normally see the results of their endeavours • Low incidence of unionisation • Low degree of resistance to change • People dominated • Lack of formal human resource strategies • Individual creativity encouraged	Advantages: Fewer employees enable closer personal contact to everyone. Innovative environment can support improvement culture.	Disadvantages: Lack of financial support, limited training budget. Ad hoc planning and a small-scale approach can stifle improvement efforts.

Every advice or recommendation on a factual level can consequently also implicate messages on the level of social relations (Zink et al., 2008). This can lead to decisions that are not only based on the facts and are influenced by the relations between all participants. A correspondent management system focusing more on processes can weaken this influence of social interdependencies by emphasising the defined structures. In summary, SMEs are more structured like networks which can be seen as one of their main advantages because of the higher degree of flexibility and reaction rate. On the other hand, network structures can lack sufficient control of information flows and therefore exacerbate the consistent repeatability of information and of final products. These aspects of repeatability and traceability of information and activities can play an essential role for customers and investors (Zink et al., 2008) and hence can create additional benefits.

3.2.4 Summary of contextual factors

In the previous chapters the wider research context was explored. The main focus was on the effects of national culture and the company size as one variable for the organisational culture. Factors and characteristics were identified that might influence the adaptation of manufacturing methodologies.

In general it was found that New Zealanders tend to have a positive acceptance of group incentives and of means of empowerment. Further there is a general tendency to put less emphasis on training which might be reinforced by the tendency of informal training and limited resources that can be found in SMEs. A lack of long-term orientation is identified as not only a characteristic for NZ but also for SMEs in general. The high performance orientation can be used as a key driver for the implementation of manufacturing methodologies. The essential role of the owner of a SME is to be taken into account for the transformation model. Other influential factors to be considered are the general lack of resources, informal structure including informal training and the high variability in demand (see Table 8).

Table 8: Summary of influential characteristics of national and organisational culture

National culture (New Zealand)	Organisational culture (SMEs)
- New Zealand is ethnically diverse - English can be the second language - Lower score for long-term orientation - Lower score for uncertainty avoidance - High performance orientation - High appreciation for egalitarianism	- Owner has influential role - Informal structure with flat hierarchies - Tendency to be short-term oriented and driven by the day-to-day business - Limited resources - Informal training - Markets are often perceived as turbulent and high demand variability

3.3 Evolution of manufacturing theory and terminology

This chapter gives an overview of current underlying theories in the context of manufacturing and operations management in order to sketch the outline of the current paradigm of best practices. Based on the definition of the term 'paradigm' and the complementary terms 'methodology', 'technique', and 'tool' in chapter 1.2.4, chapter 3.3.1 explores the underlying fundamental theories and terminology in the manufacturing context. Afterwards in the following chapters 3.3.2 to 3.3.8 the relevant methodologies like for example TQM and Lean are described and compared and herewith their evolutionary path is clarified to develop the transformation framework and to find the adequate aspects that need to be considered for the analysis of the case studies.

3.3.1 Underlying theories and terminology in the context of operations

3.3.1.1 Flow systems

A manufacturing system and its operations can be understood in its most fundamental mechanics as a flow system which contains resources (e.g. machines, workers, equipment, etc.) and flow entities (e.g. the material and products). Flow entities are the objects of transformation and resources enable the flow of these flow entities by performing certain operations in order to transform. The transformation process is triggered by a demand. Therefore Hopp and Spearman argue that the formal purpose of a production system involves the two main elements of demand and transformation (Hopp & Spearman, 2008). Table 9 gives a list of other flow systems for illustration of its variety of applicability. Applying the model of a flow system for example to a hospital, the hospital beds and staff members as e.g. nurses are typical resources, whereas the patients are the flow entities following a routing through the system. The treatment of the patients is to be seen as the transformational process.

Table 9: Examples of flow systems (Vandaele, 2008)

Flow System	Typical Resources	Typical Flows
Production line	Machines, workers	Products
Production Plant	Machines, internal transport	Products
Hospital	Hospitals beds, physicians, nurses	Patients
Airport	Counters, desks	Passengers
Traffic	Roads, traffic lights	Cars, trucks
Laboratory	Equipment, laboratory assistants	Samples
Computer network	Servers, data lines	Data, messages
Mobile phone network	Antenna's, transmitters, buffers	Calls
Insurance company	Inspectors, account managers	Files

Looking at the relationship between resources and flow entities, it becomes obvious that all these systems share common basic mechanics and characteristics:

The flow entities follow a certain routing from resources to resources in order to be processed respectively to be transformed. This processing 'consumes' capacity of the resources which can lead to a competition for resources if too many flow entities require at the same time the same resource. As a consequence flow entities may need to queue up in front of resources. This congestion in turn inflates the lead time of a flow entity through the system.

Looking at a production system out of the System Dynamics (see chapter 3.3.4) perspective, there are two main elements: stocks and flows (J. Sterman, 2000). A flow represents material or resources moving through the transformation process whereas a stock represents material or other resources waiting for transformation. It is important to acknowledge that stocks are not essential for the existence of the system, because there are systems which keep no inventory or 'work in progress' between demand and transformation (e.g. a service system). Reasons for holding inventory are elaborated in chapter 3.3.1.2.

In order to illustrate the performance measures and parameters that are essential in a manufacturing system, a production line with four single-machine stations in series is shown in Figure 14.

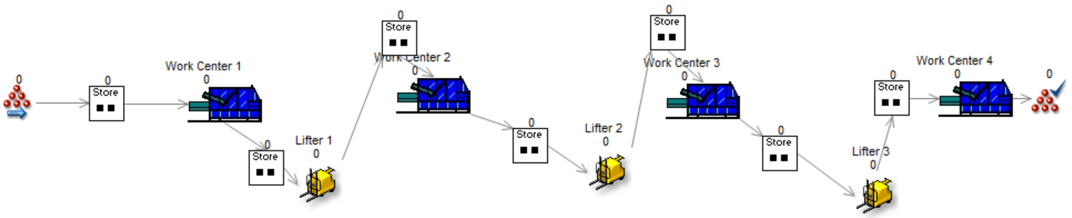

Figure 14: Production line with four work centres as a simple example of a manufacturing system

Performance measures of interest are the lead time of one product (flow entity) through the system from entrance to exit (symbolised by the red pyramids), the expected throughput rate, the safety capacity and the utilisation of each work centre. Parameters that are influencing those performance measures are the number of work centres, the processing time for each work centre and their variability (e.g. caused by scrap rate, by setup times, by downtime of machines, etc.), the bottleneck rate (for example the work centre with the longest processing times), and production control parameters like the batch size between work centres, the overall work in process (WIP) in the system and correspondent work release mechanisms (e.g. Kanban, see chapter 3.3.1.4).

While it is possible in a mass production environment to create a comprehensible snap shot of the flow of material and information due to standardised routings, the flow in a manufacture-to-order company seems to be less clear and dependant on the point in time of observation as routings and process times are variable.

3.3.1.2 Variability and the role of buffers

Stratton concludes in a review of theory developments beginning with scientific management, then describing cost optimisation models and performance trade-offs, afterwards leading over to the continuous improvement movement (TQM and Lean) that the reduction of variability has been a central common theme (Stratton, 2008). The importance of variability in the context of a manufacturing system is also emphasised by other authors (Schmenner & Swink, 1998), (Hopp & Spearman, 2008).

Flow systems are to be assumed to have stochastic characteristics which means the flow itself and the resources are affected by variability. The variability between the two main elements of a manufacturing system, the demand and the correspondent transformation in order to meet the demand creates a trade off. In an ideal world where demand and transformation are identical and perfectly aligned, there would be no inventory, the capacity of the resources would be fully utilised and lead times would be equal to the pure process time of transformation. Dettmer differentiates between variability and uncertainty whereas variability is internal to the organisation respectively manufacturing system (Dettmer, 2001). Variability can become manifest for example differences in processing, transport, or queuing times, in preemptive and nonpreemptive outages (e.g. random or planned machine downtimes), in quality problems that require rework loops, or in any human and managerial activities and decisions. Next to the variability solely of process times at individual workstations there is also the so-called flow variability when the variability of one station affects the behaviour of other stations in a line (Hopp & Spearman, 2008).

On the other hand, uncertainty is external and encompasses factors outside of the control of the manufacturing system or at least marginally influenced like for example the customer behaviour, the supplier behaviour, changes in market taste or demand, economic ‘peaks and valleys’, or natural disasters. In summary, uncertainty affects the demand for the system’s products or services (the flow entities), and variability causes changes to the system’s resources and processes to satisfy that demand. Hence, there are mechanisms in place to compensate the misaligned demand and transformation and can take according to Hopp and Spearman one of three different forms of buffers (Hopp & Spearman, 2008):

1. Inventory (extra material in the transformation process or between it and the demand process (WIP))
2. Time (a delay between a demand and satisfaction of it by the transformation process)
3. Capacity (extra transformation potential needed to satisfy irregular or unpredictable demand rates)

The ‘Operations Management Triangle’ of Lovejoy (see Figure 15) which is based on the Pollacek-Kinchine formula nicely illustrates the interdependencies between variability and the buffers (Lovejoy, 1998) and visualises the tradeoffs between those elements.

Pollacek-Kinchine formula (Heyman & Sobel, 1984):

$$Inventory = K \cdot \frac{\rho}{1-\rho} \cdot Var \quad \textbf{(1)}$$

Inventory = long-run average inventory

K = constant

ρ = long-run utilisation = demand rate / capacity

Var = variability

Hopp and Spearman list as a relative measure for the variability the so-called coefficient of variation (C_V) which is the standard deviation divided by the mean (Hopp & Spearman, 2008).

Coefficient of variation (c_V):

$$c_V = \frac{\sigma}{t} \quad \textbf{(2)}$$

c_V= coefficient of variation

σ= standard deviation

t=mean

They generally differentiate between three levels of variability:

Low variability for	$c_V < 0.75$
Moderate variability for	$0.75 \leq c_V \leq 1.33$
High variability for	$c_V \geq 1.33$

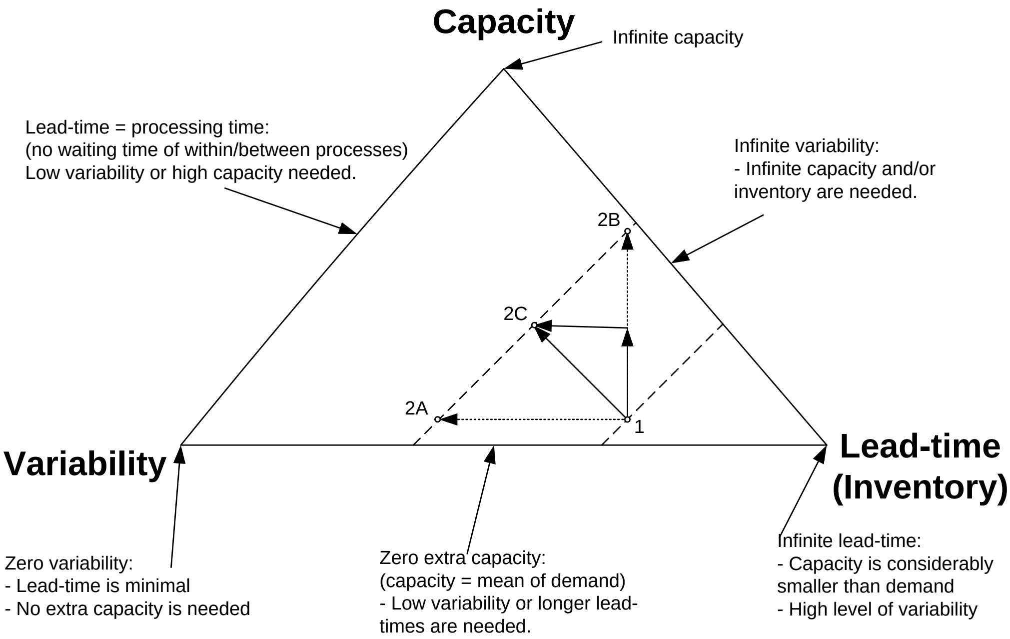

Figure 15: The 'Operations Management Triangle' adapted to an one-of-a-kind environment (Lovejoy, 1998)

Looking at Figure 15 every point within the triangle represents a certain level of variability being inherent in a manufacturing system and that is buffered against by using a combination of inventory (or lead time) and excess capacity. The left lower corner represents a manufacturing system with no inherent variability, the lead-time is identical with the processing time and no extra capacity is needed. The right corner stands for the theoretical state of a manufacturing system where the lead-time is infinite. An infinite long lead-time can be caused by a capacity which is considerably smaller than demand or/and by high levels of variability. The side of the triangle opponent to a corner represents the opposite extreme, for example the side that is opposite to corner with zero variability stands for infinite variability in the system. If a manufacturing system manages to reduce the variability it faces, it moves towards the lower left corner and the need for inventory and capacity buffers is reduced. Techniques aiming at improving quality or reducing downtime are examples for this reduction in variability, which are leading to freed up capacity and a lower need for inventory as a safety buffer. The example shown in Figure 15 can be interpreted by a corporate strategic decision to reduce lead times (see point 1). The change of the objective is represented by the isobar where three potential exemplary target points (2A, 2B, 2C) are plotted. All three points would achieve the same reduction in lead time but by a different manipulation of variability and capacity. Point 2A can be reached by a reduction of variability (e.g. reduction of downtime or reduction of rework loops) without changing the level of capacity. On the other side, point 2B can be achieved by simply increasing the capacity while keeping the level of variability constant. The state 2C represents a combination of reducing variability and increasing capacity.

The author wants to recommend to add to Lovejoy's original Operations Management Triangle the substitute of lead time for the dimension inventory for manufacture-to-order and one-of-a-kind environments (see Figure 15). Usually in these companies, hardly any inventory of finished goods exists and therefore the throughput of the system is mainly influenced by the capacity and the WIP level which directly correlates with the buffer of time. If the WIP level exceeds the capacity of the system, the only way to compensate is to extend the lead times for the products. In reality this usually leads to the inability to keep promised delivery dates and to a vicious circle of multi tasking where the workforce tries to simultaneously work on several projects at once believing to keep the delivery times while actually loosing efficiency.

3.3.1.3 Theories and laws for a manufacturing system

Within the last decade several publications can be found trying to determine the fundamental theories and to derive laws for operations management in order to better understand the underlying mechanisms and hence to increase the performance of production and service systems [(Hopp & Spearman, 2008) (Vastag, 2000) (Schmenner & Swink, 1998) (Stratton, 2008) (Vandaele, 2008) (Ferdows & De Meyer, 1990)]. Schmenner and Swink argue that theory usually deepens our understanding of phenomena in question. One of the most fundamental questions they raise in this context is why one operation (factory or service) is more productive than another (Schmenner & Swink, 1998). As this question is obviously relevant for this research as well, this chapter aims at giving an overview of current research activities in the field of operations theory and will contribute to the theoretical underpinning for the development of the Lean transformation framework and for the explanation of phenomena observed in the case studies of chapter 5.

Variables of variability and the buffers time, capacity and inventory presented in the previous chapter are also objects of fundamental laws defined by Hopp and Spearman (Hopp & Spearman, 2008) (see Table 10).

Table 10: Excerpt of laws of Hopp and Spearman (Hopp & Spearman, 2008)

Law	Description
Law of variability	Increasing variability always degrades the performance of a production system.
Corollary (Variability placement)	In a line where releases are independent of completions, variability early in a routing increases cycle time more than equivalent variability later in the routing.
Law of variability buffering	Variability in a production system will be buffered by some combination of 1. Inventory 2. Capacity 3. Time
Corollary (Buffer flexibility)	Flexibility reduces the amount of variability buffering required in a production system.

Another widely acknowledged law is known as Little's law. John D.C. Little provided the mathematical proof that at every work in process (WIP) level, WIP is equal to the product of throughput (TH) and cycle time (CT).

Little's Law: $$WIP = TH \cdot CT \qquad \textbf{(3)}$$

WIP are all the flow entities respectively products between the start and end points of an examined sequence of production processes. TH is defined as the average output of the production process chain per unit time. It is also known as throughput rate. The upper limit of TH of a production process is determined by its capacity. Hopp and Spearman comment that releasing into the system at or above the capacity causes the system to become unstable. This phenomenon also finds endorsement in the Japanese philosophy of avoiding muri (English: overburden) and mura (English: unevenness) which are seen as systemic types of waste for a production system (Rother & Shook, 1998). Overburden can be interpreted as the state where the current workload exceeds the capacity to cope with it.

As the academic community gained a deeper understanding of the trade-off of manufacturing lot sizes (The Economic Order Quantity model by Harris (1913)) and their costs and later the performance trade-off relationship between focus and alignment [(W. Skinner, 1969), (Wickham Skinner, 1974)], Ferdows and De Meyer proposed a new theoretical model by reversing the traditional focus on cost: *"To build cumulative and lasting manufacturing capability, management* *attention and resources should go first towards enhancing quality, then – while the efforts to expand quality are further expanded – attention should be paid to improve also the dependability of the production system, then – and while efforts on the previous two are further enhanced – production flexibility (or reaction speed) should be improved, and finally, while all these efforts are further enlarged, direct attention should be paid to cost efficiency"* (Ferdows & De Meyer, 1990, p.168). They summarised these findings under the so-called "Sand Cone Model" which clearly gives suggestions within a strategic roadmap in which sequence improvement activities should be taken. But it lacks in the opinion of the author a distinctive contribution to the manufacturing theory itself as also other authors mainly of the quality movement already proposed similar strategies (Deming, 1986).

Schmenner's theory of 'Performance Frontiers' provides a better understanding of the interaction of the laws of trade-offs and the 'cumulative capabilities model' proposed by Kane (Nakane, 1986) and must be seen as a further development of the concepts known as 'production function' and 'trade-off curve'. Nakane suggested that quality improvement is the basis of all other improvements and therefore is the precondition to cost efficiency improvements. In this context Schmenner and Swink proposed the law of cumulative capabilities (seeTable 11).

Table 11: Laws of Schmenner and Swink (Schmenner & Swink, 1998)

Law	Description
Law of variability	The greater the random variability, either demanded of the process or inherent in the process itself or in the items processed, the less productive the process is.
Law of bottlenecks	An operation's productivity is improved by eliminating or by better managing its bottlenecks. If a bottleneck cannot be eliminated in some way, say by adding capacity, productivity can be augmented by maintaining consistent production through it, if need be with long runs and few changeovers. Non-bottleneck operations do not require long runs and few changeovers.
Law of scientific methods	The productivity of labour can be augmented in most instances by applying methods such as those identified by the Scientific Management movement.

Law of quality	Productivity can frequently be improved as quality is improved and as waste declines, either by changes in product design, or by changes in materials or processing. Various techniques of the quality movement can be responsible for these improvements.
Law of factory focus	Factories that focus on a limited set of tasks will be more productive than similar factories with a broader array of tasks.
Law of trade-offs	A manufacturing plant cannot simultaneously provide the highest levels among all competitors of product quality, flexibility, and delivery, at the lowest manufactured cost.
Law of cumulative capabilities	Improvements in certain manufacturing capabilities (…) are basic and enable improvements to be made more easily in other manufacturing capabilities (…). The most adequate sequence in which manufacturing capabilities need to be addressed is quality, delivery, cost, and flexibility.
Law of diminishing returns	As improvement (or betterment) moves a manufacturing plant nearer and nearer to its operating frontier (or asset frontier), more and more resources must be expended in order to achieve each additional increment of benefit.
Law of diminishing synergy	The strength of the synergistic effects predicted by the law of cumulative capabilities diminishes as a manufacturing plant approaches its asset frontier.

(Continuation of Table 11)

Borrowing from economic theory, Schmenner and Swink defines a "performance frontier as the maximum performance that can be achieved by a manufacturing unit given a set of operating choices" (Schmenner & Swink, 1998, p. 108). Clark argues that performance frontiers are mainly influenced by the set of policies used to manage quality, production planning and control in a manufacturing system and therefore lists methodologies like just-in-time (JIT), statistical process control (SPC), total quality management (TQM), and cross functional integration as 'advanced' manufacturing systems (Clark, 1996). These methodologies will be further explained in the following chapters. Schmenner and Swink extend this view and classify two types of performance frontiers: The asset frontier that is characterised by the design and investment and the operating frontier which is determined by the choices in plant operation (see for illustration Figure 16).

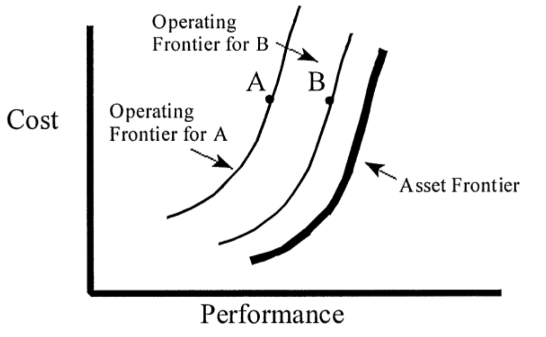

Figure 16: Operating and asset frontiers for exemplary firm A and firm B.

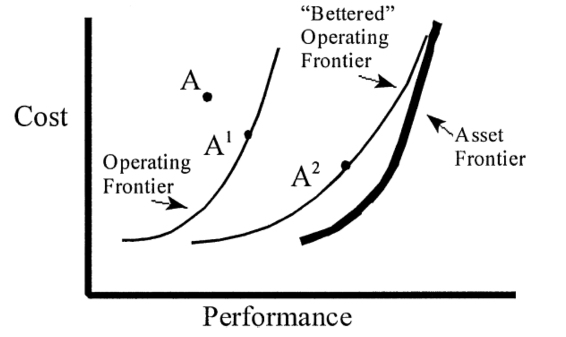

Figure 17: Three operating states for the firm A, A1 and A2 symbolise different operating policies.

Figure 16 shows the differing operating frontiers of two firms with the same asset frontier (a very similar use of technologies and other physical assets). The difference in operating frontier results out of different operating policies and procedures, e.g. company A could still operate in a traditional mass-production approach while company B embraced concepts of the Toyota Production System. Hence, the shape and position of the operating frontier is determined by the accepted operating policies and procedures in the company. In this context Schmenner differentiates between improvement and betterments. Improvements are measures that bring a company closer to its current operating frontier. Betterments will change the position and shape of the operating performance itself by altering manufacturing operating policies; one could argue that a betterment is a switch to a new operating paradigm which can start new potential improvements (see Figure 17). As the operating frontier is also determined by soft issues (e.g. involvement of employees, characteristics of leadership) and is specific to a given firm and therefore difficult to replicate, Vastag argues that the operating frontiers are in general more important than the asset frontiers in achieving a sustained competitive advantage (Vastag, 2000).

One further theory Schmenner and Swink developed is known as 'The Theory of Swift, Even Flow' (Schmenner & Swink, 1998).
It states that the better and more continuous the flow through a system, the more productive is the system. They list the following theoretical concepts in order to be able to improve the productivity of a flow system:

1. Separation into value-added and non-value-added work
2. Understanding the bottleneck of the system
3. Reduction of variability in processes and demand. Variability is measured by the deviation of the timing or quantities demanded or of the time spent in various process steps.

It is interesting that according to Schmenner labour efficiency and machine utilisation are not associated very much with productivity (Schmenner & Swink, 1998).

3.3.1.4 Push and Pull

Push and Pull generally stand for two main principles how a flow system can operate. They mainly describe the mechanism of a flow control system that triggers the release and movement of work (Hopp & Spearman, 2008). Hopp & Spearman define a pull system as a system that "establishes an a priori limit on the work in process, while a push system does not" (Hopp & Spearman, 2008, p. 358). Another major difference is the source of information that triggers the work release mechanism: a push system schedules work releases based on information outside the system (demand forecasts), whereas a pull system authorises releases on the basis of information from inside the system (work in process levels). Out of a measurement and control perspective Spearman states that a push system controls throughput and measures WIP while a pull system controls WIP and measures throughput (Spearman & Zazanis, 1992).

Essentially, any material planning and control system can be classified as push, pull or hybrid push-pull systems (Karmarkar, 1986). The Push principle is widely associated with the MRP system, while Just-in-Time (JIT) and Kanban are known as the main methods to realise Pull. Kanban and JIT techniques have later been popularised under the name of "Lean Manufacturing" (J.P. Womack, Jones, & Roos, 1990) which also uses Pull as a main pillar of its framework. Advocates of pull systems have written about the disadvantages of push/MRP systems and have proven the superiority of pull/Kanban strategies in simple repetitive manufacturing environments (J.P. Womack & Jones, 2003) (Spearman & Zazanis, 1992). However Suri et al. argue that in markets with a high degree of variability and low volume, pull/Kanban is not the superior system (Suri & Krishnamurthy, 2003). Spearman illustrates that the effectiveness of pull systems does not result from pulling but from limiting WIP and WIP variability, e.g. within a Kanban system (Spearman & Zazanis, 1992). Further he demonstrates that a pull system is generally easier to control than a push system.

3.3.1.5 From Manufacture-to-stock to Engineer-to-order

Before defining the term of manufacture-to-order, the commonly known product process matrix of Hayes and Wheelwright is presented and explained in Figure 18. There is a close relationship between the key variables that mainly determine the process type which is most appropriate to be chosen for an organisation (Slack, Chambers, & Alan Betts Robert Johnston, 2006) and the categorisation from manufacture-to-stock to engineer-to-order environments (see Figure 18 and Figure 19).

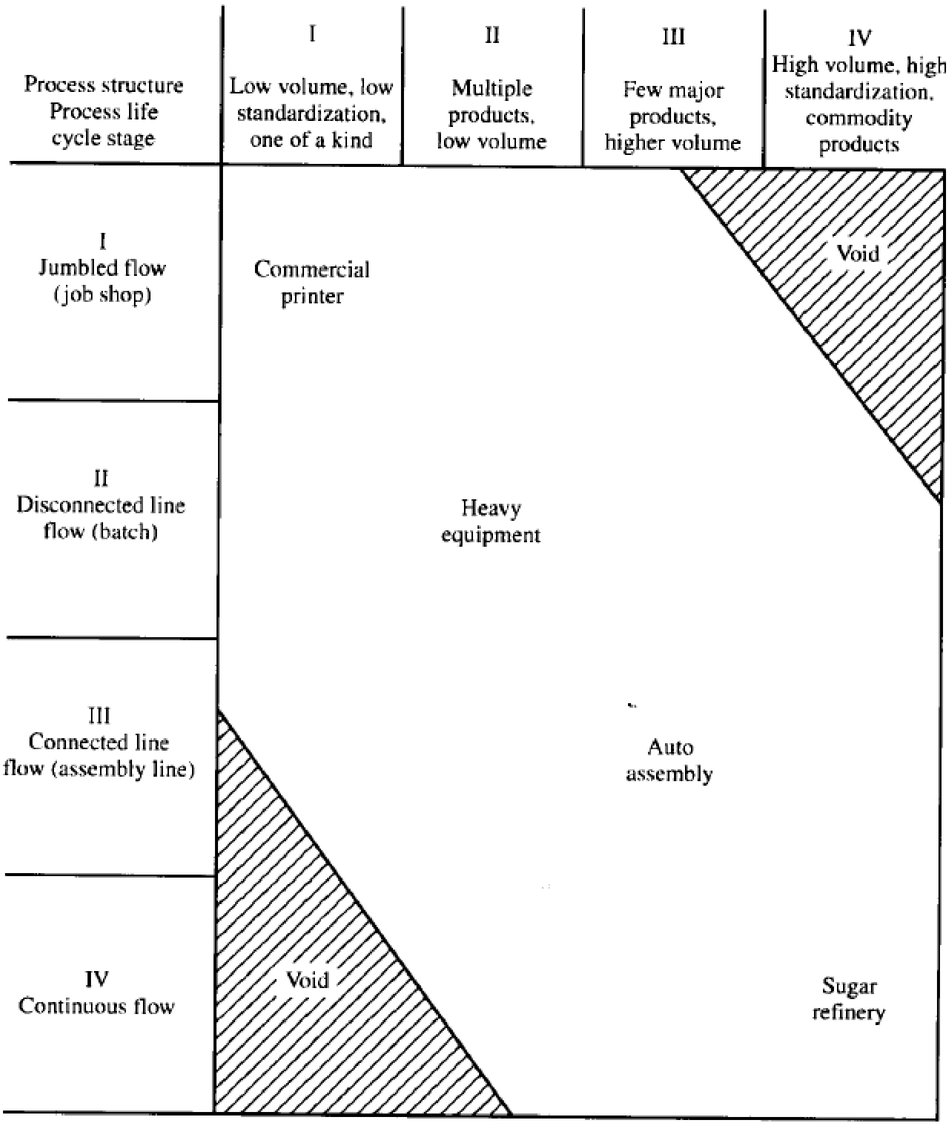

Figure 18: The product process matrix (Hayes & Wheelwright, 1979)

Slack et al. state that there are four key factors that determine the process type which is most appropriate:

- The volume of the products or services
- The variety of the different products or services
- The variation in the demand for the products or services
- The degree of visibility that customers have of the production of products or service.

In this context the speed of flow (throughput time) also characterises the process type and can therefore be seen as an adequate measure for the categorisation of process types in the opinion of the author (see Figure 19).
For example in the matrix of Figure 18 a job shop can be described as a firm that usually produces small batches of a large number of different products, most of which require a different set or sequence of processing steps (Hayes & Wheelwright, 1984).

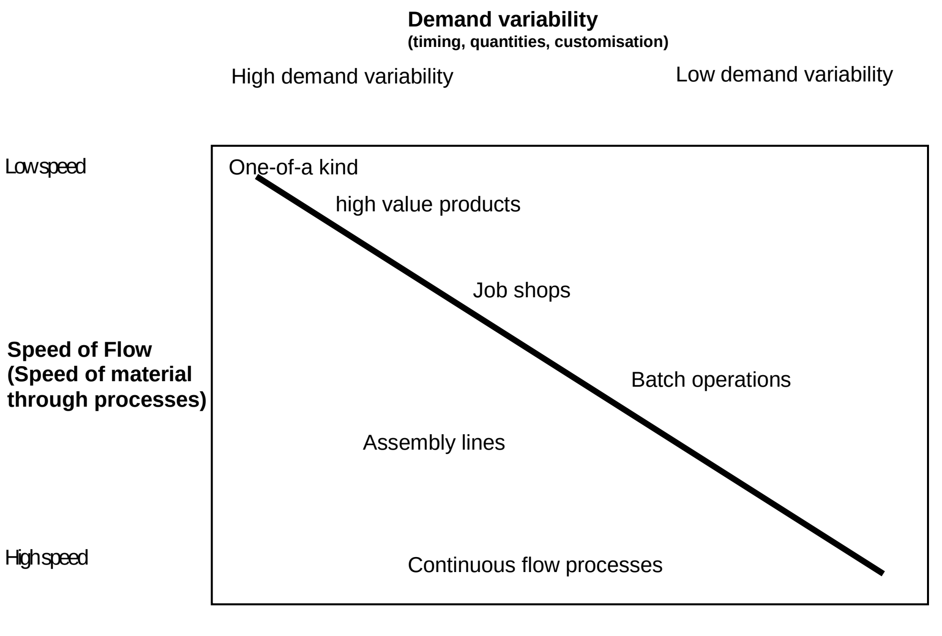

Figure 19: Slightly adapted version of the product-process matrix (adapted from (Schmenner & Swink, 1998))

Hayes and Wheelwright present in general four process types (y-axis in Figure 18): job shop process, disconnected line process (batch process), connected line process, and continuous flow process. As a fifth type Samson and Singh mention the project process (Samson & Singh, 2008). This project process can be found in one-of-a-kind production environments and must be seen as a special case where variety of products is extremely high and the volume of a manufactured product is very low.

Kingsman et al. state as the basic distinction between Make-To-Stock (MTS) and Make-To-Order[2] (MTO) manufacturing its timing of the receipt of the customer order relative to producing the end item (B. Kingsman, Hendry, Mercer, & De Souza, 1996). This is closely related with the possible degree of customisation of the product and can further be characterised by the amount of work that has been conducted after the customer order was received (Stevenson, Hendry, & Kingsman, 2005). The ability of manufacturing operations to accommodate such customising of its products can be described on a continuum from a pure MTS environment to a pure engineer-to-order situation (see Figure 20). In the MTS situation the final product is already available in stock at the manufacturer and can be despatched immediately to the customer. In consequence the customer chooses out of a relatively low variety of products with pre-defined specifications. There is no customising possible since the customer's order is met by finished stock. Referring to Hayes and Wheelwright's product-process matrix, the field of MTS companies is usually characterised by a higher volume of products with relatively low variety and with a relatively low variability of processes. On the other hand, MTO environments are mainly characterised by the fact that customers can change or at least choose certain combinations of product specifications and therefore the final product is produced (at least to a certain extent) after the customer's order. In the MTO category, there are sub-categories going from assemble-to-order to engineer-to-order.

[2] Make-to-order and Manufacture-to-order are to be seen as synonyms.

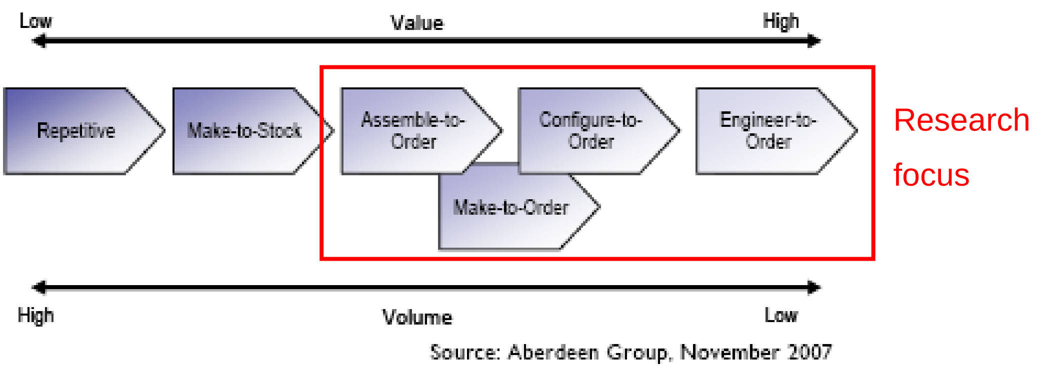

Figure 20: Manufacturing concepts

In assemble-to-order manufacturing, major components, subassemblies and materials are held in stock awaiting the customer order. This allows some customising within a very restricted range. The manufacture-to-order operation requires that any materials and component parts ideally have to be purchased on receipt of the customer order. Either the customer supplies the design or it involves producing a product whose basic design was developed earlier. For every order, the manufacturer has to determine what materials to use, which manufacturing processes are necessary, what machines to use and in which sequence, and what amounts of processing times are required on each machine to estimate the capacity utilisation. Therefore the production planning and control function is essential for operational success. There is often a high level of variability with respect to the routings and processing times, so it is difficult to predict how the work will be distributed among the various machine groups in the factory at any point in time which makes capacity planning very difficult. This phenomenon could be observed in the case studies A and E. There are usually significant demand fluctuations on the factory due to the erratic supply of customer orders (B. G. Kingsman, Tatsiopoulos, & Hendry, 1989).

The situation with the highest degree of variability is the engineer-to-order case where the customer only specifies the purpose for which the product is required. Hence, in the pure engineer-to-order company (ETO), the order is received before the design stage. Companies in this category usually produce one-off products, hence the term one-of-a-kind manufacturing is to be understood synonymously.

This research project mainly considers only the last two categories, make-to-order and engineer-to-order as the MT0 sector of manufacturing industry.

Except of case study C which is mainly operating as an assemble-to-order company, all other case studies belong to the category make-to-order or engineer-to-order.

The variability classification matrix shown in Figure 21 will be used in chapter 4 to compare the presented case studies regarding their product-process variability. Lander determined in this context two dimensions of variability: task variability and demand variability (Lander, 2007). Demand variability refers to the level of fluctuation in demand resulting from changes in both volume (volume variability) and mix (mix variability) from time period to time period. According to Lander demand variability[3] is commonly used in the literature as a factor characterising the external environment. Task variability refers to the repetitiveness of the internal work performed. It is caused by the difference in the jobs required for each product made (processing variability), and by the number and level of interaction of the process routes that exist through the facility to accommodate all those products (route variability).

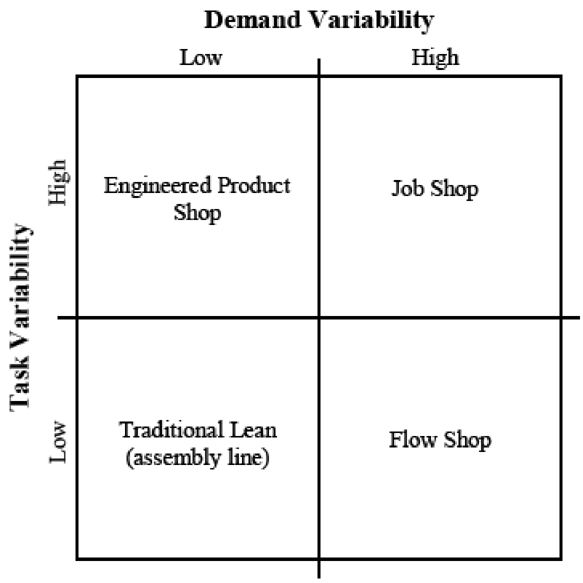

Figure 21: Variability classification (Lander, 2007)

In summary manufacture-to-order companies are mainly characterised by the amount of work that needs to be done after the customer order and by the level of customisation. This usually implies a tendency to a higher task variability (process routing and process durations), a higher variability in demand, and hence restricted possibilities of product and process standardisation.

[3] The term seems to be used in a synonymous sense to uncertainty, see chapter 3.3.1.2

Additionally the speed of flow tends to be lower or appears to be disrupted and lead times are consequently longer. It is more difficult to identify patterns of standard routings taken by the flow entities. By definition, a manufacture-to-order company is to be more categorised as a ‘Pull’ system as the level of WIP directly correlates with the number of customer orders.

The following chapters will explore the prevailing manufacturing methodologies.

3.3.2 Total Quality Management

In Figure 22 Feigenbaum illustrates that Total Quality Management is the consequent further development of Statistical Process Control (SPC) and Total Quality Control (Feigenbaum, 1991).

Within mass-production the role of quality inspection (100% inspection, later statistically with samples) became a regular part of the production process. The method of improving the quality by extracting faulty components became more efficient with the introduction of statistical measures which reduced the sample size and therefore reduced the costs of inspection. In this context Shewhart is acknowledged as the father of SPC. His main contribution lies in the distinction between chance-cause and assignable-cause origins of variations and the development of the quality control chart (Shewhart, 1980).

Seeing excellence in quality not only as a problem of the production unit but as a company wide responsibility, Feigenbaum historically allocates TQM into the early 1980s. Some of the most influential people in the quality movement are Shewhart (control charts), Deming, Juran, Feigenbaum, Ishikawa, Crosby, and Taguchi.

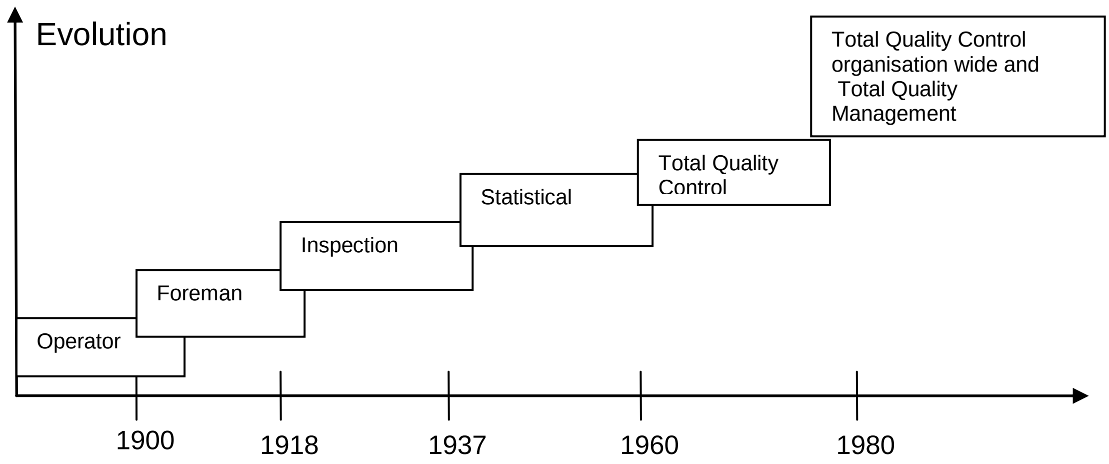

Figure 22: Historical evolution of quality methods (Feigenbaum, 1991)

After being invited by the Japanese Deming developed the so-called system of profound knowledge in the late 1940s and early 1950s where he also visited Toyota and taught his 14 key principles for management (Deming, 1986). Hence there is a number of authors who award Deming an influential role with regards to the Toyota Production System (J.P. Womack et al., 1990) (J. K. Liker, 2003). It needs to be noted that the established problem solving process called PDCA cycle can also be traced back to Shewart and Deming.

In 1954, J.M. Juran, an advisor in the American Management Association at that time, was invited to Japan by Japanese quality management researchers. Juran emphasised managerial aspects of quality management. This concept was implemented by Feigenbaum in the United States, whereas it emerged in Japan as total quality control (TQC) in the second half of the 1960s. TQC stresses not only presentation of the PDCA cycle as top management's policy but also the company wide promotion of job improvement.

The Total Quality movement reached its peak of academic interest in the mid 1990s (also refer to Figure 33).

Feigenbaum defines TQM as "an effective system for integrating the quality-development, quality maintenance, and quality-improvement efforts of the various groups in an organisation so as to enable marketing, engineering, production, and service at the most economical levels which allow for full customer satisfaction" (Feigenbaum, 1991).

Therefore, TQM is the art of managing the whole to achieve excellence by focusing on quality. TQM is defined as both a philosophy and a set of guiding principles that represent the foundation of a continuously improving organisation. It is the application of quantitative methods and involvement of people to improve all the processes within an organisation and to exceed customer needs now and in the future.

Seeing Deming as one of the most influential precursors of the quality movement, his fundamental principles presented in the system of profound knowledge (SPK) needs to be mentioned here. Deming advocated that all managers need to have what he called a system of profound knowledge consisting of four parts:

- Appreciation of a system: understanding the overall processes involving suppliers, producers, and customers (or recipients) of goods and services;
- Knowledge of variation: the range and causes of variation in quality, and their effect on efficiency;
- Theory of knowledge: the concepts explaining knowledge and the limits of what can be known (see also: epistemology);
- Knowledge of psychology: concepts of human nature.

Most quality management techniques were invented and developed to solve quality problems and to improve quality. The probably most well known techniques are the seven quality tools, which can be found in any common quality management handbook (e.g. (Taguchi, Chowdhury, & Wu, 2005)): control charts, pareto charts, histograms, graphs, cause-and-effect diagrams, scatter diagrams, and check sheets.

Within the quality movement there is a number of established frameworks mainly for evaluation purposes that developed over the years in different industries and regions. There is no argument that ISO 9001, the Baldrige award, and the EFQM *(*European Foundation for Quality Management) model as the main representatives share the same fundamental elements and principles emphasising the importance of a quality focus out of the perspective of the customer, the significance of leadership and employees, the role of a process perspective and the development of a continuous improvement culture (refer to Figure 23 and Figure 24).

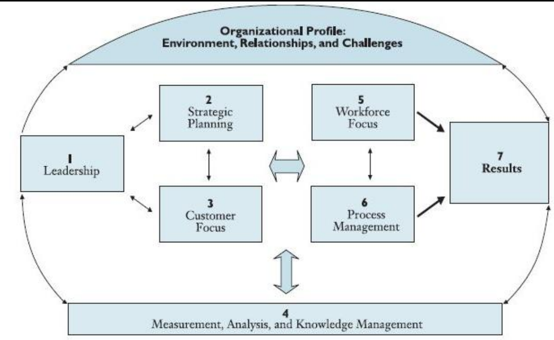

Figure 23: The criteria of Baldrige award (National Institute of Standards and Technology, 2009)

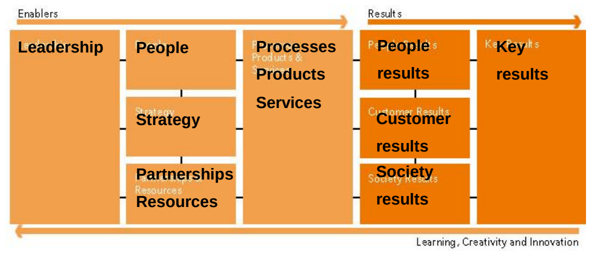

Figure 24: The EFQM model (European Foundation for Quality Management, 2009)

Looking particularly at the TQM research for SMEs, Gobadian and Gallear made a few noticeable conclusions based on case studies: Firstly they question whether management concepts appropriate to the needs of large organisations prove to be effective in SMEs. They found that concepts developed in large organisations and applied unmodified by SMEs are likely to produce adverse results. The TQM concept could be used in two of his case studies with considerable success. One of the benefits of an implementation is the focus on long term survivability. In comparison with larger organisations they conclude that it was easier for SMEs to affect cultural change and there is likely to be found less resistance to change. They identified as an essential inhibiting factor the low availability of resources and also observed the setting of unrealistic targets as a problem in three of the cases (Ghobadian & Gallear, 1996).
Haksever identified as key factors for the implementation of TQM in SMEs the manager's or owner's lack of business experience and knowledge and a shortage of financial and human resources (Haksever, 1996).

3.3.3 Theory of Constraints (TOC)

Theory of Constraints (TOC) was introduced by E. Goldratt in his business novel 'The Goal' in 1984 (Goldratt, 2004). The core of this theory resembles Liebig's law which states that growth is not controlled by the total of resources available, but by the scarcest resource (limiting factor). The roots in a manufacturing environment can be traced back to the development of a commercially successful shop floor scheduling software product known as optimised production technology (OPT) in the late 1970s (Jacobs, 1983). It needs to be noted that TOC does not have its origins in the automobile industry and found applicability in various industry fields. Based on this core principle Goldratt postulates that every organisation has at least one constraint or only a few which limit the organisation's overall performance according to its goals. To improve the overall performance of the system Goldratt developed five focusing steps. By improving and 'exploiting' the constraints the throughput of the whole system can be increased. Additionally TOC states that non-constraints need to be 'subordinated' to the constraints, as improvements in those areas will probably only lead to additional work in progress and inventory. The main methodology for the coordination of constraints and non-constraints is the technique drum-buffer-rope (DBR). The constraint takes the role of a pacesetter for the whole system (drum) and it is important to fully utilise the constraint. Therefore and to protect the constraint of idle time, a buffer of work needs to be installed in front of the constraint. The rope symbolises the work release mechanism into the system to assure the buffer size.

The Theory of Constraints contains four inherent assumptions which can be applied to all systems.

1. Every system or organisation has a goal in order to achieve its purpose (Goldratt, 2004).
2. The optimum of the system is not the sum of the local optima (efficiencies) (Goldratt, 1990).
3. There are only one or a few variables (constraints) that limit the performance of the system (Goldratt, 2004) (compare with chapter 3.3.1.3, law of bottlenecks).
4. All systems operate in cause-and-effect chains or networks (Goldratt, 2007).

Looking at high variability environments, especially at one-of-a-kind environments, Goldratt developed the so-called critical chain project management (CCPM) methodology (Goldratt, 1997), which also found applicability in two of the case studies of this research. This approach applies the fundamental principles of TOC to project environments. The difference to more traditional project management approaches like PERT (Project Evaluation and Review Technique), critical path management and Gantt charts lies mainly on the different perspective on the resources. Resources are seen as finite and need correspondently to be levelled. Hereby the critical chain is the sequence of resource-dependent tasks that prevent the overall project to be completed in shorter time. In case of the assumption of infinite resources the critical path would be identical with the critical chain.

CCPM aggregates the safety time inherent in every task in project buffers to protect the final due date. Hence it makes the local safety time that is hidden in every estimate for each task available for the overall project. The main idea is to use this safety time to protect the critical chain (Goldratt, 1997) (Newbold, 1998) (Leach, 2000).

In the case studies, particularly those that represent one-of-a-kind environments, the potential of the methodology with the purpose of scheduling the work load was identified and acknowledged by the companies (see chapter 4). However it was also observed that TOC does hardly provide any advice how to exploit the identified constraints.

3.3.4 System Thinking and System Dynamics

System Thinking and System Dynamics (SD) are not primarily associated with manufacturing and its more traditionally renowned methodologies.

However Ackoff's definition of a system raises very important elements that have profound implications on the understanding of a manufacturing system: "*A system is a whole consisting of two or more parts (1) each of which can affect the performance or properties of the whole, (2) none of which can have an independent effect on the whole, and (3) no subgroup of which can have an independent effect on the whole. In brief, then, a system is a whole that cannot be divided into independent parts or subgroups of parts*." (Ackoff, 1994, p. 175)

SD provides a perspective on how to analyse dynamic complexity and how to expand the mental models in order to understand the structure and the behaviour of complex systems. Hence, SD can be mainly defined as a modelling methodology providing conceptual techniques for the analysis of policy and strategy in business environments (J. Sterman, 2000). The main purpose lies in understanding the structure and dynamics of complex systems.

This perspective on a manufacturing system and its multitude of variables and trade offs proved to be helpful during the interaction in the case studies. Also other authors try to bridge the field of SD with other methodologies of the field manufacturing and operations (Hidaka, 1999) (Davies, Mabin, & Cox, 2004) (Thun et al., 2008). Though there could not be found any research particularly exploring the role and applicability of SD techniques in SMEs.

Typical techniques of System Thinking and System Dynamics include Causal Loop Diagrams (CLD), Behaviour Over Time (BOT), Stock and Flow Diagrams, Microworlds, and Learning Laboratories (P. Senge et al., 1999).
In summary System thinking provides support for the long-term alignment of the manufacturing system and delivers insights in the effects of the transformation process by containing means for shared understanding and illustration. Therefore System Thinking and System Dynamics need to be seen as valuable elements of the strategic decision process by bringing inherent assumptions of management to the surface.

3.3.5 Six Sigma

Since the 1980s, all types of industries have introduced quality management activities.
Six Sigma was started in Motorola by engineer Bill Smith in the late 1980s in order to address the company's chronic problems of meeting customer expectations in a cost-effective manner. Within improvement projects quality problems were systematically analysed at the front end of the process and continued throughout the manufacturing process using four phases (Measure, Analyse, Improve, Control). Jack Welch, the CEO of GE, applied this program across all of GE integrating training of Six Sigma into the promotion structure. GE added an extra phase to define and manage the improvement project. Define, Measure, Analyse, Improve, and Control (DMAIC) has now become the accepted main process for Six Sigma projects.
In summary, Six Sigma started as a problem-solving approach to reduce variation in a product and manufacturing environment. This methodology has expanded to process improvement and other areas of the business, including product or process redesign, research and product development as well as operations management and is heavily data driven. Based on the DMAIC process, it offers a standardised package of techniques to systematically address problems in a variety of business areas. Additionally the Six Sigma methodology offers an organisational structure where certified experts (so-called Master black belts, black belts and green belts) lead the improvement projects. According to Kedar et al. Six Sigma gives clear change of structure and is much more oriented on fast results in comparison with TQM, TPM, and Lean (Kedar, Lakhe, Deshpande, Washimkar, & Wakhare, 2008). Hereby the

main focus lies in the elimination of variation (from customer specifications) which is seen as the primary cause for many problems. DMAIC enables a results-focused approach that is driven by data and facts. Further work is strongly project-oriented. Wilson argues that Six Sigma is neither a manufacturing system nor a manufacturing philosophy and reduces its importance to a set of techniques that enhance problem solving in a wide range of organisations (L. Wilson, 2010).

Näslund concludes that Six Sigma is a further development of TQM. He found similarities in the problem solving process (Deming wheel and DMAIC cycle), the importance of top management commitment, the necessary employee involvement, and in the statistical methods and other quality techniques (Näslund, 2008).

Techniques to be found in Six Sigma are mainly focusing on statistical methods. Further, techniques evolved in the quality movement are adopted and integrated.

3.3.6 Toyota Production System and Lean Production

3.3.6.1 History of Toyota Production System and Lean Production

The history and evolution of the Toyota Production System (TPS) has been widely analysed and covered (Toyota Motor Corporation, 1988) (Ohno, 1988) (J.P. Womack et al., 1990) (Fujimoto, 1999).

In 1970 the entire system – with all the innovations that had been added to it over the years – became to be called the “Toyota Production System” (Toyota Motor Corporation, 1988). The fundamental challenge from a production control point of view was to facilitate a smooth production flow despite a varied product mix and lower production volumes in comparison with the American industry.

