Environment, resource, and surroundings based dynamic project schedule model for the road construction industry in New Zealand

Abstract:

Purpose: The purpose of this paper is to provide insights into the environment, resources, and surroundings factors to develop a system dynamic model of dynamic project scheduling that aids on-time project delivery by reducing the project delay for the road construction industry in New Zealand (NZ).

Design/methodology/approach: This study adopted a narrative inquiry methodology that involved semi-structured interviews/ expert opinion and systematic literature review data to determine the environment, resources, and surroundings factors to develop a system dynamic model of dynamic project scheduling that aids on-time project delivery by reducing the project delay for the road construction industry in New Zealand. The data were analysed by using descriptive analysis, Likert scale, and thematic analysis techniques to understand the relationship of these factors to propose a system dynamic model.

Findings: This study concludes that weather, pandemic, material, geotechnical, and disaster factors highly influence while other factors such as equipment shortage, breakdown, design error, labour, and event had mixed impact on the dynamic scheduling that aids on-time project delivery. The proposed system dynamic model can enhance the understanding of factors affecting dynamic scheduling. The model can reduce the uncertainty and scheduling errors during the planning phase and aid in the lesser scheduling modification during the execution phase. In practice, this study will be helpful for road contractors to understand the environment, surroundings and resource in-control and out-of-control factors, overcome road construction delays, reduce cost, and aid in stakeholder management and sustainable development.

Limitations: Systematic literature review is limited to English literature. The limitations of a Semi-structured interview and small sample size **are** acknowledged.

Originality: For the first time in a road construction dynamic project scheduling model that collectively included and linked environment, resource & surroundings factors to determine the in-control and out-of-control factors for an organisation. The novelty in the paper is provided by the inclusion of the events, disasters, and pandemics' influence on dynamic scheduling in the NZ road construction industry for the first time.

Key Words: Road Construction; Construction; Dynamic Scheduling, scheduling, Project scheduling

1. Introduction

Fahmy et al. (**2020**) stated that most of the construction projects are executed under dynamic environments and subjected to various real-time events. These real-time events can be described as daily weather change, availability of competent operators, raw materials availability, machinery breakdowns, community events, traffic management, and geological data but are not limited to these events. It becomes difficult for project managers to effectively schedule and control road construction projects by employing traditional predictive scheduling techniques **such as the Critical Path Method (CPM) and Project Evaluation and Review Technique (PERT)** which do not consider real-time events as a

factor influencing schedule. Hence, there exists a need to develop a dynamic model that is different from traditional models and helps to deal with these real-time events during the execution and planning stage of the project.

According to Strang (2019), last year project failures and road project delays resulted in half of the project delivery rate than what was expected by the New Zealand Transport Authority (NZTA). In recent years project failures caused delays and large damage in NZ due to scheduling errors, for example:

Project Failure 1 - Wellington's Transmission Gully Project: Recent example of road construction project failure is wellington's transmission gully highway project. The initial project cost for the transmission gully project was 850 million NZD. However, due to unforeseen events, this project is running behind schedule and over budget by 191 million NZD (Maxwell, 2020). The main reasons behind these delays were underestimated scheduling of earthwork required and the weather forecast Strang (2019). Maxwell, (2020) states that NZTA has decided to wipe off the previous penalty fees for the delays. NZTA decided to enforce NZD16000/ day late penalty fees for the delays based on a new specified date. The 16000 daily rates are equating to 496000/month (Maxwell, 2020).

Project Failure 2 - Kapiti Expressway Repair Project: Another example of road construction project failure was the Kapiti Expressway Repair Project. This project is currently running nine months behind schedule and the main reason for this delay is the scheduling error concerning bad weather and equipment's availability (Fallon, 2020). The cost and penalty of these delays are yet to be established by NZTA (Fallon, 2020).

The above examples of roading project failures relate to real-time events. Due to the dynamic nature of these projects, predictive optimal scheduling techniques become neither feasible nor optimal (Fahmy et al., **2020**).

Recently New Zealand (NZ) government has announced a 5.3 billion NZD worth road construction budget (Coughlan, 2020), which means in future there is going to be a huge demand for road construction work. If these construction projects are well managed from start to finish, the road construction industry can provide a positive result for the NZ economy. To control and manage the projects effectively there is a need to develop a scheduling model based on the real-time critical characteristics that affect the project's success.

The underlining reason and aim for this research are to identify and analyse these dynamic real-time events (referred to as characteristics) and then develop a scheduling model. The following was the research question:

- What are the critical factors that interlink to each other to influence project dynamic scheduling delivery in the NZ road construction industry?