When after WW II the automotive industry in Japan had its revival, Toyota struggled with limited financial capacity to invest in specialised expensive mass-production manufacturing technologies. After the owner of the company, Eiji Toyoda, visited Ford in 1950 in the USA together with his leading production engineer Taiichi Ohno, they realised that the inflexible and capital-intensive mass-production does not fulfil the requirements of the Japanese market and surrounding conditions (Fujimoto, 1999).

The conditions forced Taiichi Ohno, Kiichiro Toyoda and later his son Eiji Toyoda to rethink some of the most basic principles of the predominant mass production model. “Kiichiro’s goal was to match Toyota’s unit cost of producing 20,000 to 30,000 units per year to that of American models’ producing several hundred thousand units per year. Therefore, Toyoda modified the Ford production system for small-volume production.” (Fujimoto, 1999, p. 36)

In consequence under the leadership of Ohno a production system evolved at Toyota that is based on two main pillars (Ohno, 1988):

1. Just-in-time
2. Autonomation, also known as automation with humane touch or by the Japanese word Jidoka.

In the 1970s and 1980s the term just-in-time (JIT) collectively stood in Western literature for the distinctive style of manufacturing in Japan and the underlying manufacturing techniques. JIT refers to the ideal state of a flow system where the right parts reach the assembly line at the time they are needed and only in the amount needed. This will lead under ideal conditions to zero inventory. The second pillar, autonomation or also called Jidoka, represents the ability of machinery to stop immediately as soon as processes are out of the defined specifications.

The IMVP researcher John Krafcik originally coined the term “lean production” (Krafcik, 1988). IMVP is an abbreviation of the International Motor Vehicle Program established at Massachusetts Institute of Technology in 1985. During the following 5 years, the IMVP staff carried out an in-depth benchmarking study of the international automotive industry. The study collected data from automobile assembly plants all over the world in order to understand the differences in quality and productivity and found enormous international attention through the book ‘The Machine That Changed The World’ written by J.P. Womack, D.T. Jones and Daniel Ross (J.P. Womack et al., 1990) as it revealed the superiority of Toyota’s production system. Therefore the term ‘Lean Production’ of the 1990s needs to be mainly understood as a Western reflection of Toyota’s manufacturing methodologies. As Figure 25 makes evident, in recent years, the term Lean is used as an umbrella for many advanced manufacturing methodologies and techniques that were even developed outside of Toyota (e.g. Six Sigma or Theory of Constraints) and not only covers the operational but also the strategic level (Hines, Holweg, & Rich, 2004). Beyond that it also embraces other business aspects and elements of organisational behaviour, leadership, and organisational learning (Hines, Found, Griffiths, & Harrison, 2008) which particularly became important for the adoption and transfer of the principles and methodologies to other organisations.

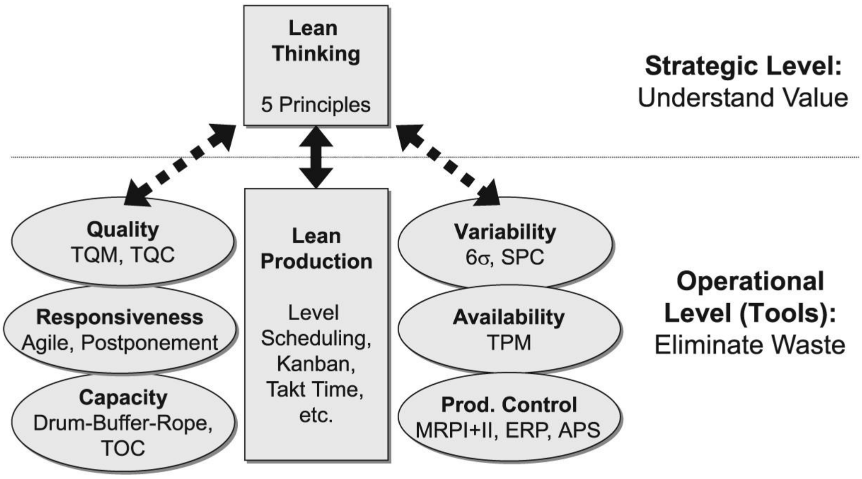

Figure 25: Strategic and operational level of Lean (Hines et al., 2004)

3.3.6.2 Lean paradigm – definitions and principles

In the early phases Womack defined Lean as a systematic way of removing waste and paraphrased its definition with a more human-centred perspective by describing Lean Production as a *"superior way for humans to make things … Equally important, it provides more challenging and fulfilling work for employees at every level, from the factory to headquarters*" (J.P. Womack et al., 1990, p. 225). Shah and Ward's more concrete definition emphasises that Lean Production is an integrated socio-technical system with the main objective to eliminate waste by reducing external (supplier and customer) and internal variability (Shah & Ward, 2007). Hopp and Spearman present a dynamic definition that relates even closer to the manufacturing theory presented in chapter 3.3.1. A system is defined as Lean when the buffers present in the system are restricted to the minimum level necessary in order to support the target performance (Hopp & Spearman, 2008).

As main objectives of the TPS, Spear and Bowen list the reduction of production and set up time, the integration of suppliers, the elimination of waste, to synergise the entire business process, and to gain support at all levels for this system (Spear & Bowen, 1999). Ohno simply defines the goal of the Toyota Production System as an effort to make goods as much as possible in a continuous flow (Ohno, 1988).

The benefits of Lean Production commonly mentioned on the operational side are reduced lead/cycle time, decreased work-in-process (WIP), increased resource (equipment, operator) utilisation, a more streamlined flow, a reduced floor space, improved quality and improved worker morale (J.P. Womack et al., 1990) (Shah & Ward, 2007) (Holweg, 2007). Current research in mass-production environments revealed productivity increases of 15%-35% per year during Lean implementations (Pavnaskar, Gershenson, & Jambekar, 2003). Bhasin and Burcher present a quite extensive literature review for empirical evidence of the benefits of a Lean transformation and hence should be referred to for the interested reader (Bhasin & Burcher, 2006).

Regarding the financial benefits of Lean Production, Camacho-Miñano et al. found that in 63% of 22 analysed articles a positive relationship, in 27% no relationship between JIT as one of the major pillars of Lean and financial performance could be found (Camacho-Miñano, Moyano-Fuentes, & Sacristán-Díaz, 2009). A study of Demeter et al. confirm the positive impact of Lean Production on the operational performance, but it also reveals that the impact on the business performance is statistically less clear. They found as significant factors, that influence the business performance more than the operational performance, low market growth, too low spare capacity to handle demand fluctuations, and a supplier selection process that pays low attention to supplier's overall performance. This clearly shows the importance of variability (uncertainty) that is external to the manufacturing system itself.

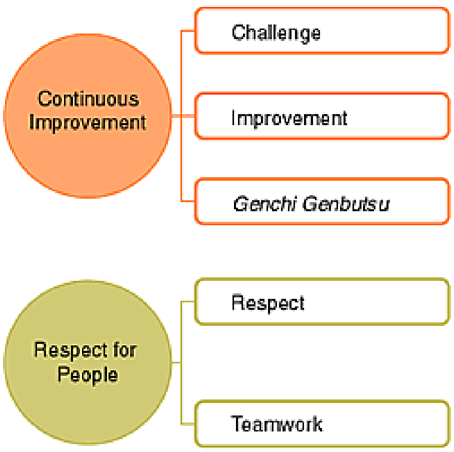

Figure 26: Main elements of the "The Toyota Way" (J. K. Liker & Hoseus, 2008)

In recent internal publications of Toyota (The Toyota Way, referred to in (J. K. Liker & Hoseus, 2008), see also Figure 26), Toyota emphasises the importance of their corporate culture and placed Lean techniques like Kanban and SMED as a subset of the foundational element of continuous improvement (kaizen). If kaizen is broken down further in Toyota's model, one gets the sub-elements of kaizen, mind and innovative thinking, building Lean systems and structure, and promoting organisational learning. Also other recent literature with an external perspective sees Toyota's success not only grounded in the manufacturing methodologies but even more in their management system and their corporate culture which is based on long-term thinking, respect for people, and the responsibility of leaders to be teachers and trainers (Mann, 1995) (Bhasin & Burcher, 2006) (J.K. Liker & Meier, 2006) (Hines et al., 2008). Liker for example argues that the foundation of the Toyota Way model is long-term thinking and that patience and perseverance are both highly valued within Toyota. In fact the biggest impediment Liker has observed in American companies wishing to learn from the Toyota Way is their short-term orientation and need for every action taken in the name of Lean to pay itself very quickly (J. K. Liker & Hoseus, 2008). This observation of Liker is certainly of relevance for this research as on the one hand New Zealand as a nation shows tendencies of a low degree of long-term orientation (see 3.2.1.3) and on the other hand also SMEs in general tend to be more short-term oriented (see 3.2.3.3).

Takeuchi et al. revealed in a six year lasting study that beside the 'hard' innovation of the TPS, Toyota has mastered a 'soft' innovation that relates to corporate culture and continuously *"creates contradictions and paradoxes in many aspects of organizational life"* (Takeuchi, Osono, & Shimizu, 2008, p. 98). Although Toyota grows steadily and constantly records sales and market share growth, senior executives emphasise values like humility and putting the customer first with messages like "Never be satisfied." and "There's got to be a better way." (Takeuchi et al., 2008). Another contradiction lies between the obvious operational efficiency and apparent inefficient use of human resources, e.g. the number of people attending meetings without participating on discussions seem to be quite high (Osono, Shimizu, & Takeuchi, 2008). Besides it spends enormous sums of money on manufacturing facilities, dealer networks, and human resource development. This culture of fostering contradictory viewpoints leads according to Takeuchi to innovative ideas by challenging employees.

Table 12 presents a literature review of high level elements and principles that are associated with Lean Production or the TPS. It becomes clear that the taken perspective and level of abstraction varies from author to author. As major categorisation themes the author defined the following elements:

- Human resource and leadership development
- Continuous improvement and problem solving
- Product and process standardisation
- Vision, strategic alignment and value definition
- Measurement and transparency
- Flow and synchronisation
- Customer and supplier relations

These elements were derived by analysing the high level elements and principles and will be integrated into the Lean transformation framework developed in chapter 5.

Table 12: Analysis of Lean principles

	HR and leadership development	Continuous improvement and problem solving	Product and process standardisation	Vision, strategic alignment and value definition	Measurement & transparency	Flow & synchronisation	Customer and supplier relations
Source: (Mann, 1995)							
1. Discipline	x		x				
2. Leader standard work	x		x				
3. Visual controls			x		x		
4. Daily accountability process	x		x				
Source: (B. A. Henderson & Larco, 2002)							
1. Vision				x			
2. Strong line management	x						
3. Expert training and support	x		x				
4. Aggressive performance targets					x		
5. Impatience by management to move forward and deliver tangible results	x						
Source: (J.P. Womack & Jones, 2003)							
1. Specify value out of the customer perspective				x			
2. Define value streams				x		x	
3. Strive for perfection	x	x					
4. Create within a value stream flow				x		x	
5. Create pull						x	
Source: (J. K. Liker, 2003)							
1. Long term philosophy				x			
2. Add value to the organisation by developing your people and partners	x						x
3. Continuously solving root problems (learning organisation)		x					
4. The right process will produce the right results			x		x		
Source: (Flinchbaugh & Carlino, 2006)							
1. Creating a learning organisation	x	x	x		x		
2. Systematic method for problem solving like PDCA or the 5 Why's		x	x				
3. Establishment of high agreement (standardisation) of what and how to deal with selecting priorities and methods for continuous improvement		x		x	x		
4. Systematic waste elimination		x		x	x	x	
5. Direct observation of work, activities and flow		x	x				
Source: (J. K. Liker & Hoseus, 2008), (Ohno, 1988)							
1. Continuous Improvement a) Challenge b) Improvement c) Genchi Genbutsu ("Go and see for yourself")		x	x				
2. Respect for people a) Respect b) Teamwork	x			x			
Source: (Takeuchi et al., 2008), Three forces of expansion							
1. Impossible goals	x				x		
2. Local customisation		x	x				
3. Experimentation	x	x					
Three forces of integration							
4. Values from the founders	x			x			
5. Up-and-in people management	x						
6. Open communication	x				x	x	

3.3.6.3 Lean methodologies and techniques

Holweg emphasises that there is no agreement on which practices belong to Lean. One explanation for this lies according to Holweg within the changing perception in the set over time (Holweg, 2007). This can be interpreted in the way that the academic understanding on what Lean is underlies itself a relatively early maturity stage. This refers to the phenomenon that methodologies seem to be subject to life cycles as well. Hereby methodologies that often have their origin in one or a few companies or industries initially find the attention of academics. While finding in fact indicators for improvements in performance and with raising number of publications in the field of interest, the attention of competitors, other industries and consultants are attracted (E. Schein, 1996). Over time the methodology embraces other techniques and mind-sets of precedent methodologies and consequently a new theoretical operational best practice frontier is developed. Hence, the presented overview of methodologies and techniques does not take the claim of totality but rather as a recent reflection of the current understanding. Referring to Kuhn's definition of a paradigm (see chapter 1.2.4), it might help in the opinion of the author to sketch the current manufacturing paradigm and its methodologies and techniques.

Bednarek and Fernando present a comprehensive literature analysis (see Table 13) of Lean techniques and identified the following methods to be unique to Lean manufacturing (Bednarek & Fernando, 2008):

- Pull System
- Takt time
- Production stability and work balancing (heijunka)
- One piece flow
- Value stream mapping

The concept of pull is explained in chapter 3.3.1.4. **Takt** time is in general the average rate at which a customer orders parts or products. As this is equivalent to the term demand rate, the objective is correspondingly to align the transformation rate, in other words the products should be produced at the same rate. Hence the takt time sets the pace for a production line. The pure takt time can be calculated as:

$$T = \frac{T_A}{T_C} \text{ [time/unit]} \quad \textbf{(4)} \qquad \textbf{(G. Lane, 2007)}$$

T: Pure takt time

T_A: Time available to work e.g. [h/d]

T_C: Customer demand rate e.g. [required units/d]

In order to calculate a more realistic takt time Lane suggests to multiply the pure takt time with the overall equipment effectiveness (OEE) of the correspondent machine or line.

Heijunka refers to the process of levelling and smoothing the workload and product mix over a specific time period. The objective is to produce in smaller quantities that are more aligned with the actual customer consumption and herewith to reduce batch sizes and consequently WIP. This increases the flexibility to changing customer demand (J. K. Liker, 2003). Fundamental requirements for heijunka are a high process quality level, controllable and relatively small down times of resources and the reduction of set-up times (Shingo, 1985).

One piece flow (also called single piece flow) refers simply to the ideal theoretical state of a batch size of one that is directly transferred between process steps. In assembly lines one piece flow can for example be achieved by establishing a takt time for the whole line and correspondently balance the workload for the single stations.

The technique of **value stream mapping** received public attention through the book 'Learning to See' from Rother and Shook (Rother & Shook, 1998). Value stream maps identify ways to get material and information to flow without interruption, improve productivity and competitiveness, and help people implement systems rather than isolated process improvements (J.P. Womack & Jones, 2003). Therefore value stream maps assist in recognising waste that exists in processes. Waste is defined as an activity (J.P. Womack & Jones, 2003) or behaviour (M. L. Emiliani, 1998) that adds cost but does not add value. By eliminating waste one can concentrate on the value creating activities that customers desire (also see chapter 5.4.4.2).

Bednarek's list of techniques that are specific to Lean Production is complementary to Dettmer who argues that takt time and work balancing in combination with one piece flow are the most significant differences to the methodology of Theory of Constraints (Dettmer, 2001).

Bednarek and Fernando's analysis of Lean techniques (see Table 13) is slightly amended as it was reviewed and is extended by the authors Hines, Kobayashi, and Takeda (Hines et al., 2008) (Kobayashi, 1995) (Takeda, 2006). An additional level of categorisation is added that shows the overlap of techniques with other methodologies, e.g. TQM and TPM.

Table 13: Analysis of Lean techniques by often quoted authors (extended analysis of (Bednarek & Fernando, 2008))

		(Ohno, 1988)	(Shingo, 1989)	(Monden, 1993)	(Womack, 2003)	(Conner, 2001)	(J. K. Liker, 2003)	(Hines et al., 2008)	(Kobayashi, 1995)	(Takeda, 2006)
TQM	Self-inspection								x	
	Statistical process control			x		x				
	Process orientation							x		
	Standardisation		x	x		x	x	x	x	x
	Quality circle		x	x		x				
TPM	Preventative & autonomous maintenance					x	x	x	x	
	Team empowerment, human factor	x	x	x	x	x	x	x	x	x
Visual management	5 S	x			x	x	x	x	x	x
	Andon boards		x	x			x			
	Planning boards					x			x	
	Coupling points								x	x
CI (Kaizen)	Lean metrics			x	x	x		x	x	
	5 Why's & 5M	x	x				x	x	x	x
	PDCA cycle				x		x	x	x	
	QC Tools					x	x	x	x	x
	Improvement suggestion system							x	x	x
	Value Stream Mapping				x	x	x	x		
JIT & flow	Pull	x	x	x	x	x	x	x	x	x
	Takt					x	x	x		x
	Inventory control, kanban	x	x	x				x	x	x
	Supplier involvement		x		x			x	x	
	One piece flow	x		x	x	x	x	x		x
	Shojinka		x	x		x		x	x	x
	Work cells (e.g. u-shaped layout)			x		x	x	x	x	x
	SMED, set up reduction	x	x	x	x	x	x	x	x	x
	Production levelling (heijunka)	x	x	x	x	x	x	x	x	x
Jidoka	Andon line	x	x	x		x	x			
	Autonomation	x	x	x				x	x	x
	Poka-Yoke	x	x	x	x	x	x	x	x	x

Further methodologies that have been found in the context of Lean Production are:

- Chief engineer system (M. N. Kennedy, 2003) (Morgan & Liker, 2006)
- A3 reports (Sobek, publication date unknown)

- Hoshin Kanri (J. K. Liker, 2003) (Yang & Su, 2007)
- Gemba and Genchi Genbutsu ("Go and see for yourself") (J. K. Liker, 2003)
- Hansei (Morgan & Liker, 2006)
- Concurrent engineering (Morgan & Liker, 2006)
- Improvement suggestion system (Pil & MacDuffie, 1999)

The right selection of those techniques first of all applicable and secondly with the biggest effect on one's organisation obviously imposes difficulties especially to SMEs due to the lack of expertise. Hence it certainly requires some more guidance in form of selection criteria that narrow down the number of techniques. An analysis of which techniques have been used in the case studies is discussed in chapter 4.8.2.

The Aberdeen Group recently published a study that compares the usage of selective Lean techniques between 'best in class' companies (BIC) and the rest of their sample (see Figure 27) (Aberdeen Group, 2007). Best in class companies tend for example to incorporate the technique of Value Stream mapping more often, take the design of work cells more into consideration, are more involved in continuous improvement teams and embrace the technique of 5S more often. On the other hand it is conspicuous that the pure application of Kanban is less used in BIC companies than in the rest of the sample.

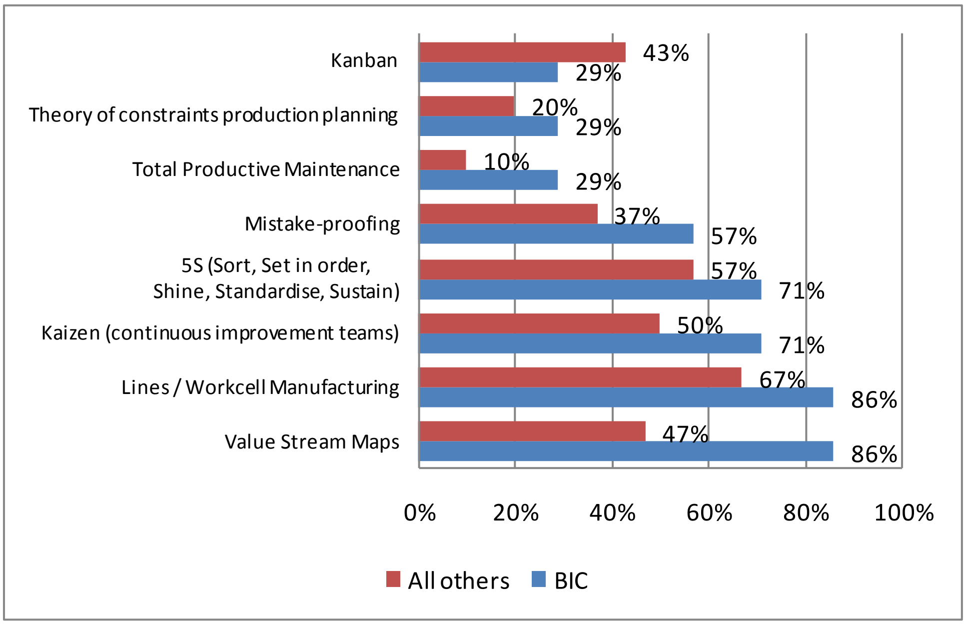

Figure 27: Usage of selective Lean methodologies according to (Aberdeen Group, 2007)

3.3.6.4 Critical success factors in Lean transformations

This chapter presents a discussion of correspondent literature about critical success factors.

In general the critical success factors for the improvement initiatives TQM, Six Sigma, and Lean were found to be very similar (Näslund, 2008). The frequently mentioned success factors in Näslund's study include the importance of a vision and strategy, top management support and commitment as well as the importance of communication and information. Further Näslund questions the practical applicability of those too generalised factors and identifies the lack of a systemic approach to organisational change and improvement. Hence he argues that the theories behind systems thinking in combination with a strong process focus can provide the framework needed to facilitate and maintain successful organisational improvements. Looking for example at critical success factors for the implementation of TQM (see (Yusof & Aspinwall, 1999) and (S. R. M. Yusof & E. M. Aspinwall, 2000)) , commonalities become obvious. For the successful implementation of TQM the role of leadership, the importance of the involvement of employees and the alignment of the measurement system are seen as critical factors.

Table 14: Critical success factors for Lean transformations

Boyer (1996)	Tracey and Flinchbaugh (2006)	Askin (2002)	Keyte and Locher (2004)	Achanga (2006)
'Quality leadership'		Strong leadership	Organizational leaders must understand and embrace Lean concepts	Leadership & Management
The use of teams for collective problem solving	1. Development of teams as a supporting structure of Lean		Key team leaders must develop detailed kaizen or short-term continuous improvement implementation plans	
Training of the workforce	3. Communication among organisation members, particularly across organisational barriers based on a strong process focus	Education		Skills and expertise
Worker empowerment	4. Communication to employees regarding their specific role in Lean transformation			Organisational culture
	2. Calculation and communication of 'owned' and predictive metrics		Future VSM must be aligned with the organizational strategic business objectives	
	5. Acknowledgement and celebration of successes toward Lean transformation by communicating and rewarding progress			
		Time	Value stream managers must be given the time and resources required to implement the future state VSM	
				Financial capabilities

Sources: (Boyer, 1996), (J. Flinchbaugh, Tracey, W., 2006), (Askin & Goldberg, 2002), (Keyte & Locher, 2004), (Achanga, 2005)

Boyer (Boyer, 1996) concludes that the commitment for a Lean implementation is shown by mainly long-term investments in infrastructure providing 'quality leadership', training of the workforce, worker empowerment and the use of teams for collective problem solving. His research reveals that those infrastructural investments are critical for the success of Lean Production and serve as a "catalyst for achieving increased productivity" (Boyer, 1996, p. 57).

Askin argues that converting to Lean thinking of product cell layouts, single-unit mixed model production, continuous material flow, mistake-proofing, and balanced production represents revolutionary change. Such change only comes through strong leadership, education, and time (Askin & Goldberg, 2002).

Keyte and Locher list critical success factors for a successful Lean transformation (see Table 14) (Keyte & Locher, 2004) and emphasise the importance of leaders on all organisational levels and assigns to the application of value stream mapping and the correspondent mind set a critical role.

By identifying common themes in Table 14 the following elements were defined by the author:

- Leadership and Management
- Development of a team structure
- Training and education
- Empowerment and clear communication of roles
- Communication of objectives and metrics
- Acknowledgement of time (Lean is a journey, not a project)

These themes served next to the main insights of the manufacturing theory elaborated in chapters 3.3.1 to 3.3.6 as a theoretical initial concept in the development of the framework.

3.3.7 Industry and research activities about best practices for New Zealand

There are a few initiatives and research activities in recent years about best practices in the manufacturing industry in New Zealand. This summary does not claim to be complete but is supposed to give an outline of activities that either are cohered with the research project or influenced it in one way or another and has provided valuable insights.

One of the probably most comprehensive studies with regards to best practices in New Zealand companies was conducted by Knuckey et al. beginning in 1994 and followed by two subsequent studies (Australian Manufacturing Council, 1994) (Knuckey et al., 1999) (Knuckey et al., 2002). The main underlying model in order to analyse best practices in the manufacturing industry is shown in Figure 28 and comprises in general the three main dimensions of strategising, practices and outcomes. There is an emphasis on a holistic understanding of the model and that in consequence all elements must be connected in order to achieve sustainable outcomes. By differentiating the sample of more than 1000 NZ companies with regards to their outcomes into leaders (top 20%) and laggers (bottom 20%), it is possible to draw conclusions on which elements are more likely to be found in successful companies.

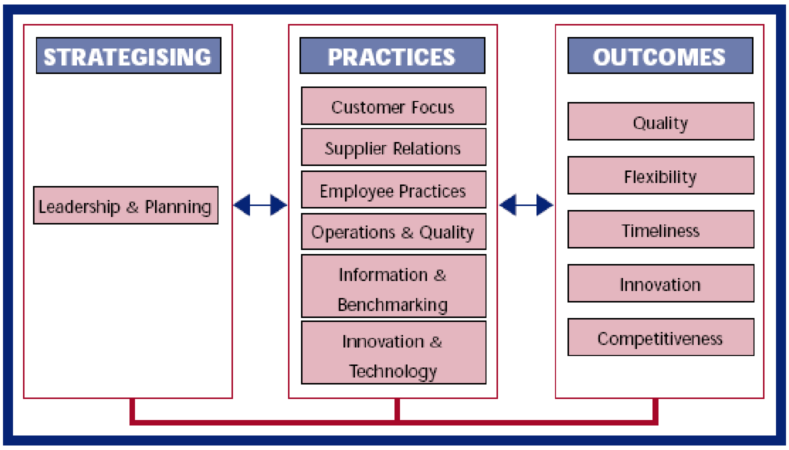

Figure 28: The best manufacturing practices model (Knuckey et al., 1999)

The most recent study revealed that leaders put more emphasis on 'soft' dimensions of business development, like for example employees' welfare, the development of comprehensive systems for measuring and rewarding staff performance, and providing internal and external training and development possibilities. Apart from that, leaders tend to have a more proactive approach to customers and look for more direct channels to work effectively with them.

Additionally leaders pay attention to a more balanced strategic alignment concentrating on the dimensions of flexibility and innovation, along with quality and delivery (Knuckey et al., 2002). It was also noted that many manufacturers still appear to lack a strategic approach to organisational development.

Another project consisting of industry leaders, manufacturers and government representatives called Manufacturing+ Vision Group published their results in the "Manufacturing+ report". The project has consulted widely with New Zealand manufacturers through a series of workshops and meetings over an 18 month period. It identifies 4 key success drivers as strategy, creativity, connectivity, and operations (The Vision Group & M. Pratt (Chairperson), 2006). Based on those key success drivers Pratt et al. advocate the following four step process:

1. Develop a creative and strategic purpose and business model.
2. Establish close connectivity to target markets and customers by sharing your creative ideas.
3. Based on the close relations to the customer, align all your activities and operations along the value chain.
4. Combine operational excellence with the strategic determination of product designs and manufacturing infrastructure to make products of outstanding value.

This four step value creation cycle is presented in Figure 29.

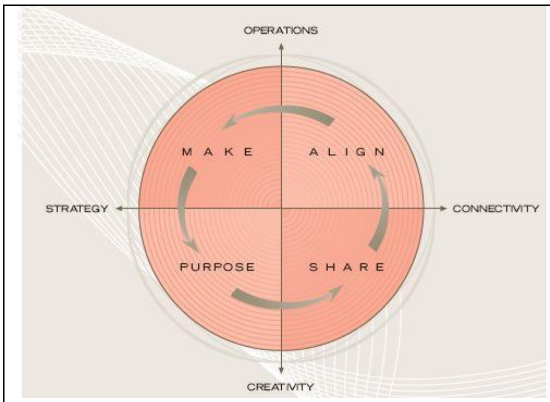

Figure 29: Value creation model (The Vision Group & M. Pratt (Chairperson), 2006)

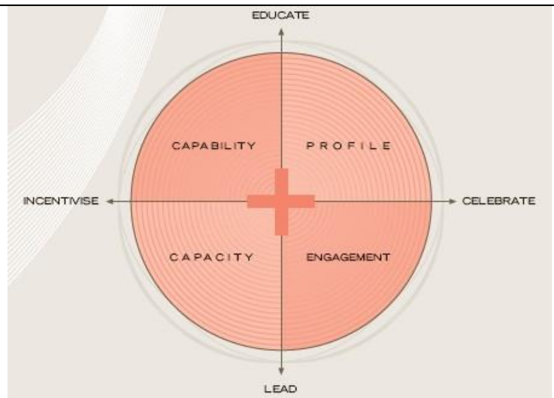

Figure 30: Transformation model (The Vision Group & M. Pratt (Chairperson), 2006)

Based on the value creation model the Vision group developed in a series of workshops a transformation model with the purpose of giving recommendations how to enable organisations to move forward. The 2 axes model represents transformational drivers that create four sectors of recommendations for a transformation (see Figure 30). The model of how successful New Zealand manufacturers create and sustain value applies at the firm or micro level, whereas the transformation model relates to the manufacturing sector's contribution to the economy as a whole.

In the opinion of the author these high level models lack a practical reference and provide little guidance for a typical NZ SME in the manufacturing industry how to operate on a micro level.

An initiative driven by New Zealand Trade and Enterprises (NZTE) started as the so-called Aichi programme around 2005 with the objective of raising the productivity in the NZ specialised manufacturing industry. Four companies supported by a consultant started their ‘Lean journey’ based on a workplace improvement program called 20KEYS (Kobayashi, 1995) (also see Table 13). In the following years further groups of companies were involved and also other consultants joined the network. Regular meetings were organised in order to share experiences and provide assistance. All case studies presented in this thesis are selected out of this Aichi network.

The study ‘Supporting Lean manufacturing initiatives in New Zealand’ conducted by Wilson et al. on behalf of NZTE summarised the experiences and outcomes of the first 22 companies mostly of the Aichi network, analysed the role of consultants and examined the current state of Lean education in NZ universities. The results imply that for a sustainable Lean transformation a time frame of at least three years is required. The role of external consultants is assessed to be critical as the level of knowledge and experience of Lean Production systems in New Zealand is minimal at both managerial and operational levels. All firms achieved noteworthy savings and performance improvements across a range of measures. Also ‘soft’ indicators like staff morale, job satisfaction, and motivation have generally improved, whilst absenteeism has declined.

The following intermediate conclusions can be drawn out of the initiatives and research studies for the development of a Lean transformation framework: firstly the framework must be formulated on an abstraction level that is still ‘meaningful’ with regards to practical day-to-day problems of NZ SMEs. It needs to provide guidance out of strategic and managerial perspective but should also provide support with the selection of the appropriate techniques. Secondly, the active involvement of leadership mostly in form of the owners seems to have an essential role for the success of a Lean transformation. NZTE already reacted to this insight and offers a two day executive training for companies who want to begin a Lean transformation. Additionally the role of external consultants is initially important, but internal capabilities and elements need to be quickly developed to achieve enough momentum and a self-sustaining culture of continuous improvement.

3.3.8 From Taylorism to Toyotism[4]

In the previous chapters the author outlined his understanding of the main manufacturing methodologies. The objective of this chapter is to contribute to a clearer understanding of the evolution of the manufacturing methodologies. The inherent historic driver and social needs are presented and the existence of a 'paradigm shift' from Taylorism over Fordism to Toyotism is discussed. The author in his role as action researcher following an interpretive research approach believes that this 'big picture' of best practices of manufacturing might assist the reader in the interpretation of the AR case studies and their outcomes.

Figure 31 chronologically summarises the evolution of manufacturing methodologies based on the dates of the earliest publications known to the author. Further the main needs and main drivers are presented and explained below.

In the early 20th century the automobile market was clearly dominated by the manufacturer as seller. The Taylorist reorganisation of production increased the productivity of labour (referred by (Souza, year unknown)). The main underlying principles are the division of labour dividing tasks into simple repetitive movements which is based on the interchangeability of parts and on the achievements of scientific management. Scientific management attempts to increase worker efficiency by setting standards for the various factors in an industrial system. These factors include the worker, the quality of the equipment, and the methods of doing work (Epstein, 1978). The division of labour led to a clear differentiation between the activities of planning and execution and consequently to a separation of mental and physical work. Souza mentions this as the so-called classical management model which mainly emerged out of the contributions of F. W. Taylor and H. Ford.

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[4] Partly published in (Stamm, Neitzert, & Singh, 2009)

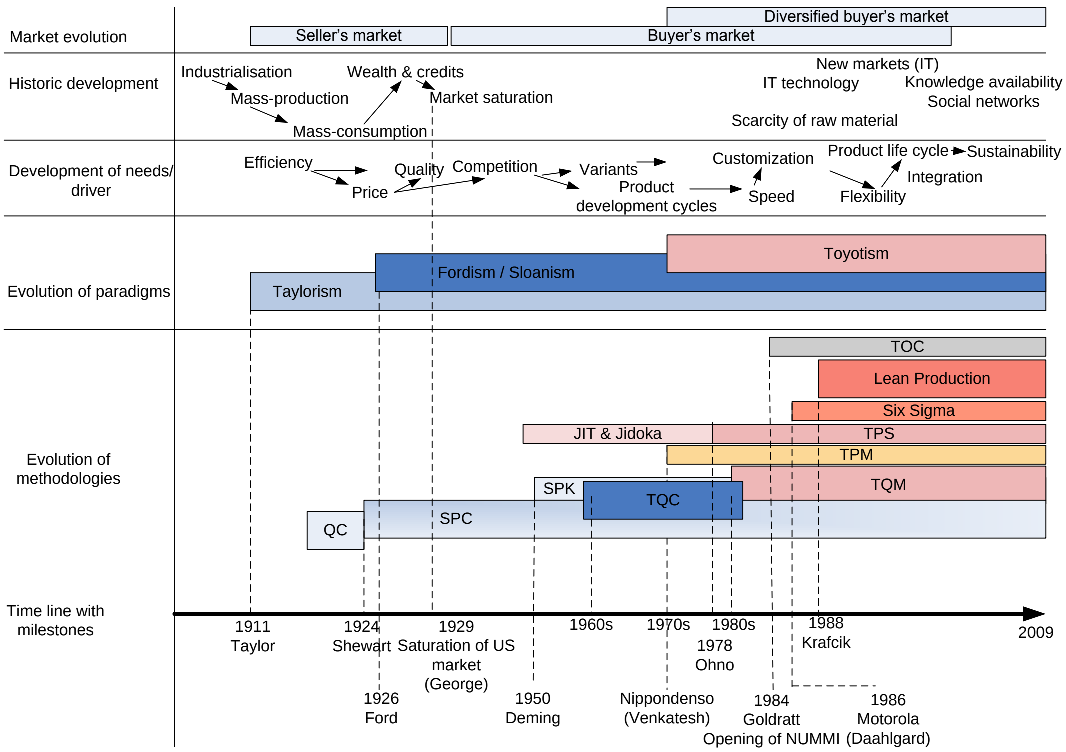

Figure 31: Historical evolution of methodologies (Stamm et al., 2009)

The expression of Fordism was coined by Gramsci (1972) and reflected the automobile assembly line dominated thinking. In Fordism, teams were not that necessary, as individuals were responsible for discharging job tasks defined by engineers (Martin Kenney, year unknown). Ford's production system fulfilled the need of a growing economy and its characteristic as a seller's market and built the basis for mass-production. According to Souza the classical management conception was successful until the 1970's when economic, social and political contexts changed the world markets and caused economic recession. The ability of mass-production sparked an era of mass-consumption which led to a reinforcing loop. The more efficient and sophisticated the means of mass-production became the faster and cheaper the still growing market could be satisfied. The state of a seller's market and the reinforcing loop of the ability of mass-production and mass-consumption found its limitations in industrial countries because of the saturation of consumer-goods. The American automobile market showed first signs of saturation in the late 1920s (Flink, 1990). In 1927 the share of new cars sold on time dropped from 73 % (1922) to 58% which was accompanied by an estimated decline of $643 million in the volume of instalment sales of both new and used cars (Flink, 1990). According to George, competition for market shares rather than the continued growth became a major concern (George, 1982).

When after WW II the automotive industry in Japan started again, Toyota did not have the financial strength to invest in specialised expensive mass-production manufacturing technologies. Additionally they faced the problem that the smaller Japanese market compared with the American asked for an increased product variety with smaller lot sizes (J. K. Liker, 2003). After the owner of the company, Eiji Toyoda, visited Ford in 1950 in the USA together with his leading production engineer Taiichi Ohno, they realised that the inflexible and capital-intensive mass-production does not fulfil the requirements of the Japanese market and surrounding conditions and designed their production system to face their specific constraints (Fujimoto, 1999). Vogel refers to the limited resources of Japan and the herewith evolving “specific organisational structures, policy programs, and conscious planning” (Vogel, 1979) as the main sources of their success. The main manufacturing methodologies of the Toyota Production System, Just-in-Time and autonomation, have been started in Toyota around 1945. Though those methodologies hadn’t come to more public attention in Western industries and Western academia until the 1980s ((Schonberger, 1982), (Ohno, 1988), (Shingo, 1989), (J.P. Womack et al., 1990), (Monden, 1993)). As the Japanese market saturated in the 1970s, Japan started to target export markets. This led to an intensified competition in the American and European automobile market.

Kenney elaborates that in a competitive world with ever-shortening product life-cycles, the ability to motivate workers and the power to increase the intellectual part of products and consequently the creation of new knowledge are central to corporate viability. In a consequence the usage of humans for physical activity is of less significance as a source of value. The need of not only producing but continually improving production led to close connection of research and engineering to production and the awareness that learning-by-doing and training are not goals by themselves but they are necessary to create means by which to improve production (Martin Kenney, year unknown). The effects of saturation on the concept of a mass-production system have been amplified by the growing awareness of the scarcity of raw materials and by the trend of diversity caused by the increase in income and wealth (Piore & Sabel, 1984). It is obvious that the scarcity of raw materials (e.g. USA reached its maximum oil production in 1972 (Energy Information Administration, 2008)) and the capacity of the planet to cater for increased production and effects on the environment

(Victor, 2008) will have a significant influence on our current understanding and meaning of manufacturing methodologies. In this context, elimination of waste and the need of sustainability will keep its validity and will further gain importance. This can be confirmed by a growing number of publications on sustainability with regards to the areas of operations management (Stamm et al., 2009). Current manufacturing methodologies are based on the policy of increasing operational efficiency by reducing costs or increasing throughput. The hidden assumption of continuous growth of markets and demand is existential to the efficacy of the current manufacturing methodologies. As the scarcity of raw materials and energy resources will increase in the next decade(s) the concept of ever growing markets and economies becomes questionable. It is indisputable that the elimination of waste and continuous improvement regarding quality and timeliness are fundamental necessities in order to stay competitive. But in the opinion of the author the need of long-term sustainability requires a supply chain integrating systemic approach which takes the whole life cycles of resources (raw material, energy, secondary use) and of products into account. Therefore, changes in operations management from a focus on local optimisations (Youngman, 2009) (e.g. linear programming, MRP scheduling) and a “mechanistic” linear cause-effect perspective (Johnson, 2007) to more systemic optimisation efforts taking into account nonlinear complex cause-effect connections (living systems) are necessary.

3.3.9 Combination and complementarity of methodologies

This chapter summarises research that compares the methodologies presented in the precedent chapters. The complementarity and also contradictions of the methodologies are elaborated which should contribute to a better understanding of the current paradigm of manufacturing.

One recent trend in literature is the combination of Lean Production and Six Sigma. Branded as Lean Six Sigma, it adds according to Hambleton the concepts of velocity, value and flow to the DMAIC concepts (Hambleton, 2008). Hambleton mentions that DMAIC provides the big picture view and process stabilisation and capability, while Lean introduces speed, the elimination of waste between processes and flow concepts at a more detailed level. Lean concentrates on process timing, overall cycle time, including the timing between process steps by removing non-value-added activities. In summary Hambleton sees Lean as an important part of the Six Sigma 'arsenal' and considers it as an important cornerstone of the Six Sigma approach. Muir argues that Six Sigma techniques focus on fixing processes whereas Lean methodologies concentrate on the interconnections between processes (Muir, 2006). Andersson et al. conclude that the methodologies Six Sigma and TQM show many similarities and are complementary to Lean Production (Andersson, Eriksson, & Torstensson, 2006). Dahlgaard (Dahlgaard & Dahlgaard-Park, 2006) agrees with Andersson in his comparison of those methodologies that both Lean Production and Six Sigma comprise management and manufacturing philosophies and concepts, which have the same origin as the methodology TQM. Additionally he concludes that the principles, concepts and tools of Lean Production and Six Sigma should not be seen as alternatives to TQM but rather as a collection of concepts and tools, which support the overall principles and aims of TQM (see Figure 32).

In summary Lean focuses on the reduction of waste in order to increase the effective capacity and to enable flow. Six Sigma addresses the variability in the production process whose improvement leads to a lower need of costly buffers. However Hopp and Spearman object that Lean and Six Sigma only offer limited focusing mechanisms to understand the interrelations between the buffers capacity, time, and inventory and other commonly used parameters like cycle time, utilisation and variability in order to prioritise improvements (Hopp & Spearman, 2008).

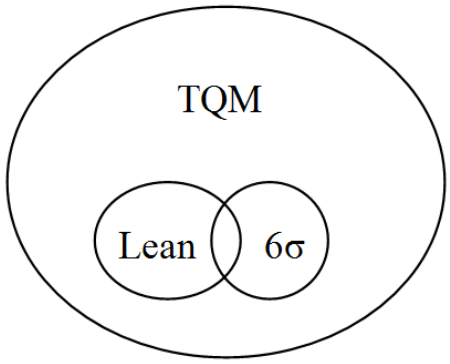

Figure 32: TQM as methodology (Dahlgaard & Dahlgaard-Park, 2006)

Nave compares Six Sigma, Lean Thinking and Theory of Constraints (TOC) based on which theory, focus and underlying assumptions are inherent (Nave, 2002). The theory, its focus and the underlying assumptions will lead to primary and secondary effects which are quite similar (e.g. secondary effects for all three programs are improved quality and less inventory). While describing them all as improvement programs, Nave identifies as the primary theory of Six Sigma the reduction of variation, the reduction of waste as the one of Lean Thinking and the reduction of constraints as the theory of TOC. Six Sigma focuses on existing problems. Lean Thinking puts its emphasis on flow, whereas TOC has its focus on the constraints of the system. In the opinion of the author flow and the exploitation of constraints are causally interdependent. Identifying the overall constraints of a system, exploiting those and subordinating all non-constraints, are necessities to achieve an improved flow through the system.

Dettmer argues that since TPS was not formally known by that name in America until Ohno's book "Toyota Production System", other terms such as statistical process control, concurrent engineering, cause-effect analysis, five whys, team work, supplier/supply chain management, horizontal integration, and just-in-time gained wider recognition instead. And the collection of these (and other) tools came to be generally known as "total quality management" or "continuous process improvement." (Dettmer, 2001)

There is a growing body of literature (see Figure 33) (e.g. (Dettmer, 2001), (Srinivasan et al., 2004), (Spector, 2006), (Gupta & Snyder, 2008) , (Youngman, 2009)) that analyses or compares the methodology of TOC with Lean Production or other methodologies. Some authors conclude that TOC serves as a focusing mechanism where to apply Lean techniques and Six Sigma techniques to achieve best results for the overall system. Wilson for example argues that in a manufacture-to-order company with multiple routings and highly variant processing times (cycle times), many techniques of Lean Production become less effective whereas some of the techniques of TOC become more effective (L. Wilson, 2010). Figure 33 shows the steadily growing number of publications with the keyword "Theory of Constraints". But in this context the term "Theory of Constraints" needs to be understood as a management philosophy focusing on the management of constraints without considering the technique DBR as the ultimate scheduling algorithm. Trietsch coins the term "Management by Constraints" which stands for the underlying management principles of TOC without embedding DBR. Reason being is that Trietsch discusses some disadvantages of DBR as scheduling algorithm in deterministic systems (Trietsch, 2005).

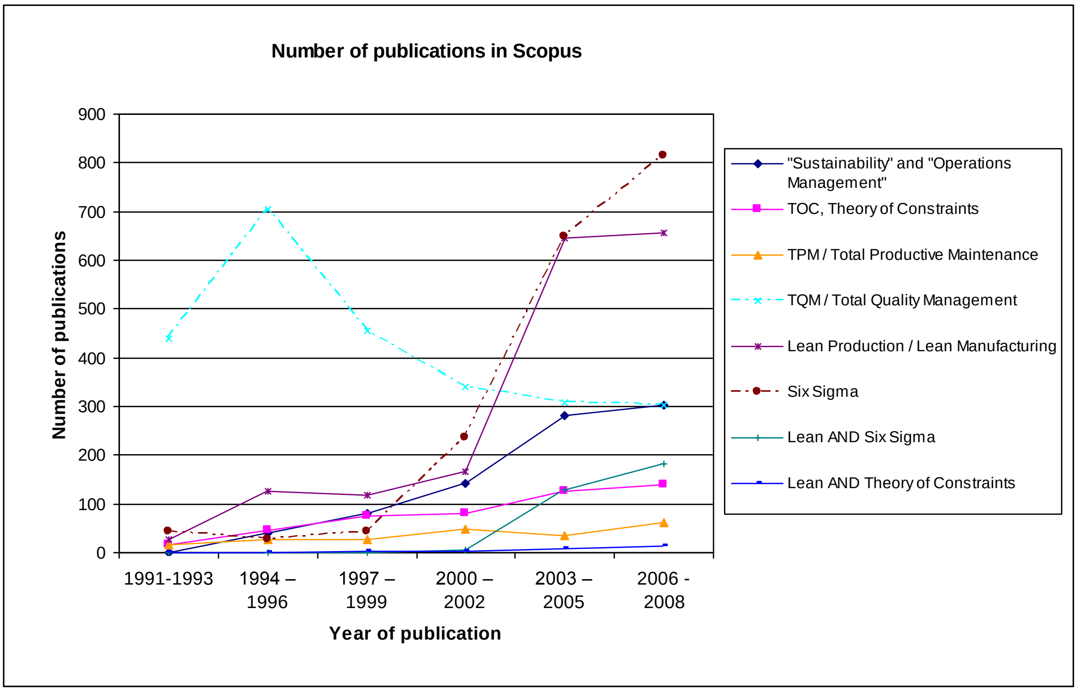

Figure 33: Number of publications with keywords in title or abstract in database Scopus[5]

Davies et al. analysed based on the Mingers-Brocklesby framework the TOC methodology and its existing techniques. They generally conclude that the TOC methodology provides guidance in phases from problem identification and representation, the definition of objectives, the creation and analysis of alternatives through to implementation. Hence they argue for the complementary nature of the TOC methodology with respect to other operations management methodologies.

Also the methodology of System Thinking might have synergetic effects in combination with Lean Manufacturing. Wolstenholme argues that both Systems and Lean Thinking share the aim of changing cultures and improving thinking for change. System Thinking and System Dynamics can provide guidance for the long-term strategic alignment of the company while Lean Manufacturing gives assistance with operational improvements (Wolstenholme, 2006).

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[5] Published in (Stamm et al., 2009)

3.3.10 Summary

Chapter 3.3 gives an outline of the wide field of advanced manufacturing paradigms and methodologies. It started with fundamental underlying principles by comparing a manufacturing system with a flow system. Then manufacturing methodologies were presented and put into a chronological context. Table 15 summarises again the essentials of the presented methodologies.

Having shown that this field is very wide and complex and borders are not clear, it became obvious to the author that there are firstly practical difficulties for NZ SMEs to gain this knowledge and secondly to assess which elements suit to their organisations and how to make best use of them in their organisational context.

Table 15: Overview of methodologies (Stamm et al., 2009)

	TQC / TQM	TPM	Theory of constraints	Lean (JIT, TPS)	Six Sigma
First mentioned	1960s / 1980s	1970s	1984	1988 (Krafcik)	Late 1980s
Origin	'Gurus' like Shewart, Juran, Deming, and Crosby	Nippondenso	Goldratt	Toyota (Toyoda, Ohno and Shingo) and NUMMI (Womack and Jones)	Smith of Motorola and General Electrics
Focus	Reduction of variation, quality of processes and product	Waste, loss, reduction of downtime	Exploitation of constraints and subordination of non-constraints to the constraint in order to increase throughput	Value creation – material and information flow/pull - perfection	Reduction of variation
Distinguishing and value adding contribution	Statistical Quality Control, involvement of other departments, process orientation, the reduction of variation increases quality System of profound knowledge (Deming)	Team involvement on the shop floor, preventive maintenance leads to reduction of downtime, a higher process capability; zero defects.	Focus mechanism on constraints	Pull, takt time, heijunka, one-piece-flow, value stream mapping, respect for people	Organisational structure with improvement experts (black belts and green belts), project oriented, quantification of cost savings , set of techniques for problem solving

Having also discussed the complementarity of the methodologies the author agrees with Hines et al. that "Lean is one of the most influential new paradigms in manufacturing" (Hines et al., 2004, p. 13). Looking at Figure 25 and having the historic evolution of those methodologies in mind (see chapter 3.3.8), the author wants to propose for this research project to use the term 'Lean' as the collective term for advanced manufacturing methodologies and further the term

Toyotism as a symbolic term for the manufacturing paradigm outlined in this thesis. Therefore the term ‘manufacturing paradigm’ stands for the collective and combined understanding and assumptions that might lead to performance improvements in a manufacturing system (elaborated in chapters 3.3.1 to 3.3.10).

3.4 Change of an organisational system

Many authors discussing the adaptation of TQM and Lean methodologies emphasise the need of a cultural change in organisations (Mann, 1995) (Ahlstroem & Karlsson, 1996) (J.P. Womack & Jones, 2003) (J. Hansson & Klefsjo, 2003) .

Purpose of this chapter is to provide a practically oriented review of literature in order to find an appropriate perspective for the contextual factors that are relevant for change initiatives. This will assist in identifying and categorising ‘underlying cultural phenomena’ observed in the case studies. First organisational culture is defined in chapter 3.4.1. The following two chapters analyse the literature of change management and explore the particular role of leadership in change processes.

3.4.1 Organisational and corporate culture

Schein defines the culture of a group as a *“pattern of shared basic assumptions that was learned by a group as it solved its problems of external adaptation and internal integration, that has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems”* (E. H. Schein, 2004, p.17). Kleinberg defines culture as the acquired knowledge people use to give order to their world, to interpret their experience and to generate social behaviour. Cultural knowledge is widely shared by a group of people, it is distinctive to the group, and it is constructed, passed on, and reinforced through social interaction. Cultural knowledge may be explicit, or it may reflect the tacit assumptions that many consider to be the innermost core of culture (Kleinberg, 1994).

A model to analyse the levels of culture is shown in Figure 34. Artefacts are phenomena that are visible and can be directly perceived by an external observer. It includes for example the company’s products, its language, its dress code, its manners of address and published lists of values. Schein argues that artefacts are easy to observe but difficult to decipher. Espoused beliefs and values are generally created by problems and tasks a group collectively faces. The individuals in the group who can influence the group to adopt a certain approach to a problem are then identified as leaders. If a leader convinces a group to act according to his/her belief and the group succeeds, the perceived value transforms into a shared value and belief and with repeating success into a shared assumption. Over time the direct connection to the initial event or problem might get lost and the danger arises that routines do not lead to the expected outcome (E. H. Schein, 2004).

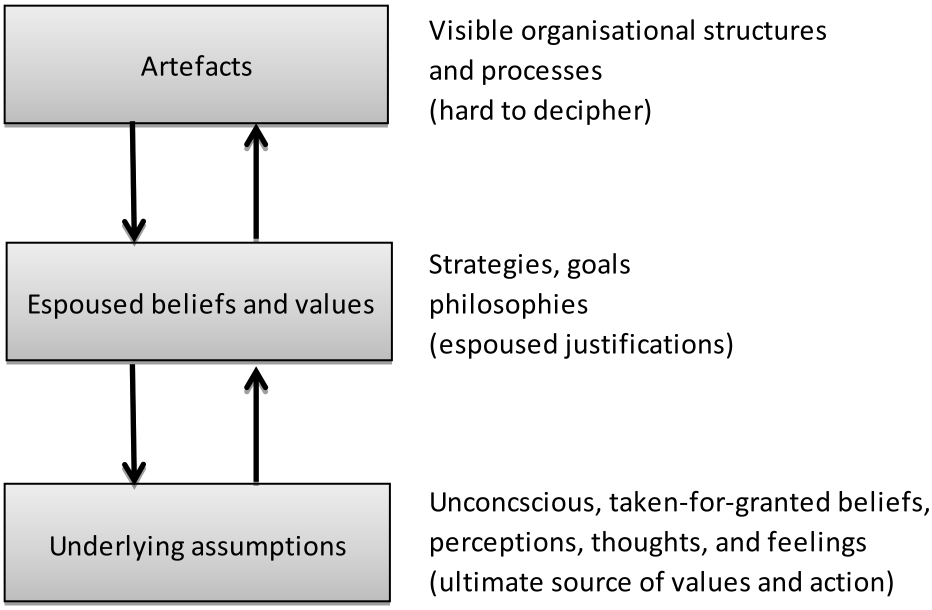

Figure 34: Levels of culture (E. H. Schein, 2004)

As shown in the previous chapters there are a few fundamental principles that underlie advanced manufacturing methodologies, e.g. the focus on quality and value and the emphasis on flow and perfection (see chapter 3.3.6.2). It is commonly discussed that an adaptation of these principles might imply a change in organisational culture in order to become sustainable and an integral part of the organisation (Hines et al., 2004) (Dahlgaard & Dahlgaard-Park, 2006). However the underlying relationship of national culture and organisational culture seems to be less clear. Wagner concluded that the complex interaction between the national culture of the host country, the organisational culture and cultural values implicit in the adaptation of improvement initiatives is not fully understood (Wagner et al., 2009).

3.4.2 Change management

At first the term 'change' is defined. The terms 'organisational change' and 'transformation' are used in a synonymous way in this thesis. A transformation is defined on the basis of Burchell's definition as any organisational feature or facet that is associated with new ways of thinking, behaving, or doing things differently. An organisational change is typically associated with terms like innovation, adaptability, responsiveness, proactiveness, flexibility, competitiveness and diversity (Burchell, 2004). In this thesis the term transformation is also used to emphasise the continual character of the adaptation of a current manufacturing paradigm and its methodologies, as these continuously evolve as shown in the previous chapters. Hence, an organisational transformation needs to be understood as a continuous process. This view is supported by Burnes who suggests to understand change more as an open-ended and continuous process than as a set of discrete and self-contained events (Burnes, 1996).

Change processes in organisations are widely discussed in academic and popular management literature (Beer, Eisenstat, & Spector, 1990) (Kanter, Stein, & Jick, 1992) (Kotter, 2007). 'Managing change' is seen as a necessity when new methodologies and procedures need to be adapted or integrated in order to stay competitive and viable. Change management itself is defined by Moran and Brightman as the "process of continually renewing an organisation's direction, structure, and capabilities to serve the ever-changing needs of external and internal customers" (Moran & Brightman, 2001, p. 111).

By summarises under the so-called 'emergent change approach' that change should not be perceived as a series of linear events, but as a continuous open-ended process of adaptation to changing circumstances. This emergent change approach –compared to the 'planned change approach'- emphasises the dynamic nature of change, and views it as a process that develops through the relationship of a multitude of variables within an organisation. Apart from that, By stresses that change is also perceived as a process of learning and in order to cope with the complex and dynamic nature of change, organisations need to become open learning systems where strategy deployment and change emerges from the way a company processes any kind of internal and external information (By, 2005). Other literature emphasises the need for organisations to adapt and to learn in changing environments as well (P. Senge, 1990) (Rubinstein, 1999). Organisational learning has been defined as a process of improving organisational actions through better knowledge and understanding (Fiol & Lyles, 1985). As an adaption to a Lean manufacturing system implies an organisational transformation, the ability to learn as an organisation takes a crucial role. Rubinstein emphasises in this context the organisational ability of problem solving (Rubinstein, 1999) which also seems to be an essential element of Toyota (Balle, Beauvallet, Smalley, & Sobek) (Shingo, 2007). This attitude of problem solving is based at Toyota on a strong culture of experimentation in combination with the scientific approach (Spear & Bowen, 1999). Rubinstein and also Marks state that this culture of experimentation allows a trial-and-error learning and hence, in the context of change, enables an organisation to constantly challenge their processes and structures (Rubinstein, 1999) (Marks, 2007).

It is worth to refer at this point back to the essential principle of continuous improvement (kaizen) of Lean Production. The principle of continuous improvement leads to an ongoing evolution of processes and organisational structures and therefore clearly falls into the characteristics discussed above.

Senge et al. found based on several long-term studies of business contexts involving the redesign of workplace environments the following three core learning capabilities (P. M. Senge & Käufer, 2000):

First Senge identified that a certain individual and collective aspiration is required to clarify a personal vision and values. This is the fundament for building shared visions. Secondly the ability of personal reflectiveness, especially regarding individual and shared mental models, and developing capabilities for dialogue and productive discussion within work teams is seen as essential for organisational learning. Finally in order to conceptualise highly independent issues and to distinguish high- from low-leverage strategies and measures, it is necessary to develop systems thinking abilities and an understanding of detailed and dynamic complexity (also see (P. Senge, 1990)).

The authors Kanter, Kotter and Luecke provide more practical guidance by proposing change models to organisations. The three models are displayed in Table 16.

Table 16: A comparison of three change management models

Ten commandments for executing change (Kanter et al., 1992)	Kotter's eight-stage process (Kotter, 2007)	Luecken's seven steps (Luecke, 2003)
1. Analyse the organisation and its need for change		1. Mobilise energy and commitment through joint identification of business problems and their solutions
2. Create a vision and a common direction	3. Developing a vision and strategy	2. Develop a shared vision of how to organise and manage for competitiveness
3. Separate from the past		
4. Create a sense of urgency	1. Establishing a sense of urgency	
5. Support a strong leader role		3. Identify the leadership
6. Line up political sponsorship	2. Creating a guiding coalition	
7. Craft an implementation plan		
8. Develop enabling structures	5. Empowering broad-based action	
9. Communicate, involve people and be honest	4. Communicating the change vision	
10. Reinforce and institutionalise change	8. Anchoring new approaches in the culture	6. Institutionalise success through formal policies, systems, and structures
	6. Generating short-term wins	
	7. Consolidating gains and producing more change	
		4. Focus on results, not on activities
		5. Start change at the periphery, then let it spread to other units without pushing it from the top
		7. Monitor and adjust strategies in response to problems in the change process

Kotter analysed 100 companies during change initiatives labelled as e.g. total quality management, reengineering, rightsizing, restructuring or cultural change (Kotter, 2007). He concluded that there are eight general mistakes that distinguish the failing companies from the more successful ones. Based on these eight general mistakes he presented an 8-step approach how to successfully transform an organisation (see Table 16).

Lewin notes that every person and organisation encounters forces for maintaining the status quo and forces for change (K. Lewin, 1947). Forces for maintaining the status quo can be initially expressed through resistance to change or the absence of a will to act and are mainly caused by emotions. Already Machiavelli in 1532 stated that *“Reorganisation is usually feared, because it means disturbance of the status quo, a threat to people’s vested interests in their jobs, and an upset to established ways of doing things. For these reasons, needed reorganisation is often deferred, with a resulting loss in effectiveness and an increase in costs”* (Machiavelli, 2008 (Original 1532)).

An effective leader copes with those emotions by bringing them to the surface and by understanding their consequences on work activities (Urch & Wolff, 2001).

Regarding resistance to change Sterman argues that well-intentioned efforts to solve the current problems of an organisation can lead to unanticipated side effects which have not been taken into account. This can result in a so-called policy resistance, a “tendency for interventions to be defeated by the response of the system to the intervention itself” (J. D. Sterman, 2002, p. 504). As an impediment to overcome this policy resistance Sterman does not see the root causes in neither a lack of knowledge or resources nor in a lack of commitment to change. The main obstacle lies in our limited system thinking capabilities, the capability to understand complexity, stocks and flows, time delays and feedback. Besides he postulates a commitment to highest standards, the thorough application of the scientific method and the commitment to expose our hidden assumptions and biases in order to create a dialogue to overcome resistance to change. According to him it also requires the curiosity of constantly asking ‘why’ which strongly correlates with Toyota’s well known method of “5 Whys” (J.P. Womack & Jones, 2003).

As an example for resistance to change, Applebaum et al. observed in a case study of a Canadian medium sized manufacturer the coherence between transformational cultural change and employee turnover. The transformational cultural change was initiated by an acquisition and by the introduction of TQM philosophies and methods. In this period of changes the company experienced a historical increase of employee turnover (Appelbaum et al., 2008).

As more concrete means to change an organisation Hellriegel et al. list the following measures (Hellriegel, Slocum, & Woodman, 1995):

(1) changing what managers and teams pay attention to

(2) changing selection criteria in the recruitment process

(3) changing criteria for promotion

(4) changing criteria for allocating rewards

(5) changing organisational habits and ceremonies.

During this review it became obvious that current literature mainly addresses change management in larger organisations. Hence this research project will contribute to the body of knowledge how SMEs out of a practical point of view approached their transformation and which measures proposed for a larger cooperation can be also found in the case studies.

3.4.3 Leadership

A growing body of literature has identified the significant impact that the leader's characteristics can have on both strategic direction and overall organisational performance (Gueldenberg & Hoffmann, 2000) (Yukl, 1999) (Lotter, 2006) (House, Javidan, Hanges, & Dorfman, 2002). As one study of Collins revealed, leadership is one of the most important critical success factors for the overall success of a company (Collins, 2001), it might be a crucial factor for the success of an organisational transformation as well.

The importance of leadership especially in Lean transformations has been emphasised in several publications (Lean Enterprise Institute, 2007) (Mann, 1995) (B. Emiliani, 2007). For example Harris states the role of leadership as the main reason for a successful or unsuccessful Lean transformation (Harris & Harris, 2008). According to Bennis and Nanus there is a difference between leaders and managers with regards to their objectives and time orientation (Bennis & Nanus, 1985). Leaders are oriented towards change and long-term effectiveness, whereas managers are oriented towards stability and short-term efficiency. Also authors of Lean literature take this thought up and emphasise its relevance for Lean transformations (J. Flinchbaugh & Carlino, 2006). Yukl argues that efficiency and change are competing objectives and notes the lack of research that examines what effective leaders do to achieve an appropriate balance between efficiency and change. In his opinion stereotyping leaders and managers as opposites detracts attention from empirical research on this issue (Yukl, 1999).

Organisational leadership is defined by House within the GLOBE project: “the ability of an individual to influence, motivate, and enable others to contribute toward the effectiveness and success of the organisations of which they are members" (House, Javidan, & Dorfman, 2001).

Another definition that does not only understand the term leadership out of an individual perspective sees the essence in the capacity of a human community to shape its future and to sustain significant change (P. M. Senge & Käufer, 2000).

According to Spearman and Hopp, manufacturing managers have been under constant pressure to change the way they operate (from MRP to JIT and TQM to Business Process Reengineering (BPR) etc.). In consequence there have been continuous changes regarding the responsibilities of various positions and the set up of transition teams to execute and lead desired changes. Hence Spearman and Hopp state that the importance of the person(s) being in charge of the change effort is enormous and therefore formulate a law for advocacy: "For almost any program, there exists a champion who can make it work – at least for a while" (Hopp & Spearman, 2008, p.390). Further they believe that many programs of change fail in spite of the existence of a champion. On the other hand champions can have an enormous influence on the success of a system. An effective champion does not only have to be a convincing and charismatic salesman but also a "thinker and creator" being able to develop and adapt the system to fit the needs of the target application. Additionally, Spearman and Hopp postulate that to be truly effective, champions must be intimately involved with the systems they are trying to change (see Shingo and Ohno).

Senge and Käufer differentiate three types of leaders that are crucial in initiating and sustaining change: the local line leaders, the executive leaders and internal networkers. They argue that these three types of leadership are highly interdependent and developing a network of these types of leaders is critical for any change initiative (P. M. Senge & Käufer, 2000). Looking at the organisational structure of SMEs, the substitute for local line leaders can be the team leaders of shop floor teams. Senge states that they are a critical source of innovative ideas themselves, both operational and strategic. The owners and the CEO of a SME take the role of executive leaders. Their role is to mentor line leaders and to provide a long-term purpose to the organisation by developing core business strategies and long-term visions. Networking leaders are characterised by their mobility, their ability to move freely within the informal

networks which operate in all organisations. They play an essential role of connecting isolated line managers to new ideas and practices, and to other like-minded managers. Further they serve as mentors and internal consultants by providing new insights and perspectives. In SMEs the networking leader most probably needs more to be seen as a function rather than as directly personified staff members, as the number of employees is low. In small organisations these function can be facilitated by creating space for informal talks (e.g. at the coffee machine) and by regular staff meetings and social events.
Looking at the New Zealand context, Kennedy concluded that although many of the building blocks for New Zealand's leadership style can be found in other countries, the overall profile is unique. His findings of the qualitative and quantitative analyses show that the NZ style of leadership is participative, grounded in the team, and provides the opportunity for shared success. At a general level, Kennedy summarises the characteristics of an outstanding leader in New Zealand: She/he is *"… a positive, optimistic person who is able to generate confidence, enthusiasm, and excitement among followers, challenging them to exceed expectations in pursuit of future goals… the leader must not be a micromanager, and must be willing to share the decision making with capable team members. …".* Trevor-Roberts summarises in his comparison of leadership in Australia and New Zealand that leadership can be characterised in both countries as 'egalitarian leadership' (Trevor-Roberts, Ashkanasy, & Kennedy, 2003). He concludes that NZ leaders must place emphasis on motivating and inspiring, be team orientated, and focus on the work at hand.

In order to analyse the specific leadership profiles of the case studies and to explore the relationship of this profile to the 'success' of the Lean transformation, the GLOBE leadership questionnaire in a slightly adapted version is used to evaluate the leadership profiles of the case studies (see chapter 4.1.1 for more information). GLOBE empirically identified universally perceived leadership attributes that are contributors to or inhibitors of outstanding leadership. Project GLOBE's leadership questionnaire items consisted of 112 behavioural and attribute descriptors (e.g., "intelligent") that were hypothesised to either facilitate or impede outstanding leadership.

3.5 Summary of theoretical background

The purpose of chapter 3 was to outline the current manufacturing paradigm and to present the main representatives of manufacturing methodologies. Further the context of this research was analysed and particular contextual factors were discussed. It became clear that New Zealand certainly exhibits specific characteristics that influence its manufacturing industry and its maturity level with regards to best practices.

Further there is evidence in literature that SMEs have specific characteristics compared with larger organisations that might hinder or facilitate organisational change and hence might influence the extent of implementation of manufacturing methodologies.

Out of the perspective of SMEs the field of advanced manufacturing methodologies is very wide and most probably difficult to decipher. Hence this study summarises current best practices in manufacturing under the umbrella of the term ‘Lean’ (discussed in chapter 3.3.10) and extracts the main principles.

There is a lack of literature that specifically addresses the adaptation of best practices in SMEs. Further it can only be found a few NZ studies that address best practices for manufacturing companies. However these studies concentrate on high-level strategic views and clearly lack insights and assistance for SMEs on the operational side which methodologies to select and how to implement them. Additionally literature that explores high variability environments where a bigger part of SMEs operate is quite young and still raises many questions.

The understanding of a manufacturing system as a flow system with buffer mechanisms that compensate for a multitude of variability factors is found to be helpful to guide SMEs in their understanding and selection of manufacturing methodologies and its techniques. Further, understanding the adaptation of advanced manufacturing methodologies as a long-term change process (transformation) can be essential for a successful implementation. Effective leadership was identified as a critical success factor for change processes. However the literature that analyses the role of leadership in SMEs particularly in the manufacturing industry is very limited. The involvement and commitment of the owner seem to be essential for a sustainable transformation. Hence a questionnaire of the GLOBE study was adapted to explore the specific characteristics of the owners and senior managers of the case studies.

4 Transformation case studies

4.1 Introduction and methods of data collection

Chapter 4 presents the five case studies. Case study A and case study E are longitudinal action research case studies. The company that provides case A was visited on average twice a week over a period of almost three years. Case study E was visited once a week over a period of seven months. Case studies B, C, and D are pure observational case studies. To compare all five case studies with each other, the same data collection methods were used during company tours and semi-structured interviews with the managing directors and other management members (see Appendix E to Appendix J). Figure 35 shows the major three areas of interest for the data collection: the actual Lean transformation, the leadership profile, and the performance development since start of the improvement initiative. Additionally in the action research case studies further data was collected based on observations, informal discussions, the participation in meetings and additional corporate data.

As leadership was found to be essential in a Lean transformation (see chapter 3.4.3), the leadership profile of every company is created by a questionnaire based on the GLOBE study (see chapter 4.1.1 for more detail). The evaluation of the Lean transformation status is explained more in detail in chapter 4.1.2. Chapter 4.1.3 describes the data collection method to analyse the performance development of the case studies (see also Appendix J). The graphical composition of Figure 35 should imply that the three dimensions are connected and interdependent. The proposed model for data collection orientates on the GLOBE conceptual model (House et al., 2001). Its central proposition of theory is that the attributes and characteristics that are responsible for a unique specific organisational culture is determined by the practices of its organisation and its leaders' behaviour and attributes that are most frequently enacted and effective in this organisation. This model implies that societal and cultural values and practices affect what leaders do. Further there is a bidirectional influence between leadership and organisational culture, structure and the organisation's practices.

In other words the leadership characteristics might have an impact on the maturity level of the Lean transformation. Very plainly spoken, outstanding leadership might facilitate or even accelerate an organisation in its Lean transformation and hence it could reach a higher Lean maturity level which might also entail gains in operational performance (see chapter 3.3.6.2 for benefits of a Lean implementation).

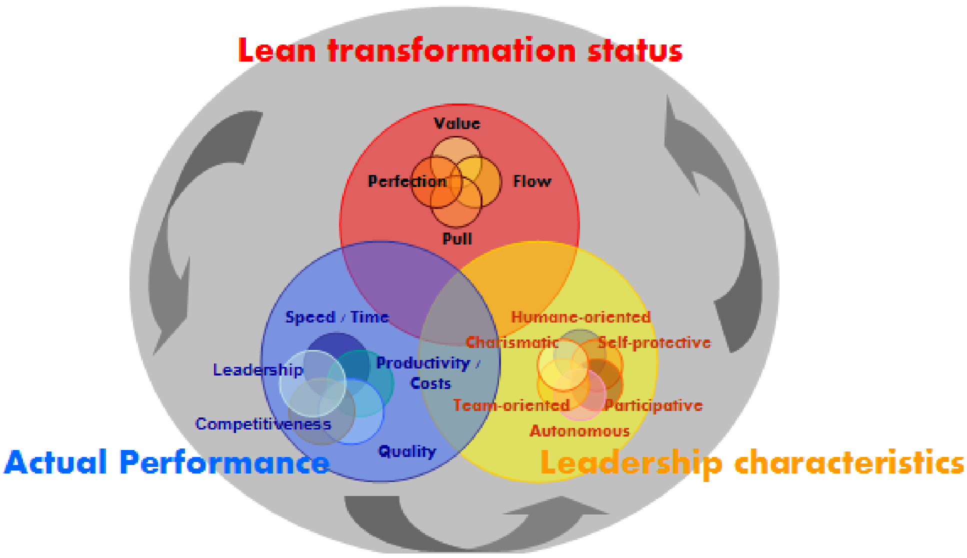

Figure 35: Areas of data collection

4.1.1 Leadership characteristics

Based on the leadership characteristics developed in the GLOBE study (see for further explanation: (Javidan, Dorfman, Luque, & House, 2006)), a profile for every case study is generated. In every company all staff was asked to evaluate their leaders by an anonymously completed questionnaire (see Appendix E). In this questionnaire the respondent has to rate on a Likert scale from one to seven the behaviour of his/her direct leader based on 112 characteristics. This Likert scale is translated to a scale from -3 to 3 in all further analyses in this thesis for a better visualisation. These 112 characteristics can be aggregated into two levels. The more detailed level (level 1) consists of 21 characteristics which can be again aggregated to a high level (level 2) overview consisting of the following six characteristics:

1. Charismatic/Value-Based: This dimension reflects the ability to inspire, to motivate, and to expect high performance outcomes from others on the basis of firmly held core beliefs. Charismatic/value based leadership is generally associated with outstanding leadership.

2. Team-Oriented: This characteristic emphasises effective team building and implementation of a common purpose or alignment among team members.

Team-oriented leadership is generally reported to contribute to outstanding leadership.

3. Participative: Participative leaders involve others in making and implementing decisions. Participative leadership is seen as a contributing factor to outstanding leadership.

4. Human-Oriented: A human-oriented leader is characterised by a supportive and considerate style which also includes compassion and generosity. Human-oriented leadership is reported to be almost neutral in some societies and to moderately contribute to outstanding leadership in others.

5. Autonomous: This newly defined leadership dimension refers to independent and individualistic leadership. There are no contradictory results whether autonomous leadership impedes or supports outstanding leadership.

6. Self-Protective: This newly defined leadership dimension focuses on ensuring the safety and security of the individual. It is self-centred and face saving in its approach. Self-protective leadership is generally reported to impede outstanding leadership.

The results are analysed and discussed in chapter 4.8.

4.1.2 Lean transformation status

In order to explore the Lean transformation of the case studies two main questionnaires for data collection were used (see Appendix H and Appendix I). Both were the basis for a semi-structured interview with the owner(s) and/or the CEO of the companies.

The first questionnaire (Appendix H) analyses the maturity level of the usage of Lean methodologies and techniques. The interviewees are asked to allocate the listed Lean techniques into the three categories shown in Table 17.

Table 17: Maturity levels for implementation of Lean techniques

Level	Description
Level 1	Methodology or technique is not implemented at all.
Level 2	The value of the technique is acknowledged, first pilots have been started. First gains can be seen (performance improvement, improvement of motivation and involvement, etc.).
Level 3	Technique has been adapted and constantly improved, and is widely spread in the organisation. The underlying principles are driving the purpose and development of this technique. The technique is embedded in an integrated system of Lean methodologies.

The second method used a general template (see Appendix I) to explore the transformation history. The interviewees are asked to chronologically list the methodologies and techniques that are used in their companies. Hereby additional attention is paid to the reasons (e.g. constraints or challenges they faced) for the selection of the techniques (see Figure 36). As it is difficult to list all Lean activities, the focus is on the major methodologies and 'milestone' projects that are perceived as major changes to the organisation.

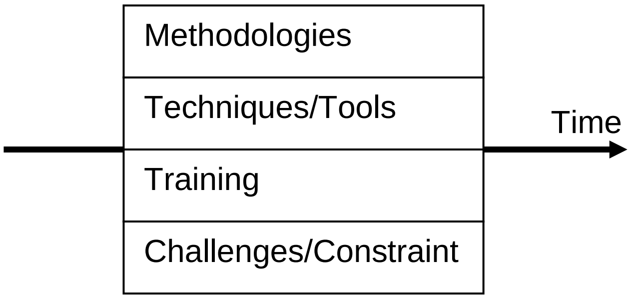

Figure 36: Construct in order to determine the Lean transformation history

4.1.3 Actual performance

The third dimension of data collection focuses on the actual business performance from the beginning of the announced improvement initiative of the companies. Figure 37 shows the developed concept that covers six relevant key performance dimensions which are orientated on the criteria of the Baldrige Award, EFQM model and the criteria of the Shingo Prize for Operational Excellence (The Shingo Prize Headquarters, 2010). Therefore the traditional dimensions of quality, competitiveness, speed and time, productivity and people are used and extended by the dimension of leadership. The companies were asked to evaluate their annual state in the sixteen subcategories. The subcategories base on used KPIs within the case study companies and on various metrics presented in 'Lean' literature (Maskell, 2004) (Bhasin, 2008). Hereby it was left to the companies how they exactly calculate these measures, but examples for calculation are provided. An example is given in Appendix J. The underlying idea is that companies adjust their measures according to their specific business environment and correspondently design those measures so that they are relevant and meaningful in the particular context. The emphasis for the data collection lies on identifying trends over the observation period rather than on annual absolute values. Out of confidentiality reasons those trends are expressed by the following colour and numbering code: green (or ‘1’): positive development of measure; red (or ‘-1’: negative development of measure; yellow (or ‘0’): no clear trend; white: no data available or measure not relevant.

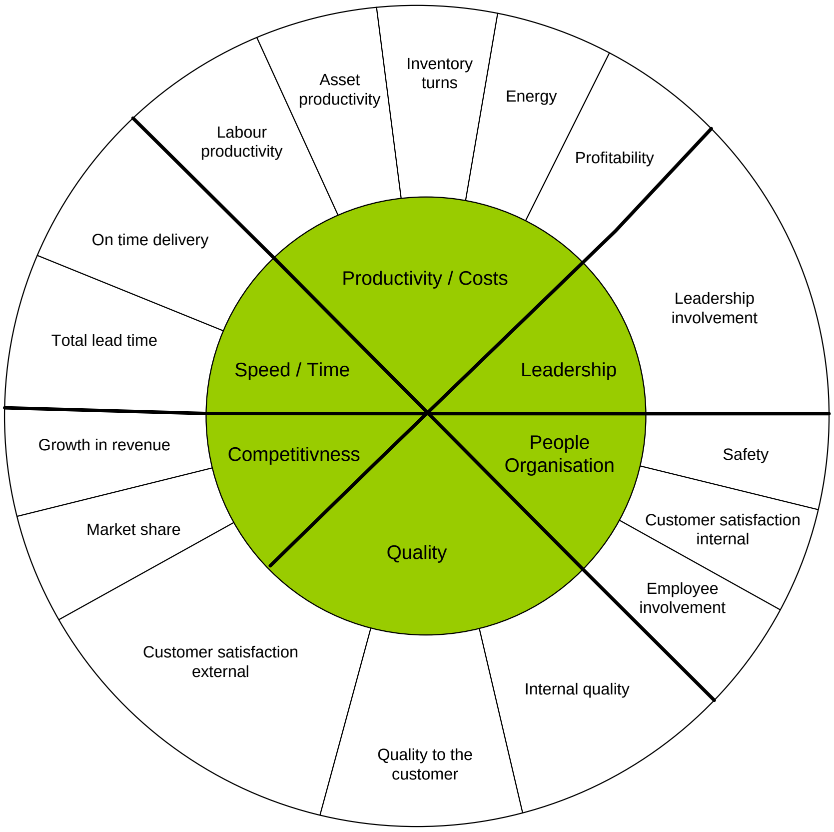

Figure 37: Performance measures

4.2 The case studies in the variability matrix

In order to compare the case studies, the 2-by-2 classification matrix of Lander is used (Lander, 2007). The matrix evaluates the case study companies with regards to the two dimensions of task variability and demand variability. For each of these dimensions two sub dimensions are to be rated. Task variability is subdivided into processing and routing variability. The criteria for demand variability are the monthly volume variability and demand mix variability. For each of these four dimensions Lander offers an evaluation table with defined criteria to assess the variability between the values 1 to 4 (1 generally stands for a low variability and 4 for a high variability). The position of each of the five case studies in the matrix is shown in Figure 38 whereas values between two and eight can be achieved by adding up the values of each subcategory.[6]

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[6] For more detail with regards to the calculation refer to Appendix K

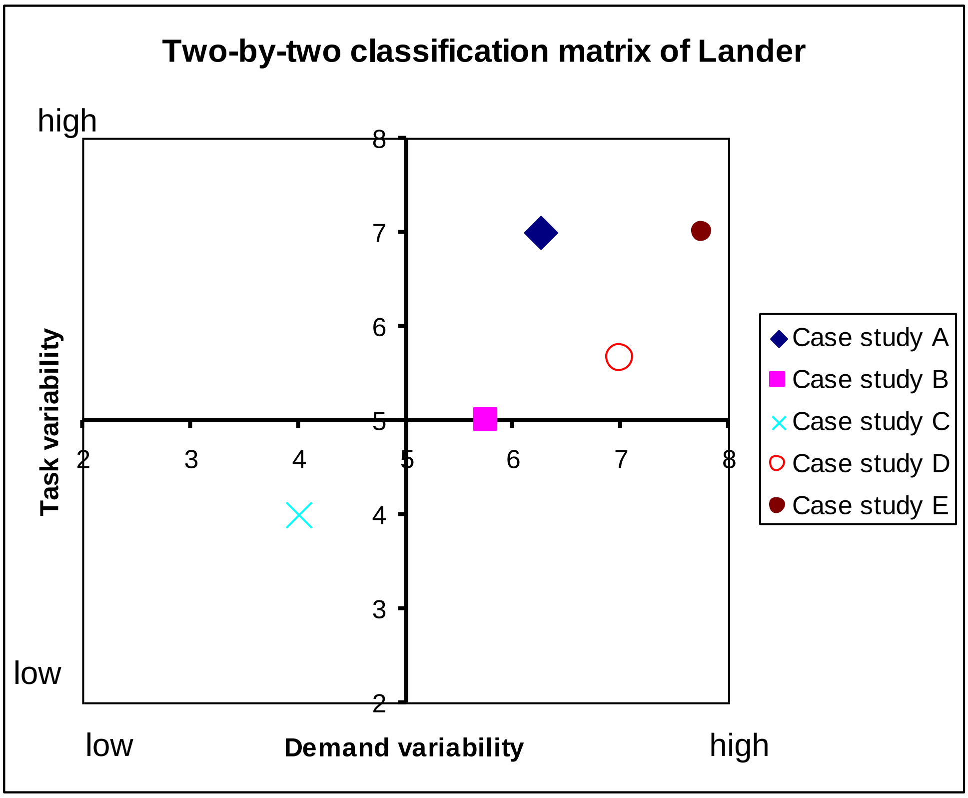

Figure 38: Comparison of case studies with regards to variability

Case studies A and E achieved the highest rating regarding the task variability. Looking at the demand variability case studies E and D have the highest rating. The lowest rating in both dimensions scores case study C. Case study C is the only company that operates in an assembly-to-order environment where customers can order out of a specific range of catalogue products. Additionally the company concentrates more on the end assembly. Many components are manufactured by suppliers. All other case studies offer manufacture-to-order or even engineer-to-order products. This explains the higher ratings in task variability. Further the products of case studies A, B, D, and E are mostly one-off products with a high degree of customisation and in a higher price range which implies a higher complexity and longer lead times (lower speed of flow).

4.3 Case study A

4.3.1 The role of the researcher and background of case study A

Case A represents the main case study of this research. Based on the action research methodology, the researcher became an integral part of the company over a period of almost three years. The main responsibilities were to coordinate and support all Lean activities as an additional support person and to evaluate and monitor progress. In this role, the researcher spent during the three years on average two full days per week in the case organisation, participated in weekly management meetings and was part of improvement teams. Further the researcher discussed in review meetings with members of the management the progress of the Lean transformation by analysing the developed performance measures, the field notes and experiences that resulted out of the other case studies and the literature review. In order to develop an effective Key Performance Indicator system, the researcher had access to almost all corporate data. Further the researcher could attend several meetings of the Aichi network where he could record the experiences of participating companies. In addition to that, the researcher was involved in meetings and workshops with consultants who were employed at some point at the case organisation.

The company, a NZ owned company with approximately 40 staff members, is specialised in the manufacturing of plastic injection tooling, press tools and customised manufacturing equipment and therefore operates in a classical high variability and low volume environment as shown in Figure 38. There is no inventory of finished products as most of the products are engineered to order using a project management approach. Most of the raw material is individually ordered for the projects. A small amount of orders is manufacture-to-order products where design and CNC programs are already available or are provided by the customer. After a customer enquiry, the responsible sales person estimates the material costs and manufacturing times and creates a quote. Hence, the price of the tooling is defined before the actual design starts which requires experience by the sales staff and must be seen as one of the main influential factors for the profitability of a project. If the quote is won, the customer order is released to design as a job. The project schedule is created backwards driven by an agreed required shipment date. The realisation process is shown in detail in Figure 39. Various projects share respectively compete for the manufacturing resources. The task variability is relatively high as most of the tooling projects are one-off products. The components of the tooling follow different routings through the shop floor and require different processing times. Looking for example at an injection moulding die, it consists of standard vendor parts (e.g. screws, where no further processing is required), semi-finished parts (e.g. guide pins, ejector pins that need to be fitted to the required size) and unique components (e.g. those defining the cavity)[7]. Latter components can usually pass several manufacturing steps:

- rough cutting of raw material
- heat treatment
- wire-cutting and/or CNC machining of the cavity details
- grinding
- sparking
- polishing

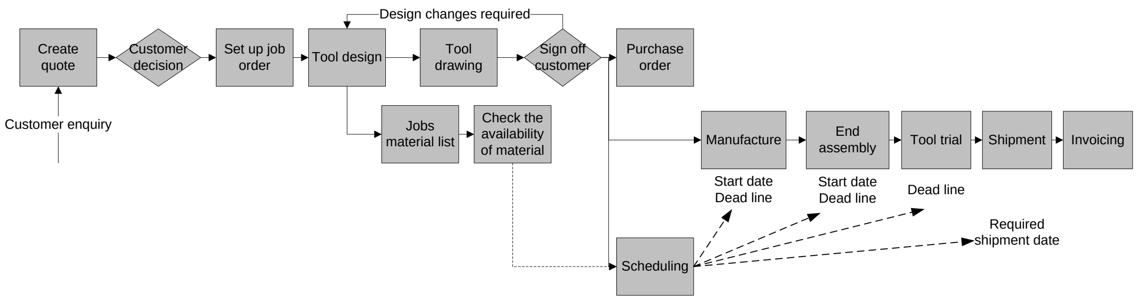

Figure 39: Case study A's realisation process

Processing times are estimated and rarely known before the process is finished. An analysis of processing times on the CNC machines revealed a very high variability between jobs (see Figure 40). Roughly 50% of jobs require a job duration between 0-5 hours, further 30% of jobs take between 5-10 hours. The remaining 20% of jobs stretch from 10 to 48 hours[8]. The high variability of these processing times in combination with the fact of not knowing them before the start of production is perceived in the company as a major impediment for an effective mid- to long-term capacity planning process. This impediment is amplified, if many projects require at the same time the same resources. This resource contention is a typical phenomenon in a multi project environment (Newbold, 1998).

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[7] More details about characteristics of injection mould tooling can be found in (Stamm & Neitzert, 2008a)

[8] Data for all CNC machines over a period of 4 months are used.

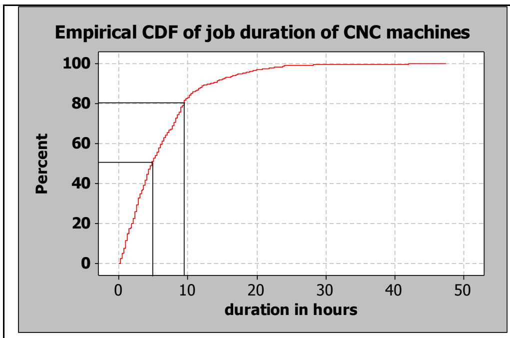

Figure 40: Cumulative distribution function of job duration on CNC machines

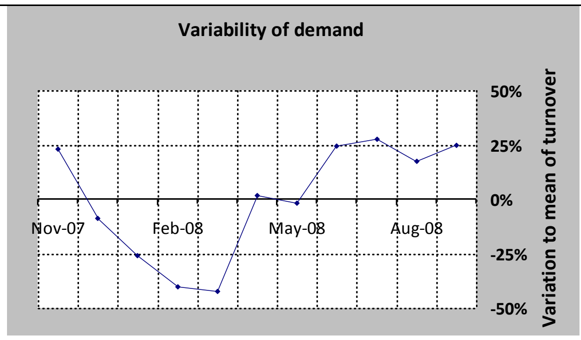

Figure 41: Variability in demand volume (Case study A)

The demand variability is to be categorised as high as well. As more than 50% of the turnover is generated by engineer-to-order products, the product mix is to be categorised as high. Over the observation period the monthly sales volume varied regularly within a range of 60% of the average turnover (see Figure 41). This also needs to be categorised as a high variability in demand volume. One reason for this is that tooling is an asset invested with a high value whereas the demand does not follow a regular pattern as the tooling is purchased dependant on lifecycles of products.

Employees on the shop floor are mainly highly skilled toolmakers and CNC operators characterised by a traditional Craftman's attitude. Being able to build specialised tooling, toolmakers show a great pride in their work and generally strive for a high finishing quality of their daily tasks. Further there is a strong awareness of their high degree of specialisation and its requirement for high craft skills. Comments like "Toolmaking is different", "things, the mass producer do, won't work in our environment" and "don't talk about, let's just build the tool" sketch the attitude of 'getting things done' and of the perception that toolmaking has a separate position in the manufacturing industry and that methodologies developed under mass production conditions do not work in a toolmaking set up.

It is common that customers require modifications to the tooling before and even after release to the shop floor which lead to changes in schedules and sometimes in required shipment dates. The impact of these changes and correspondently the question how to charge for modifications taking into account the influence on other projects on the shop floor is difficult to assess. These dynamics influence the workload of designers, the management of delivery dates for purchased material and the workload on the shop floor and hence, are seen as one of the major challenges in levelling the workload and in synchronisation of resources. All the mentioned insights were revealed in analyses of the researcher and continuously discussed with management and staff.

The following chapter elaborates on the major action research cycles and the chronological sequence of implemented methodologies and improvement activities.

4.3.2 AR cycles and history of Lean transformation of case study A

The research period in case study A can be mainly divided into two major AR cycles followed by a third 'validating' cycle in a second case organisation (case study E). The first cycle started with the aim to understand the current state of the organisation by exploring the current business processes. Another important objective in the early phase was to establish the access and development of corporate data and necessary systems in order to evaluate the progress and effectiveness of the transformational process. In this early stage of the research, the researcher had a slightly passive role of data gathering as an observant in Aichi meetings and as an auditor of already established methodologies and techniques. For example the establishment of a communication structure and the creation of a more effective team structure were in a pilot phase. In this phase of understanding the current state of the organisation, the researcher could develop first theoretical concepts by linking initial observations and analyses to insights of the literature review. The Value Stream Mapping (VSM) represents the major first active involvement by the researcher. Members of management and of the shop floor were involved in the initial collection of relevant data and the review of the current state map. In a workshop to review the results of this VSM with management and team leader, strategies for further activities were derived. Hence the VSM approach led to a phase of a number of improvement activities where the researcher was actively involved with or took part as an observant. This first phase of observation, planning and action took ten to twelve months. By the end of this first phase the researcher developed first concepts of a transformation framework by combining the experiences within the case study and the theoretical insights gained out of the literature review to that point. This first iteration can be described as tool-orientated as the organisation mainly focused on the implementation of specific Lean methodologies on the shop floor. As in the first phase, the strong influence of variability on the implementation of some of the Lean techniques, the initial framework included a perspective on how the individual elements are addressing variability aspects (see appendix L).

In the second cycle of the research, the unit of analysis was expanded from the initial focus on the manufacturing system to the purchasing, quoting, product development and human resource processes. The decision to widen the focus of improvement activities to almost all parts of the business was made based on the review of the effectiveness and progress of the previously initiated improvement activities. In a meeting with management, improvement activities that either did not show the targeted performance increase or that failed so far to become an integral part of the organisation were analysed. In this discussion, facilitated by the researcher with System Dynamics techniques, it was brought to the surface that many activities failed or did not show the desired outcome as factors outside the manufacturing system were affecting their success. It became clear, that the variability caused in the quoting process, in the supply chain or during the design phase has a significant impact on the disruptions in production. Hence the second iteration opened up its focus on the whole organisation including processes directly linked to the customer and to the suppliers.

Consequently in the second planning phase the researcher reviewed the processes before and after the manufacturing system of the business. Derived actions were for example the production standardisation in design stages (e.g. pre-manufactured tool die sets), improvements to the quoting process (e.g. database about tools and manufacturing times, establishment of a standardized quoting procedure), improved project management embedded in the daily capacity planning and scheduling process including milestones to synchronize resources, the development of strategies to outsource work in times of high workload, the restructure of the organisation and the responsibilities of the owners and strategies to concentrate on core competencies (focus on value creation and on specific markets). Further activities included a review of the reward policies and cross training of staff to overcome resource constraints. It needs to be noted that in this second iteration shop floor focused and tool-oriented activities continued. The second iteration stretched over a period of roughly 18 months. There were several meetings and workshops to analyse the achievements and to reflect on the outcomes together with management and staff members. The researcher was able to further develop the theoretical framework by adding the elements ‘internal and external interfaces’, ‘human resource development’ and the aspect of leadership. With the developed framework the researcher contacted the organisation of case E and offered assistance in their Lean transformation by being part of the AR project. The implementation in case organisation E guided by the framework is to be seen as the third cycle of the overall research project and is described in chapter 4.7.

Case study A commenced its Lean implementation as part of an improvement program initiated by NZTE. Four NZ SMEs started supported by a consultant to implement Lean methodologies. The consultant mainly used the so-called 20KEYS workplace program by Kobayashi (see chapter 3.3.6.3, Table 13 for more detail). This program provides, based on the so-called 20 keys, guidelines, procedures, techniques and for each key a benchmark evaluation checklist. It is mainly orientated on Lean principles. The initial involvement and buy in of the owners and managing staff was realised by introductory workshops about Lean, a study trip to Japan to companies that have already successfully implemented elements of the 20KEYS program and regular meetings and visits of the participants’ company sites to share the progress and experience of implemented techniques on the ‘gemba’.

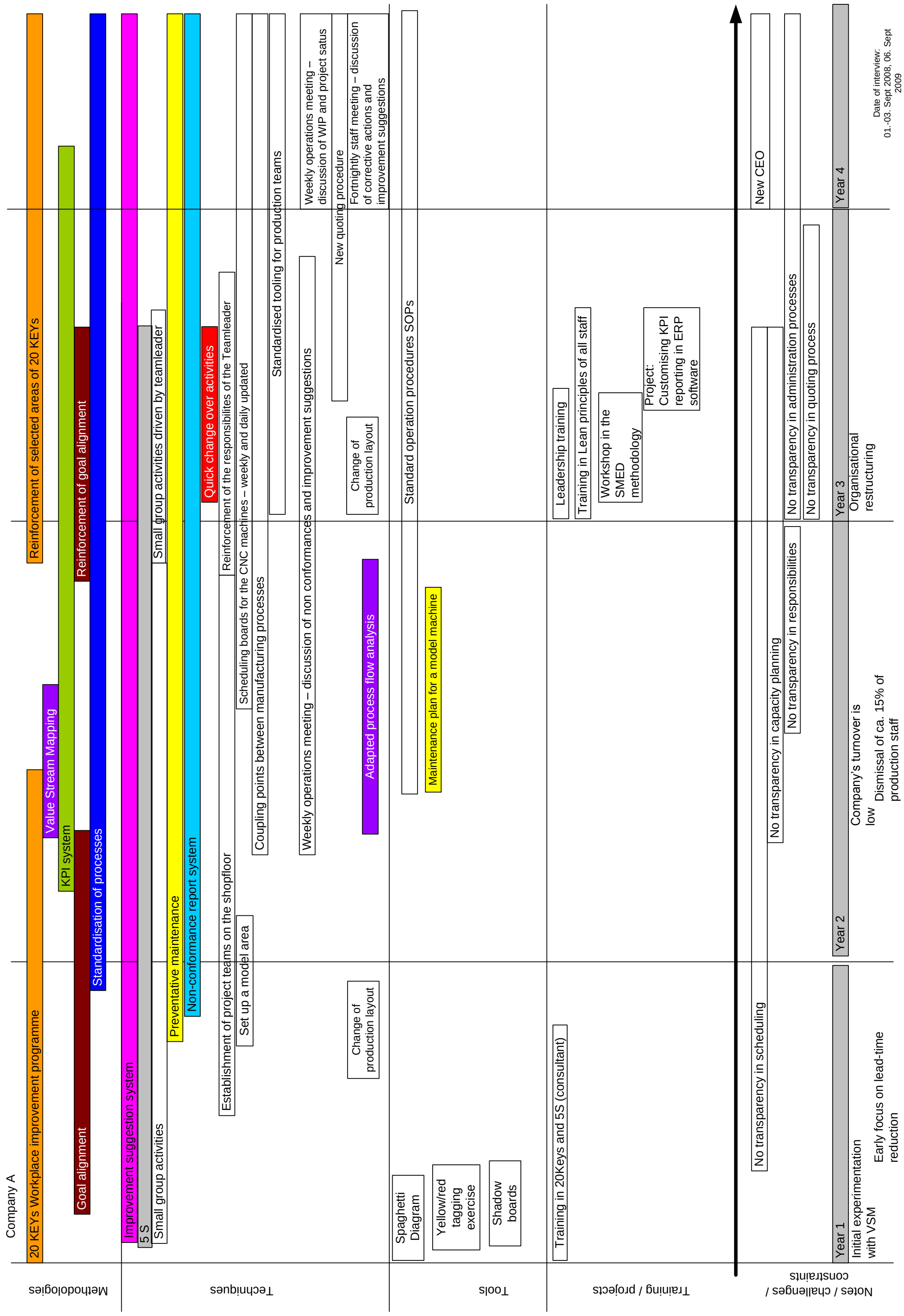

Figure 42: Lean transformation history of case study A

Within the first AR cycle, the company began with the implementation of 5S on the shop floor introducing shadow boards for tooling and cleaning equipment (see Figure 42). The acceptance of 5S by staff is perceived as good, although it was noticed that a continuous process of auditing the current state is necessary to prevent a backsliding to old habits. Additionally the layout for the tool assembly area was changed and customised workbenches were designed and manufactured that enabled a more team-centred approach. In a traditional toolmaking environment usually one toolmaker works on one moulding tool. In the more team-centred approach a team of toolmakers led generally by the most experienced and capable member works simultaneously on one tool until it gets to the end assembly. In this approach tasks that do not require high skills like for example blocking up the initial steel blocks for the CNC machines can be delegated to lower skilled staff. Besides by concentrating more toolmaker on one tool, the lead time can be shortened and hence throughput increased. On the other side, a team-centred approach requires more coordination and communication and clear standards for the allocation of material and for provision of manufacturing information (e.g. drawings and setup sheets). Further initial methods that were implemented are an improvement suggestion system and a reporting system for corrective actions. The main purpose of the corrective action system is the documentation of quality costs and to identify more systematically quality problems. For example during the second year, the number of rework cases originated by mistakes during the sparking processes was high. Correspondent measures were discussed and taken by a defined improvement team. In the following year there were hardly any incidences originated by the sparking process.

In order to evaluate the state of the company in the second year the researcher conducted a value stream analysis which was adapted to the specific requirements of a one-of-a-kind environment (see publication (Stamm & Neitzert, 2008b) for more detail). The purpose of this analysis was to develop an understanding how material and the appending information flow through the manufacturing process. Hereby very quickly limitations of the traditional VSM methodology were brought to surface which led to a customised VSM methodology for a one-of-a-kind environment. In the adapted VSM methodology the critical components that are supposed to have the longest processing times are followed through the manufacturing process and waiting (queuing), processing and set up times are recorded.
Based on this data the Relative Flow Velocity (I) was introduced in the case study to emphasise the improvement potential concerning the overall lead time, if the waiting time can be reduced, and is expressed as:

$$I = \frac{\sum_{i=1}^{m} t_{Q,ij}}{\sum_{i=1}^{m} (t_{P,ij} + t_{S,ij})}$$ **(5) Relative Flow Velocity I**

t_Q: time of queuing in front of next process
t_P: processing time
t_S: set up time
i: process index
j: component index

This indicator proved to be comprehensive during discussions and is suggested to be used for all major projects. It clearly shows the ratio of the waiting time t_Q to the manufacturing time (processing time t_P + setup time t_S). This indicator clarifies the degree of synchronisation of the process chain and the degree of flow of material. The ideal value is I=0, which means, there is no waiting time between the manufacturing processes of an observed component, i.e. the component flows through the whole value stream without any interruptions. Further improvements can be achieved by reducing the setup time t_S which leads to a reduction of the index I as well. This index used in early stages of a Lean implementation also encourages to consider the improvement of the whole value stream instead of local efficiency improvements. In the initial evaluation of the company values between 4.3 and 12.9 could be achieved for the relative flow velocity. This means that the waiting time for the critical components that are determining the overall length of a project is more than four times longer than the actual manufacturing time (processing and set up time). This analysis further revealed that the waiting time in front of the CNC machines took a significant part of the overall waiting time (between 29.2% and 52.0% of the overall waiting time). After a discussion with managing staff about the possible reasons for this observation, it could be concluded that the CNC machines are the constraining resource of the manufacturing system and hence initial measures of improvement should concentrate on the exploitation of this constraint and the subordination of all other manufacturing processes. The following main activities were derived out of the initial VSM analysis:

- the introduction of the SMED technique to CNC operators
- the implementation of measuring the spindle time as the ultimate measure for the value adding time at the bottleneck resource

- the implementation of a centralised capacity planning and scheduling system that concentrates on the CNC machines and subordinates the remaining resources
- coupling points with designated areas for incoming and outgoing material and corresponding manufacturing information.

As toolmaking requires an intense usage of CNC machines and other milling and sparking operations, the downtime due to machine failures has a large impact on the overall productivity. Hence, preventative and more proactive maintenance plans for all machinery were introduced, but lacked from the beginning a consistent implementation and has required constant reinforcement by management.

The KPI-system indicated in Figure 42 is elaborated in chapter 4.3.4.

To enable an efficient flow of information a customised meeting structure evolved over the observation period. There are daily scheduling meetings on the shop floor where daily activities for each toolmaker and CNC operator are defined and jobs of the previous day are reviewed. In these daily meetings scheduling boards are updated by the team leaders. In a weekly operations meeting the production manager and the team leaders review the progress of tooling projects. The main information is an automatically produced report for every project illustrating the usage of hours for every resource (e.g. team hours, CNC hours, wire cut hours, etc.) and comparing it with the hours of the initial quote that are to be seen as targeted hours. A fortnightly meeting open to all staff gives the opportunity to discuss corrective actions and improvement suggestions that are relevant for a larger group of staff, provides a forum for health and safety issues and provides information about ongoing and future projects and the financial performance of the business. Other meetings are project-specific with the purpose of determination of manufacturability, project scheduling and final project reviews. At managerial level a fortnightly sales meeting discussing current and future projects is installed and a monthly board meeting which concentrates on market development strategies, governance policies, financial planning etc. It needs to be noted that on all levels meetings have been regularly cancelled or postponed because of day-to-day activities. Additionally the adherence to meetings was mainly dependant on the availability of the production manager who has been the main driver for all Lean activities. When the production manager was absent, it was very likely that the correspondent meeting was cancelled. The researcher collected data about the adherence to meetings and discussed based on this data the struggle to maintain with the meeting schedule with the management. The production manager in general admitted the inconsistency with regards to the adherence of the meeting schedule and showed reinforced efforts and discipline.

4.3.3 Excursus: comparison of case study A with a supplier of Toyota

Morgan gives some valuable insights in how the Motomachi Tool and Die plant as one of the main suppliers for tooling for Toyota adapted Lean principles (Morgan, 2002). Comparing this toolmaker with a tool manufacturer for North American automotive companies Morgan revealed at the Motomachi plant much shorter lead times from the design of a die to the first trial of it. One might assume that the Motomachi plant developed under the guidance of Toyota a streamlined ‘lean’ toolmaking process that is aligned with the needs of its main customer. Hence, in Table 18 the particular characteristics that Morgan found are listed and compared with case study A. It must be noted that the Motomachi plant has a higher degree of streamlining as it mainly supplies Toyota, whereas case study A has several customers in different industry fields and different applications. It was found that this higher variability in customer specifications combined with the variability in their demand of new tooling equipment and hence more inaccurate forecasts for the production utilisation exacerbates the streamlining process. Looking at the diversified and relatively small NZ tooling market, streamlining and allocating the manufacturing equipment to specific ‘product families’ can be only partly realised. Planning and levelling the workload at the Motomachi plant seems to be greatly facilitated by its integration into the design process and its project milestones of Toyota’s design departments. In the case study, orders for new tooling are generally communicated on a short to mid-term basis by the customer. Besides, the company has to compete, mainly driven by price, with national and international (mainly Chinese) competitors for most of the tooling projects. This quotation process increases the additional uncertainty of the future work load.

At case study A the CNC machines and CNC spark eroders as high value machines must be shared between the cells.

Table 18: Comparison of Motomachi plant with case study A

Characteristics of Motomachi [extracted of (Morgan, 2002)]	Comment with regards to case study A
Flexible capacity strategy: they regularly utilise subsidiary companies such as Toyoda Auto Loom to support their own Motomachi Tool and Die plant.	As there is not only one main customer, more long-term capacity planning is very difficult. Generally customers decide short-term depending on the quoted price which supplier receives the order. Hence, the outsourcing of workload to allied smaller job shops is difficult to plan in advance but is regularly considered.
Detailed resource scheduling. Each piece of each die for each step in the process is scheduled (fundoshi).	The need for a more detailed schedule is recognised. The company strives based on continuous improvement for raising their scheduling capabilities.
JIT basis for all purchased components such as guide pins to the right places (construction cells).	Purchased components are generally ordered just in time to meet required delivery dates. Although because of frequent changes in schedules, there are limitations to the efficacy.
Dies are classified in categories of which each category has a line of milling machines, construction bays, and spotting presses. The categories mainly determine size and surface finish of the final products.	Dies are classified according to the value (e.g. tool die between NZ$ 40,000 and NZ$ 60,000). The teams of toolmakers are specialised according to these categories. CNC machines are shared between the toolmaking teams.
Standard procedures and standardised times support scheduling.	Standard procedures are being developed. The value of collecting manufacturing times in a centralised database to support scheduling is acknowledged and data is currently collected. This data will also serve as guidance for the estimation of hours in the quoting process.
Department specific schedule boards, jobs are scheduled by the hour of the day that they are to be completed. A job ticket will be removed upon completion by the responsible mill attendant and placed in a bin that is hourly emptied.	Department specific schedule boards, jobs are scheduled by the day with a forecast period of roughly one week.
Right sized equipment machining, smallest possible machine is always used.	Based on the experience of the production manager and scheduler, appropriate machines are selected.
Specialised machine tools and methods to operate at high speeds at very low tolerances which reduce the processing time during blanking and fitting.	The company maintains a high standard of tooling and machines in comparison with national competitors.
Regular checking of cutters' dimensions with laser measuring machines.	This has not been considered yet.
Cells' task times are equalised (as measured in days) which leads to synchronisation between the line sections and sequenced construction cells.	Every project has a master schedule. The correspondent team derives their daily tasks from this schedule. Although synchronisation problems between the cells and the shared resources still occur.
Marked die locations	There are coupling points (in and out areas) between CNC machines and toolmaking teams in order to facilitate the material flow. Besides there are marked areas for incoming material and dies that are currently not worked on.
Checklists for each cell serve as a procedural reference and quality assurance tool.	Checklists are implemented in every team and are continuously under review.
No paper drawings within the cells, as all cells are equipped with CAD computers.	All cells are equipped with CAD computers, paper drawings are provided for the main components.

4.3.4 Performance development of case study A

This chapter tries to find evidence for the improvements in operational and business performance. For this purpose, the performance concept presented in chapter 4.1.3 is used. Additionally, as the researcher has been an integral part of the company, also other data could be used to analyse the effects more detailed. In early stages of the research, the researcher proposed a key performance indicator (KPI) concept[9] to the company in order to evaluate and monitor the progress and effects of Lean activities. It covered the following five dimensions: leadership, costs, quality, time as well as people and organisation. As stated by Bozonne and Suri, lead time is to be seen as an essential KPI in job shops and other high variability low volume environments (Suri, 1998) (Bozonne, 2002). This insight was also acknowledged by the management of case study A. In the early Lean implementation phase the company established corporate goals that jobs of a certain value category are to be manufactured in a defined lead time range. Figure 43 to Figure 46 show the lead time from entering a job into the ERP system until its shipment date. The data contains in chronological order all jobs for the first two and a half years of the Lean transformation. One job is represented by one data point. As the Lean activities do not only concentrate on manufacturing but also address improvements in the quoting and design areas, a reduction of this lead time was seen as a good ultimate indicator for the effects of the organisational change. Monitoring the manufacturing time was due to a lack of correspondent data not possible. In the category under $10,000 no improvement in lead time could be found in the data set. The reason for that is many jobs are entered into the system without being urgent, in other words the actual manufacturing time is much shorter than the time the job is open in the ERP system. This also explains the extraordinary high variability in all categories. In the three categories over $10,000 a reduction in lead time could be proved. A clear improvement in lead time is noticeable for jobs from $10,000 to $60,000. For jobs above $60,000 a trend is less clear. With increasing scope of tooling projects the interaction with the customer increases due to the high degree of customisation and consequently greater design and project coordination efforts.

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[9] The concept with examples of correspondent KPIs is described in more detail in (Stamm & Neitzert, 2008a)

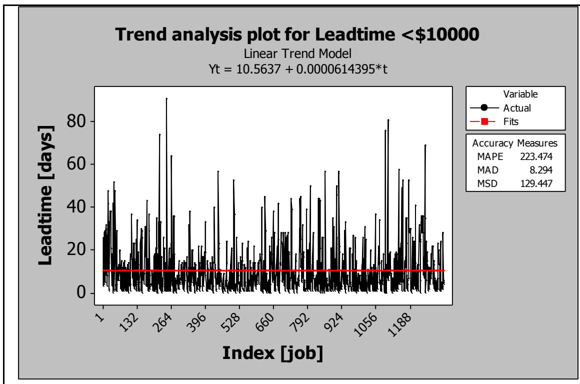

Figure 43: Leadtime analysis of jobs < $10,000

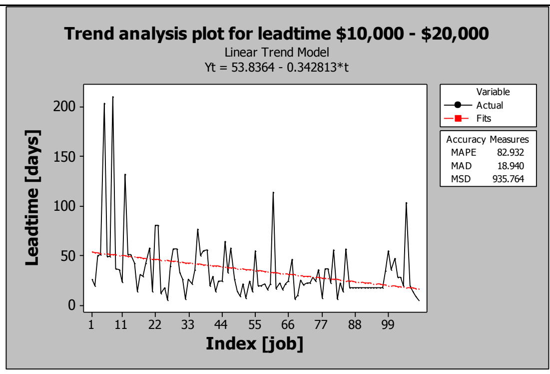

Figure 44: Leadtime analysis jobs between $10,000 and $20,000

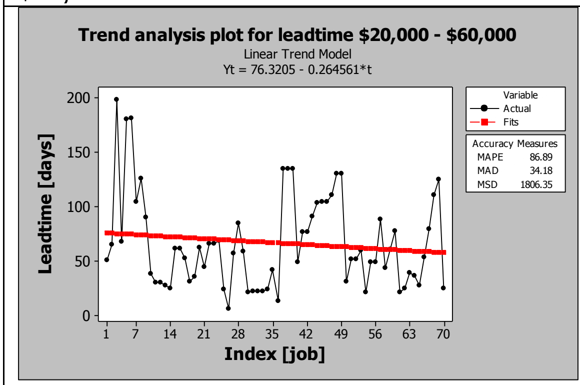

Figure 45: Leadtime analysis of jobs between $20,000 and $60,000

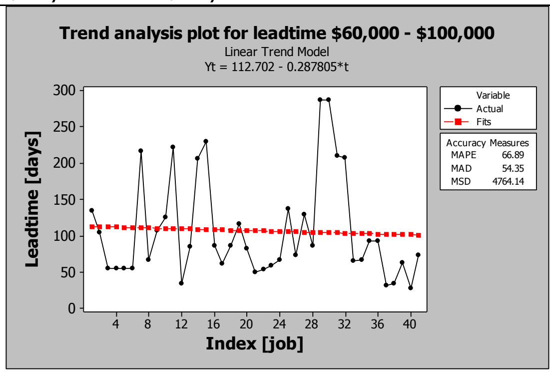

Figure 46: Leadtime analysis of jobs between $60,000 and $100,000

The main KPIs for the evaluation of leaders' and staff's involvement are the numbers of new versus implemented improvement suggestions per month. Figure 47 shows the total number of improvement suggestions and the fraction of implemented ones over the whole period of research. Within the observation period two slumps in sales occurred, that triggered dismissals. The reduction of staff is followed by a period of a low number of improvement suggestions. Also an extreme increase of workload seemed to decrease the involvement of staff in the improvement suggestion system. A reinforcement of Lean activities in January and February 2008 initiated by a staff meeting and by several in house training courses about Lean Manufacturing obviously encouraged a high number of new suggestions over a period of four months.

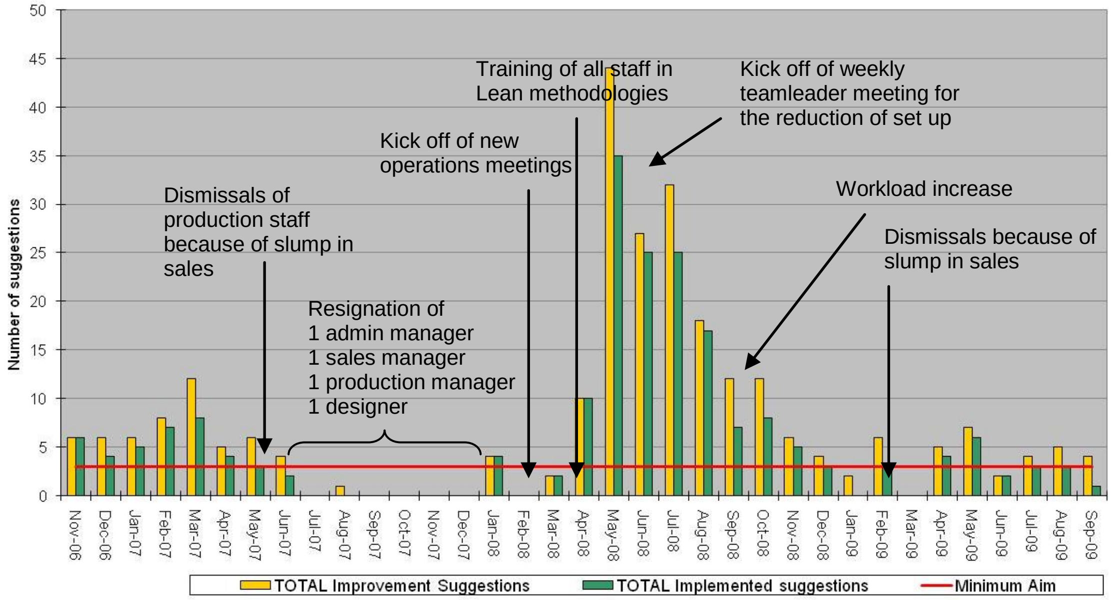

Figure 47: Development of improvement suggestions

Table 19 gives an outline over the internal rework costs as a percentage of turnover. This KPI has been selected to monitor the improvement of internal quality. As the figures show, quality costs could be reduced in three years to one fifth. Rework costs are reported on corrective action forms which are usually discussed in the correspondent meetings and countermeasures are taken. Additionally every half year all occurred corrective actions are analysed to find common themes of failure phenomena.

Table 19: Development of internal rework costs

Year	Internal rework costs as percentage of turnover
2007	2.3%
2008	1.4%
2009	0.4%

Looking at the overall trends of the actual annual performance, all five case studies are evaluated based on the performance concept presented in chapter 4.1.3. Figure 48 shows the results for the total observation period (three years) of case study A (Green: positive development of measure; red: negative development of measure; yellow: no clear trend; white: no data available or measure not relevant). In the dimensions of quality, people/organisation and leadership, there are clear trends of improvement. However in the areas of competitiveness, productivity and costs as well as speed and time, improvements were less distinct.

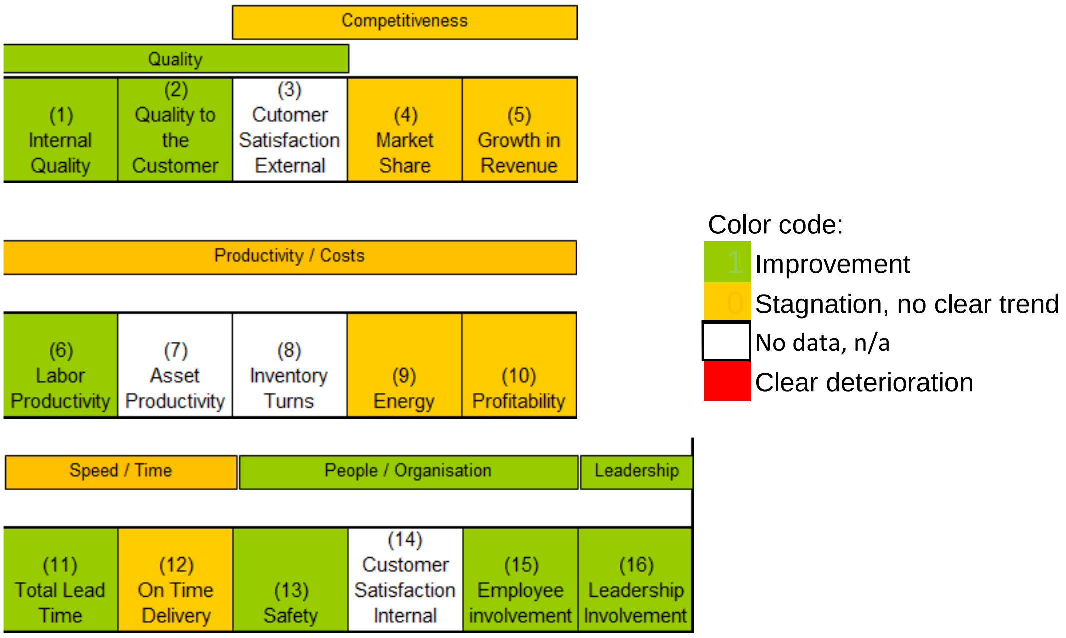

Figure 48: Development of performance of case study A

4.3.5 Further observations for case study A

In the early stage of the Lean transformation the researcher noticed that the managing directors were not immediately involved in Lean activities but acknowledged their value. The central person and main driver for the major Lean initiatives has been the production manager. In busy times the managing directors were also involved on the shop floor but lacked the discipline in 5S and undermined the new roles of team leaders. An involvement from the beginning in all Lean activities, e.g. the regular attendance in improvement meetings, would have prevented some tension between staff and owners. Staff regularly questioned the purpose of improvement activities if new developed standards were not applicable for the managing staff. This observation led to the conclusion that the element of leadership needs to be represented in the final framework of the research project.

Another impediment for continuous improvement activities has been the high variability in work load. Over the whole research period one of the major challenges was to make the current and future work load visible. Jobs for the

CNC machines were rarely scheduled over a longer period than one week. One major reason for that is the delay between the point when actual monthly turnover is earned respectively booked into the system and when the physical work is actually released to the shop floor. A phenomenon that could be observed at many projects with regards to the work done is the so-called ‘hockey stick effect’. When new projects are released to the shop floor the progress is very slow until the project becomes more urgent and more resources held in other projects are drawn off and reallocated to the more urgent project. These insights are manifested in the framework by the elements of flow and synchronisation and by the element of transparency.

This difficulty of measuring current WIP and also forecasting future workload led to a very short term based scheduling process where mainly the tomorrow’s and today’s work is scheduled. As the research followed the action research methodology, the researcher tried to introduce alternate scheduling methodologies to cope with the variability in WIP and capacity utilisation. Methods that were presented to management staff and were introduced on a pilot basis were the adaptation of Goldratt’s ‘critical chain’ approach and the material control system called POLCA. POLCA is designed for high-variety or custom-engineered products. It is a hybrid push-pull system that combines features of card-based pull (Kanban) systems and push (MRP) systems (Suri & Krishnamurthy, 2003). Those methods never exceeded the pilot phase and never became an integrated part of daily scheduling. Potential reasons for the failed impact of the pilots are based on the observations of the researcher the high pressure of the day-to-day workload and the lack of detailed practical knowledge about these scheduling methods.

4.4 Case study B

4.4.1 Background of case study B

Case study B is a low involvement case study. Data were collected during two company visits within one year. The company has roughly 75 staff and operates in a design-to-order and manufacture-to-order environment. One part of the business on which the data collection concentrated is specialised in the fabrication of large capacity stainless vessels for the food and dairy industry. Looking at the variability matrix (see Figure 38) the variability in demand is to be seen as high due to the irregular demand. Similar to case study A, vessels are high value investment assets and are usually needed when new processing facilities are built. The task variability is lower than of case study A and case study E, because less manufacturing processes are required. Additionally the number and diversity of components for the finished product is lower. This reduces the complexity in routing and scheduling and hence the coordination of the material flow. The core competencies lie in the area of welding, folding and laser cutting.

The qualification of staff varies from experienced welding operators who need to regularly renew their welding certification to operators for folding machines and laser cutters where lower skill levels are appropriate.

4.4.2 History of Lean transformation of case study B

Case study B started its Lean transformation with the workplace improvement program 20KEYS supported by the same consultant as in case study A. Hence the type and sequence of applied techniques is very similar. Like in case study A the consistent adherence and execution of proposed 20KEYS procedures (e.g. the regular 20KEYS checksheet to monitor the maturity level) started to fade away in the second year of transformation. Main driver and commitment were created by the owner and the operations manager. According to the owner his daily activities largely changed during the implementation. The owner's focus went away from a reacting to a more proactive and more facilitating role. Further it was noted that all Lean activities led to higher problem awareness.

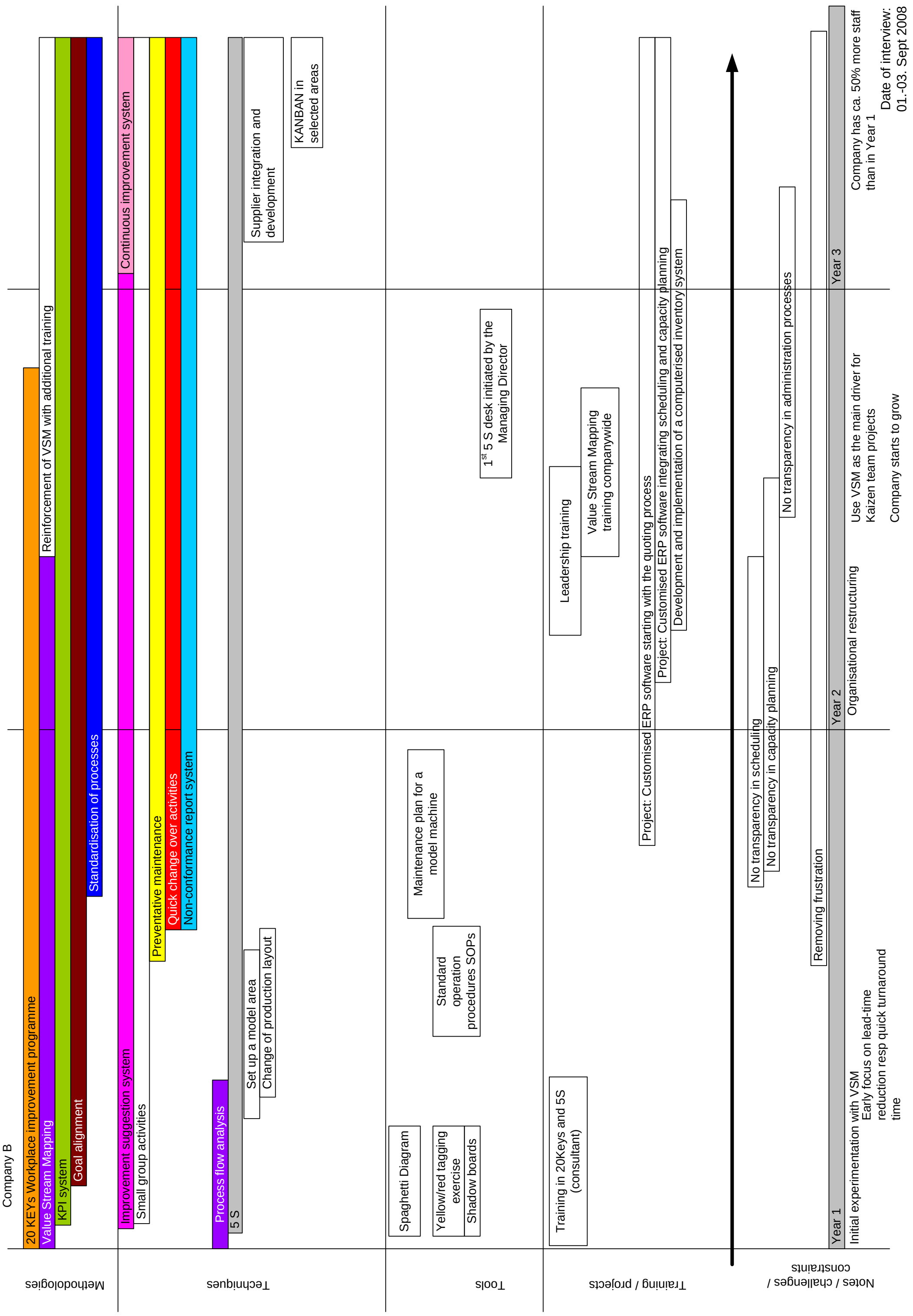

Figure 49: Lean transformation history of case study B

The company experienced strong growth over the transformation period, growing from 50 staff to over 75 in three years. At the end of the first year the lack of transparency in the quoting, scheduling and capacity planning process was acknowledged as a major constraint for further improvements. Therefore the company decided to develop in cooperation with an IT company a customised integrated ERP system. At the second visit to the company, the ERP system was operational and the advantages of it were emphasised. The efforts invested in the customised development of the system increased the understanding of processes in the company and hence led to an improvement in the organisational abilities for process development. Staff members who are supposed to daily use the ERP system were involved in the development of the ERP system. This not only assured that the system was customised in the best way to the company's requirements but it also facilitated the acceptance of the new system during implementation. In the second year the owner and operations manager decided to reinforce all Lean activities by providing training in leadership for all managing staff and a series of Lean workshops for all staff provided by an external training institute. According to the owner this 'wave' of intense training sparked new ideas for improvements. Value stream mapping was reinforced and is seen as the major analysis tool in order to identify new improvement areas.

In the third year the company expanded their Lean activities to administrative areas and started to integrate suppliers based on the improved planning and scheduling capabilities. With regards to the transfer of Lean principles to administration, it was interesting to hear that the owner initiated the activities with his own desk designing it on the basis of 5S.

4.4.3 Performance development of case study B

The inspiration and commitment of the owner, the managers and shop floor staff that was experienced during the company visits are also clearly shown in the development of the business performance (see Figure 50). The company shows clear improvement in all six areas of the performance framework.

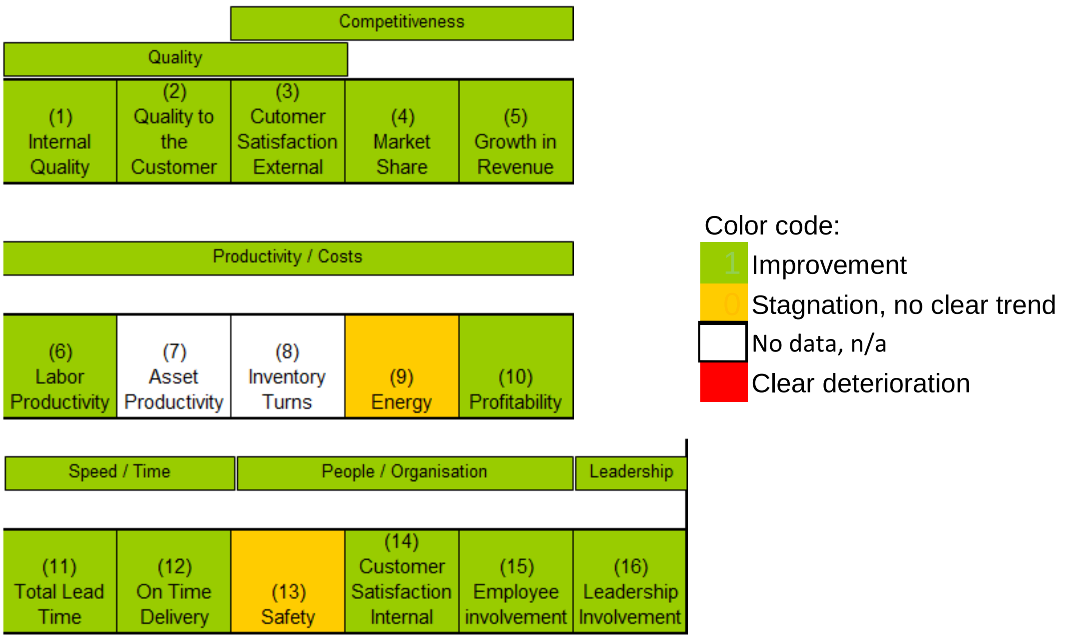

Figure 50: Development of performance of case study B

4.5 Case study C

4.5.1 Background of case study C

The company providing the observational case study C designs and manufactures entertainment and specialised luminaires. The company was visited twice within six months by the researcher. During the first visit the researcher discussed with the Managing Director and the Operations Manager their Lean transformation and collected data in order to complete appendices G to K. This was followed by a detailed plant tour where a variety of implemented methodologies were discussed. During the second visit the history of the Lean transformation was reviewed based on appendix I and more data for the evaluation of the performance development was collected (appendix J).

The company has roughly 60 staff and the main internal operations concentrate on the assembly of the end products and the logistics and supply. Most of the sub-components, e.g. the casted housing or other plastic components are externally manufactured. Most of the products were initially manufactured to stock. A manageable number of variants were offered in their catalogue. Initial value of finished goods in the warehouse was very high to meet the highly fluctuating demand. Customers usually order in large numbers, as the lighting is usually required as initial equipment of buildings, theatres and museums. After the implementation of Lean methodologies the company operates mainly as an assemble-to-order operation. In comparison with the other case studies in the variability matrix, this company has low task variability, as it mainly concentrates on assembly activities of very similar products. In comparison with the case studies A and B, a low investment in machinery is necessary. The demand variability is to be seen as relatively stable with the exception of some larger orders that are for example initiated by providing the lighting for larger building complexes.

4.5.2 History of Lean transformation of case study C

The company was visited twice within half a year of its third year of Lean transformation. It provides compared with the previous cases new insights as it operates on a different task and demand variability and further, as it started their Lean activities with different consultants (see Figure 51). The implementation started with a stock analysis by the consultants. It was noted that the value held in finished stocks was very high and the reduction of inventory of finished goods was immediately recommended. Additionally it was recommended to initially concentrate on 5S activities and on the introduction of Kanban in the end assembly. Then, Kanban should be expanded to other processes. Though, the operations manager described initial problems with the introduction of Kanban. As planned, inventory levels and cycle times began to drop. But the output of the plant was endangered as the plant struggled to keep up with demand. Looking at the manufacturing theory in chapter 3.3.1, Kanban reduced the time buffer without addressing the underlying reason that the buffers existed in the first place. As a result, the company was forced to introduce alternative buffers in capacity and time. The company experiences from time to time large orders for the initial installation of buildings or theatres. These fluctuations in demand were not considered in the first layout of the Kanban system and its effects were amplified by the reduction of the finished goods inventory. Countermeasures were taken by improving the forecasts for orders and by a more transparent way of managing the finished goods area.

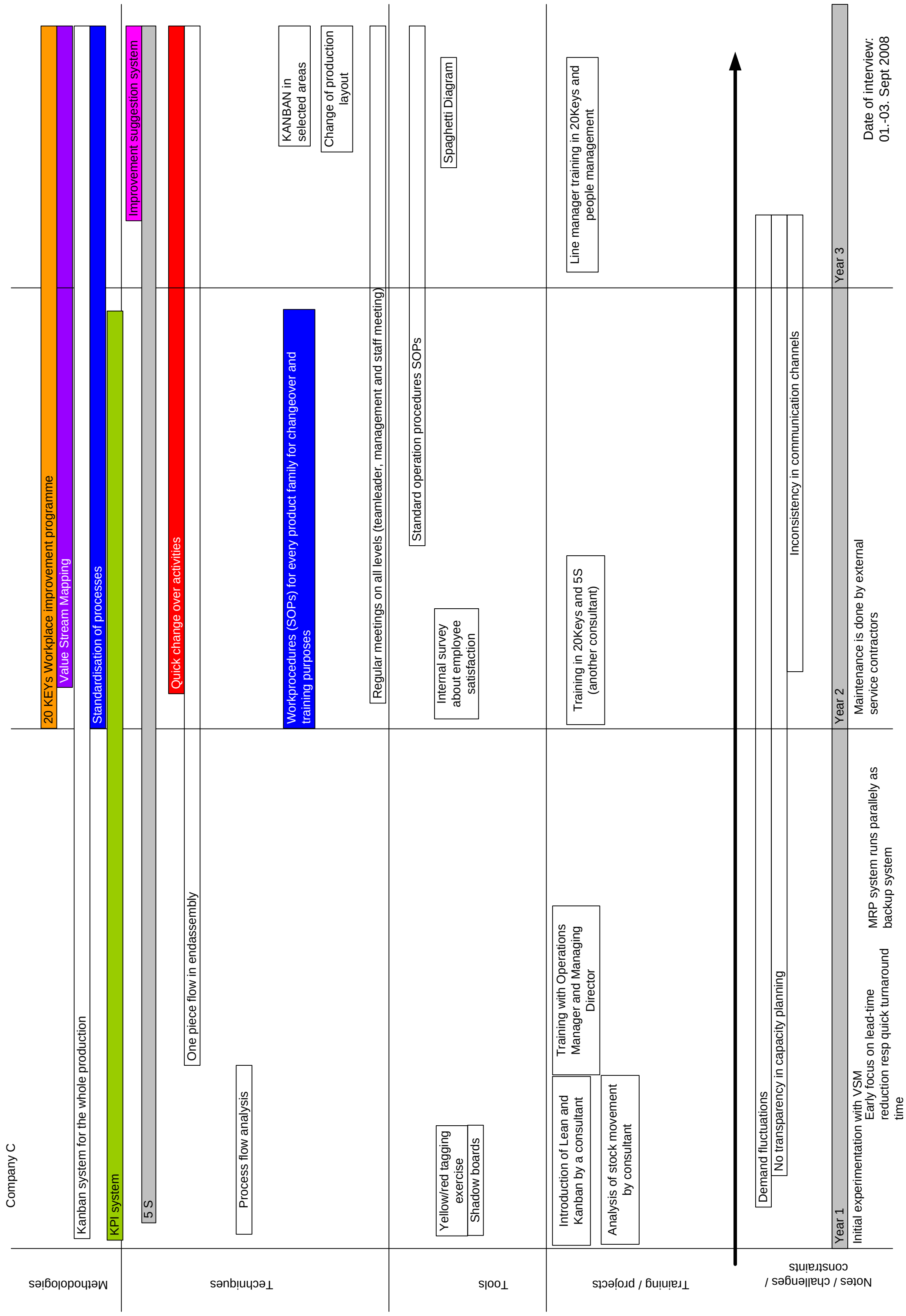

Figure 51: Lean transformation history of case study C

In the second year the company changed the consultant and was also introduced to the 20KEYS program. Lean activities around 5S and standardisation were reinforced and an emphasis was put on standard operating procedures in the assembly area, a further development of the Kanban system including the connection to purchased components, and the introduction of quick change-over procedures between the changes of product lines. Additionally management mobilised by a satisfaction survey all staff members. The internal survey revealed a lack of communication between departments. To cope with this, a correspondent communication structure was implemented covering daily team meetings to schedule work, daily team leader meetings and regular staff meetings. Further management committed to regularly held meetings on strategy and market development. In the third year, as the researcher just visited the site, the company had recently improved the floor layout of the assembly lines in order to improve the material flow and further reduce lead time. Within this improvement of the production layout, the Kanban system was expanded to almost all purchased parts.

4.5.3 Performance development of case study C

As expected the performance development in case study C is in all dimensions except of the leadership section positive (see Figure 52). Reason being the company operates in a lower variability environment where Lean methodologies and techniques could be partly directly implemented with minor adaptations.

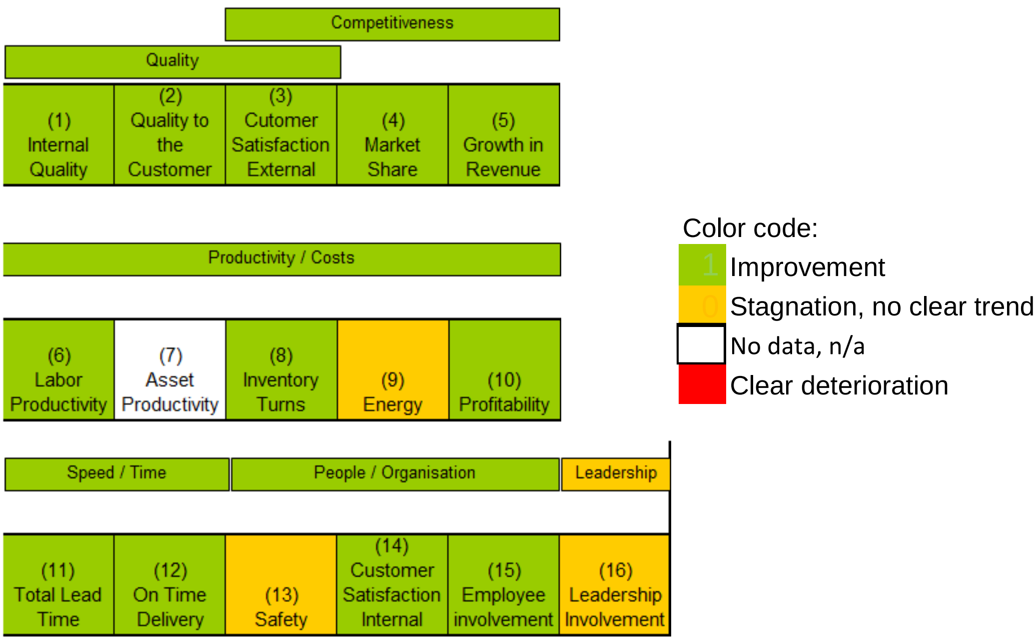

Figure 52: Development of performance of case study C

The Kanban system in combination with the more accurate forecasting system and the quick change over activities proved to be very valuable techniques to reduce lead time and inventory. This led to a higher throughput which the company found further market opportunities for. The increased throughput based on increased productivity could be directly converted into a higher profitability.

4.6 Case study D

4.6.1 Background of case study D

Case study D is the only company of the sample that is not located in the Auckland area, nor located in one of the other urban centres of Wellington and Christchurch. As the company was visited, it was in its second year of Lean transformation. The forms in appendices G, H, I and K were used in a semi structured interview with the two Managing Directors. After the interview the researcher was invited to a plant tour where some of the aspects discussed in the interview were explored. The form for the collection of performance data (appendix J) was sent to the case organisation afterwards and results were discussed in a phone interview. Within this phone interview the transformation history was also reviewed and updated (based on appendix I).

The company that has roughly 50 staff joined the second group of the Aichi initiative funded by NZTE. It specialises in the design and manufacture of retail systems and fixtures. In the variability matrix it takes a special case as the demand variability is to be seen as relatively high comparable with case study A and E. But the task variability is lower due to the nature of the products. Generally retail chains (e.g. supermarket chains) approach the company for the initial installation of a new store or a refurbishment project. These projects are to be seen as individual as every building has specific requirements on shelving, but within a project the product itself can have a highly repetitive character. One can imagine the large shelves in a common big supermarket that are used in large numbers. The manufacturing expertise lies in extrusion, welding, powder coating, joinery and laser cutting and installation of the retail systems. Compared with the other case studies the technical requirements are relatively low. However the managing director remarked that due to the rural location of the plant, the company regularly faces difficulties in getting and keeping qualified staff. Projects share the common manufacturing resources, e.g. the powder coating facilities.

The demand variability is high because of the project character due to initial fixture of large stores. There can be two or more larger projects with similar required shipment dates which often overload the internal manufacturing resources and lead therefore to a high workload resulting in overtime peaks. These overtime peaks can also be observed in the case studies A and E.

4.6.2 History of Lean transformation of case study D

In case study D the company started with the workplace improvement program 20KEYS (see Figure 53). The initial motivation came from a drop in sales and the need to increase the productivity and flexibility of existing resources of the plant. From a research perspective it was quite interesting as the company was part of the second group supported by the same consultant. It was noted that the consultant slightly changed his initial approach putting more emphasis on value stream mapping and on the training of staff and leadership. Major initial challenges of the company lied according to the owners in a lack of trust and hence, to get staff in the early stage 'on board'. It was also decided to customise the 20KEYS program and to rename it to 'Company D Worldclass' to increase the acceptance. This customisation can also be found in larger corporations who adapted elements of the Toyota production system (e.g. Ford Production System, Bosch Production System, etc.).

Comparable with the challenges of the other case studies with a high task and demand variability, the lack of transparency in scheduling and in capacity planning were seen as the major impediments to improving the material flow of the plant.

This company is the only one of the sample that puts an emphasis on the evaluation of individuals and their characters by using a personality profiling questionnaire for all staff.

In the second year the company concentrated on goal alignment and the standardisation of processes. Additionally it started improvement projects to reduce change-over times and changed the production layout by making the store an integral part of the layout. As the production manager changed, the owners decided to take this opportunity to rearrange the overall organisational structure. Further the company acknowledged in their second year the further need for training of all staff in Lean principles and methodologies.

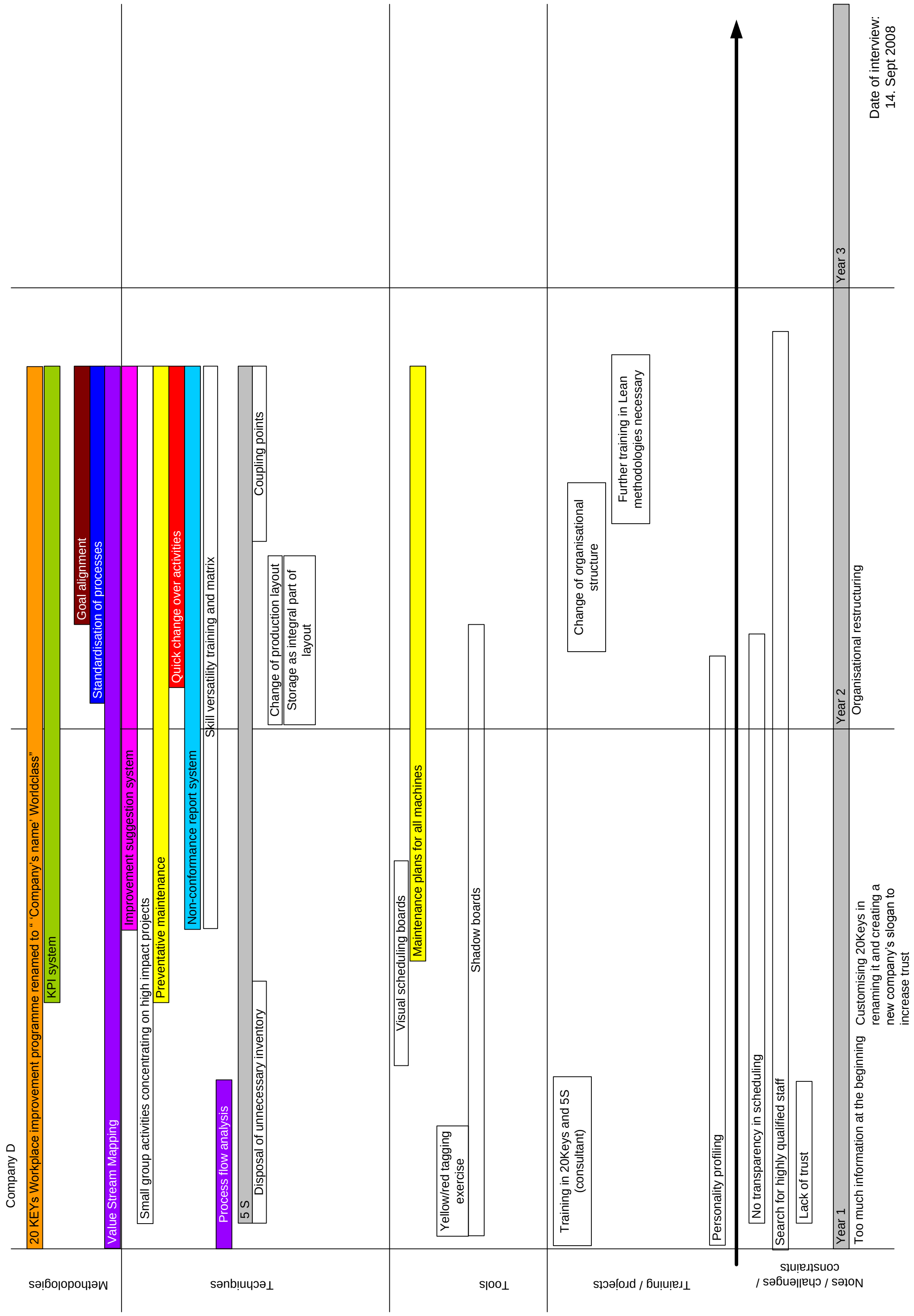

Figure 53: Lean transformation history of case study D

4.6.3 Performance development of case study D

The company experienced over the observation period a high demand fluctuation from one year to the following one by more than 50% of retail sales (Figure 54). As the company decided to avoid lay-offs it resulted in a deterioration of the KPI labour productivity. Although it is argued that the negative trend in labour productivity had been dampened by the achieved workplace improvements.

Immediate improvements after the first one and a half years could be established in quality. Further inventory turns could be increased and the percentage of jobs delivered on time could be improved. As in all other previous case studies the start of the Lean transformation also led to a perceived improvement of staff involvement.

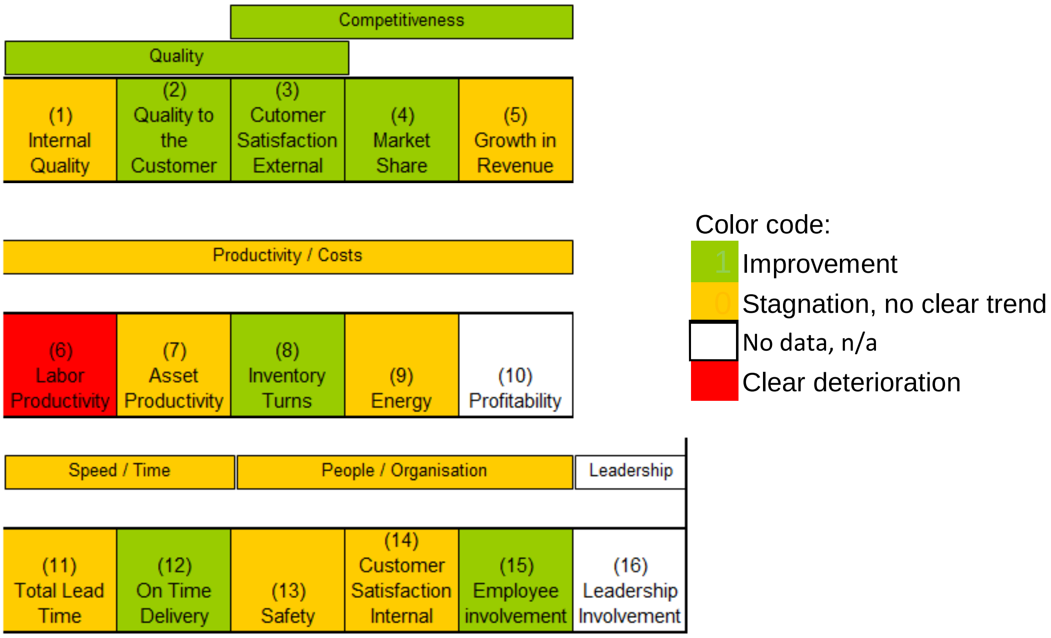

Figure 54: Development of performance of case study D

4.7 Case study E

4.7.1 The role of the researcher and background of case study E

The company providing case study E takes in the variability matrix the highest scores both in demand and in task variability and represents the second AR case study. The researcher contacted the organisation in his third year of research. At this stage, the second AR cycle in case A had led to a further development of the Lean transformation framework. Hence the aim of the researcher was to validate how the framework was perceived by another company that is in an early stage of Lean transformation and in a similar environment of high variability and low volume. The involvement in the organisation stretched over seven months with at least two weekly visits. In the first two weeks the researcher held one-on-one interviews with the management team to collect data about the business processes and the previous experience of the Lean transformation. At the end of the two weeks the forms of appendices G, H and I were completed in a semi structured interview where the Managing Director and the Improvement Manager participated. The collection of the performance data was done in collaboration with the Improvement Manager during the research period. Initially the framework was discussed with the Managing Director. She commented that the simple graphical representation of the main elements is helpful in order to develop a holistic understanding of what needs to be involved within a Lean transformation. However with regards to the element of 'Value focus' (refer to appendix L, page L-3) she pointed out that in their business environment, the development of the brand significantly contributes to what the customer perceives as value. With regards to the other elements of the framework, the Managing Director commented that it felt easy to identify areas where their staff already worked in collaboration with consultants and also to identify areas that still need to be addressed within their Lean transformation. The researcher participated over the whole period in a number of improvement projects to observe and validate how the elements of the Lean transformation framework were implemented and realised. However in case E, the researcher intentionally was more involved on the management level to transfer the concepts of the framework and to receive feedback on its workability.

The company of case study E is specialised in highly customised luxury motor yachts with a range of length between 54 to 82 feet. The main competencies lie in the consultation of the client, the fabrication of the fibre- glass hull based on standardised moulds, the manufacture of the interior and the final fittings and all necessary engineering activities (electricity, plumbing, engine instalment etc.). The company with a capacity of roughly 80 staff members is able to manufacture around five to six boats per year. All processes are due to the high degree of customisation very labour-intense. But in comparison with the previous case studies the necessary investment in machining equipment is low.

The difficulty in manufacturing lies mainly in the high finishing requirements and the large logistical and timing efforts due to the high number of (sub-) components resulting in a high complexity of the end product. It is easy to imagine that a variation in sold boats per year leads immediately to an underutilisation or excessive overload of the manufacturing resources, as one boat contains roughly 25,000 to 30,000 men hours.

Case study E is the only company in the sample that directly communicates with an end customer and consequently operates in B2C (buyer to customer) environment whereas all other cases are B2B (buyer to buyer) companies. Further it is a pure project environment with an extremely high degree of customisation and high value of the final product. The lead time from the final order to the handover to the customer is in comparison with the other case studies very long (generally around 14 months). Also characteristic for this business is the high value of some purchased components (e.g. engines) and generally high percentage of material costs. Materials except of general consumables are individually ordered for each project.

4.7.2 History of Lean transformation of case study E

The company of case study E is the only company that has not embraced the 20KEYS workplace improvement program. Approached by a consultancy the company started together with the consultants to determine the goals of the initial Lean project (see Figure 55). A correspondent KPI system was established and a non-conformance report system was introduced. Unfortunately within the observation period of the researcher this system never became an integral part and has hardly been used. The 5S methodology was implemented in all departments and was to be found by staff as useful.

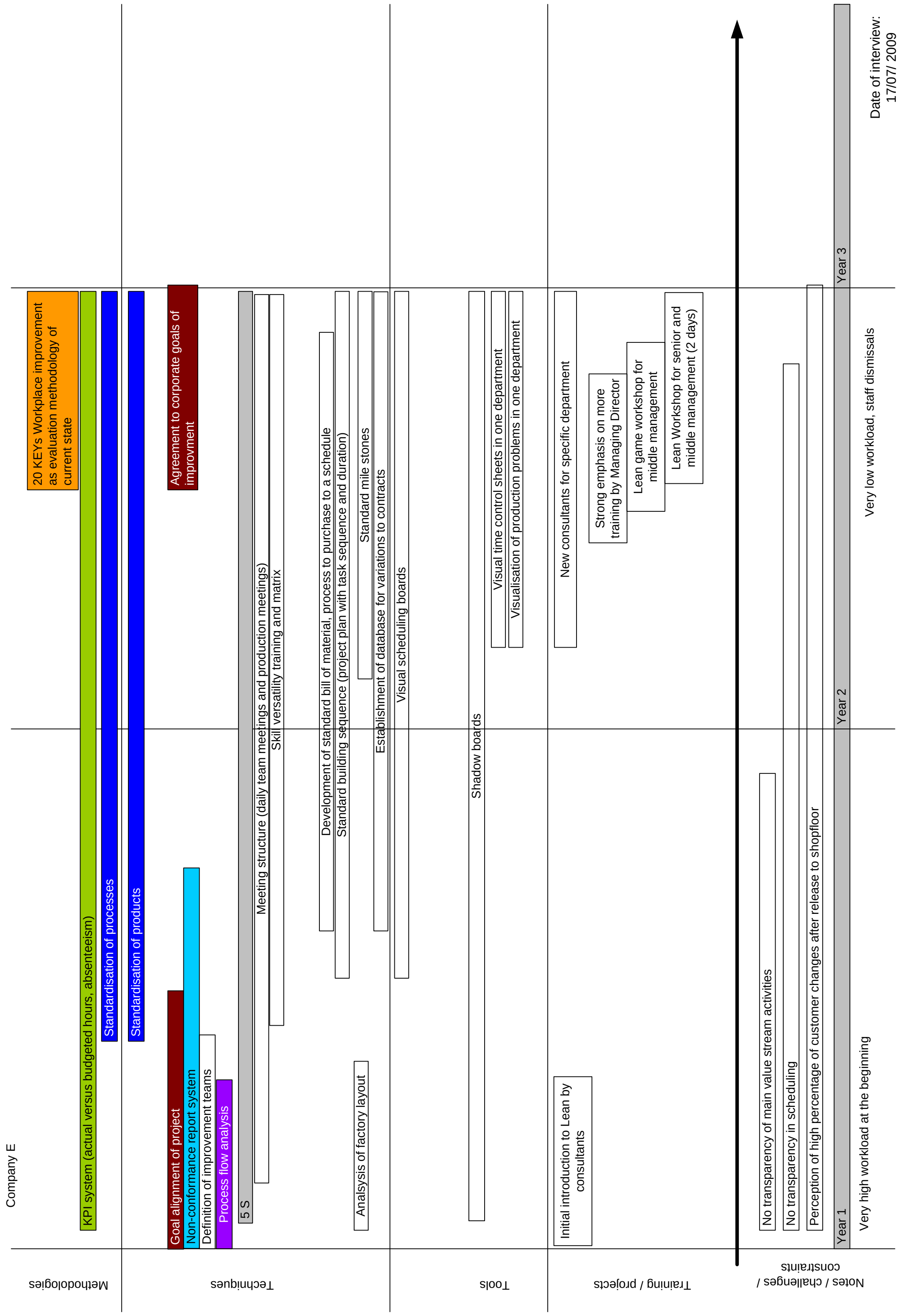

Figure 55: Lean transformation history of case study E

The most valuable gain in the early stage is seen by staff and management in the improvement of the communication structure. Team leaders meet daily in the morning with the team members to allocate the daily tasks and discuss problems. Afterwards there is a daily meeting of all team leaders led by the production manager. This meeting proved to be a very useful forum for synchronisation of the departments and to agree on the sequence and dates of subcomponents. Further the company acknowledged very early the need of standardisation of the product itself and of all manufacturing processes. These standardisation efforts include for example standardised building sequences and a derived template of a project schedule dependant on the size of the boat and the development of a standardised bill of material. The elaboration of the project template helped to understand the main project stages of the company. The next fundamental step supporting the synchronisation between all departments was the introduction of main milestones for each project. Those milestones are communicated to the correspondent responsible persons and are daily monitored by the production manager. Because of the high degree of complexity and customisation and the long lead time, the customer is often involved during manufacturing as there are regular changes of design details requested. A database was introduced for each project to keep track of all variations to contract which might not only have an impact on the budget but also on the schedules of other boats.

The involvement of the consultants was limited to the initial six months. In an interview with the managing director, it was pointed out that many Lean activities started immediately to fade away after the consultants had left. In the second year management decided to revitalise the Lean transformation. All management members and selected team leaders were sent to Lean workshops. Besides another consultancy specialised on Lean was approached. The consultants initially focused their efforts on the department that was identified as the constraining resource. Introduced methodologies mainly concentrate on the shop floor visualisation of work load and the comparison of budgeted and actual hours, the analysis of manufacturing problems, and improvement suggestions. It was noted by the consultants that the already existing meeting structure supported the implementation of all boards.

4.7.3 Performance development of case study E

The company has been one and a half years into their Lean transformation as the data collection for the development of their performance was conducted. Improvements could be measured in the area of people/organisation and leadership (see Figure 56). In all other areas no improvement could be confirmed. It needs to be noted that the company experienced in the second half of the observation period a strong slump in sales which also led to lay-offs. As the company tried to keep as many staff members as possible, the labour productivity dropped due to the decrease in revenue. Another difficulty of the monitoring process lies in the long lead time for one boat. As major milestones for each project were recently introduced, the actual improvement in lead time could not be measured yet. Although out of the current adherence to milestones management concluded that improvements during the progress of the projects can already be noticed.

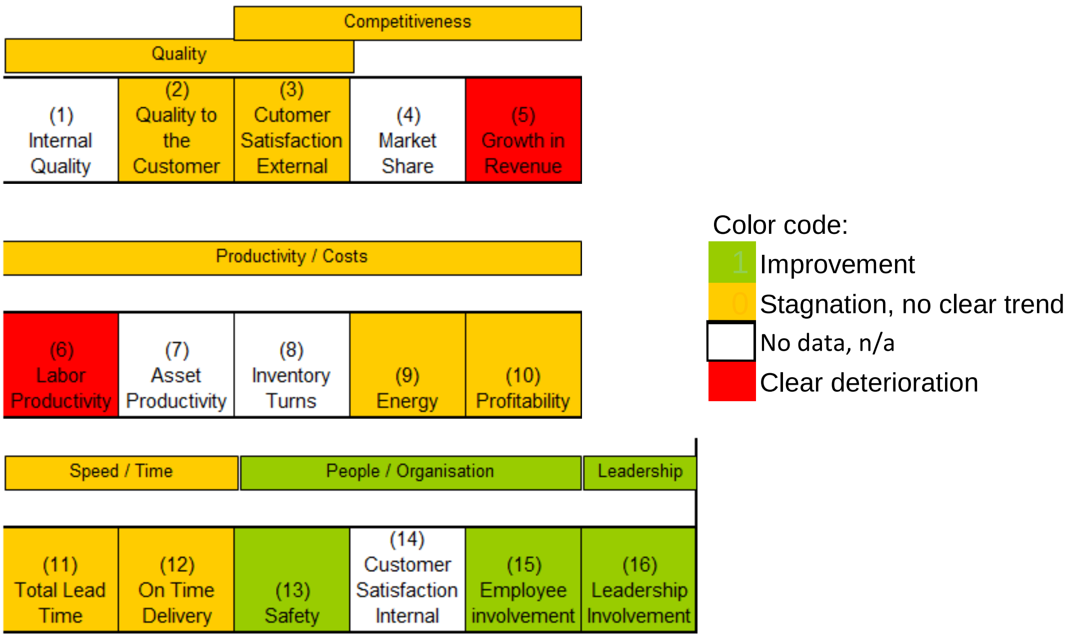

Figure 56: Development of performance of case study E

4.8 Comparative analysis of case studies

4.8.1 Leadership profile

As already described in chapter 4.1.1 the leadership profiles of the case studies are determined based on the GLOBE study's construct. As the literature review revealed, leadership can have an essential impact on the success of organisational transformations. Hence, the objective is to elaborate the relationship between the leadership profiles and their success in the Lean transformation. The success of the Lean transformation is measured by the KPIs (see 4.1.3) and their trends over the transformation period. Figure 57 illustrates the results with regards to the aggregated level 1. The results are sorted to the mean of all five case studies and the Likert scale was transferred to an offset scale from -3 to +3. Positive values imply that the characteristics describe the leadership of the case study company whereas negative values mean that staff did not associate the correspondent characteristics with their leadership.

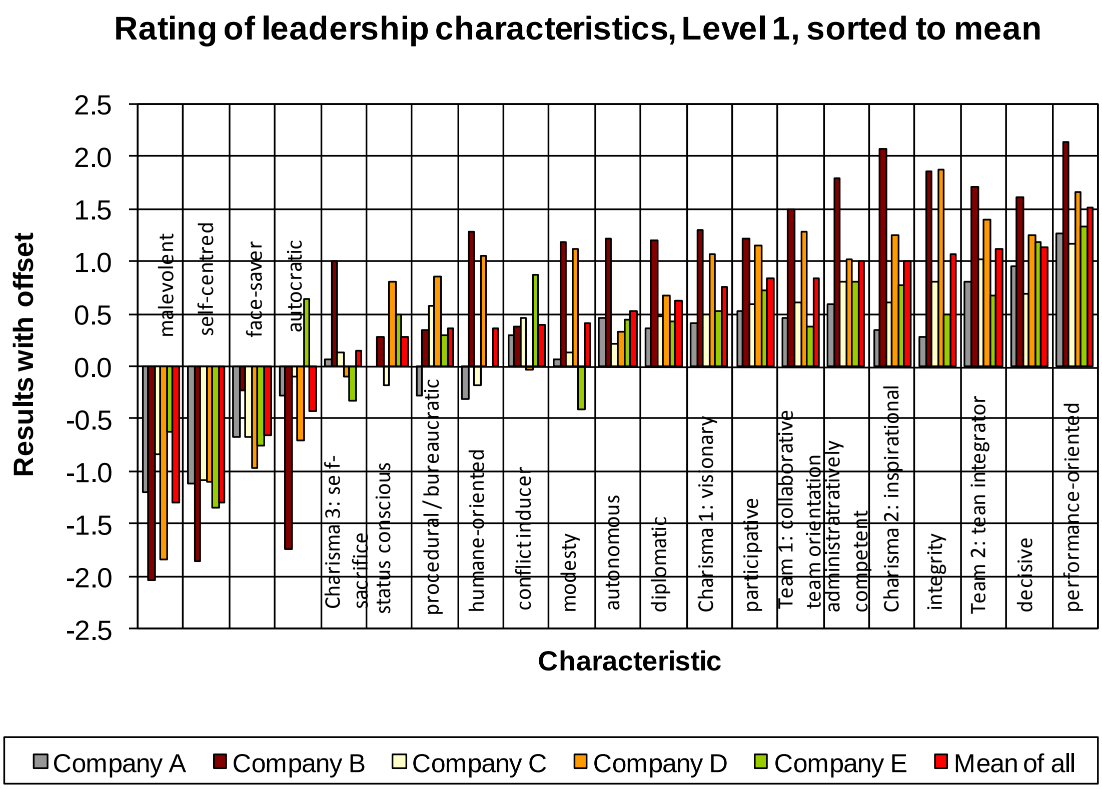

Figure 57: Results for leadership characteristics (Level 1)

Firstly the sample of leadership of the case studies confirms the tendency of New Zealanders to be performance-oriented. Further the leaders are perceived as 'decisive', 'team builder and integrator'. On the other side the sample is generally not associated with the characteristics 'autocratic', 'face-safer', 'self-centred' and 'malevolent'. A more detailed analysis of the leadership data can be found in Appendix F.

Looking at the level 2 in Figure 58, the characteristics of being team-oriented and charismatic/value-based achieve the highest mean. Being self-protective is the only criteria that achieves on average a negative value and is therefore the least associated with the sample's leadership. It is interesting that with regards to the characteristic 'human-oriented', the sample has generally two different leadership styles. Applying an agglomerative hierarchical method of clustering, the split in general two different leadership styles can be confirmed.

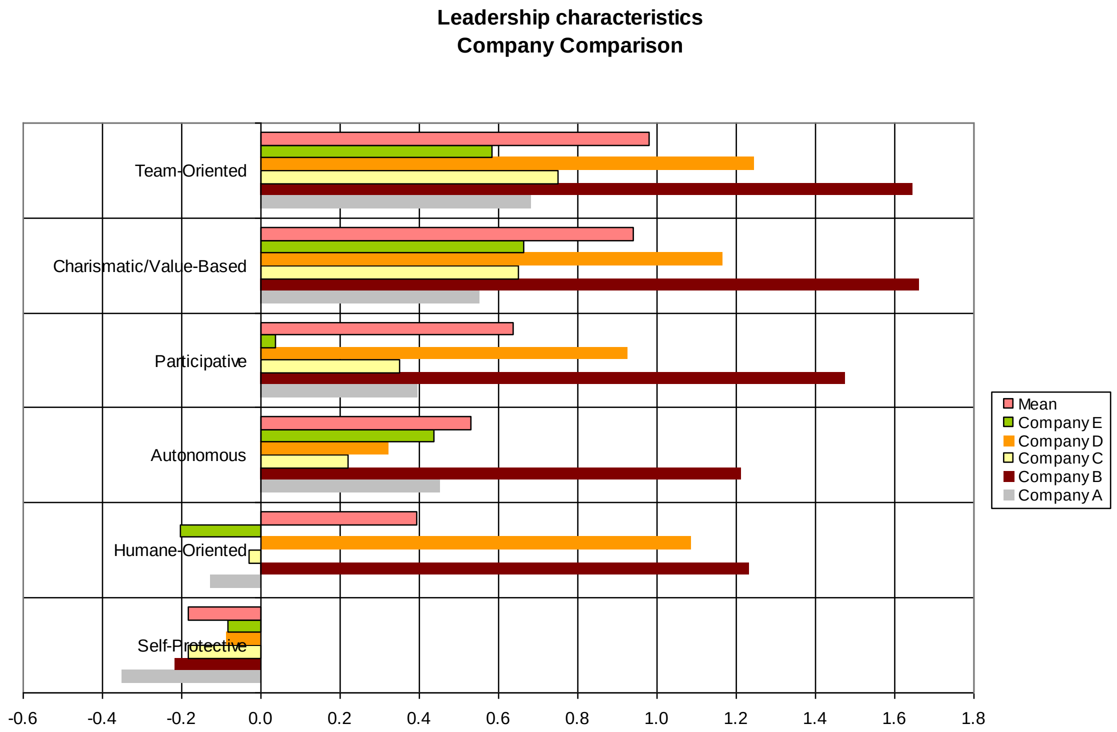

Figure 58: Results for leadership characteristics (Level 2)

The dendrogram in Figure 59 visualises the clusters that were calculated in Minitab. A dendrogram generally illustrates by a hierarchical tree diagram the clusters. It begins with all variables separately, each forming its own cluster. In the first step, the two variables closest (distance is selected as measure) together are joined. In the next step, either a third variable joins the first two, or two other variables join together into a different cluster. This process will continue until all clusters are joined into one. The cluster consisting of case study B and D have therefore the largest difference in distance to the cluster containing the case studies A, C and E.

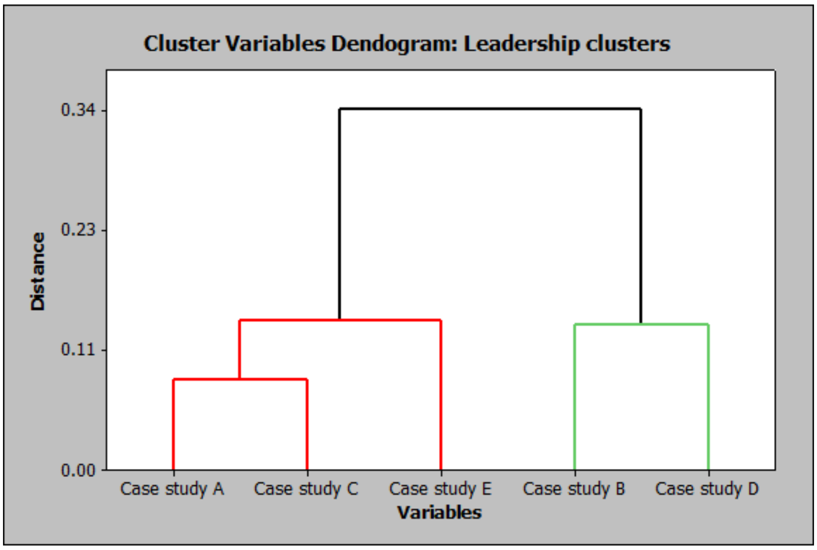

Figure 59: Cluster dendrogram: leadership characteristics

Figure 59 reveals that case study B and D build one group with similar leadership characteristics, the second group contains the case studies A, C, and E whereas E slightly varies from A and C. The case studies B and D are mainly differentiated by higher scores for the characteristics ‘team-oriented’, ‘charismatic/value based’ and ‘participative’ and by the significant difference in human orientation.

In the opinion of the author there are generally two ways of interpreting the data. Firstly, one might argue that all case study companies belong to a group of early adopters and of leaders within their industry, as they are the first being committed to the improvement program initiated by NZTE. This assumption can be supported by the relative low difference in the scores of the cluster analysis. In other words, the presented sample of companies might already consist of a certain type of leadership that encourages organisational change and the willingness to strive for manufacturing excellence. Hence, it could be argued, that leaders with similar characteristics shown in the sample are more likely to be open for organisational changes towards continuous improvement and advanced manufacturing paradigms.

Secondly, the two main clusters within the sample give the opportunity to analyse whether these slightly varying types of leadership profiles already show any statistical evidence for a higher or lower success rate of a Lean transformation. Although it needs to be stated that the small sample size requires a diligent interpretation of the results. In chapter 4.8.3 the characteristics of leadership are correlated with the trends of the KPIs in order to assess whether there are certain characteristics that might lead to a better performance.

4.8.2 Analysis of maturity level and Lean history

In the interviews with the case study partners, management was asked to evaluate their maturity level in specific Lean techniques and methodologies (see Appendix H for the questionnaire and further information about the analysis). Figure 60 compares the maturity level that was self-assessed by the representatives of the companies. It is conspicuous that the methodology Six Sigma is not implemented in any of the case studies. This was also noted by other NZ researchers who argue that Six Sigma requires - in order to be successfully applied - a higher and more advanced quality management maturity level (Grigg, 2008). Besides the author wants to point out that Six Sigma as a more statistically driven methodology requires a certain quality and quantity of data, which in smaller companies in a high variability context are hardly available or not collected. The application of Lean product development and its techniques is to be seen in an early maturity stage. Methodologies about process standardisation, visual controls (e.g. 5S) and the implementation of a KPI system are perceived to be implemented to the most mature and self-sustaining way. But with exception of case study C, the average of 2.4 for these three categories implies that most companies believe that they have not reached a sufficient self-sustaining state. Case study C as the case study with the lowest variability sees itself in most of the Lean methodologies at a daily sustainable level of usage.

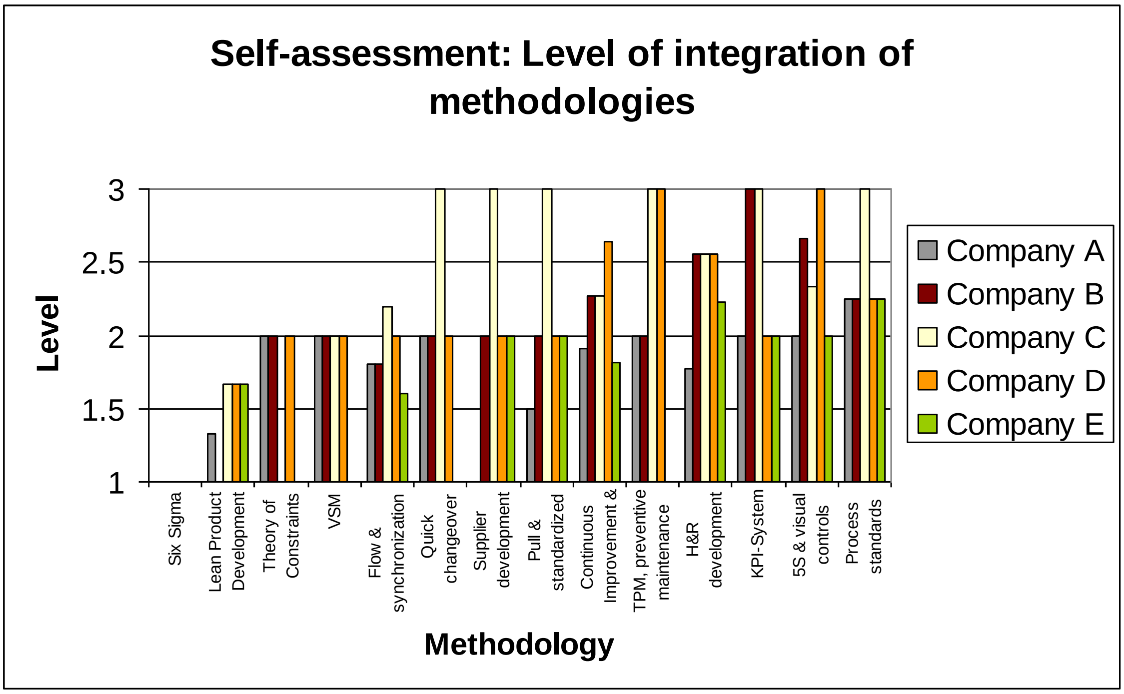

Figure 60: Self-assessment of maturity level of Lean methodologies [1: not implemented, 2: implementation pilot/in progress, 3: daily sustainable use]

Looking at the transformation history of the case studies Table 20 chronologically lists the methodologies and techniques according to the year it was started. All companies initially started their Lean transformation with the 5S technique. Preventative maintenance was introduced in the first year as well as a non-conformance reporting system, a Lean KPI system, the empowerment of staff through small group activities, visual scheduling boards and the development of an appropriate meeting structure. Also the technique of VSM is used in all case studies in early phases. Table 20 also illustrates that Lean activities with regards to the integration of suppliers are started in later stages. The colour code refers to the elements of the developed transformation framework in chapter 5 (Figure 64).

Table 20: Year of implementation of methodologies[10]

	Case A	Case B	Case C	Case D	Case E
5S	1	1	1	1	1
Preventative maintenance	1	1		1	
Non-conformance report system	1	1		1	1
One piece flow in endassembly			1		
Establishment of a Lean KPI system	2	1	1	1	1
Small group activities	1	1	2	1	1
Visual scheduling boards	2	1	1	1	1
Regular meeting structure	1	1	2		1
Value Stream Mapping	2	1	2	1	1
Process standardisation	1	1	2	2	1
Goal alignment	1	1		2	2
Improvement suggestion system	1	1	3	1	
Skill versatility training and matrix	2				1
Change of production layout	2	1		2	
Quick change over, SMED	2		2	2	
Coupling points	2	2		2	
Kanban		3	1		
Supplier integration and development		3	3		

A common theme confirmed by all case studies is the overload of information at the beginning of a Lean transformation. All companies mentioned that in the early stage the amount of information provided by the 20KEYS program was excessive and it was difficult without the right guidance of the consultant to prioritise their Lean activities. Hence, all companies reported that in the first year too many projects were started and it was advisable to reduce the number and to concentrate on the high impact projects to 'bundle' the resources. In Table 20 shows that the majority of methodologies were started within the first year.

4.8.3 Correlation analysis

In this chapter the development of the KPIs, the leadership characteristics and the maturity level of Lean methodologies (see Figure 60) of the five case studies are correlated. Further the degree of variability is taken into account by

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[10] Color code refers to Lean transformation framework in Figure 64

summing up the values for demand and task variability resulting in a theoretical value between 2 and 16 (see Appendix K).

For the trend development of the KPIs the data according to chapter 4.1.3 are used. A matrix is created by stating the value '1' for a positive trend of the KPI, the value '0' for no trend or no data, and the value '-1' for a negative trend over the observation period (see Appendix J). For each case study, the values are added resulting in theoretical values between -16 and 16 due to 16 performance dimensions.

Table 21 shows the correlation coefficients[11] for the performance development (in the table the term 'performance' is used), the variability and the leadership characteristics in the highest aggregation level. There is a high negative correlation between variability and performance development which means the higher the degree of variability, the lower was the overall improvement in performance. Hence, it seems that the companies with a higher degree of variability achieved lower improvements in performance. With regards to the leadership characteristics, the coefficients for performance are all small. The highest value is r=0.609 for the correlation of participative leadership to performance.

Table 21: Correlation[12] of performance, variability and leadership characteristics (Level 2)

	Performance	Variability	Charismatic/Value-Based	Team-Oriented	Self-Protective	Participative	Humane-Oriented	Autonomous
Performance		**-0.88**	0.49	0.53	-0.27	0.61	0.41	0.46
Variability			-0.18	-0.20	0.07	-0.26	-0.17	-0.01
Charismatic/Value-Based				**0.99**	0.31	**0.95**	**0.93**	0.78
Team-Oriented					0.19	**0.99**	**0.96**	0.76
Self-Protective						0.04	0.33	-0.16
Participative							**0.93**	0.77
Humane-Oriented								0.55
Autonomous								

Table 22 lists the correlation coefficients for performance development and variability in comparison with the self-assessed Lean maturity level of the case studies. There is a tendency that those companies with a higher maturity level in the technique of quick changeover and in their development of a Lean KPI

11 Pearson product moment correlation coefficient

12 Pearson product moment correlation coefficient

system achieved better improvements in performance. On the other hand, companies with a higher degree of variability seem to rate themselves with a lower maturity level. Especially for the technique quick changeover and the implementation of pull, a KPI-system and process standards, a negative correlation to the dimension variability can be demonstrated. Companies with a high degree of variability and hence of high customisation might struggle more to introduce measures to reduce set up times as every set up can be unique. With regards to pull and standardised inventory buffers, the more customised products are, the more difficult it is to have inventory buffers. The variability is mainly absorbed by the time buffer or by carrying a larger amount of capacity buffer in the manufacturing system. With regards to process standards, it seems to be reasonable that with increasing level of variability and customisation, it can be more difficult to find commonalities in the processes and value streams.

Table 22: Correlation of performance and variability with maturity level of Lean methodologies[13]

	performance	variability
Lean Product Development	-0.56	0.09
Theory of Constraints	0.20	0.18
5S & visual controls	0.34	-0.28
Supplier development	0.39	-0.72
Continuous Improvement & Problem solving	0.40	-0.45
H&R development	0.45	-0.57
Pull & standardized inventory b	0.45	**-0.80**
Process standards	0.49	**-0.84**
TPM, preventive maintenance	0.53	-0.69
Flow & synchronization	0.58	-0.83
VSM	0.74	-0.62
Quick changeover (SMED)	**0.78**	**-0.92**
KPI-System	**0.91**	**-0.88**
Six Sigma	**	**

Table 23 shows the effects of leadership on performance. Therefore the case studies are joined into two clusters (identified in Figure 59) and correspondently the means for the leadership characteristics and the results for performance development and the degree of variability are calculated. With regards to the leadership dimension there is a significant difference in the dimensions 'human-oriented', 'participative', 'charismatic/value-based' and 'team-oriented'. The two companies B and D achieved higher improvements in their KPIs while the degree of variability is very similar. This may give an indication that companies

[13] Six Sigma was not used in any case study company.

with a more human-oriented, participative, charismatic and team-oriented leadership profile will achieve better results in their Lean transformation. Table 21 would even provide further opportunity for interpretation as the single correlation coefficients for the leadership characteristics are low. This implies that not one single characteristic is decisive rather a stronger profile through a combination of several characteristics is necessary in order to have a noticeably positive effect on a Lean transformation. As the sample size is five, this is a vague speculation and certainly requires further data and analysis.

Table 23: Comparison of leadership clusters

	Self-Protective	**Humane-Oriented**	Autonomous	**Participative**	**Charismatic/Value-Based**	**Team-Oriented**	**Performance**	Variability
Cluster ACE	-0.2	**-0.1**	0.4	**0.3**	**0.6**	**0.7**	**7.0**	12
Cluster BD	-0.2	**1.2**	0.8	**1.2**	**1.4**	**1.4**	**9.5**	11.7

4.8.4 Further observations

This chapter intends to list further more general observations and conclusions the author made in meetings of the Aichi network, the interaction with the action research companies, during company visits and in interviews or discussions with managers and shop floor staff. These observations are certainly taken out of a more subjective and individual perspective of the researcher and hence also need to be interpreted in this context. Nevertheless for some of the observations the author tries to close the loop to already mentioned cultural aspects revealed in the literature review in order to confirm the observation and find additional evidence.

- Hesitation to standardise as a potential barrier for process development.
  In several continuous improvement activities an inertness and passivity towards standardisation was perceived. The short term orientation, the low score for uncertainty avoidance and the high score for individualism for NZ support this observation. On the one hand standards are supposed to be established to ‘do it the next time’ as good as today which requires a certain attitude for long term alignment. Further New

Zealanders tend to feel less uncomfortable in uncertain ergo not standardised situations. The high score for individualism supports a culture where every worker is encouraged to optimise his own workplace environment which might lead to locally optimised solutions.

- Low problem awareness enforced by a strong attitude to hesitate with / avoid criticism.

  The No.8 wire mentality is generally associated with Kiwi ingenuity and a high degree of innovativeness. But it could be also interpreted in a way that there is a tendency to rather fix problems than solve them. This tendency in combination with the high scores in individualism and masculinity might create in the opinion of the author an unfavourable environment for systematic problem solving by the reluctance towards criticism. Commonly used sayings in the context of dealing with problems are 'she'll be alright' or 'no worries'. These support the observation of a tendency towards carelessness or light heartedness towards a more systematic approach of problem solving.
- Hesitation to take the leadership initiative to lead change to the better.

  The phenomenon 'tall-poppy syndrome' and the low score in power distance are in favour of the researcher's observation that staff avoided in several occasions to take strong and charismatic leadership initiative in order to drive improvement activities.
- Owner's (manager's) behaviour and capabilities have an essential influence on the growth potential of the SME in terms of finances, and the development of individual and organisational capabilities.
- In all case study companies, it could be observed that the owner's involvement, character and behaviour have a strong influence on the organisational culture. The researcher gained the strong impression that not only commitment but also active involvement of the owner energises the Lean transformation and hence is essential for its success.
- Almost everyone is part of the value stream. The owner and staff have several functions with overlapping responsibilities. The overlap of responsibilities might lead to problems in coordination and to a loss of momentum.
- Changes are done easily and informally and happen during the whole design and manufacturing process. The high dynamic with regards to the

progression of a project is perceived as the ‘way it is’, which might impedes the initial momentum for improvement activities especially in the area of standardisation.

- Companies in a project environment (high variability) struggled with the traditional concept of Value Stream Mapping and an adaptation is necessary.
- The companies seem to struggle with the allocation of resources for improvement programs. As most of the employees are directly involved in the value stream, it is difficult to release out of the management’s perspective a certain percentage of staff time to improvement projects.
- The uncertainty of the market is strongly influencing the improvement initiatives. In several of the case studies, improvement initiatives were negatively influenced either by a too high workload or by a too low turnover resulting in layoffs.
- The role of an external consultant who brings methodological expertise in advanced manufacturing methodologies was perceived as essential. This is also confirmed in a study of Wilson (M. Wilson et al., 2008). The consultant takes the function of a knowledge provider, teacher and an additional resource for administrative tasks that are necessary in improvement projects. Although in the opinion of the author and on the observations made in the case studies, there is the danger that after a consultant leaves the company, the improvement initiative ceases.

5 Conceptual Lean transformation framework

5.1 Impediments of a Lean transformation

This chapter gives some insights into impediments of a Lean transformation. For this purpose a questionnaire[14] was developed to explore Lean obstacles that are perceived in current NZ Lean transformations. Further the respondents are asked to execute a 5 Why analysis starting with their obstacle they rated as the biggest. The 5 Why analysis itself is methodology applied in Toyota to find root causes to manufacturing problems. In the context of obstacles to a Lean transformation, the 5 Why analysis is used to systematically find underlying causes by starting with the most obvious obstacle.

The questionnaire was to be completed online and anonymously. The target group for the questionnaire are NZ SMEs that are in an early stage of a Lean transformation. The link to the questionnaire was sent to 32 recipients of 14 affiliations (on average 2 recipients per affiliation) per email. All companies were or are involved in the Aichi project. The results are based on eight individual answers (response rate of 25%) of six affiliations (coverage of 42.9%) which all employ less than 100 staff members.

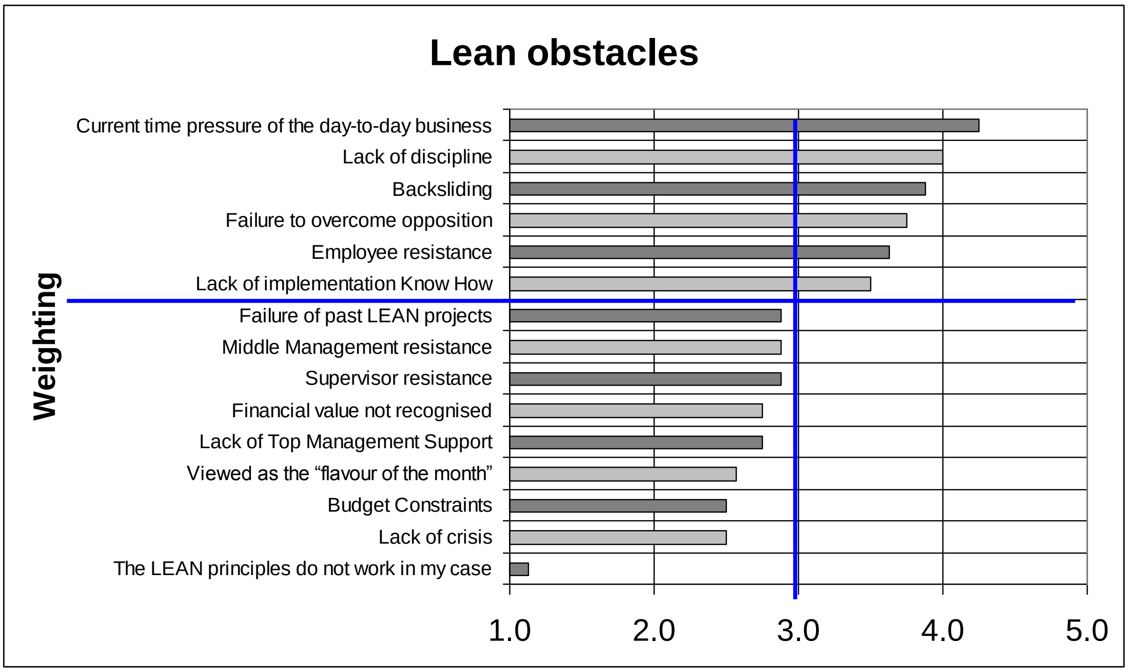

Figure 61: Lean obstacles (results of survey of Aichi project, September 2007) [1 := I totally disagree, 3 := neutral, 5 := I totally agree]

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[14] See Appendix C for the full questionnaire.

The question resulting into the diagram of Figure 61 is oriented on the survey of the Lean Enterprise Institute in order to compare the results (Lean Enterprise Institute, 2007). The respondents were asked to rate on a Likert scale of one to five a list of pre-determined Lean obstacles.
It is important to note that all participating companies have been involved in Lean activities for not longer than two years. Hence it can be argued that the sample represents companies in earlier stages of a transformation and therefore might give specific conclusion on their perception and needs in these stages. The outcome needs to be interpreted in this way, that the results of the ranking of the obstacles cannot be generalised and are most likely not identical with a different sample population. The outcome gives specific insights into the perception of obstacles of NZ SMEs that are implementing Lean methodologies.

Looking at the percentage of responses that rated a particular item as the biggest obstacle (rating it with 5), 50% of the respondents rated the current pressure of day-to-day business as the highest obstacle. This is in alignment with the illustration of means in Figure 61. The second and third places are the lack of discipline and employee resistance with each 38% evaluating it as the highest obstacle. As the number of respondents is low, the researcher decided to use the mean of all values as a better indicator for its relevance than the percentage of respondents that rate the item as the biggest obstacle. The blue vertical line in Figure 61 represents the neutral value. Every value above the blue line is perceived as an obstacle for a Lean transformation. Held up by the time pressure of the day-to-day business is perceived as the main obstacle by the respondents. This can be explained by the lack of resources that SMEs usually experience. The second and third biggest impediment seems to be closely connected to the first one. If no resources are allocated to improvement activities, the involved employees might feel overburdened and improvement projects loose their priority in order to stay ahead of the day-to-day business. The next two obstacles address resistance. Also the lack of implementation know how is perceived as an impediment. This could be also found by a study of Wilson as well (M. Wilson et al., 2008). Further, out of the perspective of consultants three major barriers in the Lean adoption are revealed by this study: Firstly, the lack of knowledge and experience with Lean; secondly, the lack of internal resources to fund an external consultant, and finally, the lack of skills amongst the work force at managerial and operational levels.

In order to compare the national results Figure 62 shows the results of a survey conducted by the Lean Enterprise Institute (LEI) with the same question. This online survey was sent via an e-letter to all subscribers of LEI. It is based on 2,444 respondents. Unfortunately there is no data available about company size and national culture. As LEI is an internationally acknowledged institute, it can be assumed that the sample is multi-national and also regarding the company size it is most likely not homogeneous. However the response pattern slightly varies to the sample of NZ SMEs. The resistance of middle management is perceived as the biggest obstacles which may be a hint to larger companies in the sample. The resistance of employees and supervisors take high rankings as well.

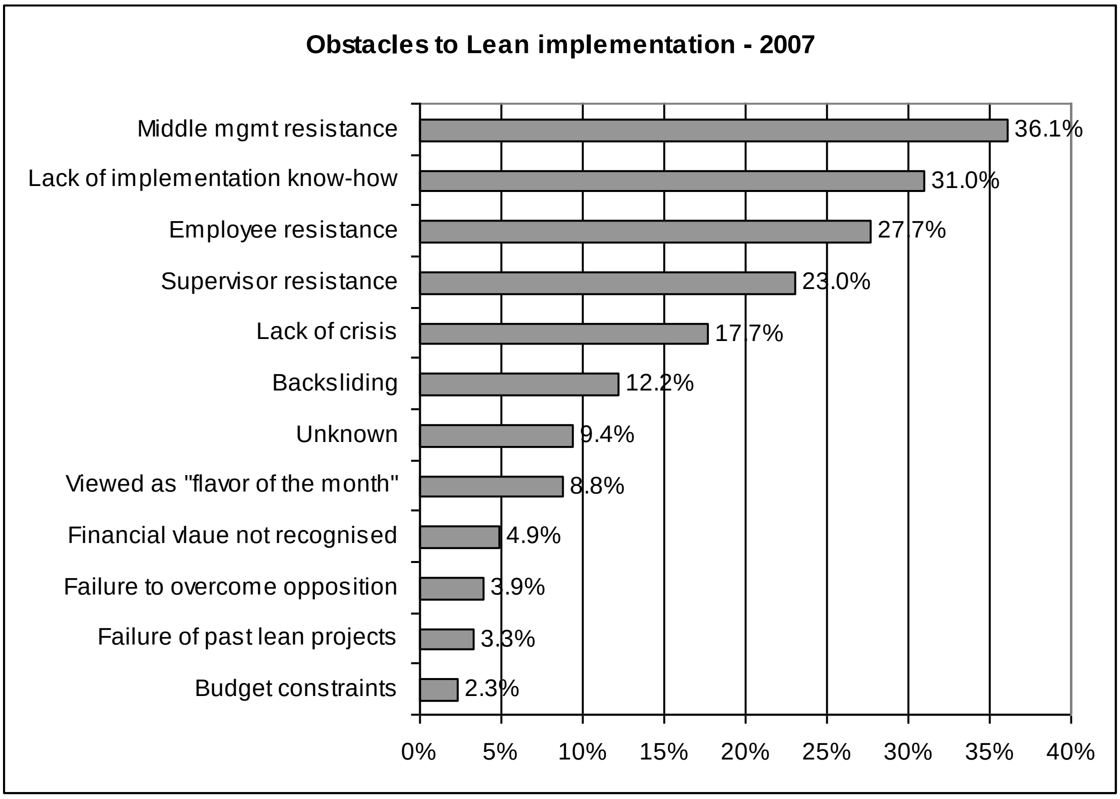

Figure 62: Obstacles of Lean implementation (Lean Enterprise Institute, 2007)

In the second part of the questionnaire within this research the respondents were asked to conduct a 5 Why analysis starting with the obstacle they rated the biggest. The assumption behind this methodology was that the most obvious obstacle perceived by the respondents is not necessarily the real root cause for a failed or slowed down transformation. Hence the respondents were supposed to develop a causal chain trying to explore their underlying obstacles.

The template allowed to stop the 5 Why analysis after the third 'why'. Table 24 shows the start and end points of the 5 Why analyses. The whole causal chain can be found in Appendix D.

One main theme that can be identified at the end of the causal chains is the lack of knowledge and understanding of Lean. This is closely related to the mentioned lack of training. Further, the lack of a clear structure of the change process and a lack of defined goals were identified by two respondents. This advocates the development of a Lean transformation framework as it contributes to a better understanding of Lean by providing a structure of necessary elements.

Table 24: Start and endpoints of the 5Why analysis

Start of argumentation chains	End of argumentation chains
– Lack of knowledge of staff about the benefits for the whole company – Lack of senior leadership commitment	– Lack of training – Lack of holistic understanding of Lean principles
– Employee resistance/passivity	– Lack of knowledge at management level – Management fail to transfer knowledge
– Backsliding, no discipline	– No structure and goals
– Not enough pressure by management	– Wrong persons as change agents
– Lack of systematic planning	– Eagerness to get the end result

Another important inherent impediment found in literature within the context of change is the lack of acknowledgement of the influence of omitted activities (Ackoff, Year unknown). Ackoff argues that this so-called error of omission occurs when an individual or organisation fails to do something it should have done. This aspect is strongly dependant on the attitude and commitment towards open reflection (hansei) by the leaders. Besides the impact of errors of omission is difficult to measure and to evaluate and therefore the capability of dealing with them is generally not considered as an essential criterion for the selection of appropriate change leaders. The actual impediment is created when it is easy for management not to start initiatives and improvement activities which would have clearly brought benefits to the organisation. In traditional rewarding structures managers are not held to account for errors of omission. In regular reflective meetings of management reviewing recently taken decisions and activities, this impediment could be weakened. These reviews have therefore the function of feedback loops.

In summary there can be drawn the following conclusions from the results of the questionnaire: Firstly, the time pressure of the day-to-day business is to be addressed. For example the owner(s) have to provide enough resources for any improvement activities and encourage staff to invest more time in those initiatives. Secondly, the lack of understanding and knowledge about Lean is another essential barrier. Commitment for training and the involvement of experienced Lean practitioners (e.g. consultants or new staff members with correspondent experience) need to be brought into the organisation. Thirdly, a clear structure of the transformation process including the formulation of strategies and objectives should be developed in early stages. It is necessary to have mechanisms in place to regularly review this developed roadmap.

5.2 Critical success factors perceived by the case study companies

The previous chapter discussed the obstacles of a Lean transformation. This chapter explores the question of what are critical elements for implementing Lean principles and methodologies. As part of the semi- guided interviews the case study participants rated a list of critical factors according to their relevance. Figure 63 shows the result of the evaluation of critical success factors mentioned in literature. During an interview with managing staff of the case study companies, they were asked to rate the statements according to their importance and relevance. To have an experienced change agent was perceived as very essential. Further to develop internal Lean leaders and to involve the stakeholders in the transformational process received high ratings regarding its relevance. On the other hand, sending staff to formal Lean education programmes is rated as less important. This might reflect the New Zealand's tendency of hands-on and 'do it yourself' mentality. Also the need to adapt the incentive system is perceived as less important.

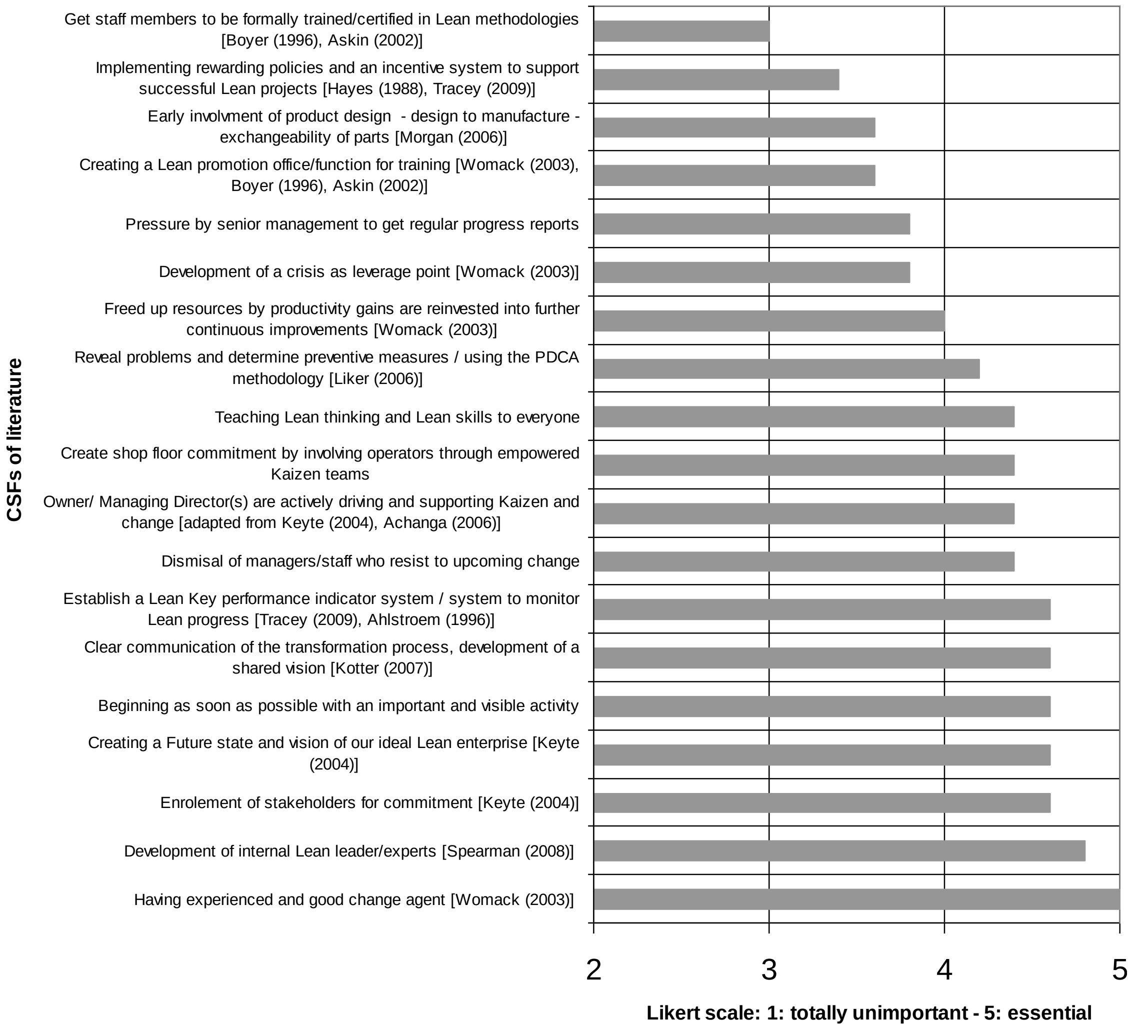

Figure 63: Evaluation of CSFs by the cases studies [values represent the mean of all five case studies]

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Based on the observations and discussions with management and shop floor members of the case studies it became obvious that in order to address the questions ‘what to implement?’ and ‘how to implement?’, at least two perspectives are advisable: A more high level perspective creating a big picture for the transformation and giving guidelines for the owners and management and a more operational and technique-oriented perspective to provide support on the shop floor level. Hence the framework presented in chapter 5.3 provides the high level perspective in order to achieve a simple structure reduced to the essentials of the current manufacturing paradigm. This high level perspective more likely addresses the questions ‘what is necessary…’ and ‘what are the leverage points for the transformation’. In order to provide more guidance on the shop floor level, correspondent techniques found in literature or used in the case study companies are allocated to the main elements of the framework. A correspondent high level perspective addressing the question ‘how to implement’ is elaborated in chapter 5.4. As the case studies showed, the degree of variability can have an influence on the applicability and efficacy of some Lean techniques and consequently more or less influence on the performance development of the companies. This leads to the conclusion that on a more detailed level a pre-defined implementation process is in the opinion of the researcher not advisable, as the degree of variability requires a customisation of the approach. Examples are the Kanban system of case study C which initially did not fulfil the expectations without improving the forecast of demand and levelling of the workload and the varying relevance of the techniques SMED and preventative maintenance. Hence, the focus should rather be on understanding and reducing the sources for variability and on identifying and exploiting the constraining resources of the manufacturing system. But as shown in Table 20, there are tendencies that certain methodologies and techniques were implemented earlier than others and may serve as guidelines.

5.3 Lean transformation framework

5.3.1 Introduction and high-level view

Based on the literature review about manufacturing theory, the analysis of Lean principles and by consideration of New Zealand’s cultural and of organisational characteristics of SMEs, the Lean transformation framework shown in Figure 64 was developed. In order to keep it out of the perspective of SMEs manageable and straightforward, a clear and simple visualisation of the essential elements was created.

Generally the framework can be regarded from two slightly varying perspectives. Firstly a more theoretical view categorising the elements according to its contribution to the reduction of variability sharpens the viewer’s attention to the leverage points regarding the variability of a manufacturing system (see Appendix L). The element of flow is to be seen as one of the central elements of the framework which is tightly connected to the element of synchronisation of resources. The undisrupted flow of material and information without any non-value adding activities has to be regarded as the ultimate desired state on the operational level of a manufacturing system. Hence the ultimate goal of a Lean Manufacturing system is to reduce its variability to the minimal level in order to achieve the minimum of buffer requirements by meeting the customer's requirements and perception of added value.

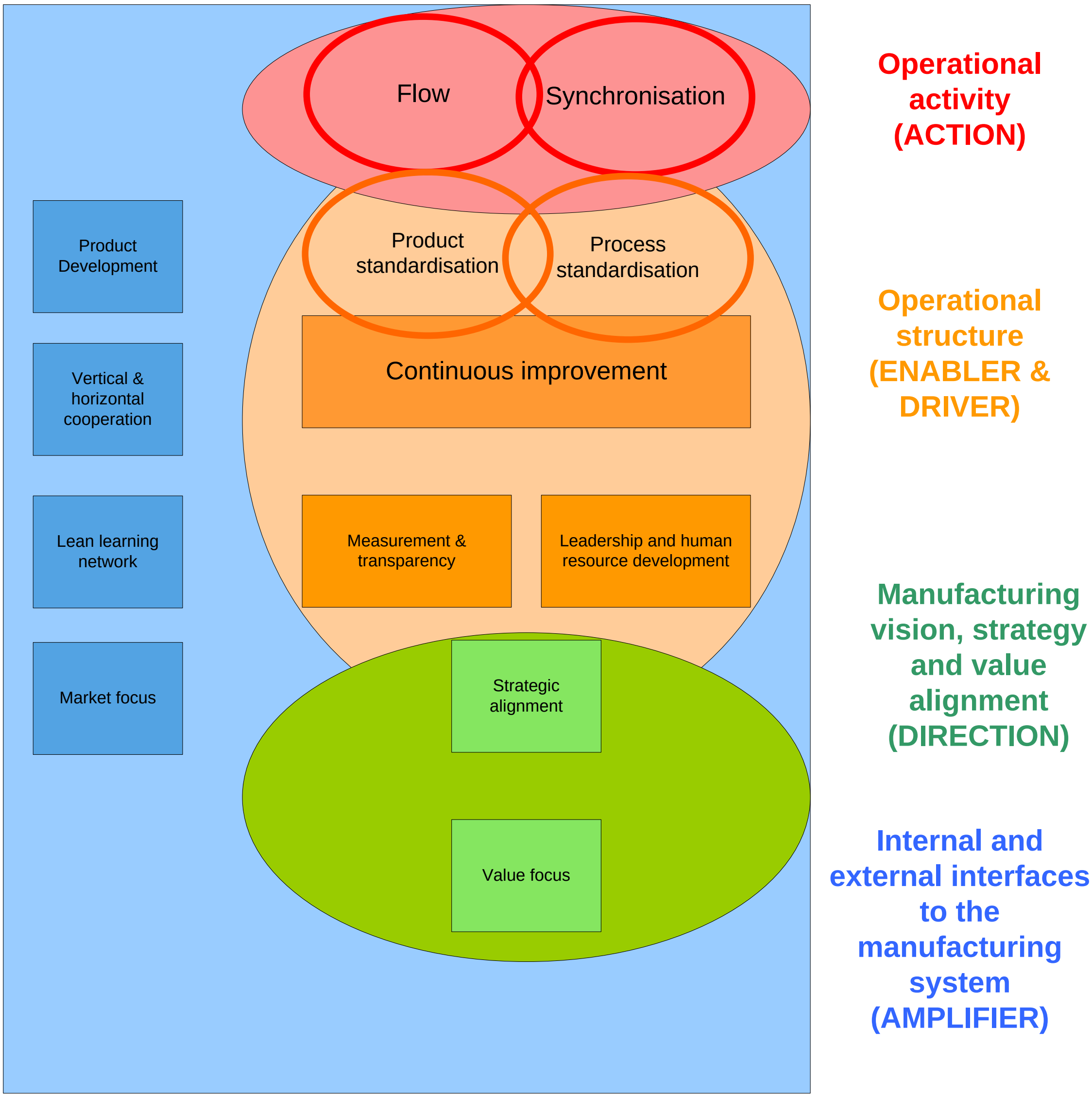

Figure 64: Lean transformation framework

The second perspective which is shown in Figure 64 is more practical and divides the framework into four main areas. It emerged out of the interchange with the action research companies and hence is favoured in the context of usability in SMEs:

- Manufacturing vision, strategy and value alignment (DIRECTION): one of the essentials of Lean principles is the alignment of all activities to the creation of value for the customer. This perceived value by the customer should be the central element for the long term alignment of the company. Driven by the owner and management the corporate vision and strategies need to be developed based on the understanding what the real value is, the company and its manufacturing system create or contribute to its customers.

- Operational activity (ACTION): this area contains all activities that are directly adding value within the manufacturing system. The main elements and at the same time objectives are ‘flow’ of material and information and ‘synchronisation’ of resources.
- Operational structure (ENABLER & DRIVER): this area contains all supporting infra-structure that is necessary to achieve flow and synchronisation. The central element in this area is continuous improvement in combination with product and process standardisation. A sustainable culture, where continuous improvement can flourish, requires long term commitment and involvement by the owner(s) and leadership and an emphasis on ongoing training of staff. Further essential and integral functions of an enabling operational structure are measurement and transparency. It needs to be made sure that targeted and current state and progress of work can be seen at any time by any employee. Measurement stands in this context for the adequate way of capturing and intensifying manufacturing and performance data whereas transparency emphasises the availability of the information at the right time and place in the right form. The endeavour of a simple visualisation of material and information flow is generally an essential pillar for the establishment of a transparent and meaningful measurement. In summary, the operational structure should be mainly developed by team leader and shop floor staff. The responsibility of the owner and management lies in giving the right incentives through the vision and manufacturing strategies and in fostering empowerment of staff by providing sufficient authority and resources.

  The first AR cycle in case company A mainly focussed on the elements ACTION and ENABLER & DRIVER.
- Internal and external interfaces to the manufacturing system (AMPLIFIER): The second AR cycle in case study A shifted its focus on elements outside of the immediate manufacturing system. Determining out of a clear value focus the potential markets narrows down all activities with regards to customers, suppliers and product development.

If it is possible for a company to reduce uncertainty and variability on this high level by concentrating on specific markets or even niche markets, this can already have an amplifying effect on all standardisation and improvement activities within the manufacturing system. Additionally out of the perspective of a SME, to collaborate not only with suppliers but also with other companies in a Lean learning network has proven to be a very valuable additional source for exchange of knowledge and experience. This insight could be gained through the action research case studies, as it became several times obvious that the improvement activities and their success often relied on external factors like the customer's involvement and the sales variability.

It is necessary to see this framework with its four main dimensions as a systemic model. Hence it is difficult to look at the individual elements independently which makes it difficult to find a general answer for the questions where to start and which elements initially to concentrate on. Nevertheless in the action research case studies it was found very useful to apply the fundamental principles of TOC. TOC can be applied as a focusing mechanism for every level of the framework to find the correspondent constraining factors or out of a systemic perspective to identify the leverage points. Concentrating the resources on the constraints can give SMEs a pragmatic guide for which techniques are to be used. Although it needs to be stated that other TOC methodologies like DBR did not find a sustainable application in the case studies. Additionally there can be found general trends in which sequence techniques are implemented. This is presented and discussed in chapter 5.4.

In the following chapters the elements of the framework and correspondent techniques are explained in detail.

5.3.2 DIRECTION: Value focus and strategic alignment

Demeter et al. statistically showed that Lean management in itself is a necessary but not sufficient condition in order to guarantee business success (Demeter, Losonci, & Matyusz, 2009). They concluded that the degree of using Lean methodologies and techniques correlates with operational performance, but there is no clear correlation with the business success. Further they identified as factors outside the operations system: market dynamics (Lean companies in more dynamically growing markets have a better business performance), the focus on product attributes rather than on service quality, the use of equipment overcapacity and a higher level of temporary workers, and the importance of supplier delivery performance. This implies the importance of a mid- to long-term alignment of all business activities by an adequate development of a business vision and strategies going beyond the manufacturing system itself. Ates emphasises in this context the importance for SMEs to strategically focus rather than to concentrate on short-term financial performance only (Ates & Bititci, 2009). Referring to the Lean principles stated by Womack, the central element should be the determination of value. Value for the ultimate customer is created if specific needs are met. By meeting these needs of the customer, value is created by the producer (J.P. Womack & Jones, 2003). The tendency to low uncertainty avoidance and low long-term orientation of New Zealanders might be a natural impediment to a more strategic focus of businesses.

Commonly cited dimensions of value for the customer are quality, timeliness, price, flexibility and emotion. Owners and management of a business should illuminate which dimensions of value are appreciated by their customers and correspondently the business goals need to be aligned. A common methodology for strategic alignment developed under the TPS is 'hoshin kanri' (policy deployment). It stands for a process of cascading objectives from the top of the company down to the work group level. These objectives are most effective when defined in a measurable and concrete way. Generally, goals are defined at the executive level and then each level in turn develops measurable objectives in order to support the higher corporate goals (J. K. Liker, 2003).

In the interaction with the case study companies the technique of causal loop diagrams proved to be valuable. Sketching all elements and its causal connections that might influence strategic decisions led to a better understanding and facilitated valuable discussions within the management team.

5.3.3 ENABLER & DRIVER: Leadership and human resource development

The commitment and involvement of leaders and the organisational culture are influential factors for a Lean transformation. In a SME, the literature review revealed that the role of leadership and also the development of the organisational culture are greatly coined by the owners. Hence it is important that within a Lean transformation the owners and managers redefine their leadership role. In the case study A it was observed that a clear definition and separation of roles and responsibilities not only of staff but also of management and owners is necessary to avoid conflicts of interest and confusion regarding daily decisions. It needs to be noted that Japanese job classification of manufacturing companies tends to be much simpler and broader in comparison with American firms (M. Kenney & Florida, 1993). This broader description of job responsibilities is assumed to promote the development of kaizen (Hayashi, 1994).

Besides, aligned with the vision and strategies of the business, a long-term understanding of human resource development and correspondent strategies need to be developed. Cross training of staff allows more flexibility and the ability to better level the workload (called shojinka in Japanese). The reward system is to be designed to enable continuous improvement. In the opinion of the author, criteria for rewards should be defined with a more holistic and systemic emphasis fostering contributions for the company as a whole rather than encouraging local departmental improvements. The criteria for recruitment of new staff should be aligned with the need of cross training and the attitude of continuous improvement. For example with regards to leadership positions, Mann lists the following eight leadership behaviours that are in favour with a Lean culture (Mann, 1995):

1. Passion for Lean
2. Lean Thinking
3. Tension between applied and technical details
4. Effective relationships with support groups
5. Project management orientation
6. Disciplined adherence to process accountability
7. Balance between production and management systems
8. Ownership

In summary, based on the observations in the case studies and the literature review, human resource development needs to focus on leadership, on the development of the owners (their knowledge about Lean and about change), on cross-functional training and on long term relations to core staff (see Figure 65).

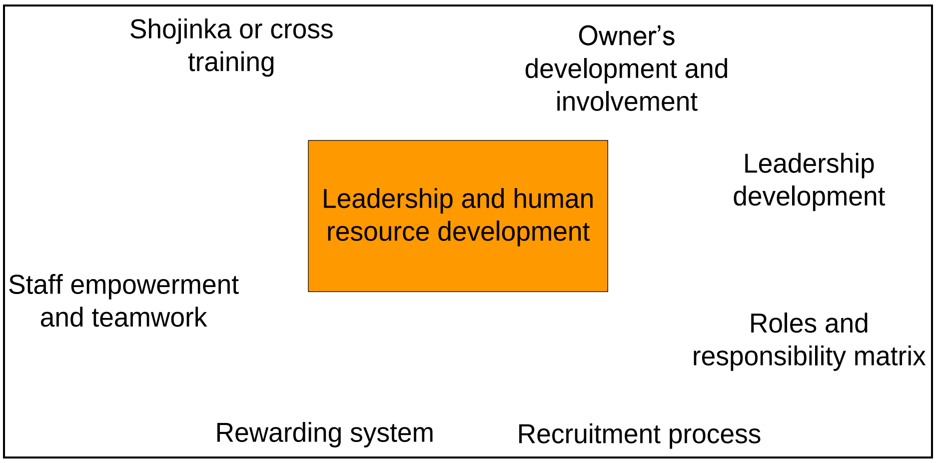

Figure 65: Dimensions and elements of leadership and human resource development

With regards to the question when training has to start for a Lean transformation, the case studies generally showed that training in Lean principles and techniques is necessary on all levels in very early stages. Routines of regular training of leadership and staff should be developed and implemented. In this context Von Axelson who developed an implementation program for a Swedish network of SMEs concluded that the leadership and continuous improvement workshops could be conducted very early in the program (von Axelson, 2009).

5.3.4 ENABLER & DRIVER: Continuous improvement

In this thesis the term continuous improvement is widely a synonym for the Japanese word 'kaizen' which has been viewed as a key element in Japanese management and has been presented as one of the sources of the competitiveness of Japanese manufacturers. Imai defines it as "ongoing improvement involving everyone – top management, managers, and workers" (Imai, 1986). In the presented framework, continuous improvement takes a central role and must be seen as an essential systemic driver of all other activities within the organisation. Also Knuckey argues that it is essential for an organisation who is adopting best practises to develop a culture that is closely linked to a strong attitude of continual improvement (Knuckey et al., 1999).

Carlberg mentions the following requirements to develop teams to self-improve processes: empowerment, enablement, and education (Association for Manufacturing Excellence, 2009, p. 112). Empowerment transfers the decision-making authority to the team members. Employees can develop their own solutions, keeping management informed rather than asking for permission.

Enablement strongly correlates with the amount and quality of information which is provided to employees in order to make the right decisions. One further very important critical success factor for the sustainable transfer of a ‘kaizen culture’ is the appreciation of the close systemic coherence with the principle of standardisation (also see 5.3.6). This is embodied the best way by Imai’s well known citation: “There can be no kaizen without standardisation” (Imai, 1986). Steenhuis et al. conclude based on an analysis of two case studies that the main variables that influence the success of the transfer of kaizen is 1) the organisation culture, and 2) the way in which the adapting organisation is organised, i.e. more organic versus mechanistic (Steenhuis, Yokozawa, & Bruijn, 2009). Their findings support their hypothesis that a more organic organisation facilitates the kaizen transfer, whereas a more mechanistic organisation impedes a successful adaptation of the philosophy of continuous improvement. An organic organisation is characterised by a lower level of staff specialisation, by a higher tendency towards decentralisation of responsibilities and by more horizontally structured communication paths, by a lower degree of formalisation and standardisation, and by a high degree of flexibility (Burns & Stalker, 1975). Imai’s emphasised strong positive relationship between kaizen and standardisation and Steenhuis’ preference of more organic organisations for a successful kaizen transfer implying a lower degree of standardisation and formalisation seems to be contradictory and probably indicates a trade-off respectively a local optimum of the degree of formalisation of standards allowing to stay flexible enough to continuously improve processes.

In order to facilitate the philosophy of continuous improvement, the author considers based on the observations in the case studies two main processes and the correspondent systems as essential:

1) Quality improvement system

2) Improvement suggestion system

Within a quality improvement system processes need to be developed to deal with internal (scrap and other production problems, e.g. downtime because of machine failure) and external (customer complaints) quality issues. These processes should be supported by key responsible persons as drivers and by the development of correspondent forms and/or a database (e.g. a simple spreadsheet). This facilitates the monitoring process of defined measures and also provides means to measure internal and external quality.

An improvement suggestion system should encourage all staff members to be involved in any improvement activities. Staff should be enabled to bring forward any kind of improvement for their immediate workplace or for the organisation in general. A correspondent process, forms and responsible persons need to be determined to secure a quick processing of new improvement suggestions. It is advisable to link the improvement system to staff incentives and other mechanisms of staff recognition and rewarding. The degree of participation and the efficacy of an implemented improvement suggestion (e.g. saved costs, reduction in waiting time) can be key performance indicators that can be taken into account for the evaluation and recognition of staff.

Further important elements are 'Genchi genbutsu' (translated as 'Go and see for yourself'), which stands for the attitude of examining problems at the place where they happen in combination with system thinking. Techniques that support a more systematic problem solving approach are the PDCA cycle and the 5Why analysis (see Figure 66).

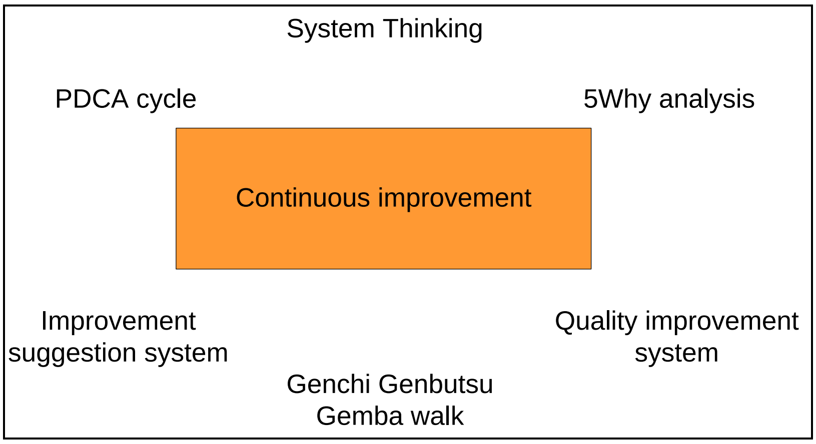

Figure 66: Elements of continuous improvement

5.3.5 ENABLER & DRIVER: Measurement and transparency

A system in general responds to how it is measured (P. Senge, 1990). When measures badly affect a system it results in "creative tension" which affects a person being tempted to do the right thing at the expense of measures. Therefore the choice of proper measures consistent with desired behaviours and organisational goals is vital to performance measurement. Inappropriate measures encourage dysfunctional behaviour, fuzzy judgement, sub-optimisation and manipulation (P. Senge, 1990). An important feature of the Japanese view of the management of measures is according to Hiromoto

(Hiromoto, 1988) that it should play more of an “influencing” role than an “informing” role and be subservient to corporate strategy, not independent of it. In order to develop a measurement system that is clearly lined up with the corporate strategy, the element of transparency needs in the opinion of the author to be an integrative part of the organisation. If the principle of transparency is an accepted virtue in the organisation and advocated by the owners and management, the visualisation of KPIs and of the progress of work on the shop floor might find a better acceptance by staff. Appropriate visualisation of manufacturing information as a positive factor on productivity is discussed by several authors (Greif, 1991) (Conner, 2001). Visualising the current workload by andon boards and scheduling boards on the shop floor reveals quicker manufacturing problems which reduces the reaction time to overcome these problems. Additionally it is assumed that a prompt display of manufacturing information that is relevant for shop floor staff creates a target-oriented involvement. Harris found that the shop floor is a direct reflection on the leadership of a facility. In those facilities where management invested more time on the production floor, the business tends to be more successful and to have a better informed workforce. Using for example visual boards on the production floor that show KPIs and the activities and state of the Lean transformation mainly depends on the commitment of the managers and supervisors. If they do not facilitate, lead and use the boards regularly, it is likely that shop floor members do not buy into this visualisation tool (Harris & Harris, 2008). This could be confirmed by the observations in the case study companies.

Hence in the opinion of the author measurement and transparency are two highly interwoven necessities that enable a Lean transformation. Further in the context of New Zealand with a higher tendency of being performance-oriented, the development of an appropriate KPI-system in the early phase of a Lean transformation is to be seen as essential. The early development of KPIs in the case studies advocates this.[15] The relevant elements are illustrated in Figure 67.

[15] A KPI system for the company of case study A was developed within this research project and published in (Stamm & Neitzert, 2008a)

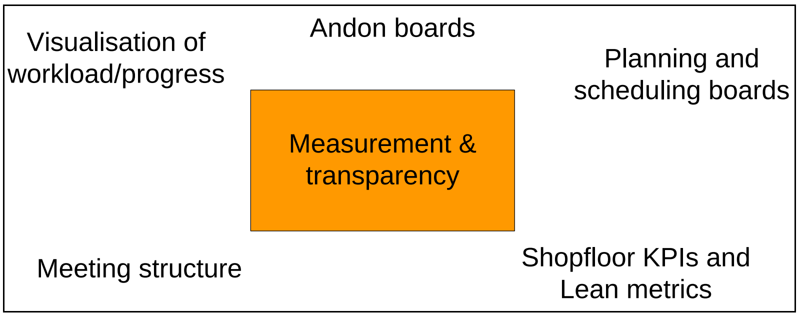

Figure 67: Elements of measurement and transparency

5.3.6 ENABLER & DRIVER: Product and process standardisation

As already stated by Imai there cannot be kaizen without standardisation (Imai, 1986), it is revealed in the case studies that standardisation is not only possible but also essential in high variability low volume environments. This can also be confirmed by other authors (Lander & Liker, 2007) (G. Lane, 2007).

Essential elements found in literature and during the field work are shown in Figure 68. Generally standardisation should be aimed for at product and process level. In case study A, it was observed, that the standardisation of processes is difficult due to the high variability of processes and settings. Additionally the craftsman attitude of staff was observed to be an impediment in finding standards for basic processes. One of the most fundamental process standardisation techniques tightly connected to the principle of transparency and visualisation is 5S. In all case study companies, this technique served as the initial activity in the Lean transformation. Further in the high variability environments, the standardisation of processes in pre-order phases, e.g. the quotation process, were identified as great benefits to the flow in the manufacturing system.

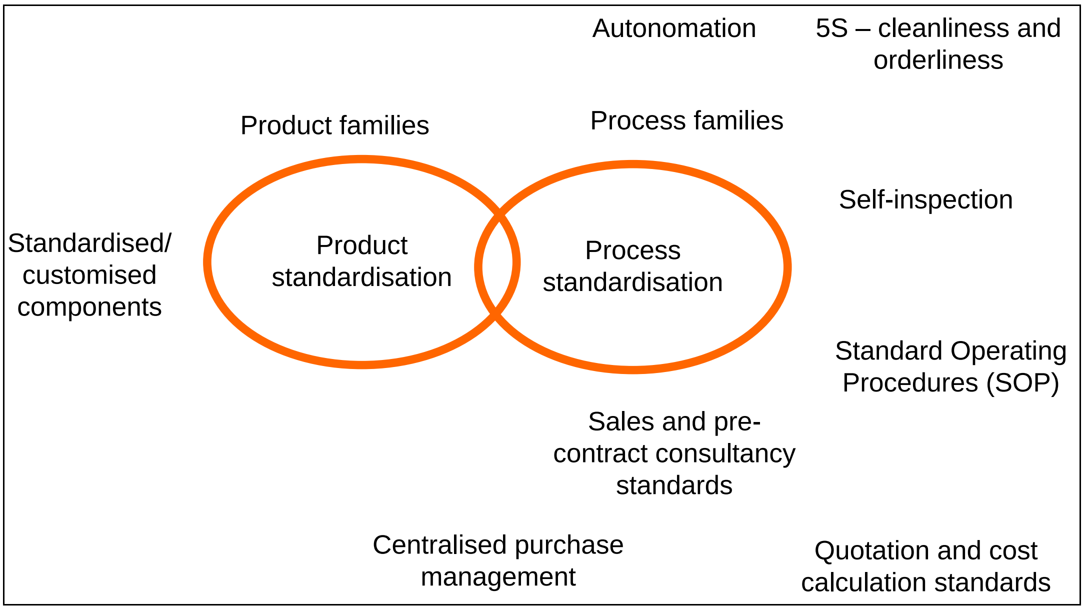

Figure 68: Elements of product and process standardisation

5.3.7 ACTION: Flow & Synchronisation

The central elements for the design of all operational activities are defined as flow and synchronisation. By reducing or even erasing all non value-adding activities and by increasing the efficiency of value-adding activities the perfect flow of material and of information is the ultimate objective. As discussed in the literature review, variability is the main limiting factor. Flow is largely dependent on the synchronisation of resources and the optimisation of buffers which compensate the effects of variability. The fundamental enabler to achieve flow and synchronisation is in the first instance the standardisation of products and processes. Hence the first challenge in a high variability context lies in identifying the repetitive activities, e.g. the setup of CNC machines, and in breaking them down into measurable and formalised incremental sub activities. Herewith typical losses in efficiency caused by searching or waiting can be eliminated. In case study A, it could be observed that there is a tendency to reunite manual labour with mental work. On the team leader level the integration of coordinating tasks led to more project management responsibilities. Team leaders possess more authority for decisions and more autonomy in the coordination of team work. This required the transfer of management authority in the areas of problem solving, staff responsibility and further planning and scheduling activities. This is interpreted by the author as a development towards a more organic organisation in order to effectively incorporate a continuous improvement mentality. In summary, in a high variability environment a compromise between the approach of the division of labour of Taylor and the integration of indirect operational activities might be necessary.

Looking at Figure 69, techniques that will create immediate benefits to the flow of material are the implementation of quick changeover and coupling points that serve as visual material exchange stores between departments or machine resources. Further a more value stream orientated product layout which minimises the motion of material will have immediate impact on productivity. Besides the reduction of random downtime especially at bottleneck resources by the introduction of preventative maintenance plans improves the planning process and hence the material flow. In this context Krajewski's simulation results show that there are more benefits to be gained by reducing setup times and increasing worker flexibility than by switching to a kanban system from a MRP system (Krajewski, King, Ritzman, & Wong, 1987).

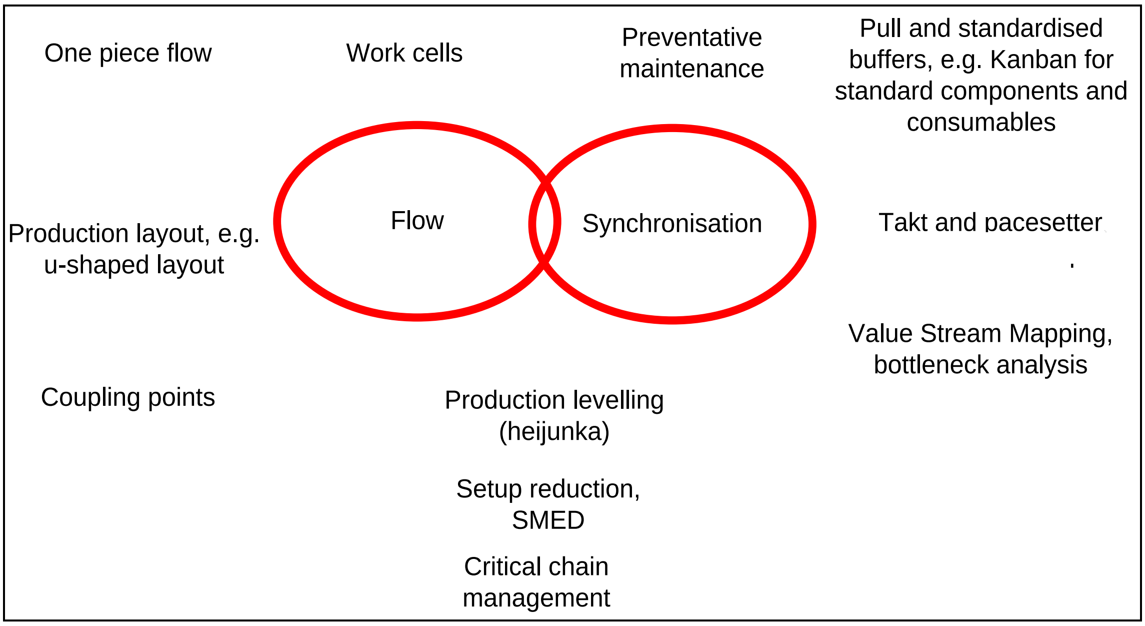

Figure 69: Elements of flow and synchronisation

5.3.8 AMPLIFIER: Market focus

Looking at one-of-a-kind manufacturing as the extreme case of a high variability low volume environment, it is obvious that the effects of learning and of economy of scale are low and difficult to achieve as variability and complexity are maximal. This situation cannot be entirely resolved with current advanced manufacturing paradigms and methodologies. In fact in order to improve efficiency the initial situation of high variability needs to be changed. As already

Ford focused on one variant of his product, companies committed to Lean Production principles need to concentrate on relevant value streams of their business according to lucrative markets and to their core competencies. By concentrating on specific market segments it is possible to reduce the product and process variety due to the reduced number of value streams. The profitability of existing markets and the existing core competencies are to be diligently taken into account in order to set the focus on specific customers and markets. Narrowing down the markets and therefore the reduction of product and process variability will act as an amplifier for the efficacy of Lean principles and methodologies.

5.3.9 AMPLIFIER: Product Development

As mentioned in the previous chapter, the variability of product and process can be reduced by a consequent focus on specific market segments. This allows to align the activities in product development and hence has a positive effect on the efficacy of Lean methodologies in the area of product development. As this thesis focuses on the manufacturing system, but nevertheless the systemic interdependency of product development and manufacturing are undeniable, the importance of the product development system and its adaptation to Lean principles is denoted for the sake of completeness. Lean methodologies and techniques for research and development as well as product development (see Figure 70) are elaborated in detail by the authors Morgan, Kennedy and Hoppmann (Morgan, 2002), (M. N. Kennedy, 2003), (Hoppmann, 2009).

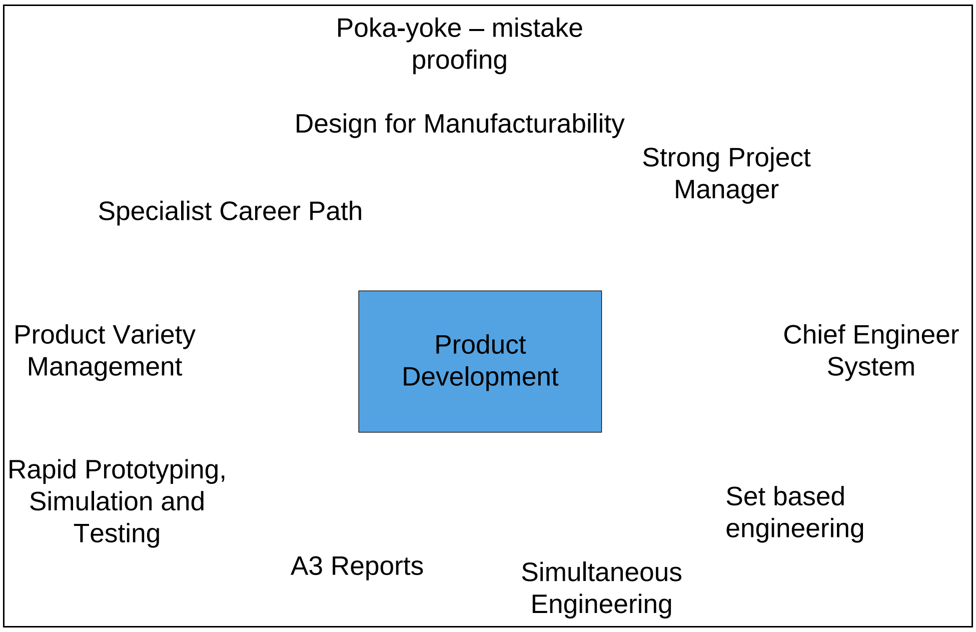

Figure 70: Elements of product development

5.3.10 AMPLIFIER: Vertical and horizontal cooperation

There are generally two directions of cooperation: vertical and horizontal. In a vertical cooperation, suppliers and on the other end of the value stream the customers are to be integrated in business and Lean activities. On the supplier side, the supply of standard components (e.g. screws or cutters for CNC machines) can be automated by a vendor-managed system operating similarly to a Kanban system. According to defined reorder levels, the supplier takes responsibility to automatically refill correspondent items[16]. Further by narrowing down the product and process variability, sub components can be outsourced to suppliers specialised in those components (e.g. in case study A, the company buys pre-machined die sets from suppliers and concentrates on the cavity details and the finish of the mould). In larger companies, smaller suppliers are supported with Lean activities by training and transfer of experience. Looking at the characteristics of SMEs, the provision of intense training in other supplying companies seems to be difficult due to the low staff numbers and therefore lack of resources. Lean learning networks were found to have a similar function and are presented in the following chapter. On the customer's side, long-term strategic alliances should be aimed at. This can be often achieved by offering additional services to the customer. There is clearly a trade-off relationship between the offer of additional services and the reduction of product and

[16] Example of case study A

process variability. Here the horizontal cooperation might bring some additional benefits by allying with producers in very similar areas or even with competitors. Hence a horizontal cooperation where each participant contributes specific, ideally slightly varying core competencies, can act as a system provider and therefore might add additional value out of the customer's perspective.

5.3.11 AMPLIFIER: Lean learning network

A learning network should be understood as "a network formally set up for the primary purpose of increasing knowledge, expressed as increased capacity to do something" (John Bessant & Francis, 1999). Axelson finds the following attributes for a perfect network of Swedish SMEs trying to implement Lean Production in their factories (von Axelson, 2009): the ideal size of network participants consists of 5-7 companies whereas it is noted that the companies share similar characteristics regarding their production volume. Further Axelson emphasises the geographical closeness of network members but also of the knowledge providers in order to enable mutual company visits and to provide a better network support. It is important that the network partners develop an "open attitude based on mutual trust and a willingness to share" (von Axelson, 2009, p. 6). Besides Axelson stresses the importance of the Lean expert who is generally proposed by the facilitating and coordinating organisation (e.g. NZTE in New Zealand). This can be confirmed by findings of a study of Lincoln University who evaluated New Zealand based Lean manufacturing initiatives (M. Wilson et al., 2008). Bessant sees benefits of networks within the implementation of advanced manufacturing methodologies in the acceleration and improvement of the process of knowledge acquisition and capacity building through shared learning (J. Bessant & Tsekouras, 2001).

In summary networks can take different forms and refer to different sources. In the case study companies, owners and staff have benefited by participating in government initiatives (e.g. the AICHI project where regular workshops took place to exchange experiences between the companies), in internet forums that are specialised on manufacturing topics, by reading correspondent popular science literature and by exchange with academics and students in research projects.

5.4 Lean transformation process

The precedent chapter 5.3 elaborated the theoretical concept of the Lean transformation framework. By discussing the elements and stressing the systemic and interdependent character of the framework, it gave an overview of 'what' is necessary. This chapter addresses the 'how' and presents guidelines for the sequence in which a Lean transformation should be initiated based on an analysis of transformation processes in literature. Additionally experiences and insights the researcher gained out of the case studies are considered in the presented process road map.

Before analysing in the following chapter transformation processes of recent literature, two fundamental thoughts backed up by research results are briefly pointed out and discussed. Firstly, Bhasin and Burcher found in a comprehensive literature review about Lean, that successful Lean transformations are not only dependant on the application and adaptation of Lean techniques but also requires changes in the organisation's culture and the whole value chain. Further they emphasise that Lean needs more to be embraced as a philosophy rather than understood as a set of tactical techniques (Bhasin & Burcher, 2006). In consequence there is a need to address both dimensions of a Lean enabling culture and the mastery of Lean techniques. Based on the observations of the case studies, the participation and engagement of the owners and staff is in a high variability environment even more essential, as many Lean methodologies and techniques require further development and adaptation. Further the reduction of variability makes it necessary for staff who are used to work in a typical craftsman culture to partly embrace elements of industrialisation, e.g. the standardisation of processes and the measurement and monitoring of performance.

Secondly, Ferdows and De Meyer suggest that performance improvements are most effective when considering a specific sequence in different dimensions, layered one upon another and starting with a focus on quality, then concentrating on dependability (e.g. on-time delivery), afterward paying attention to speed and flexibility and finally dealing with cost efficiency (Ferdows & De Meyer, 1990). This suggested pattern is largely confirmed in the following analysis of existing transformation processes.

5.4.1 Analysis of Lean transformation processes

Table 25 presents an analysis of eight transformation processes found in recent literature. The more detailed analysis including the actual process steps can be found in Appendix B. The analysis firstly divides each process chronologically into 3 parts (early implementation (1.0), the middle (2.0) and mature stages of the transformation (3.0)). This separation into three parts was mainly done based on the number of steps one process contains and on the judgement of the author. In cases where a clear categorisation into these three sections was not obvious, the researcher decided to use values of 1.5 or 2.5. Secondly, the actual purpose of each process step is analysed based on a constraint perspective. This perspective critically questions why any particular process step needs to be considered and hence what it is supposed to overcome respectively to solve. The colour code refers to the high level perspective of the Lean transformation framework (see chapter 5.3) and allocates the process step to one of the areas of operational activity (red), operational structure (orange), strategy and value alignment (green), or interfaces (blue).

Table 25: Analysis of Lean transformation processes[17]

Why (Constraint)	Womack (2003)	Black (2005)	Green (2004)	Hines (2000)	Lane (2007)	Balle (2003)	Liker (2003)	Bednarek (2008)	How (Recommended methods/techniques by the author(s))
Lack of ownership/responsibility	1.0	1.0	1.0					1.0	Change agent Start with commitment from management
Lack of urgency/importance	1.0								Find a lever
Lack of Lean knowledge	1.0	1.0	2.0						Multilevel training
Organizational constraint	2.0							1.0	Create Lean function/department
Process variations (quality)		2.0			1.0	1.5	1.0	2.5	Stabilize product and process quality Solve quality problems Reduce downtime and instability problems Establish preventative design methodologies (FMEA, Poke-yoke,…) Standardized work
Lack of Lean understanding	1.0		2.5	1.5	2.0			1.5	Value Stream Mapping Identify a pilot Identify waste Kaikaku - first Kaizen event exercise Expand scope
Lack of transparency	3.0			2.0	1.0			1.0	Visualisation
Measurement - results conflict		1.0	3.0	3.0	1.0			1.0	Metrics adaptation Focus on change Continuous result-driven monitoring
Lack of shared vision / policy	3.0			1.0					Develop global strategy
Lack of knowledge of capacity utilization					2.0			2.0	Associate a time with each job
Improvement conflict	2.0								Devise a policy for excess people
Market constraint	2.0								Devise a growth strategy
Batch-queuing conflict		2.0			2.0	2.0	2.0	2.5	Continuous flow Kanban Setup reduction - SMED Inventory reduction Increasing the rhythm of internal deliveries Level internal demand
Local efficiency variations		2.0				2.0	2.5	2.5	Synchronize production Design or reconfigure the manufacturing system Integrate production control Implement cells and link them Start to pull Setup a perfect customer Kanban
Demand variations		2.0					3.0	2.5	Levelled production (Heijunka) Establish daily demand Takt time Balance output from suppliers OPF in subassemblies
Lack of momentum	2.0					3.0			Instill a "perfection" mind-set Continuously work at it with kaizen and quality circles
Shift of constraint to customer/supplier	3.0	3.0		2.0					Use all tools to develop your supplier Integrate suppliers Design Lean Enterprise
Resistance constraint	3.0			3.0	2.0				Establishment of a management-auditing system Relate pay to firm performance
Gap between accounting system and Lean system	3.0				3.0				Adaptation of accounting system
Shift of constraint to support processes					3.0			3.0	Office Kaizen
Lack of employee involvement	3.0			3.0					Transition from top-down to bottom-up improvement

[17] Color code refers to Lean transformation framework in Figure 64.

Comparing the eight transformation processes, two general approaches can be identified. There are processes that tend to concentrate first more on a clear definition of responsibilities; others emphasise the importance of stabilisation of quality (process variations). This is in the opinion of the author not a contradiction it rather reveals two possible perspectives that can be taken. On the one hand, out of management perspective it is essential to define clear responsibilities and establish a sense of ownership, on the other hand out of the shop floor perspective, one of the first steps needs to be the reduction of process variability, in other words the stabilisation of quality. This insight led to the conclusion that it is advisable to correspondently cover these two perspectives: converted into the dimensions of a SME, there should be one high-level roadmap out of the owner's or management perspective that focuses mainly on systemic, cultural and long term aspects. The second perspective should provide supervisors and shop floor members guidelines with regards to the technical system in order to reduce variability, e.g. the introduction of SMED or Kanban.

In the early stages most of the authors address the lack of Lean knowledge and understanding. Hence most of the authors agree that training regarding Lean methodologies must be initiated in early stages of the transformation in all levels of the organisation. The main part of a transformation is centred around the theme of 'enabling flow'. The author mainly identified three interdependent constraints that impede the flow of materials and therefore need to be addressed:

- the batch-queuing conflict
- local efficiency variations
- demand variations

These three types of constraints are mainly referring to the elements of flow and synchronisation of the transformation framework. The batch-queuing conflict refers to the effects of WIP and the trade off between the need of reducing the batch size and the calculation of the optimal batch size out of the accounting perspective. In general, the larger the batch size the larger is WIP and the longer will the lead time be in consequence, but on the other hand the cost of setup is carried by a larger number of parts and hence decreases per part. The central techniques in order to address this conflict are SMED, Kanban and JIT. The effects of local efficiency variations can easily lead in a push system to high

WIP and long lead times, as certain processes are able to produce more. Main aspects that need to be addressed are the understanding of bottlenecks and constraining resources and the synchronisation of production processes. Recommended techniques are for example the analysis of factory layouts, the establishment of connected production cells and any kind of production control policies and techniques (e.g. Kanban). The third indicated conflict refers to the variability of demand (internal and external). Balancing production lines (heijunka) in combination with the creation of takt times to directly link internal and external demand for the main products are techniques to be considered. The external amplifying elements of the framework may provide guidance how to reduce this variability by narrowing the market focus, horizontal and vertical cooperation and by the application of techniques of Lean product development.

There is also a deviation when to address Lean metrics in order to avoid conflicts in the measurement of performance improvements. One example is the inherent assumption to achieve high machine utilisations which can contradict with pull production control mechanisms or with the need of more machine set-ups in order to facilitate smaller batches and heijunka. There is a tendency in all transformation processes that improvements external to the manufacturing system, e.g. the administrative (office) and the supplier integration, should be addressed in more mature Lean stages of the organisation.

By comparing Table 20 (on page 153) which shows the chronological order of the implementation within the case studies with the processes found in literature (see Table 25), it is obvious that both the operational structure and the operational activities are simultaneously addressed in early stages. Further the development of a long-term strategic alignment is generally conducted in an early phase. In the case study companies where this was done in the second year, it was mentioned that an earlier in-depth review of the corporate vision and strategies might have been beneficial. Besides, horizontal and vertical cooperation is addressed at a more mature stage of the transformation. In the case study companies, an integration of suppliers into Lean activities was not considered before the third year of transformation.

5.4.2 Transformation process – Owner and management perspective

As indicated several times, the owners of SMEs have a significant influence on the culture and value system of their organisation. A sustainable transformation to current advanced manufacturing paradigms might therefore require an intense involvement and clear commitment by the owners. The transformation process presented in Figure 71 has been developed through the previous analysis of literature and in an iterative process of observation and interaction in the action research case studies. A first draft was developed by the experiences gathered in case study A. In early discussions with the managing director of the company of case study E, the draft was presented and discussed and continuously improved along its progress. The process is designed to provide guidance from the start of a Lean transformation. The first three blocks have the function of bringing the necessary Lean knowledge and understanding to the management level and to lay the foundation for the alignment of Lean philosophies with the organisational culture and variability characteristics. The fourth block is subdivided into three areas according to the main areas of the transformation framework. As the areas are connected and are to be understood as a system, it is in the opinion of the author not advisable to establish a clear sequence when to address the elements. However, the transformation processes of the literature analysis and of the case studies imply the tendency to concentrate first on the operational structure and operational activities before dealing with other interfaces of the manufacturing system. Although, as some elements (e.g. the standardisation of products during product development) external to the manufacturing system can have amplifying effects on Lean methodologies, it is necessary to include this area in initial stages in which the vision and strategies are revisited.

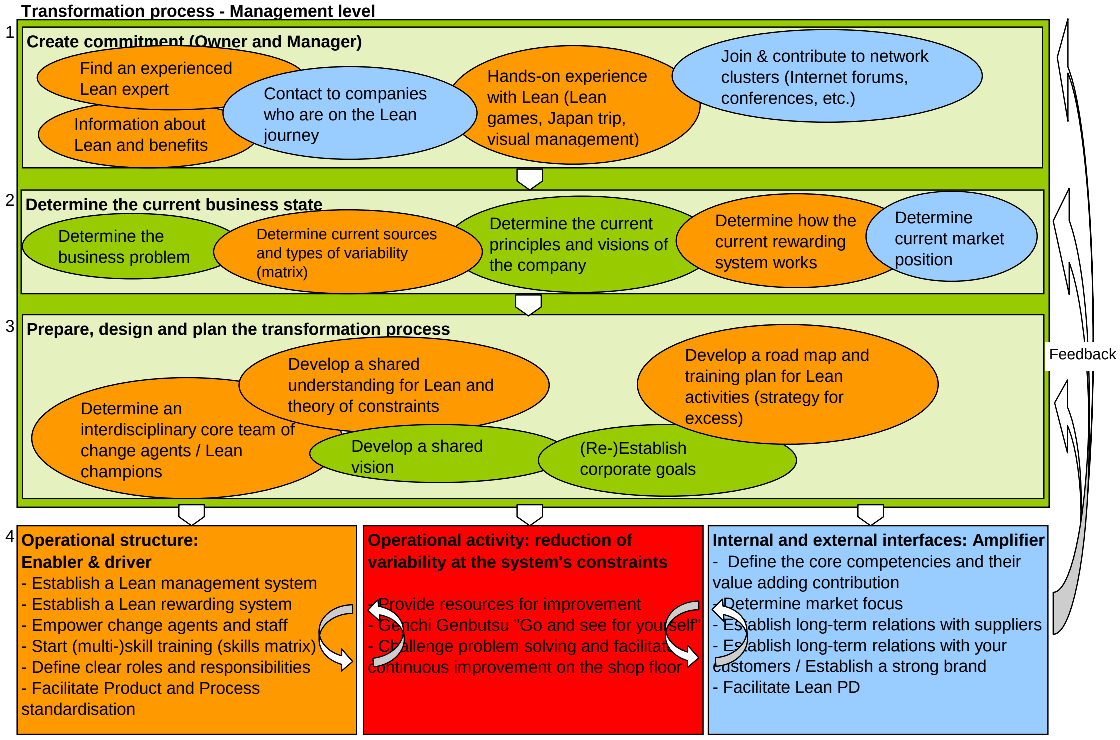

Figure 71: Lean transformation process – management perspective[18]

5.4.3 Transformation process – Shop floor perspective

Based on the transformation histories of the case studies, a general pattern for a Lean transformation on the shop floor level is recognizable (see Figure 72). In all companies one of the first Lean activities on the shop floor was the introduction of the technique 5S either in a pilot or immediately companywide. Creating a cleaner and more functional workplace requires the involvement of the shop floor staff and serves as a good technique to raise the awareness for waste elimination (muda). It was observed in the case study companies that this initial activity led to a positive attitude of shop floor staff towards the change initiative, as the immediate effects of reduced time for searching for tooling and other manufacturing equipment were obvious. All case study companies identified ‘key persons’ that are to be responsible for specific areas of the transformation. These ‘leaders’ were introduced to Lean principles and methods in workshops and/or in one-on-one training units with the collaborating consultants. In the action research case studies the importance of a clearly defined meeting structure and of improvement teams became obvious. At the case study company A, the weekly operational meetings were several times relaunched with slightly modified agendas after periods. As the meeting was

[18] Color code refers to the Lean transformation framework.

mainly driven by one member of management, in times where the day-to-day business required urgent action, meetings were cancelled. Shop floor staff disapproved this inconsistency in the meeting structure, as continuous improvement activities could not be discussed and hence were delayed and were in danger of loosing momentum. Comments of shop floor staff showed in the times where meetings were cancelled signs of frustration. This made clear how important the commitment of management is and in the early stages it is quite essential for management to adhere to the newly defined processes to create authenticity for the Lean transformation in order not to be perceived as 'the next fad'.

After a core team had been defined, one of the initial activities, either as a single event or already embedded in the meeting structure, is to determine the current state of the company with regards to material and information flow. In case study E, the meeting structure was seen by management and production staff as one of the major gains in the first year of the Lean transformation. Generally the technique of VSM was introduced in this context by the consultants. Also other researchers emphasise this initial analysis of the current state (Rivera & Frank Chen, 2007) (Bednarek & Niño Luna, 2008). Dependant on the results of this analysis the improvement team may determine further measures for improvement.

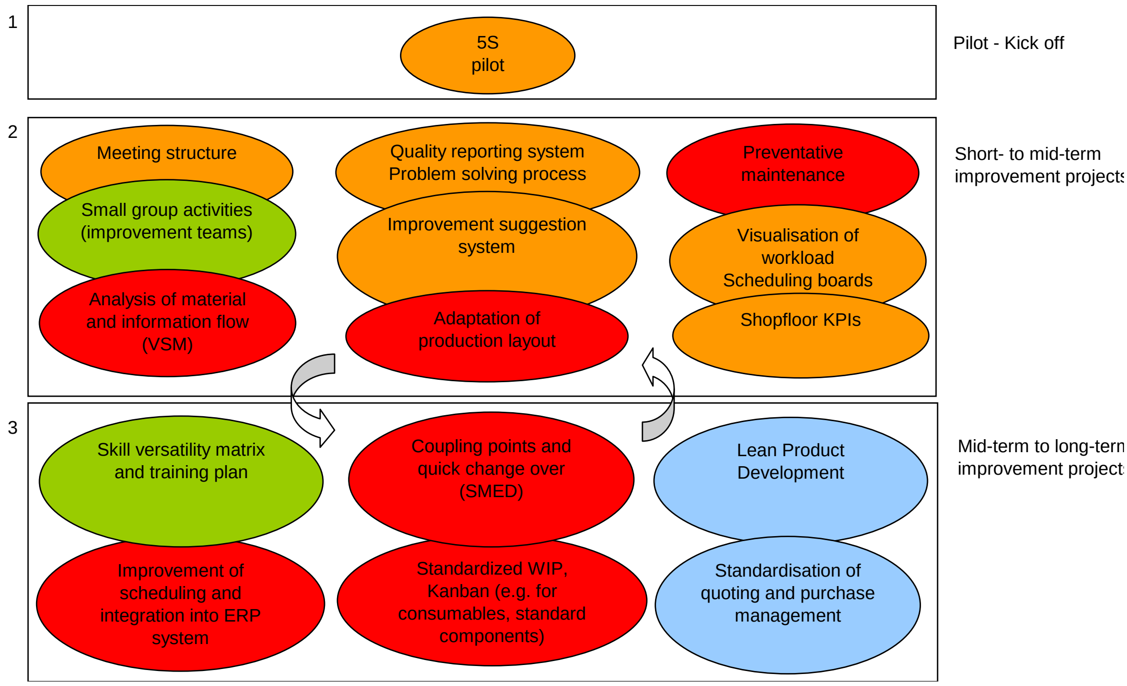

Figure 72: Lean transformation process – shop floor level perspective[19]

Methodologies that can be implemented without any major financial investment are the development of a quality reporting system and an improvement suggestion system. In the case study companies, these systems were linked to the activities of the improvement teams and problem reports or improvement suggestions were part of the agenda of shop floor meetings. As an additional driver on the shop floor it proved to be important to establish correspondent KPIs for the shop floor (e.g. measurement of jobs on time or comparison of actual with budgeted hours) that are directly linked to the company's strategies. As New Zealanders tend to be more performance-oriented in comparison with other nations, the early implementation of adequate KPIs might have a stronger effect on a Lean transformation than in other countries. In case study A, the number of implemented improvement suggestions was selected as one of the KPIs which emphasised the strategic importance of continuous improvement for the company. In the third phase the case study companies generally improved their flow of material and information by improving production control mechanisms (e.g. Kanban or standardised WIP), improved scheduling, by the implementation of material coupling points, the introduction of quick changeover techniques and by starting of improvement projects in areas connected to the manufacturing system (e.g. product development and purchasing) (see Figure

[19] Color code refers to the Lean transformation framework in Figure 64.

72). An example that seems to be characteristic for a high variability environment is the improvement of the quotation process and techniques. In case study A, the accuracy and quality of the quotation process was perceived as a competitive advantage and leverage point as it might directly affect the profitability of projects and the workload (see Figure 5). Also in case study E the development of a comprehensive data base of worked hours per boat and per process became a valuable source for the quotation of new projects and beyond provides guidance for the definition of targeted hours on the shop floor.

5.4.4 Transformation methodologies and enablers

Through the observations and active involvement in the case studies, the researcher experienced as a major challenge in an early transformation phase to find the right focus for the activities. The lack of staff that is experienced in Lean methodologies and the general pressure of the day-to-day business forced all companies to focus their efforts on a few activities and projects. In a meeting of the first Aichi group after one year, all participants noted that they started too many projects in the first year which led to an initial overburden. Further the companies were quite dependant on the consultant's advice where the owners should concentrate on and which methodologies in which areas are to be favoured. Hence, any guidance how to choose the right projects out of a management and change agent's perspective was perceived as beneficial. In the following chapters a brief outline of methodologies and enablers that were used in the case study companies is presented.

5.4.4.1 The perspective of management and shop floor

In Figure 73 a slightly adapted version of Rother's diagram about the responsibilities and focus of management and frontline employees is presented. Owners and management are responsible for the definition of strategies and policies. With regards to the Lean transformation, their focus should lie on the elimination or reduction of muri (overburden) and mura (unevenness). Muri refers in this context to workload that is beyond the capacity of the manufacturing system which generally leads to high WIP, late deliveries and because of the higher pressure to more quality defects. Mura means unevenness and refers to an unstable demand with high variability leading consequently to an uneven production schedule and either over- or underutilised resources. Further the owners need to understand their critical role as enabler and facilitator of the organisational transformation. In the interface of owners and middle management or supervisor level, the vision of the company and strategies are to be clearly communicated. On the supervisor and team leader level, ongoing training of team members in process standards and the facilitation of systematic problem solving should be part of the day-to-day duties.

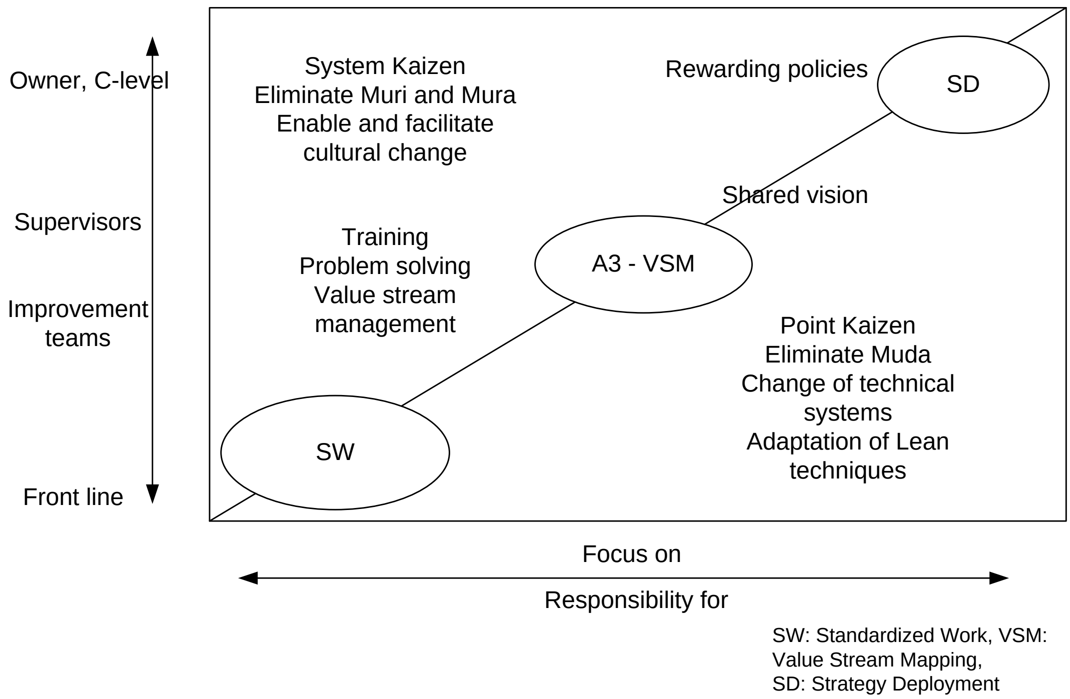

Figure 73: Responsibilities and focus of owner and front line employee (on the basis of (Rother & Shook, 1998))

In case study A, a special emphasis was put on the development and involvement of team leaders in problem solving (e.g. the analysis of quality problems with their team members), in the development of corporate process standards (e.g. process standards for quick changeovers) and the improvement of project scheduling. Over the observation period, a strong awareness for continuous improvement and waste elimination could be created on the team leader level which now has a noticeable influence on the transfer of knowledge to subordinates and new staff members.

5.4.4.2 Value stream mapping

Value stream mapping is commonly suggested as an initial methodology to start a Lean transformation (Rother & Shook, 1998) (Hines & Rich, 1997) (J. P. Womack, 2006) (Rivera & Frank Chen, 2007) (Hopp & Spearman, 2008). Value stream maps identify ways to get material and information to flow without interruption, improve productivity and competitiveness, and help people implement systems rather than isolated process improvements (J.P. Womack & Jones, 2003). VSM supports the understanding of the value stream as a whole and reveals opportunities for improvement and the priority as well as the first destination of further measures, e.g. the implementation of 5S methodologies.

In case study A which stands for a high task and demand variability, a modified approach was developed during the first year of research (see also (Stamm & Neitzert, 2008b) and chapter 4.3.1). Outcomes were an adapted methodology for a manufacture-to-order environment, a better understanding of the effects of waiting time of components, the negative effects of multi tasking on several projects on WIP levels and the understanding of the relevance of bottlenecks. In the company of case study A, this led to several improvement projects for the bottleneck resource.

5.4.4.3 Key performance indicator system

The development and implementation of adequate key performance indicators was perceived as essential by all case study companies (see Figure 63). Looking at the Lean transformation framework the key performance indicator system needs to be understood as the critical component of the element 'measurement and transparency' by providing alignment and direction to the whole organisation. In the case study companies both strategic and operational measures were identified and implemented. During the observation period, a customised key performance indicator system was developed in collaboration with the company of case study A (see (Stamm & Neitzert, 2008a)). The overall lead time of projects proved to be a meaningful main KPI taking the characteristics of the case study A company (high task and demand variability) into account. Looking at Lovejoy's triangle (see Figure 15), the relevance of lead time in a high variability low volume environment becomes obvious: as there hardly exists any inventory of finished products, the main buffers are time and capacity. If for example orders exceed the current capacity of manufacturing resources this is immediately 'compensated' by an interruption of flow through the increased waiting time of components. Having one main KPI that provides evidence for the improvement of the manufacturing system enables to channel all improvement efforts. For case study A, the improvement projects were selected according to the effects on waiting time of staff and components and on the overall lead time of a project.

5.4.4.4 Constraint perspective as focusing mechanism

A very powerful insight observed in case study A and case study E is to use the constraint perspective as a focusing mechanism for Lean improvement activities. This insight is also mentioned by the authors Dettmer, Wolstenholme, and Wilson (Dettmer, 2001) (Wolstenholme, 2006) (L. Wilson, 2010). After developing and conducting a customised value stream analysis[20], the CNC machines in case study A were identified as a major bottleneck resource. This result was presented and discussed by the researcher with the management team which led to several Lean projects around the CNC area. Understanding that the CNC machines as bottlenecks determine the overall throughput of the company provided to the teams a good focus for priorities for the potential improvement projects. One project example is the establishment of a centralised planning and scheduling system around the CNC machines as the main pacemaker for all other resources. This led to an improved synchronisation of manufacturing resources and reduced the planning complexity out of management's perspective (see Figure 74).

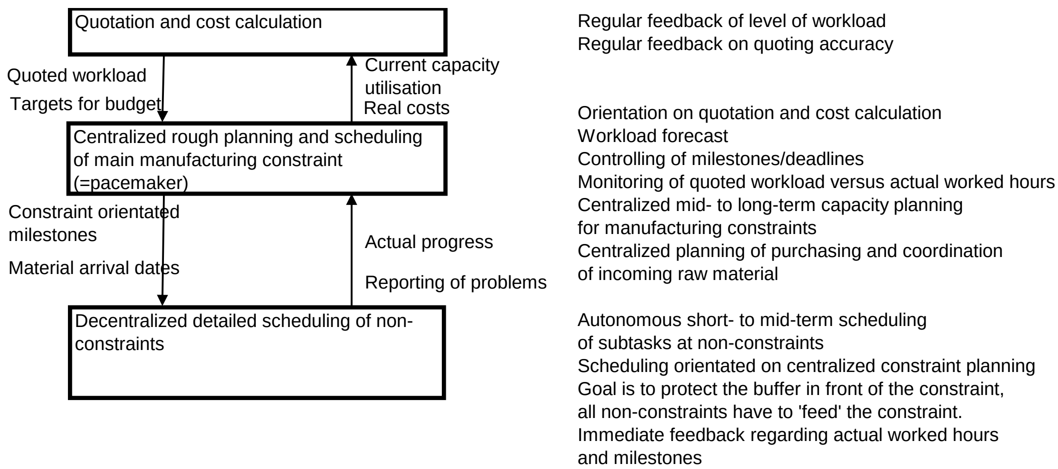

Figure 74: Planning and scheduling concept of case study A focused on constraints

[20] For more information see (Stamm & Neitzert, 2008b)

In case study E, the perspective of constraints assisted in identifying one department as a constraining resource for the overall lead time of the projects. Initially improvements concentrated on the boat builder teams that mainly execute tasks that are on the critical path. But the real bottleneck resource was the joinery department which provides most of the interiors for the boats. This led to delays on the critical path when parts were not provided on time from the joinery department. Hence the company started a series of improvement projects in the joinery department, sent the team leaders to Lean workshops and employed one Lean consultant who initially concentrated on this area. Focus of improvements was on the visualisation of workload, the comparison of budgeted and actual hours and on the visualisation of manufacturing problems to reduce rework.

5.4.4.5 Training

An important enabler experienced in the case studies is the aspect of training. As revealed in the literature review, employees of SMEs are to be said to be more generalists than specialists. Specific knowledge about Lean methodologies and techniques were in the case study companies at the beginning of the Lean transformation basically non-existent. This is confirmed by the analysis of impediments where the lack of implementation know how is rated as a major obstacle for a Lean transformation (see Figure 61). In case study A, the involvement of staff significantly increased after introductory workshops about Lean methodologies and techniques to all staff members (see Figure 47). Also in the company of case study E, increased involvement and new improvement projects were triggered by an introductory workshop for management staff and a workshop that introduced the main principles of the Toyota Production System by the simulation of an assembly line. Additionally, visits of companies that were on a more mature level of a Lean transformation inspired the participating staff. Further, training in 5S, value stream mapping and other Lean techniques was conducted.

Von Axelson mentions the following training modules in order to introduce members of a Lean learning network in Sweden to Lean Manufacturing: a Lean introduction workshop (initially for management and then for all employees), a value stream mapping workshop creating the understanding of product families and their material and information flow, a 5S workshop in order to establish stability and orderliness, an introduction to the SMED technique and its importance, a workshop about production layouts and production control systems (e.g. kanban), a workshop that addresses Lean leadership and finally a continuous improvement workshop dealing with the principles of kaizen (von Axelson, 2009).

6 Continuative discussion

This chapter continues and further elaborates on the discussion of the chapters 4 and 5. Hereby the Lean transformation framework is validated by an analysis of its application in the AR case study companies. Within the case study companies it is shown that the elements of the Lean transformation framework can be implemented in practice. Practical difficulties or limitations of the framework that were revealed in the case study work are discussed. The second part of the chapter picks up the initial research questions within a critical review.

6.1 Comparison of case studies with Lean transformation framework

In order to validate the completeness of the framework, the activities of the case study companies are checked in Table 26 against the elements of the framework. This is in line with the dynamic and iterative process of action research where theory and conceptualisation evolves out of the interaction with the research object. Table 26 shows that most of the elements of the transformation framework have either been partly or completely implemented and used in the case studies (marked with a 'x'). Hence, the practicality and completeness of the framework is proven and could be validated by the improvement in performance evident in all case study companies. In the following, elements that were not implemented or showed difficulties in its adaptation are discussed.

Although both AR case study companies are aware of the need, they struggled with a consistent long-term alignment of the organisation and the correspondent definition of strategies and of the actual customer's value over a time horizon of more than one year. As a possible reason, the researcher has to conclude, based on the interaction and observation, that the owners generally are quite involved in the operational activities of coordinating and scheduling projects, dealing with urgent customer requests and the acquisition of new projects. As these operational activities are seen as fundamental and urgent in order to 'run the business', the development of strategies and of a long-term alignment of the business suffer under a lack of time. Additionally neglecting or even omitting a consistent long-term alignment generally has hardly any immediate effect on the business which makes it difficult to directly relate its consequences over time and hence to evaluate its importance.

Table 26: Comparison of Lean transformation framework with case studies

Element of framework	Methodology or technique	Case study A	Comment	Case study E	Comment
Value focus					
Strategic alignment	Shared vision			x	Clear mission statement, management workshops about vision of company
	Hoshin Kanri				
Leadership & human resource development	Shojinka or cross training	x	Cross training in machinery	x	Skills matrix in most of the departments
	Owner's development and involvement			x	Management course and active participation in Lean learning networks
	Leadership development	x	Active participation in Lean learning networks	x	Management course and active participation in Lean learning networks
	Roles and responsibility matrix	x	Roles clearly defined	x	Roles clearly defined
	Recruitment process	x	In alignment with roles and responsibilities		
	Rewarding system	x	In alignment with roles and responsibilities		
	Staff empowerment & teamwork	x	Establishment of project teams	x	Empowerment of teams for continuous improvement
Measurement & transparency	Visualisation of workload / progress	x	Monitoring of actual vs budgeted hours	x	Monitoring of actual vs budgeted hours
	Andon boards				
	Planning & scheduling boards	x	Project schedules and scheduling boards	x	Project schedules
	Shopfloor KPIs and Lean metrics	x	KPIs for every team	x	
	Meeting structure	x		x	

Continuation 1 of Table 26

Element of framework	Methodology or technique	Case study A	Comment	Case study E	Comment
Continuous improvement	System Thinking				
	PDCA cycle				
	5Why analysis	x			
	Quality improvement system	x		x	Low participation by staff
	Genchi Genbutsu / Gemba walk	x	Daily presence of management on shop floor	x	Daily presence of management on shop floor
	Improvement suggestion system	x	Improvement suggestion database and implementation process	x	
Product standardisation	Product families	x	Categorisation according to value	x	
	Standardised components	x	Standard die sets	x	Standard hull
Process standardisation	Autonomation				
	Process families				
	5S - cleanliness & orderliness	x		x	
	Self-inspection	x		x	
	Standard operating procedures (SOP)	x		x	Standardisation of bill of materials
	Sales and pre-contract consultancy standards	x		x	
	Centralised purchase management	x		x	
	Quotation and cost calculation standards	x			

Continuation 2 of Table 26

Element of framework	Methodology or technique	Case study A	Comment	Case study E	Comment
Flow	Work cells	x			
	One piece flow			x	
	Production layout	x		x	Flow layout for final assembly
	Coupling points	x			
	Setup reduction, SMED	x			
Synchronisation	Preventative maintenance	x			
	Pull and standardised buffers	x			
	Takt and pacesetter	x		x	Milestones
	Drum-Buffer-Rope				
	Value stream mapping	x	Customised VSM approach		
	Production levelling (heijunka)				
	Critical chain management	x	as a pilot	x	as a pilot

Product development		x	Standard component database,	x	Standard CAD general arrangements
Lean learning network	Government initiatives	x		x	
	Internet forums				
	Lean literature	x		x	
	Contact to academia	x		x	
Market focus				x	Focus on specific boat length and degree of customisation
Kooperation	Horizontal	x	Collaboration with other international toolmaking companies	x	Lean learning network with other boat builder
	Vertical: Supplier	x	vendor managed cutters	x	vendor managed timber
	Vertical: Customer	x	Long-term commitment to a few customers		

It could be also noted that the adaptation of the reward and incentive system and of the recruitment process to Lean philosophies found in the first two years hardly any attention by the owners or management staff. In the case study A company, the incentive system and recruitment process in combination with the accountability and responsibility of every staff member were revisited in the third year. These changes were initiated by a new CEO in order to establish a better alignment of the corporate values and Lean philosophies with the human resource processes.

In general in both AR case studies difficulties with a more systematic approach to problem solving embedded into the quality reporting system could be observed. In the company of case study A a lack of consistently reporting and analysing all quality issues needed to be addressed several times in staff meetings. Despite of the difficulties of a self-sustaining organisational integration, evidence for the benefits of the establishment of the quality improvement system can be found in the clear reduction of internal costs caused by quality problems (see Table 19). In case study E, reporting and analysing quality problems using a corrective action form and the PDCA cycle has never become an integral part of the daily shop floor activities. Staff members argued that the documentation of quality problems rarely brought additional input to solve the problem. Problems were either too trivial, not justifying the additional effort of a more structured analysis and documentation or too fundamental where an immediate solution could not be found. In the opinion of the author the observed difficulties to integrate a more systematic approach to problem solving might find its cultural reasoning in the typical Kiwi attitude best described with expressions like ‘she’ll be alright’ or ‘no worries’.

Further mainly caused by the dynamic and complex character of routing and variability of processing times, production control and scheduling mechanisms still hold in the opinion of the researcher a large potential for the improvement of synchronisation and flow. However, in both case studies the companies struggled to fully embrace advanced production control techniques like the methodology of critical chain project management due to a lack of practical experience, the lack of resources and the pressure of the day-to-day business.

Another challenge observed in both case study companies is the levelling of workload. Both companies experienced over the observation period high demand fluctuations leading to a very unstable utilisation of resources and to lay-offs. This high variability in demand greatly affected any efforts with regards to the technique of production levelling.

Having a closer look at the amplifying elements (Table 26, blue elements), case study A revealed an interesting insight with regards to the market focus. The company had several months where the targeted turnover could not be achieved. This led to high efforts on the side of the owners continuously looking for work that is not within the core competencies of tooling. The believe arose that in order to survive and generate enough turnover, every job needed to be accepted even though the profitability was not guaranteed. This not only led to a higher task and processing variability on the shop floor, but also to a large customer base. However, in an analysis it was revealed that over one year far more than 80% of the turnover was generated by less than 20% of the customers. This literally opened the eyes of the owners and management that a much tighter market focus is possible and its realisation will have a significant effect on the time spent for dealing with customers and in consequence on the variability on the shop floor. In summary this insight which is certainly of a more general business nature shows the systemic interdependencies of the manufacturing system and the effects on the management if driven by Lean principles and focused on waste elimination. Because of the limited size of the national market and hence the restriction for a tighter market focus, it is necessary to be open for international markets and international partners for horizontal and vertical cooperation. Despite challenges in the practical realisation, management of the case study companies are aware of the potential benefits of cooperation and the effects on the efficiency of the manufacturing system and incorporated the insight into their strategic planning.

6.2 Reflection on the research questions

Generally, the case studies showed that Lean principles and most of the Lean methodologies and techniques can be applied dependent on the degree of variability of the operations and of products. But it needs to be understood that the presented manufacturing paradigm can only solve in a limited way the challenges of a high variability environment, as it mainly tries to reduce this variability by focus and standardisation. Companies that strive for covering most potential customer requirements, the requirement of focus and standardisation remains difficult to meet. However, in those companies, as case study E shows, a beneficial reduction of variability by standardisation of processes can still be achieved to a certain degree. In case study A increases in productivity were achieved by a focus on the reduction of lead time and WIP rather than on the maximisation of utilisation of resources and by a clear emphasis on product and process standardisation.

Looking at the research question A (see Figure 75), it could be clearly shown that New Zealand holds a number of unique characteristics in comparison with other nations. Based on a comprehensive literature review, chapter 3.2 explored New Zealand's context and revealed more general behaviour, attitudes, and characteristics that might affect a Lean transformation. On the one hand New Zealand's lower score for long-term orientation on the Hofstede scale might be in general conflict with the Lean principle of a long-term and strategic alignment of the organisation. On the other hand New Zealand's high appreciation for egalitarianism and the low scores for power distance give reason to award New Zealanders the characteristic to work well in functional teams. As third influential characteristic the high scores for performance orientation could be identified. This tendency of performance orientation could be observed to be taken on in the case studies and hence was incorporated into the Lean transformation framework. The researcher wants to stress the danger of a too strong generalisation of the New Zealand culture that is only based on empirical results. A too close interpretation of these results might lead to wrong decisions if the context is not adequately considered. However, generally within the case studies, characteristics like for example the short-term orientation, the low scores of power distance and uncertainty avoidance, the high score for individualism and a strong sense for egalitarianism could be perceived by the researcher who himself did not grow up in New Zealand and hence has a role of an external observer.

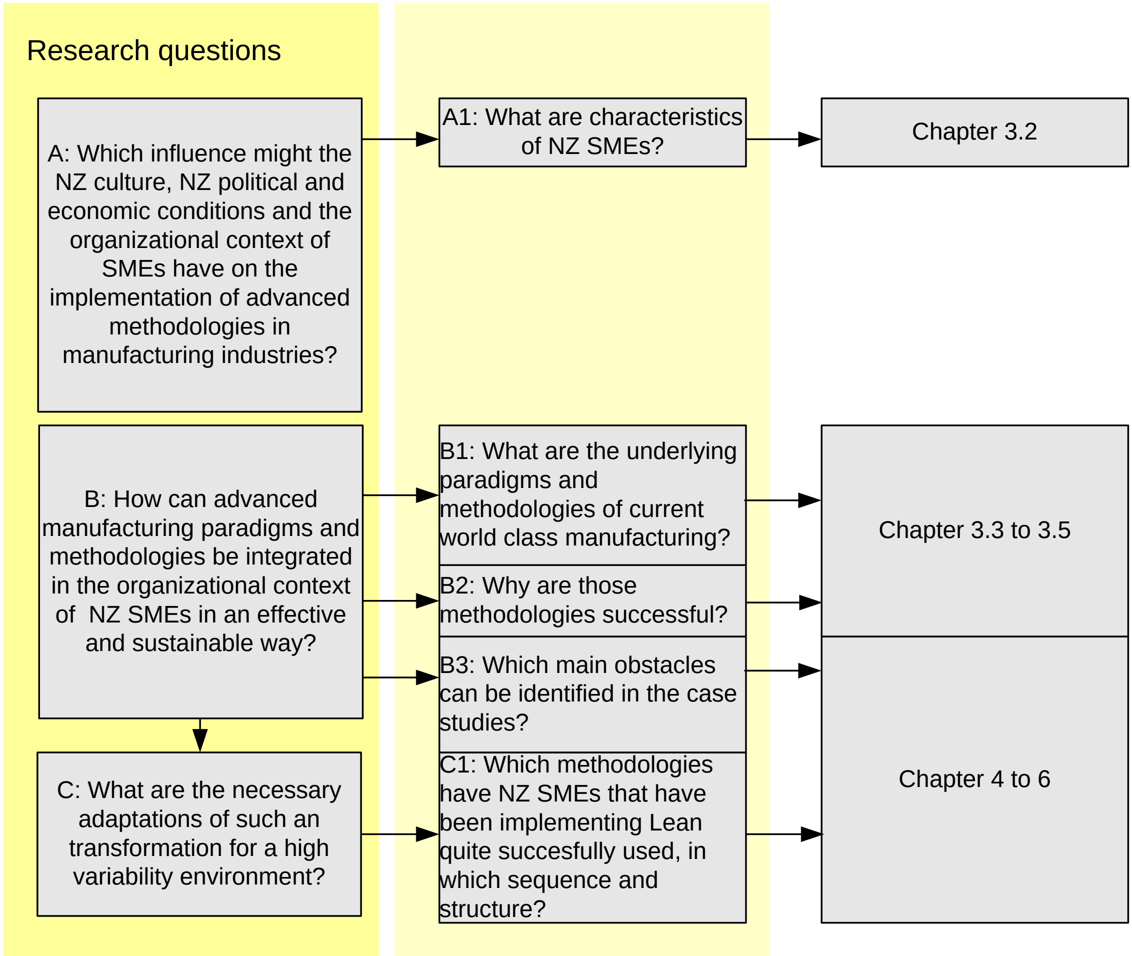

Figure 75: Reflection on the research questions

The research questions B and C and the correspondent subordinated questions are addressed in the chapters 3.3 to 3.5 and 4 to 6. Based on the observations of the case study work a unique framework and transformation process have been developed customised to the requirements of NZ SMEs. The prevailing methodologies and their underlying assumptions were presented and the current understanding of best practices was summarised under the term Lean Production. The case studies show that the implementation of Lean Production in NZ SMEs leads to performance improvements in all analysed dimensions. Further the case study work revealed particular obstacles that needed to be addressed and also resulted in guidelines in which sequence methodologies and techniques might be implemented in the organisations. The case studies also made clear that some of the methodologies being associated with Lean Production cannot be directly copied into the high variability context. Examples are the establishment of fixed assembly lines controlled by a kanban system and efforts to level the workload. One further example is the creation of takt times in a high variability environment. As the number of products is very low, the time interval for a correspondent takt would be too large and hence does not provide any practical advantage for the synchronisation of production resources. Also the methodology of VSM required adaptation as it was applied in the company of case study A (Stamm & Neitzert, 2008b). These observations could partly be backed up by quantitative results (see Table 22) indicating a negative correlation between the degree of variability and the level of integration of the pull principles, the implementation of process standards, quick changeover methodologies (SMED) and the implementation of a Lean KPI-system.

Further the tendency of lower performance improvements with an increasing task and demand variability could be observed. In the opinion of the author, these lower performance improvements are partly caused by the adaptation process for some of the Lean methodologies. Companies follow a learning curve while adapting Lean methodologies to their requirements. Hence it is difficult to immediately achieve the same efficacy these methodologies and techniques generate in their pristine mass-production environment. Looking for example at the standardisation of changeover procedures, the high variety of components to be set up on machinery forces the operators to more flexible solutions for fixtures than it would be necessary with reoccurring components.

Based on the previous paragraphs the researcher comes to the conclusion that the degree of variability has a larger influence on the Lean transformation than the national and organisational culture. There are Lean methodologies that cannot be directly transferred into a high variability environment. Kanban as an example could not be used in the core of the environment but at the periphery, i.e. with the suppliers to manage standard components. Further the limited resources in a SME made it in some cases difficult to create value stream oriented production lines that only concentrate on one or a few product families.

In summary in the context of NZ SMEs a strong initial focus on the owner, management and potential change agents is necessary. Further a more team-oriented approach with a low degree of formalisation of the transformation process is favourable. Based on New Zealand's higher tendency of performance orientation, correspondent indicators are to be established in an early stage of the transformation. This is in alignment with the observation that making early results visible and celebrate them is a good incentive source for staff. With regards to the requirements of a high variability environment, there should be a high emphasis on leadership and human resource development. Firstly, more in general, a high variability environment requires the adaptation of some Lean methodologies and techniques and hence a higher involvement of staff in the transformation process. Team leader and members need to develop a deeper understanding of Lean in order to correspondently adapt the methodologies to the requirements of the company. Secondly one further focus should lie on the flexibility of staff and in consequence on multi-skilling. This does not only allow a better utilisation of the workforce and a better levelling of workload, it also enables a more steady execution of processes. Further the standardisation of processes and products are possible in a high variability context to such a degree, that the invested efforts directly relate to performance improvements on the shop floor becoming visible either in a reduction of material consumed or in time savings (e.g. less scheduling, improved processing times).

6.3 Reflection on the quality criteria

This chapter reviews the quality criteria being discussed in chapter 2.3.4. In Table 27 the quality criteria including the questions raised by Miles & Huberman are reflected upon. As previously elaborated the outcome of AR should not be exclusively judged by the same validity criteria with which positivistic research is judged.

Table 27: Reflection on the quality criteria

Objectivity / Confirmability	The researcher’s paradigmatic stance is discussed in chapter 2.2.3 and applied procedures and methods are presented in chapter 2. The main data collection methods in form of questionnaires and interview forms can be found in the appendix. The actual sequence of how data were collected in the main AR case study is explained in detail in chapter 4.3.
Reliability / Dependability / Auditability	The researcher’s role in each of the AR case studies is explicitly described in chapter 4.3.1 and 4.7.1. The research questions are presented in chapter 2.1 and critically reviewed in chapter 6.2. The main research methodology of AR and its advantages and disadvantages are discussed. Data of five companies were collected over a period of almost three years and to a great detail as the researcher was an active member of two AR case study companies. The results mainly in the form of the framework were developed in a collaborative manner in the AR case organisations and critically reviewed by participants.

Internal validity / Credibility / Authenticity	Triangulation was used in terms of questionnaires following a more positivistic approach, semi-guided interviews, workshops, observations on the shop floor, participation in meetings, formal and informal discussions with management and shop floor staff and the statistical analysis of performance data. As areas of uncertainty, the importance to understand the results in its context was constantly emphasized. The Lean transformation framework might provide assistance and guidance for NZ SMEs but might not be used in a copy-exactly approach. The developed Lean transformation framework is in line with the theoretical concepts of current manufacturing methodologies and best practices and could be partly applied in a second AR case study. Further most of the methodologies and techniques found in all five case studies are embedded into the framework.
External Validity / Transferability / Fittingness	Characteristics of the main case study are fully described (chapter 4.3). To enable adequate comparisons data for task variability and demand variability of all case study companies are presented. Besides, the collection of historical data and performance data followed in all cases a systematic procedure assisted by specific questionnaires (see appendix). Based on the collection of identical performance data, the success of the implementation of Lean methodologies can be compared between the case studies. The generalizability of the developed transformation framework was validated within the second AR case study as the framework was perceived as valuable by management and led to further action.
Utilization / Application / Action orientation	The major findings in AR case study A were utilised in the second AR case study E. Both companies show through the improvement of their performance data the effectiveness of the elements of the framework.

Continuation of Table 27

7 Conclusion

In order to be competitive at an international level and to secure social wealth, increasing the overall productivity of New Zealand's industry has been identified as one important leverage point. New Zealand companies are forced to deal with the conflict between the leadership in costs and a clear differentiation of the product or service to the competition. With regards to a manufacturing system, this conflict lies in the tension between the highest possible customisation for the clients and its inherent high variability of processes and of demand and the delivery of this highly customised product or service in an efficient, fast, reliable and sustainable way.

Generally, the paradigm of Lean Production and its methodologies can contribute to solve this conflict of interest. Looking at the industrial mass production, Lean Production indisputably achieved a positive shift of the performance-cost frontier. However, although similar requirements with regards to quality, costs and timeliness, the implementation of this paradigm in manufacture-to-order and engineer-to-order companies who operate in a high variability environment seems to be hesitant. As most of the methodologies are developed for the context of large production lots with a relative low degree of variability, a direct transfer of these methodologies is difficult. Hence, correspondent adaptations are required. Based on five case studies this thesis explored the practical challenges of this adaptation and dealt with the research question how those advanced manufacturing paradigms and methodologies can be integrated in the organisational context of NZ SMEs. Objective and result of this work was the development and validation of a transformation framework that enables NZ companies in a manufacture-to-order or one-of-a-kind environment to adapt the paradigm of Lean Production. Therefore firstly the characteristics of New Zealand with regards to its economy, geography, society and culture were explored. A special focus lied hereby on the NZ manufacturing sector. It could be shown in chapter 3.2.1.3 that there are cultural factors that might influence Lean transformations on the company level. During the data collection period in the case study companies, characteristics like for example the short-term orientation, a high performance orientation, a low uncertainty avoidance and an appreciation of egalitarianism could be confirmed and hence were considered in the development of the theoretical Lean transformation model.

As one further contextual factor the particularities of SMEs were analysed and potential effects on the implementation of an advanced manufacturing paradigm were discussed. The special role of the leadership and of the owner(s), the scarcity of resources, and the high variability in demand were identified as important influential factors and therefore found consideration by the elements of 'leadership and human resource development', 'Lean learning network', 'vertical and horizontal cooperation' and 'market focus' of the Lean transformation framework.

Looking at the initial hypothesis H1 (see Figure 76), the identified unique contextual factors led to some recommendations for the theoretical Lean transformation framework.

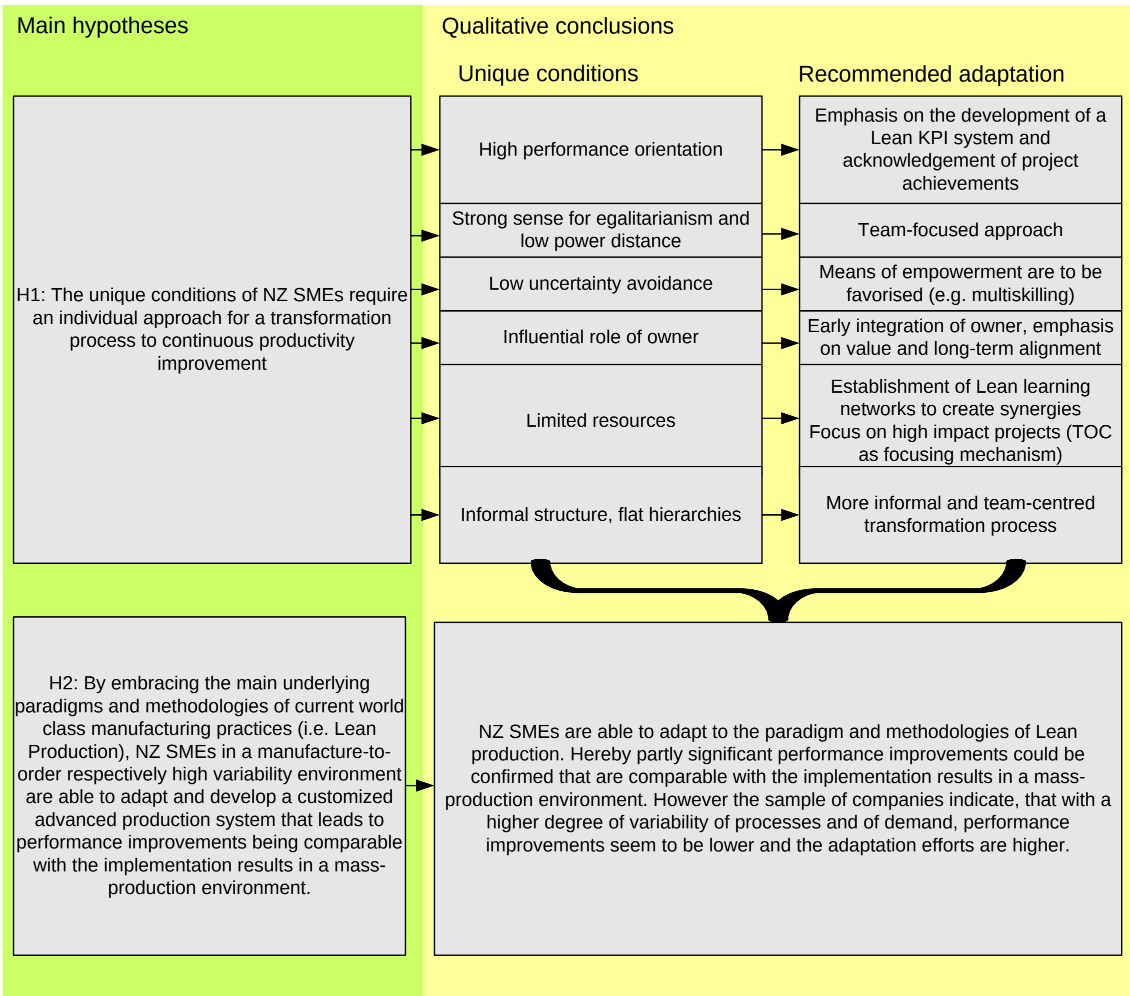

Figure 76: Reflection on research hypotheses

After the analysis of the contextual factors a comprehensive literature review led to the outline of the terms Toyotism and Lean Production as the current advanced manufacturing paradigm and its correspondent methodologies.

In order to validate the research hypothesis H2 (see Figure 76) and to develop the theoretical Lean transformation framework, it was explored in five case studies how NZ SMEs embrace Lean Production, which role the owners and other leaders have, and which effects on the performance can be achieved. In all five case studies the transferability and adaptability of Lean Production could be related to. Also the efficacy of the implementation of Lean methodologies could be widely confirmed by the demonstration of improvements in the dimensions productivity, speed/time, competitiveness, quality, people and organisation, and the added dimension of leadership. Within the sample there could not be found any significant evidence for the correlation of a specific leadership profile with the success of the Lean transformation. However it became clear that there is a negative correlation between the adaptability of Lean methodologies and the degree of variability of processes and of demand. The data also indicate, that the higher the degree of variability the lower are the improvements in the above mentioned performance dimensions.

The theoretical background of flow systems led to the central insight for the development of the Lean transformation framework: the ultimate state of a manufacturing system is an uninterrupted flow of material and information enabled by a synchronisation of all necessary resources. The elements of flow and synchronisation were consequently defined as the essential elements on the operational level of the manufacturing system. In order to achieve perfect flow, a correspondent operational structure which takes the function of an enabler and driver is to be established. The important Lean principles of reduction of variability (mainly by standardisation) and of continuous improvement were incorporated. The operational structure itself needs to be aligned with the long-term vision and objectives of the owner(s), which should, according to Lean principles, be directly derived from the value created out of the perspective of the customers. Further there were elements identified that can amplify Lean activities within the manufacturing system. In the context of NZ SMEs the establishment of a Lean learning network could be observed as beneficial.

7.1 Recommendations

Figure 76 already presented some recommendations that could be derived from particular characteristics of New Zealand and of SMEs. In this chapter further recommendations on how the adaptation of Lean principles and methodologies can be facilitated are summarised.

One more general recommendation is that the change initiative towards Lean Production needs to be more principle and philosophically driven rather than tool oriented. This seems to be in a high variability environment even more valid and more relevant than in the more traditional mass-production context as the case studies showed that a higher degree of adaptation of the methodologies is required. Therefore it is even more essential that the owners of SMEs understand and internalise the value and flow principle which both automatically lead to a better comprehension of the concept of waste elimination.

Because of the limited resources in SMEs and the consequently high day-to-day pressure, it is important to concentrate on only a few improvement projects. For the selection of the projects that lead to the greatest benefits, the methodology of VSM and other strategic techniques of TOC were successfully used in the case studies. As a good starting point, the implementation of 5S was used in all case studies and proved to create a good basis for further projects. 5S does not only directly result in time savings on the shop floor, it also greatly contributes to the organisational integration of the Lean principle of transparency and visualisation.

Another enabling element, observed in all case studies is the early creation of a communication structure at managerial and shop floor level of which scheduled meetings are a key element. Here it is advisable to incorporate the quality reporting system to foster a culture of systematically solving problems and the improvement suggestion system as a driver for the principle of continuous improvement.

With regards to a more detailed level of a Lean transformation and its process the researcher advocates a contingency perspective that supports a ‘one best way for each’ organisation approach rather than a ‘one best way for all’ approach.

7.2 Contributions to the research area

The contributions of this work to the research area are manifold. On the one hand the research methodology of a longitudinal action research case study proved to be very valuable as it was possible to collect over a period of more than three years data of one particular case. This led to a much more diversified understanding of a Lean transformation and the influence of the contextual factors. Further the observational case studies provided additional detailed information about Lean transformations in NZ SMEs. It became clear that the multifaceted high variability low volume environment creates from case to case different challenges in the adoption of Lean Production. Differences in lead time, the different usage of machinery, and differences in the complexity of the product are examples which forced companies to diversified approaches during the adaptation of product and process standardisation, the implementation of TPM and within the integration of production control mechanisms like Kanban.

On the other hand, to the best knowledge of the author, the combination and comparison of leadership profiles with data about the integration of Lean Production and with its effects on the performance represents a novel approach that opened up new perspectives and space for discussion how the role of leadership is related to continual change programs, particularly to the adaptation of Lean Production.

In addition the thesis provides valuable information and insights by concentrating on one national culture. Hence the thesis provides through the case studies an additional source for a practical validation of empirical data for the characteristics of culture and how this culture influences the adaptation of Lean Production.

For the exploration of the theoretical background, a unique presentation and comprehensive review of current advanced manufacturing paradigms and methodologies was created. Often, other research concentrates on one specific theme, e.g. on Lean or TQM or Six Sigma. Beyond that, a compilation of recent NZ research efforts in the area of manufacturing and best practices was portrayed.

Finally this thesis presents a Lean transformation framework and a two-levelled transformation process derived from the case studies and specifically tailored to the requirements of a high variability low volume environment. Thus, due to the practical nature of case study research, the developed Lean transformation framework can provide valuable guidance for NZ companies that intend to integrate Lean principles and methodologies and that are on their way to a learning and continuously improving organisation.

7.3 Future research

The thesis provides a Lean transformation framework customised to the requirements of NZ SMEs in a manufacture-to-order environment. The element of a Lean learning network has been identified as an influential driver during the transformational process. Hereby it facilitates the organisational learning process through the exchange of knowledge and experience and can create an environment of a 'healthy' competition where companies that are not necessarily in competition in their direct business can fuel and inspire each other through their continuous performance improvements and achievements. Further these Lean learning networks can serve out of the perspective of NZ government agencies and of consultants as a marketing instrument and communication channel that shows the advantages of Lean principles in a concrete and pragmatic way. As the importance and the positive contribution of these Lean learning networks are clear, the question of what is an optimal Lean learning network in the NZ context arises. In the opinion of the author, there is a need of research in how to facilitate a quick knowledge and know-how exchange in a Lean learning network. Lean learning networks could be also established in whole NZ supply chains, just to mention the dairy industry as one example.

This thesis mainly concentrated on the operational system of NZ SMEs, in other words on the manufacturing system. However out of a systemic perspective it is important to encourage more research how advanced paradigms and methodologies in the area of product development and innovation can be adopted and applied in NZ SMEs. In this context the researcher also noticed a lack of scientific knowledge about the characteristics of learning organisations with special regards to SMEs. How do SMEs create and conserve necessary information and knowledge, which learning mechanisms exist in SMEs and how can they be constructively used in change programs?

Beyond, the correlation of the leadership profiles with the success of Lean transformations indicates that the leadership style might have an influence on the transformation. However, the small sample size sets limits to the reliability of the results and correspondent interpretation is to be undertaken with care. In order to achieve the main research objectives of this thesis the time-intense approach of action research restricted the researcher to increase the sample. Further the number of New Zealand SMEs that are in a Lean transformation is very limited. The influence of a certain leadership style on the success of a Lean transformation certainly opens up new questions. However they go beyond the research objectives of the thesis at hand and require a different research design based on a larger sample. In the opinion of the author it is certainly a promising and extensive field for future research.

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9 Appendices

Appendix A List of publications

Stamm, M. L., & Neitzert, T. (2008). *Key Performance Indicators (KPI) for the implementation of Lean methodologies in a manufacture-to-order small and medium enterprise.* Paper presented at the 3rd World Conference on Production and Operations Management, Tokyo, Japan.

Stamm, M. L., & Neitzert, T. (2008). *Value Stream Mapping (VSM) in a manufacture-to-order small and medium enterprise.* Paper presented at the 3rd World Conference on Production and Operations Management, Tokyo, Japan.

Stamm, M. L., Neitzert, T., & Singh, D. P. K. (2009, 14/06-17/06). *TQM, TPM, TOC, Lean and Six Sigma – Evolution of manufacturing methodologies under the paradigm shift from Taylorism/Fordism to Toyotism?* Paper presented at the 16th International Annual EurOMA Conference, Gothenborg, Sweden.

Wagner, J. P., Stamm, M. L., Grigg, N., Mann, R., Neitzert, T. R., & Mohammad, M. (2009, 20/10). *Inside the black box: Field research methodologies of culture and continuous improvement.* Paper presented at the 13th Annual Waikato Management School Student Research Conference, Hamilton, New Zealand.

Appendix B Analysis of Lean transformation processes

The following tables show the transformation processes of selected authors. Each step was categorised according to what kind of constraint is supposed to be addressed. It also shows the separation of the processes into three chronological sections which was used in Table 25.

	Constraint	Womack (2003)		Constraint	Lane (2007)
1	lack of ownership/responsibility	1. Find a change agent	1	process variations	1. Improve your quality and stabilize the product and process quality
	lack of Lean knowledge	2. Get Lean knowledge		lack of transparency	2. Visualisation
	lack of urgency	3. Find a lever		measurement - results conflict	3. Metrics adaptation
	lack of Lean understanding	4. Map your value streams			
	lack of Lean understanding	5. Begin asap with kaikaku			
	lack of Lean understanding	6. Expand your scope			
2		1. Reorganize by product family	2	resistance constraint	4. Establishment of a management-auditing system
	lack of ownership/responsibility organizational constraint	2. Create Lean function		lack of knowledge of capacity utilization	5. Associate a time with each job
	improvement conflict	3. Devise a policy for excess people		lack of Lean understanding	6. Use of other Lean tools
	market constraint	4. Devise a growth strategy		lack of Lean understanding batch-queuing conflict	7. Value Stream Mapping, inventory reduction, push to pull, Kanban
	resistance constraint	5. Remove anchor-draggers			
	lack of momentum	6. Instill a “perfection” mind-set			
3	gap between accounting system and Lean system	1. Introduce Lean accounting	3	batch-queuing conflict	8. Layout improvements based on manpower improvements and machine productivity improvements
	resistance constraint	2. Relate pay to firm performance		address shift of constraint to support processes	9. Office Kaizen
	transparency	3. Implement transparency		lack between accounting system and Lean system	10. Product costing
	lack of shared vision / policy	4. Initiate policy deployment			
		5. Introduce Lean learning			
		6. Find right-sized tools			
	address shift of constraint to support/external processes	1. Apply these steps to your suppliers/customers			
	lack of shared vision / policy	2. Develop global strategy			
	lack of employee involvement	3. Transition from top-down to bottom-up improvement			

	Constraint	Liker (2003)		Constraint	Black (2007)
1	process variations	1. Process stabilization		lack of Lean knowledge	All levels in the plant must be educated in lead production philosophy
			1	lack of ownership/responsibility	Top down commitment is critical.
				measurement - results conflict	Top management understands that lean design will lead to financial decisions that are opposite to current management accounting practices
				measurement - results conflict	Select measurable parameters that will track the change.
2	batch-queuing conflict	2. Continuous flow		demand variations	Level and balance the manufacturing system (establish daily demand, takt time, balance output from suppliers, OPF in subassemblies
	local efficiency variations	3. Synchronous production		local efficiency variations	Design or reconfigure the manufacturing system, implement cells, standard work
			2	batch-size conflict	Setup reduction, SMED
				process variations	integrate Quality Control into the manufacturing system
				process variations	Integrate preventive maintenance
				local efficiency variations	integrate production control: link the cells, pull material to final assembly, Kanban
				local efficiency variations	integrate inventory control: reduce WIP that connect cells, expose problems and solve them
3	local efficiency variations	4. Pull authorization		address shift of constraint to support processes	Integrate suppliers
	demand variations	5. Balanced (level) production	3	process variations	Autonomation: autonomous control of quality within the cell, integrate automation which can detect defects
				address shift of constraint to support processes	Design the lean enterprise

	Constraint	Balle (2005)		Constraint	Green (2004)
1	process variations	1. Sort out as many quality problems as possible, as well as downtime and other instability problems, establish preventative design methodologies (FMEA, Poke-yoke,…) to prevent internal scrap.	1	lack of ownership/responsibility	1. Start with commitment from management
	batch-queuing conflict process variations	2. Continuous flow, which involves setting up the U-cells and making some market locations, avoiding variations in the operators' work cycle (work standards).		lack of ownership/responsibility	2. Management should appoint a c hange agent or a consultant
	process variations	3. Drive in the notion of standardized work and make sure the pace of work stabilizes through the various processes.		lack of Lean knowledge	3. Training
2	local efficiency variations	4. Start pulling, so that no parts or materials move forward until they're called for. Set up a perfect customer, look at the production scheduling and replace production weekly or daily orders with some type of frequent signal, like kanban cards.	2	lack of Lean understanding	4. Identify a pilot
				lack of Lean understanding	5. Construct a process map of the pilot area
	batch-queuing conflict	5. Even out the production **<u>flow</u>** by reducing the batch size, increasing the rhythm of internal deliveries, and levelling your internal demand.		lack of Lean understanding	6. Identify non-value activities in pilot area
3	lack of momentum	6. Continuously work at it with kaizen and quality circles.	3	lack of Lean understanding	7. Conduct the first Kaizen event exercise
		7. Pull resources out of your system and start again		measurement - results conflict	8. Measuring improvement

	Constraint	Hines et al. (2000)		Constraint	Bednarek & Niño's implementation framework (20
1	lack of Lean understanding	Understanding waste	1	Lack of Lean understanding Lack of transparency	Make a diagnosis
	lack of shared vision / policy	setting the direction		Lack of transparency Measurement - results conflict	Measure the performance
	lack of Lean understanding	understanding the big picture		Lack of transparency	Establish operative order (5S)
				lack of ownership/responsibility organizational constraint	Establish Management Order
			2	lack of Lean understanding	Establish families of parts
				batch-queuing conflict local efficiency variations lack of connectedness	Redesign the layout
2	lack of Lean understanding lack of transparency	Detailed mapping		demand variations	Plan and control the current production
	shift of constraint to customer/supplier	Getting suppliers and customers involved		lack of knowledge of capacity utilization	Estimate capacity of production
				demand variations lack of transparency	Simplify control
				batch-queuing conflict local efficiency variations	Caculate current lot size
				batch-queuing conflict	Reduce setup times
				process variations	Improve Maintenance
				process variations	Improve quality
3	lack of employee involvement resistance constraint measurement - results conflict	Checking the plan fits the direction & ensuring buy-in		batch-queuing conflict	Obtain minimum lot size / production stability
			3	local efficiency variations	Calculate time in accordance with demand
				local efficiency variations	Ensure capacity capable to reach Takt time
				process variations	Optimize work methods
				demand variations	Adapt work force to demand variation
				batch-queuing conflict	Start flow and control
				local efficiency variations	Implement pull system
				demand variations	Programm daily mix production
				address shift of constraint to support processes	Establish material supply system

	Constraint	Takeda (2006)
	Lack of transparency	The 6S
1	demand variations	Levelling and smoothing production
	batch-queuing conflict	One-piece (set) flow
	local efficiency variations	Flow production
	batch-queuing conflict	Reducing batch sizes
2	lack of transparency	Addresses and storage space
	local efficiency variations	Production in takt time
	process variations	quality management
	process variations	standardized labour
3	process variations	(Product-)Quality
	process variations	Machinery Maintenance
	local efficiency variations	Kanban

Appendix C Survey questionnaire for Lean obstacles

Challenges during implementation of LEAN in NZ

1.

This survey attempts to get to root causes of Lean implementation problems and obstacles. A similar survey has been conducted by the Lean Enterprise Institute (founder James Womack). Content of this survey has been adapted to NZ. By sending the completed survey back, both the results (of the LEI and of this) will be forwarded to you. Please try to get through all 5 of the Whys, but if you have to stop early, please submit your survey anyway. The key to "5 Whys" isn't necessarily how many "Whys?" you ask. It's the probing thought process that counts.
Results (made anonymous) of this survey may be published within a PhD research project at Auckland University of Technology (AUT).

EXAMPLE
The following questions follow the Lean "5 Whys" format. Please answer in an open ended format and take that answer into the next "Why?" Again, if you run out of responses, please skip to question #8. It is not necessary to go through all 5 Whys (in this or other cases), the point is to push your thinking to try to get to a "root cause."

Remember, you are not giving 5 separate answers, you are taking the first answer you give and taking it through a sequence of whys, as shown below.

Example:
"Supervisors didn't say anything to the people who stopped keeping tools where they belonged."

Why don't supervisors say anything? Example, "Supervisors didn't believe that 5S was important"

Why didn't they think 5S was important? Example, "The plant manager didn't get the message across to them"

Why didn't the plant manager think it was important? Example, "The plant manager didn't believe in lean."

Why didn't the plant manager believe in lean? Example, "He's more interested in getting product out the door."

1. How long have you already been on the LEAN journey?

- ☐ not started yet
- ☐ planning process and training
- ☐ less than 1 year
- ☐ 1-3 years
- ☐ 3-5 years
- ☐ > 5 years

2. What are the biggest obstacles to implementing LEAN in your organization? (evaluate ALL)

	I totally disagree	I slightly disagree	Neutral	I slightly agree	I totally agree
Backsliding	○	○	○	○	○
Budget Constraints	○	○	○	○	○
Employee resistance	○	○	○	○	○
Failure of past LEAN projects	○	○	○	○	○
Failure to overcome opposition	○	○	○	○	○
Financial value not recognised	○	○	○	○	○
Lack of crisis	○	○	○	○	○
Lack of discipline	○	○	○	○	○
The LEAN principles do not work in my case.	○	○	○	○	○
Current time pressure of the day-to-day business	○	○	○	○	○
Lack of implementation Know How	○	○	○	○	○
Lack of Top Management Support	○	○	○	○	○
Middle Management resistance	○	○	○	○	○
Supervisor resistance	○	○	○	○	○

Challenges during implementation of LEAN in NZ

Viewed as the "flavour of the month" ◯ ◯ ◯ ◯ ◯

3. (First why) Why is your TOP concern an obstacle to Lean? (Note: you can use one of the multiple choice obstacles from above or type your own)

4. Why is that the case? (2nd sequential why, answering why? to your first response)

5. Why is that? (3rd why)
(Note: You can skip to question #8 now or at any time you exhaust your "why?" responses.)

6. Why is that? (4th why)

7. Finally, why is that?
[That final "Why?" (or whichever you stopped on) should be closer to a root cause problem that you can address to help improve your Lean implementation success.]

8. The following demographic questions are optional, but will allow us to look for trends across these different dimensions, such as "do large companies have the same issues as smaller ones?" Jump to question #10 if you'd just like to leave your email address.

Challenges during implementation of LEAN in NZ

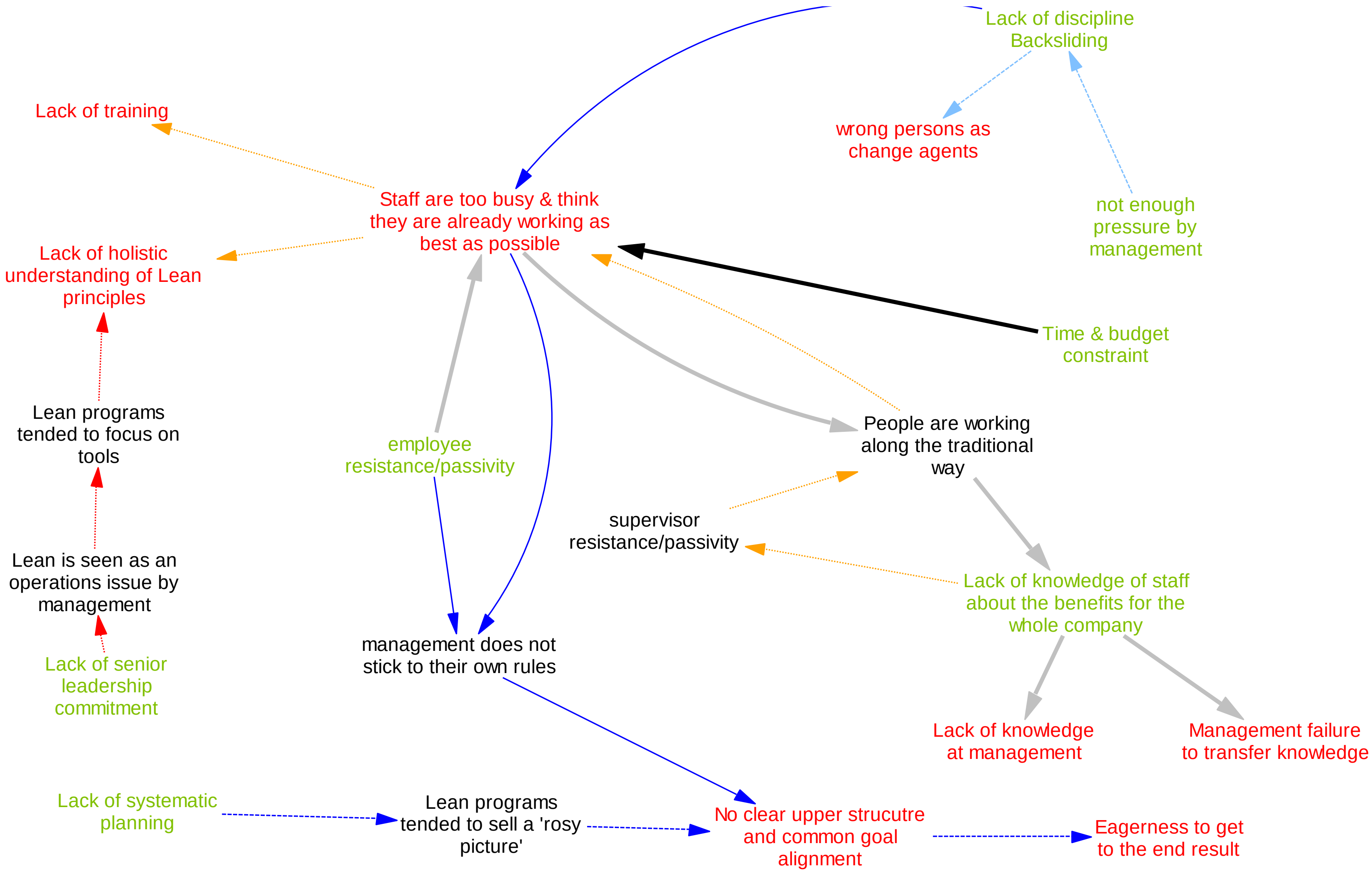
Your Level in the Organization?

- [ ] CEO/CFO, GM or other C-Level?
- [ ] Managing Director or owner
- [ ] Technical Professional
- [ ] Supervisor
- [ ] Front-line employee
- [ ] Support Staff
- [ ] Other

9. How many employees does your company have?

- [ ] 0-19
- [ ] 20-49
- [ ] 50-100
- [ ] 101-200
- [ ] 201-500
- [ ] > 500

Appendix D Survey about Lean obstacles: Results of the 5Why analysis



Appendix E Leadership questionnaire

Invitation to Participate in a Research Study
A Study of Leadership

What is the purpose of this study?
The study explores the role of **leadership** in a **Lean transformation** of NZ small and medium enterprises. The coherence between leader behaviours and the sustainability of a Lean implementation will be analysed.

What are the benefits? The benefits are that we will collect data and provide information on which leadership skills may contribute to a **sustainable Lean transformation** in your organization; the benefits to you are that you may be able to develop your leadership in a more efficient and effective manner in your business from reading the results of the study.

What happens in the study?
This questionnaire about leader behaviours will be forwarded to NZ small and medium enterprises that have already started a Lean implementation (AICHI members). The questionnaire should be ideally completed by **8-12 staff members** of various levels in every company. These samples from NZ companies will be compared with their success of the Lean transformations.

What are the discomforts and risks? There should be no physical discomforts; if you choose to participate you need to take the time to complete the questionnaire, usually about 20 minutes. There are no risks; your anonymity will be protected.

How is my privacy protected? The questionnaires will be completed anonymously; no individual data or company name will be collected. The affiliation of the company will only be identified by a letter (e.g. A) the researcher only knows. In case of any publications only these letters will be used. By completing this questionnaire you are indicating your consent to participate in this research.

Participant Concerns - Any concerns regarding the nature of this project should be notified in the first instance to Markus Stamm at 0211789400, mstamm@aut.ac.nz.

Approved by the Auckland University of Technology Ethics Committee on 30th of October, AUTEC Reference number 09/218

Section 1 — Leader Behaviours

Instructions: You are probably aware of people in your organisation or industry who are exceptionally skilled at motivating, influencing, or enabling you, others, or groups to contribute to the success of the organisation or task. We might call such people "outstanding leaders."

On the following pages are several behaviours and characteristics that can be used to describe **your** leaders. Each behaviour or characteristic is accompanied by a short definition to clarify its meaning. Rate the behaviours and characteristics of **your direct leader** on the following pages. To do this, on the line next to each behaviour or characteristic write the number from the scale below that best describe your leader(s).

SCALE
1= This behaviour or characteristic **is clearly contrary to your leader/supervisor's behaviour**.
2= This behaviour or characteristic **is somewhat contrary to your leader/supervisor's behaviour.**
3= This behaviour or characteristic **is developed at your leader slightly below average.**
4= This behaviour or characteristic **is developed at your leader at an average**.
5= This behaviour or characteristic **is developed at your leader slightly above average.**
6= This behaviour or characteristic **describes somewhat your leader/supervisor.**
7= This behaviour or characteristic **describes greatly your leader/supervisor.**

Section 1 questions start here.

	1-1	Diplomatic =	Skilled at interpersonal relations, tactful
	1-2	Evasive =	Refrains from making negative comments to maintain good relationships and save face
	1-3	Mediator =	Intervenes to solve conflicts between individuals
	1-4	Bossy =	Tells subordinates what to do in a commanding way
	1-5	Positive =	Generally optimistic and confident
	1-6	Intra-group competitor =	Tries to exceed the performance of others in his or her group
	1-7	Autonomous =	Acts independently, does not rely on others
	1-8	Independent =	Does not rely on others; self-governing
	1-9	Ruthless =	Punitive; Having no pity or compassion
	1-10	Tender =	Easily hurt or offended
	1-11	Improvement-oriented =	Seeks continuous performance improvement
	1-12	Inspirational =	Inspires emotions, beliefs, values, and behaviours of others, inspires others to be motivated to work hard
	1-13	Anticipatory =	Anticipates, attempts to forecast events, considers what will happen in the future
	1-14	Risk taker =	Willing to invest major resources in endeavours that do not have high probability of successful
	1-15	Sincere =	Means what he/she says, earnest
	1-16	Trustworthy =	Deserves trust, can be believed and relied upon to keep his/her word
	1-17	Worldly =	Interested in temporal events, has a world outlook
	1-18	Intra-group conflict avoider =	Avoids disputes with members of his or her group

	1-19	Administratively skilled =	Able to plan, organize, coordinate and control work of large numbers (over 75) of individuals
	1-20	Just =	Acts according to what is right or fair
	1-21	Win/win problem-solver =	Able to identify solutions which satisfy individuals with diverse and conflicting interests
	1-22	Clear =	Easily understood
	1-23	Self-interested =	Pursues own best interests
	1-24	Tyrannical =	Acts like a tyrant or despot; imperious
	1-25	Integrator =	Integrates people or things into cohesive, working whole
	1-26	Calm =	Not easily distressed
	1-27	Provocateur =	Stimulates unrest
	1-28	Loyal =	Stays with and supports friends even when they have substantial problems or difficulties
	1-29	Unique =	An unusual person, has characteristics of behaviours that are different from most others
	1-30	Collaborative =	Works jointly with others
	1-31	Encouraging =	Gives courage, confidence or hope through reassuring and advising
	1-32	Morale booster =	Increases morale of subordinates by offering encouragement, praise, and/or by being confident
	1-33	Arrogant =	Presumptuous or overbearing
	1-34	Orderly =	Is organised and methodical in work
	1-35	Prepared =	Is ready for future events
	1-36	Autocratic =	Makes decisions in dictatorial way
	1-37	Secretive =	Tends to conceal information from others
	1-38	Asocial =	Avoids people or groups, prefers own company
	1-39	Fraternal =	Tends to be a good friend of subordinates
	1-40	Generous =	Willing to give time, money, resources and help to others
	1-41	Formal =	Acts in accordance with rules, convention and ceremonies
	1-42	Modest =	Does not boast, presents self in a humble manner
	1-43	Intelligent =	Smart, learns and understands easily
	1-44	Decisive =	Makes decisions firmly and quickly
	1-45	Consultative =	Consults with others before making plans or taking action
	1-46	Irritable =	Moody; easily agitated
	1-47	Loner =	Works and acts separately from others
	1-48	Enthusiastic =	Demonstrates and imparts strong positive emotions for work

	1-49	Risk averse =	Avoids taking risks, dislikes risk
	1-50	Vindictive =	Vengeful; seeks revenge when wronged
	1-51	Compassionate =	Has empathy for others, inclined to be helpful or show mercy
	1-52	Subdued =	Suppressed, quiet, tame
	1-53	Egocentric =	Self-absorbed, thoughts focus mostly on one's self
	1-54	Non-explicit =	Subtle, does not communicate explicitly, communicates by metaphor, allegory, or example
	1-55	Distant =	Aloof, stands off from others, difficult to become friends with
	1-56	Intellectually stimulating=	Encourages others to think and use their minds; challenges beliefs, stereotypes and attitudes of others

Section 2 — Leader Behaviours (Part II)

Instructions: This section follows the same format as that of Section 1. You should again rate your leader behaviours and characteristics on the following pages.

SCALE
1= This behaviour or characteristic is **clearly contrary to your leader/supervisor's behaviour**.
2= This behaviour or characteristic is **somewhat contrary to your leader/supervisor's behaviour.**
3= This behaviour or characteristic is **developed at your leader slightly below average.**
4= This behaviour or characteristic is **developed at your leader at an average**.
5= This behaviour or characteristic is **developed at your leader slightly above average.**
6= This behaviour or characteristic **describes somewhat your leader/supervisor.**
7= This behaviour or characteristic **describes greatly your leader/supervisor.**

	2-1	Cautious =	Proceeds/performs with great care and does not take risks
	2-2	Organised =	Well organized, methodical, orderly
	2-3	Cunning =	Sly, deceitful, full of guile
	2-4	Informed =	Knowledgeable; aware of information.
	2-5	Effective bargainer =	Is able to negotiate effectively, able to make transactions with others on favourable terms
	2-6	Egotistical =	Conceited, convinced of own abilities
	2-7	Non-cooperative =	Unwilling to work jointly with others
	2-8	Logical =	Applies logic when thinking
	2-9	Status-conscious =	Aware of others' socially accepted status
	2-10	Foresight =	Anticipates possible future events
	2-11	Plans ahead =	Anticipates and prepares in advance
	2-12	Normative =	Behaves according to the norms of his or her group

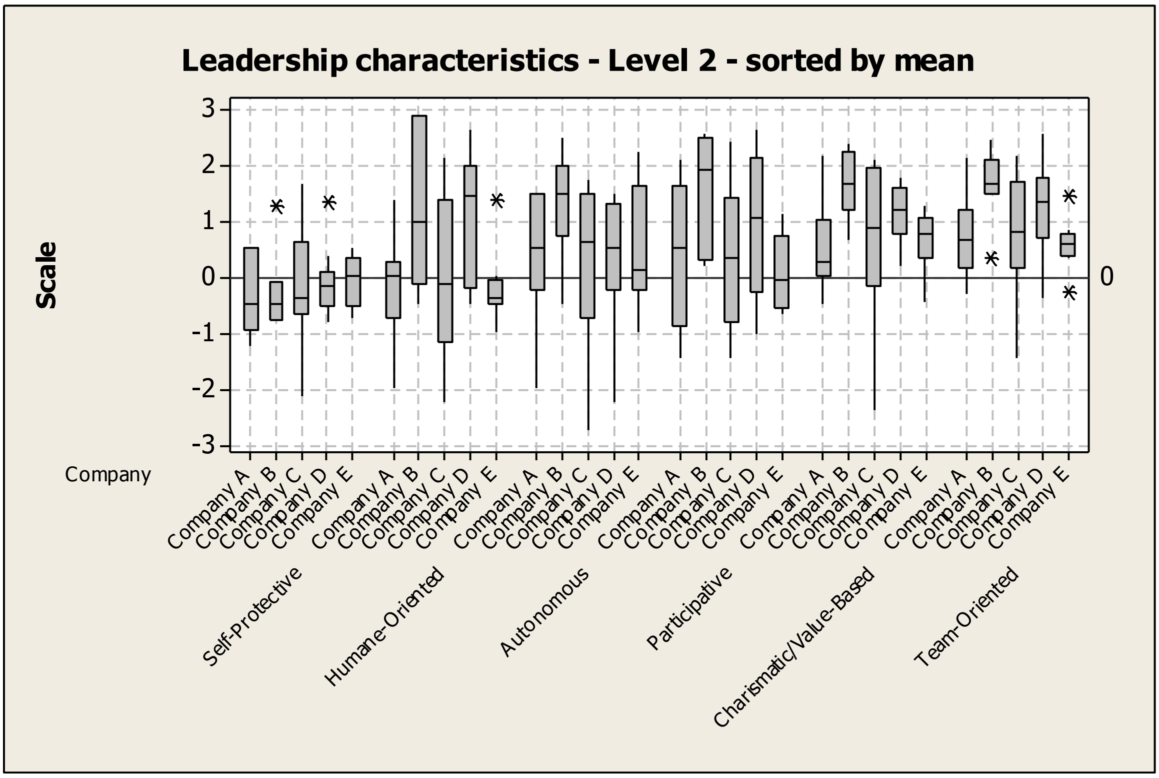
	2-13	Individually-oriented =	Concerned with and places high value on preserving individual rather than group needs
	2-14	Non-egalitarian =	Believes that all individuals are not equal and only some should have equal rights and privileges
	2-15	Intuitive =	Has extra insight
	2-16	Indirect =	Does not go straight to the point, uses metaphors and examples to communicate
	2-17	Habitual =	Given to a constant, regular routine
	2-18	Self-effacing =	Presents self in a modest way
	2-19	Able to anticipate=	Able to successfully anticipate future needs
	2-20	Motive arouser =	Mobilizes and activates followers
	2-21	Sensitive =	Aware of slight changes in other's moods, restricts discussion to prevent embarrassment
	2-22	Convincing =	Unusually able to persuade others of his/her viewpoint
	2-23	Communicative =	Communicates with others frequently
	2-24	Excellence-oriented =	Strives for excellence in performance of self and subordinates
	2-25	Procedural =	Follows established rules and guidelines
	2-26	Confidence builder=	Instils others with confidence by showing confidence in them
	2-27	Group-oriented =	Concerned with the welfare of the group
	2-28	Class conscious =	Is conscious of class and status boundaries and acts accordingly
	2-29	Non-participative =	Does not participate with others
	2-30	Self-sacrificial =	Foregoes self-interests and makes personal sacrifices in the interest of a goal or vision
	2-31	Patient =	Has and shows patience
	2-32	Honest =	Speaks and acts truthfully
	2-33	Domineering =	Inclined to dominate others
	2-34	Intra-group face saver =	Ensures that other group members are not embarrassed or shamed
	2-35	Dynamic =	Highly involved, energetic, enthused, motivated
	2-36	Coordinator =	Integrates and manages work of subordinates
	2-37	Elitist =	Believes that a small number of people with similar backgrounds are superior and should enjoy privileges
	2-38	Team builder =	Able to induce group members to work together
	2-39	Cynical =	Tends to believe the worst about people and events
	2-40	Performance-oriented =	Sets high standards of performance
	2-41	Ambitious =	Sets high goals, works hard
	2-42	Motivational =	Stimulates others to put forth efforts above and beyond the call of duty and make personal sacrifices

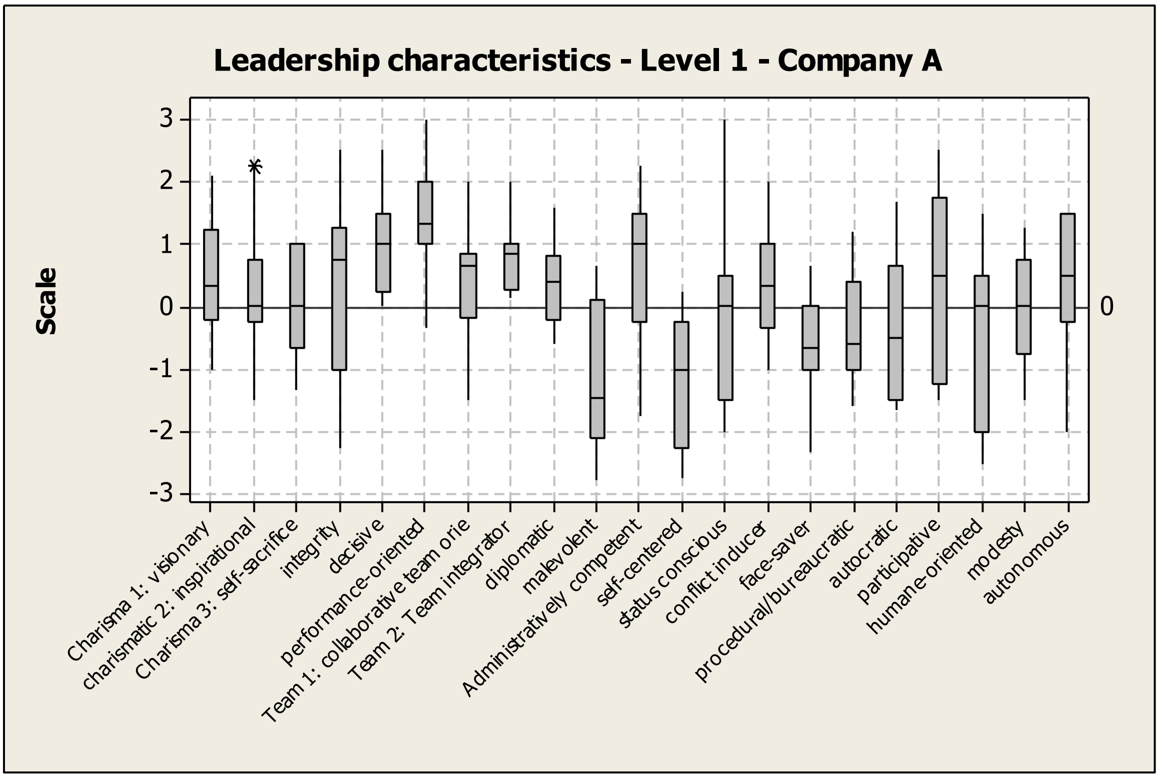
	2-43	Micro-manager =	An extremely close supervisor, one who insists on making all decisions
	2-44	Non-delegator =	Unwilling or unable to relinquish control of projects or tasks
	2-45	Avoids negatives =	Avoids saying no to another when requested to do something, even when it cannot be done
	2-46	Visionary =	Has a vision and imagination of the future
	2-47	Wilful =	Strong-willed, determined, resolute, persistent
	2-48	Ruler =	Is in charge and does not tolerate disagreement or questioning, gives orders
	2-49	Dishonest =	Fraudulent, insincere
	2-50	Hostile =	Actively unfriendly, acts negatively toward others
	2-51	Future-oriented =	Makes plans and takes actions based on future goals
	2-52	Good administrator=	Has ability to manage complex office work and administrative systems
	2-53	Dependable =	Reliable
	2-54	Dictatorial =	Forces her/his values and opinions on others
	2-55	Individualistic =	Behaves in a different manner than peers
	2-56	Ritualistic =	Uses a prescribed order to carry out procedures

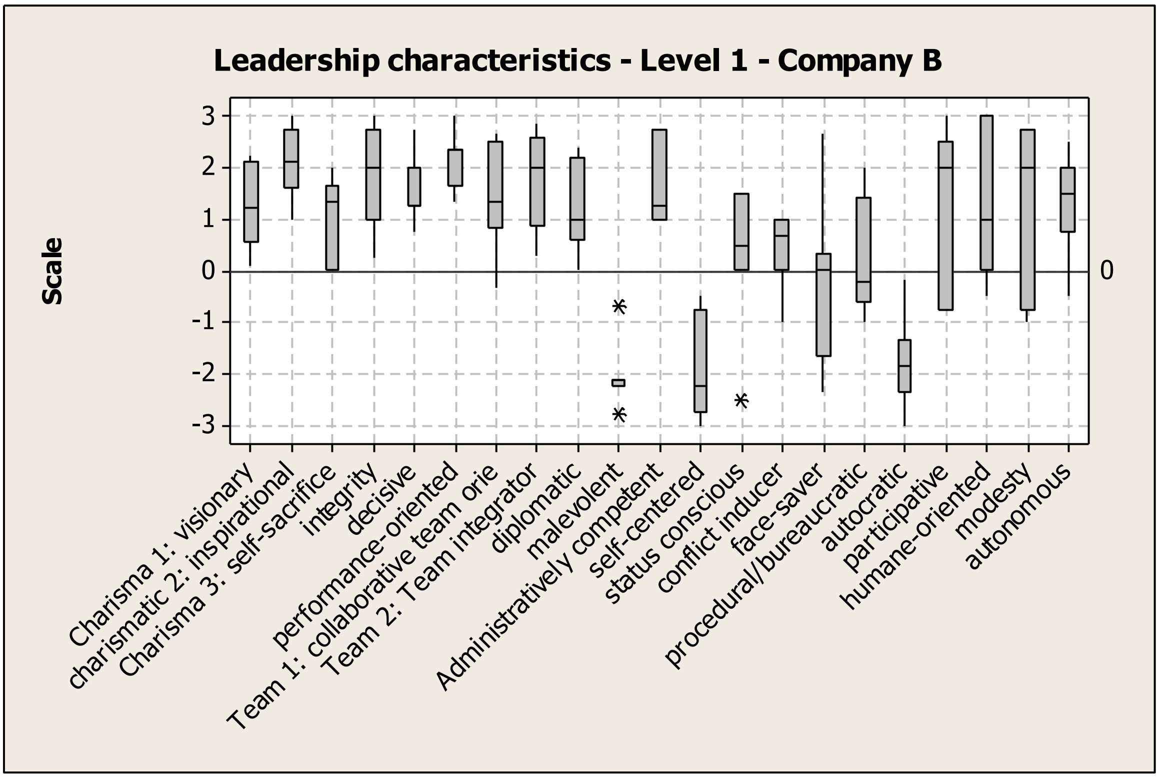
We truly appreciate your willingness to complete this questionnaire, and to assist in this research project.

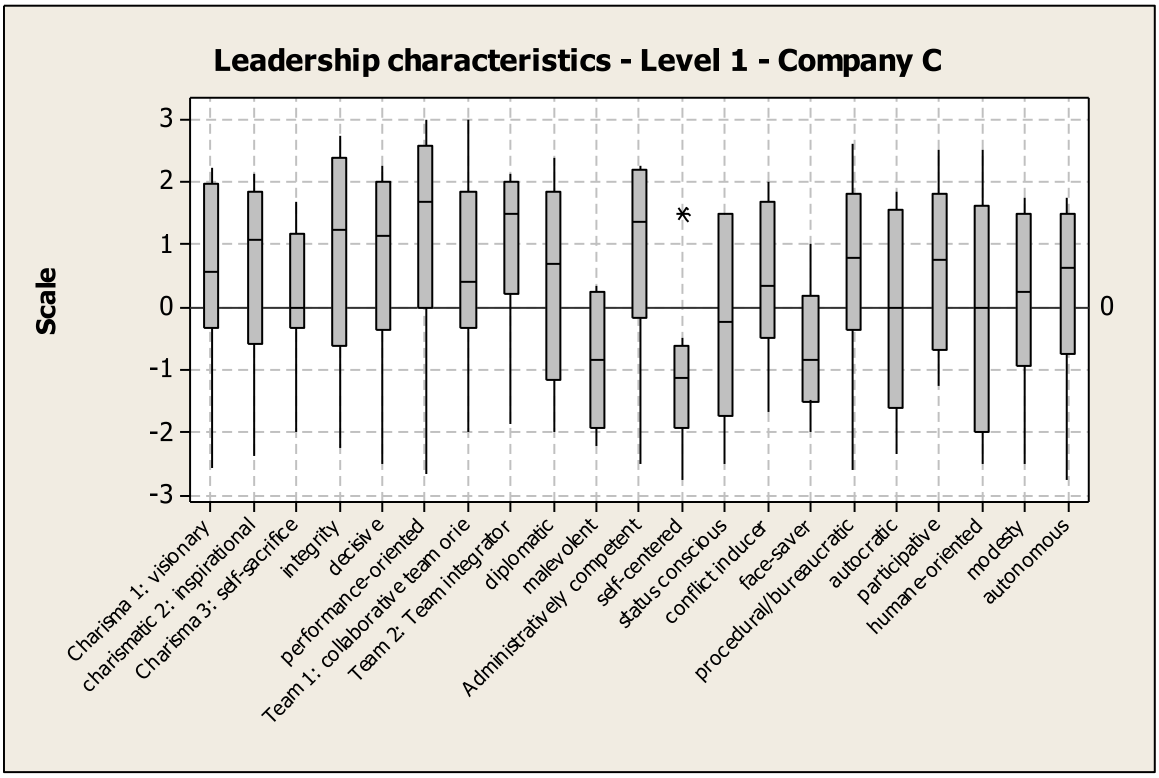
Appendix F Analysis of leadership characteristics

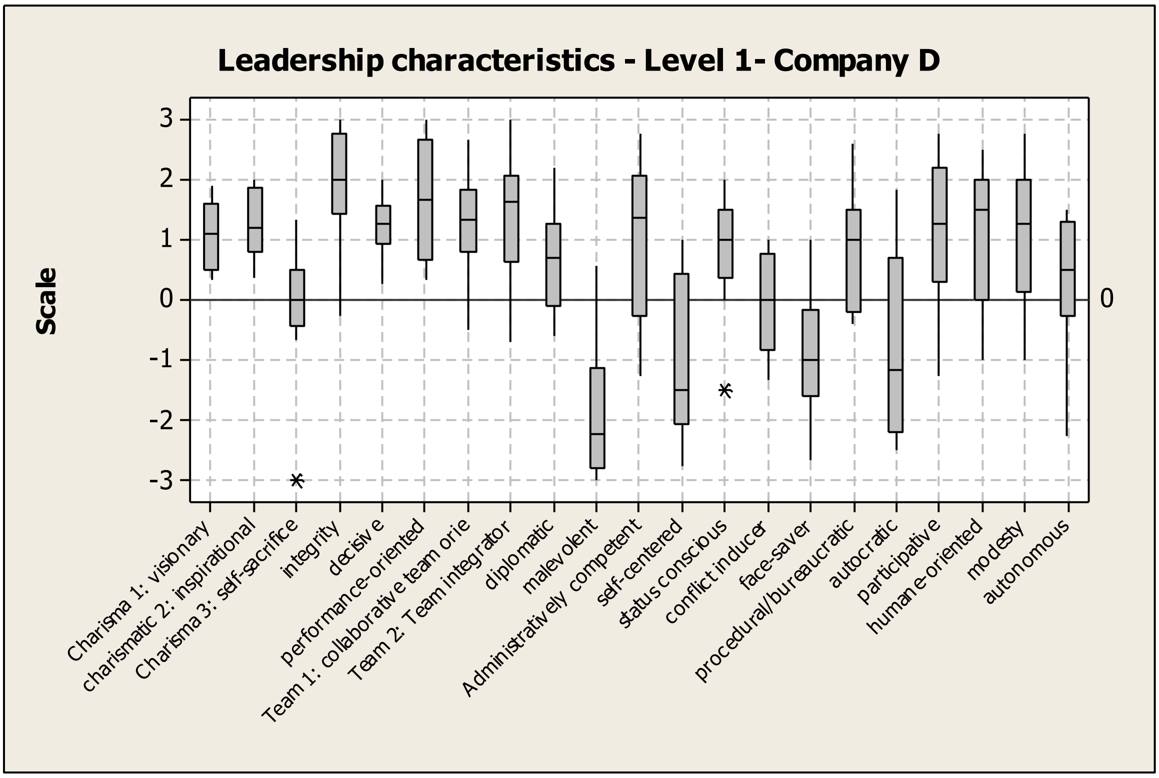
All results are based on a minimum of eight questionnaires in each case study.

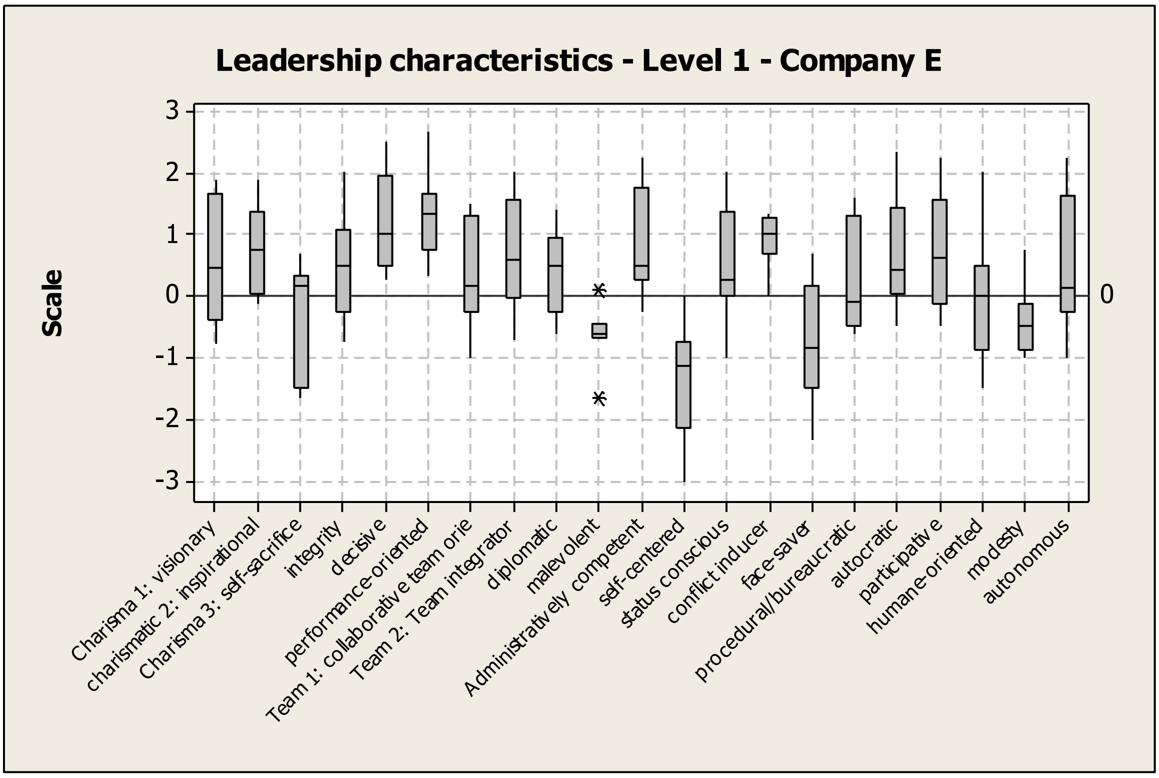





Leadership characteristics - Level 1 - Company B
Scale
3
2
1
0
-1
-2
-3
0
Charisma 1: visionary
charismatic 2: inspirational
Charisma 3: self-sacrifice
integrity
decisive
performance-oriented
Team 1: collaborative team orie
Team 2: Team integrator
diplomatic
malevolent
Administratively competent
self-centered
status conscious
conflict inducer
face-saver
procedural/bureaucratic
autocratic
participative
humane-oriented
modesty
autonomous


Leadership characteristics - Level 1 - Company C
Scale
3
2
1
0
-1
-2
-3
0
Charisma 1: visionary
charismatic 2: inspirational
Charisma 3: self-sacrifice
integrity
decisive
performance-oriented
Team 1: collaborative team orie
Team 2: Team integrator
diplomatic
malevolent
Administratively competent
self-centered
status conscious
conflict inducer
face-saver
procedural/bureaucratic
autocratic
participative
humane-oriented
modesty
autonomous


Leadership characteristics - Level 1- Company D
Scale
3
2
1
0
-1
-2
-3
0
Charisma 1: visionary
charismatic 2: inspirational
Charisma 3: self-sacrifice
integrity
decisive
performance-oriented
Team 1: collaborative team orie
Team 2: Team integrator
diplomatic
malevolent
Administratively competent
self-centered
status conscious
conflict inducer
face-saver
procedural/bureaucratic
autocratic
participative
humane-oriented
modesty
autonomous


Leadership characteristics - Level 1 - Company E
Scale
3
2
1
0
-1
-2
-3
0
Charisma 1: visionary
charismatic 2: inspirational
Charisma 3: self-sacrifice
integrity
decisive
performance-oriented
Team 1: collaborative team orie
Team 2: Team integrator
diplomatic
malevolent
Administratively competent
self-centered
status conscious
conflict inducer
face-saver
procedural/bureaucratic
autocratic
participative
humane-oriented
modesty
autonomous

Appendix G Questionnaire: Evaluation of Lean transformation status: Part A General

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Evaluation of Lean transformation status

Part A: General

Company ____________________

1 When have you started the first Lean initiative?

____

2 How many employees does your company have?

____

3 Overall the expectations on using lean principles you had were

not at all fulfilled	hardly fulfilled	partially fulfilled	largely fulfilled	entirely fulfilled

4 Which of following aspects have you considered during your Lean rollout (within the first year)? How critical do you think those aspects are? (1: totally unimportant, 2: unimportant, 3: doesn't matter, 4: important, 5: essential)

		Yes	No	Critical?
4.1	Enrolement of stakeholders for commitment			
4.2	Development of a crisis as leverage point			
4.3	Dismisal of managers/staff who resist to upcoming change			

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4.4	Pressure by senior management to get regular progress reports			
4.5	Owner/ Managing Director(s) are actively driving and supporting Kaizen and change			
4.6	Having experienced and good change agent			
		Yes	No	Critical?
4.7	Creating a Future state and vision of our ideal Lean enterprise			
4.8	Beginning as soon as possible with an important and visible activity			
4.9	Create shop floor commitment by involving operators through empowered Kaizen teams			
4.10	Clear communication of the transformation process, development of a shared vision			
4.11	Development of internal Lean leader/experts			
4.12	Freed up resources by productivity gains are reinvested into further continuous improvements			
4.13	Implementing rewarding policies and an incentive system to support successful Lean projects			
4.14	Creating a Lean promotion office/function for training			
4.15	Teaching Lean thinking and Lean skills to everyone			
4.16	Get staff members to be formally trained/certified in Lean methodologies			
4.17	Establish a Lean Key performance indicator system / system to monitor Lean progress			
4.18	Early involvment of product design - design to manufacture - exchangeability of parts			
4.19	Reveal problems and determine preventive measures / using the PDCA methodology			

Appendix H Evaluation of Lean transformation status: Part B Methodologies and techniques

A comparative study of Lean transformation,
current performance and leadership

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Evaluation of Lean transformation status

Part B: Methodologies and techniques

Company ____________________

No		not implemented at all	implementation pilot/in progress	daily sustainable use in the whole factory/organization	with/without adaptation	Comments (Why not implemented, what are adaptations, how long has been the implementation in progress)
1	self-inspection					
2	process orientation					
3	Standardization of processes					
4	quality circle / regular meetings					
5	preventative maintenance					
6	team empowerment					
7	5 S					
8	Andon Board					
9	Planning Boards					
10	coupling points					
11	5 Why's & 5M					
12	PDCA cycle					
13	QC Tools					
14	improvement suggestion system					

A comparative study of Lean transformation, current performance and leadership

AUT ENGINEERING

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Evaluation of Lean transformation status

Part B: Methodologies and techniques

Company ______________________________

No		not implemented at all	implementation pilot/in progress	daily sustainable use in the whole factory/organization	with/without adaptation	Comments (Why not implemented, what are adaptations, how long has been the implementation in progress)
15	Value Stream Mapping					
16	Pull					
17	Takt					
18	Kanban / standardized material buffers					
19	levelled production / heijunka / synchronization of lot sizes					
20	supplier involvement					
21	One piece flow / flow					
22	Shojinka					
23	u-shaped layout					
24	SMED / setup reduction					
25	Andon line					
26	autonomation					
27	Poka-Yoke					

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Evaluation of Lean transformation status

Part B: Methodologies and techniques

Company ____________________

No		not implemented at all	implementation pilot/in progress	daily sustainable use in the whole factory/organization	with/without adaptation	Comments (Why not implemented, what are adaptations, how long has been the implementation in progress)
28	Chief Engineer System					
29	A3					
30	Hoshin Kanri					
31	Gemba walk					
32	Hansei					
33	Leader as trainer					
34	discipline					
35	long term philosophy and vision					
36	customer first					
37	daily accountability process					
38	Lean KPI system					
39	rewarding policies					
40	waste elimination					
41	concurrent engineering					

A comparative study of Lean transformation,
current performance and leadership

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Evaluation of Lean transformation status

Part B: Methodologies and techniques

Company ______________________________

No		not implemented at all	implementation pilot/in progress	daily sustainable use	in the whole factory/organization	with/without adaptation	Comments (Why not implemented, what are adaptations, how long has been the implementation in progress)
42	workplace management						
43	Buffer management / bottleneck management / Theory of constraints approach						
44	Six Sigma - reduction of variation						
45	Continuous people development						
46							

not implemented at all	Methodology or technique has not been implemented. Please list reasons, if possible.
implementation pilot/in progress	The value of the technique is acknowledged, first tool-focused pilots have been started. First gains can be seen (performance improvement, improvement of motivation and involvement, etc.)
daily sustainable use	Technique has been adapted and constantly improved, and is widely spread in the organization. The underlying principles are driving the purpose and development of this technique. The technique is embedded in an integrated system of Lean methodologies.

Note:

The Lean techniques of the questionnaire are aggregated with regards to the elements of the Lean transformation framework. Figure 60 in chapter 4.8.2 shows the aggregated level.

Results:

Analysis of questionnaire, part B

No.	Technique	Methodology / Lean element	Rating Case study A	Case study B	Case study C	Case study D	Case study E
1	self-inspection	Process standards	3	2	3	2	3
2	process orientation	Process standards	2	2	3	2	2
3	Standardization of processes	Process standards	2	2	3	2	2
4	quality circle / regular meetin	Continuous Improvement & Problem solving	3	3	3	3	3
5	preventative maintenance	TPM, preventive maintenance	2	2	3	3	1
6	team empowerment	H&R	2	2	3	3	3
7	5 S	5S & visual controls	3	2	3	3	2
8	Andon Board	5S & visual controls	1	3	1	3	1
9	Planning Boards	5S & visual controls	2	3	3	3	3
10	coupling points	Flow, synchronization and takt, heijunka	2	2	3	2	1
11	5 Why's & 5M	Continuous Improvement & Problem solving	2	2	3	2	2
12	PDCA cycle	Continuous Improvement & Problem solving	2	2	3	2	1
13	QC Tools	Continuous Improvement & Problem solving	1	2	3	2	2
14	Improvement suggestion sys	Continuous Improvement & Problem solving	3	3	3	3	2
15	Value Stream Mapping	VSM	2	2	2	2	1
16	Pull	Pull, Kanban and standardized inventory buffers	2	2	3	2	2
17	Takt	Flow, synchronization and takt, heijunka	1	1	3	2	2
18	Kanban / standardized material buffers	Pull, Kanban and standardized inventory buffers	1	2	3	2	2
19	levelled production / heijunka / synchronization of lot sizes	Flow, synchronization and takt, heijunka	2	2	3	2	1
20	supplier involvement	Supplier development	1	2	3	2	2
21	One piece flow / flow	Flow, synchronization and takt, heijunka	2	1	3	2	2
22	Shojinka	Flow, synchronization and takt, heijunka	3	3	1	3	2
23	u-shaped layout	Flow, synchronization and takt, heijunka	1	2	1	1	1
24	SMED / setup reduction	Quick changeover (SMED)	2	2	3	2	1
25	Andon line	Continuous Improvement & Problem solving	1	1	1	3	1
26	autonomation	Continuous Improvement & Problem solving	1	1	1	2	1
27	Poka-Yoke	Continuous Improvement & Problem solving	1	2	3	3	2
28	Chief Engineer System	Lean Product Development	2	1	1	3	3
29	A3	Lean Product Development	1	1	2	1	1
30	Hoshin Kanri	H&R	1	2	1	2	1
31	Gemba walk	Continuous Improvement & Problem solving	3	3	1	3	2
32	Hansei	Continuous Improvement & Problem solving	2	3	1	3	2
33	Leader as trainer	H&R	2	2	3	3	2
34	discipline	H&R	2	3	3	2	2
35	long term philosophy and visi	H&R	2	3	3	3	2
36	customer first	H&R	2	3	3	3	3
37	daily accountability process	H&R	2	3	3	3	2
38	Lean KPI system	KPI-System	2	3	3	2	2
39	rewarding pollicies	H&R	1	2	1	2	2
40	waste elimination	Continuous Improvement & Problem solving	2	3	3	3	2
41	concurrent engineering	Lean Product Development	1	1	2	1	1
42	workplace management	Process standards	2	3	3	3	2
43	Buffer management / bottleneck management / Theory of constraints approach	Theory of Constraints	2	2	1	2	1
44	Six Sigma - reduction of variation	Six Sigma	1	1	1	1	1
45	Continuous people development	H&R	2	3	3	2	3

1: Methodology or technique has not been implemented.

2: The value of the technique is acknowledged, first tool-focused pilots have been started. First gains can be seen (performance improvement, improvement of motivation and involvement, etc.)

3: Technique has been adapted and constantly improved, and is widely spread in the organisation. The underlying principles are driving the purpose and development of this technique. The technique is embedded in an integrated system of Lean methodologies.

Results for the aggregated level (see above table for the affiliation)

This data was used for the correlation analysis in chapter 4.8.3.

	Company A	Company B	Company C	Company D	Company E	Mean
Six Sigma	1.00	1.00	1.00	1.00	1.00	1.00
Lean Product Development	1.33	1.00	1.67	1.67	1.67	1.47
Theory of Constraints	2.00	2.00	1.00	2.00	1.00	1.60
VSM	2.00	2.00	2.00	2.00	1.00	1.80
Flow & synchronization	1.80	1.80	2.20	2.00	1.60	1.88
Quick changeover (SMED)	2.00	2.00	3.00	2.00	1.00	2.00
Supplier development	1.00	2.00	3.00	2.00	2.00	2.00
Pull & standardized inventory buffers	1.50	2.00	3.00	2.00	2.00	2.10
Continuous Improvement & Problem solving	1.91	2.27	2.27	2.64	1.82	2.18
TPM, preventive maintenance	2.00	2.00	3.00	3.00	1.00	2.20
H&R development	1.78	2.56	2.56	2.56	2.22	2.33
KPI-System	2.00	3.00	3.00	2.00	2.00	2.40
5S & visual controls	2.00	2.67	2.33	3.00	2.00	2.40
Process standards	2.25	2.25	3.00	2.25	2.25	2.40

The data of the table above is illustrated as a graph in Figure 60.

Appendix I Evaluation of Lean transformation status: Part C Transformation history

Lean evaluation: Part C

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Evaluation of Lean transformation status

Part C: Transformation history Company ____________

Methodologies

Techniques

Tools

People/leader/responsibilities/training

time

Constraint

Other / comments

Approved by the Auckland University of Technology Ethics Committee on 30th of October, AUTEC Reference number 09/218

Appendix J Evaluation of performance development: Part D

Performance measures

Example for the data collection of KPIs of case studies

AUT ENGINEERING — CAMTEC Centre for Advanced Manufacturing Technology

October 2008

Part D: Performance Measures

Company: Company D

Dimension		Quality		Competitiveness			Productivity / Costs					Speed / Time		People / Organisation			Leadership
Measure		(1) Internal Quality	(2) Quality to the Customer	(3) Cutomer Satisfaction External	(4) Market Share	(5) Growth in Revenue	(6) Labor Productivity	(7) Asset Productivity	(8) Inventory Turns	(9) Energy	(10) Profitability	(11) Total Lead Time	(12) On Time Delivery	(13) Safety	(14) Customer Satisfaction Internal	(15) Employee Involvement	(16) Leadership Involvement
YEAR	2008										N/A						
YTD		10%	0.030%	98%	55%		60%		6	7%		28	95%	49	522	22	
LY		10%	0.040%	97%	51%	23%	73%	82%	5.5	9%		23	64%	105	524	15	
LY - 1			0.009%	95%	50%	61%	75%	77%	5.2	59%				40			
LY - 2			0.013%		42%	-44%		82%		11%				32			
LY - 3			0.012%		40%	8%		80%									
LY - 4																	
LY - 5																	

In the table below, please provide the metric that your company uses to track results in each of the above categories. Provide as many years as possible. In the text box below, please provide the formulas used to calculate each metric and any explanation necessary to understand it and how it works. Additionally the target for each metric for each period might be useful. Note: In case you cannot provide any measures for a dimension, you can comment it: not available, confidential.

Formulas and Explanations:

1. number of process improvement forms raised versus total number of jobs created
2. number of rework jobs raised versus total number of jobs
3. 100% - percentage of customer lost because of poor performance
4. comparing like product manufacturers
5. percentage of growth of retail sales
6. chargeable hours versus quoted hours, utilization of labour
7. owner's equity to total assets, return on investment
8. costs versus inventory
9. percentage of electricity usage, relative increase
10. Profitability improved according to Managing Director, but no further details.
11. lead time average in factory production
12. percentage of jobs delivered on time
13. number of reported accidents
14. days taken as sick leave, unpaid leave, leave not including annual leave
15. average number of new improvement suggestions per month
16. N/A

Color code: improvement (green) · stagnation, difficult to judge (yellow) · clear deterioration (red)

Results: KPI matrix

	(1) Internal Quality	(2) Quality to the Customer	(3) Cutomer Satisfaction External	(4) Market Share	(5) Growth in Revenue	(6) Labor Productivity	(7) Asset Productivity	(8) Inventory Turns	(9) Energy	(10) Profitability	(11) Total Lead Time	(12) On Time Delivery	(13) Safety	(14) Customer Satisfaction Internal	(15) Employee involvement	(16) Leadership Involvement	Sum
Company A	1	1	0	0	0	1	0	0	0	0	1	0	1	0	1	1	7
Company B	1	1	1	1	1	1	1	0	0	1	1	1	0	1	1	1	13
Company C	1	1	1	1	1	1	0	1	0	1	1	1	0	1	1	0	12
Company D	0	1	1	1	0	-1	0	1	0	1	0	1	0	0	1	0	6
Company E	0	0	0	0	-1	-1	0	0	0	0	0	0	1	1	1	1	2
Total	3	4	3	3	1	1	1	2	0	3	3	3	2	3	5	3	40

The values of the sum (last column, grey shaded) is used for the correlation analysis in chapter 4.8.3.

For the analysis of a negative or positive trend, linear regression was mainly used. In cases (B, C, D) the absolute values were not provided and the researcher had to rely on the company internal information with regards to the determination of the trend.

Legend:

"1": Positive trend

"0": No clear trend

"-1": Negative trend

Appendix K Explanation of variability matrix

Legend for the variability matrix

	less than 10%	between 10% and 50%	50%-100%	>100%
volume variability, monthly	1	2	3	4

mix variability	a= fraction of product to total demand with the percentage	b	c	d

		1	2	3	4
processing variability	work content / cycle time	difference between products less than 5%	difference between products between 5%-30%	30%-50%	more than 50%

Table 4-2 Classification of processing variability

Characteristic	1	2	3	4
Work content (cycle time)	Difference between products less than 5%.	Difference between products 5% to 30%[210].	Difference between products 30% to 50%.	Difference between products more than 50%.
Job of operator (tasks performed and in-process sequence)	Mostly the same (even when dealing with different products).	Somewhat different (1 or 2 operations change or are skipped).	Different (some operations and/or their sequence change).	Very different (most operations and/or their sequence change).
Products repeat	Product offering is very limited and there is no customization. All products repeat and operators can easily become familiar with them.	Product offering is limited with very minor customization possible. All products repeat (a few may have minor changes), but some are made infrequently.	Wider product offering with some customization possible. The majority of products repeat.	High customization, with the majority of products being made only once.

route variability

Table 4-3 Classification of route variability

Characteristic	1	2	3	4
Number of routes	One route.	Few routes (2 or 3 max).	Some routes (about 10 or less).	Many routes.
Interaction between routes	Zero interactions.	Low interaction (only material handling is shared).	Some interaction (1 or 2 processes shared).	High interaction (many processes shared).
Frequency of route changes	Steady routes (very few changes, once every few years if at all).	Mostly steady routes (few changes).	Frequently changing routes.	Constantly changing routes.

The evaluation was conducted based on available company data and by interviewing staff of the case studies.

Evaluation

	Demand variability				
	volume variability, monthly	mix variability			
		a	b	c	d
Case study A	3	0	0.25	0.25	0.5
Case study B	3	0	0.5	0.25	0.25
Case study C	2	0.25	0.5	0.25	0
Case study D	4	0	0.2	0.6	0.2
Case study E	4	0	0	0.25	0.75

	Task variability							
	processing variability				route variability			
	cycle time	job of operator	products repeat	average	number of routes	interaction between routes	frequency of route changes	average
Case study A	4	3	4	3.7	3	4	3	3.3
Case study B	2	3	3	2.7	2	3	2	2.3
Case study C	2	2	2	2.0	2	2	2	2.0
Case study D	3	2	3	2.7	3	3	3	3.0
Case study E	3	3	4	3.3	4	3	4	3.7

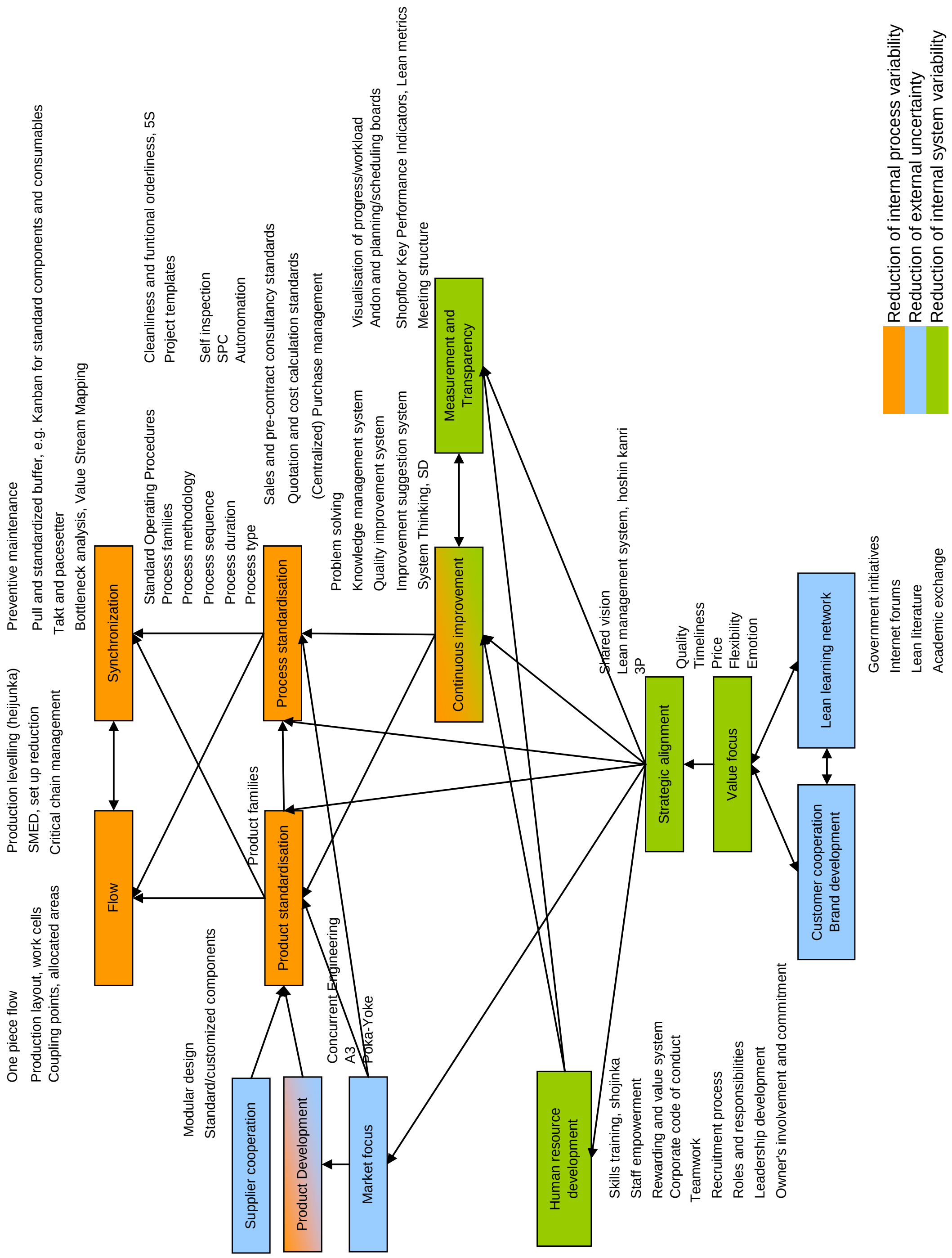
Results

	Demand variability	Task variability	Sum of Variability
Case study A	6.3	7.0	13.3
Case study B	5.8	5.0	10.8
Case study C	4.0	4.0	8.0
Case study D	7.0	5.7	12.7
Case study E	7.8	7.0	14.8

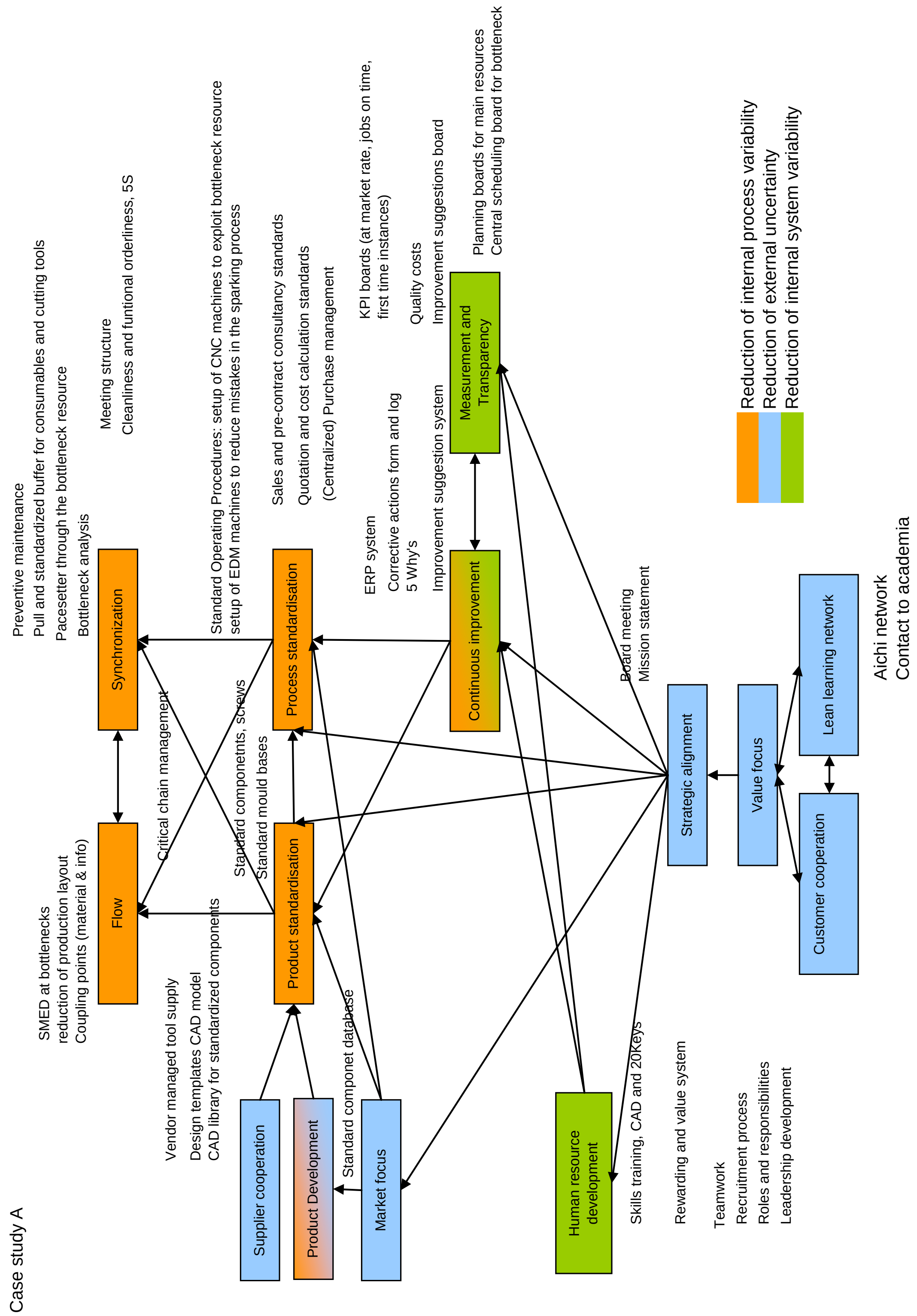
The sum of variability (see table above) was used for the correlation analysis in chapter 4.8.3.

Appendix L Lean transformation framework

Overview of Lean transformation framework: Variability perspective



Overview of Lean transformation framework: Case study A



Overview of Lean transformation framework: Case study E