This study aims to identify the various environmental, resource and surrounding factors that influence project dynamic scheduling through systematic literature review (SLR) and semi-structured interviews (SSI). The results are presented in a system dynamic mapping.

2. Literature review

The road construction industry in NZ is considered as one of the strategic industry sectors which employs over 170,000 people which equates to 7.6% of the workforce (Ministry of Business Innovation and Employment (MBIE, 2013). Road construction and the sealing industry is the fifth largest sector in NZ. “NZ roading network made of approximately 63,000kms sealed road and 32000 km of unsealed roads, owned by both local and central government” value of this roading network is estimated to be approximately NZ $79.2 billion (MBIE, 2016). Yet, only a few kinds of research are undertaken done to improve the project delivery rate. For NZ, Transport Authority roading industry project delays are one of the biggest problems. Project delay occurs on almost every single project due to scheduling errors (Fallon, 2020). Some projects are delayed by a single event, others caused by several factors with no involvement or cause for any parties. A successful project is kept within budget and delivered at the prescribed schedule. This requires successful project scheduling and good decision-making skill (Ahmed et al., 2003). To achieve this project managers often use different project scheduling techniques. The project scheduling techniques are discussed below.

2.1 Project scheduling

Project scheduling is a tool used by the Project Managers (PM) and Project Engineers (PE) to track project progress, create a list of critical activities, the time required to achieve the desired objective and the resource requirement to accomplish the objective. To manage the project efficiently PM needs to distribute and communicate project information effectively (Kumar, 2005). That is where the project schedule becomes handy for the project team. To prepare an effective project schedule there are several scheduling techniques available.

The earliest scheduling technique adopted the Gantt chart (invented in 1917 by Henry Laurence Gantt) that uses the graphical representation of the project schedule which helps the project manager in coordinating and tracking the specific task (Rouse, 2007). Gantt chart represents the project activities, the time required to achieve those activities, resource allocation and the percentage completion of the project (Kumar, 2005). In the 1950s Critical path method technique was developed during 1950s by DuPont, which was based on identifying the critical and non-critical path of activities in the project to avoid any time delays. In the CPM technique activity duration is based on a single point assumption and mostly based on the experience of the scheduler, which had a high chance of failure (East, 2015). Program evaluation and review technique, a variation of CPM later evolved. PERT techniques time estimation is calculated from an average of three-time estimates such as optimistic activity duration, pessimistic activity duration and most likely activity duration (Ballesteros-, 2017). Subsequently, the Critical chain method (CCM) was adopted in project scheduling that aimed to avoid any time delays due to uncertainty on critical activity (Valikoniene, 2015). According to Herroelen et al. (2002), the CCM scheduling technique identifies the critical project chain, has flexible activity dates or milestones, avoids multitasking, determines the precedence and resource-based baseline schedule, accommodates uncertainties during the time buffer and prepares a predictive schedule based on **an e**arly start and early finish dates.

The scheduling models were affected by various delays that led to the development of digital-based planning schedules such as Smart Construction Planner based on Building Information Modeling (BIM) information system and Lean management of construction processes Guerriero et al. (2017). Lean uses the Kanban concept to trigger a material replenishment from off-site to on-site based on real-time demand to tackle Inefficiency and waste in the construction logistics and subsequent delays caused (Zenga et al., 2019). The construction industry by the early 2010s adopted Dynamic Scheduling (DS) which emphasized updating, checking, and revising the schedule based on real-time occurrences in the project (Fahmy et al., 2020) The DS works on a predefined rescheduling strategy, policy and rescheduling techniques (Fahmy et al., 2020). DS has been based on reactive; proactive and predictive-reactive scheduling approaches (Fahmy et al., 2020). The current DS models use cost, time, resources, cash flow and weather, (Vanhoucke, 2013, Fahmy et al., 2020, Kerkhove and Vanhoucke and Murugasan, 2017).

Scheduling is a well-researched area and much research had been done on when and how to schedule a road construction or maintenance. However, there is considerably less literature on Road construction project scheduling. Hosseininasab et al. (2018) suggested a multi-objective integrated model for selecting, scheduling, and budgeting road construction projects, Mohammadi et al. (2020) stated Lean approach leads to significant gains in road maintenance projects and Ding et al. (2004) had published dynamic scheduling specific to road construction Machines. A prerequisite to the creation of good dynamic schedules is the consideration of various factors and estimating the project outcome when the factor affects the project. (Kerkhove and Vanhoucke, 2017). Many researchers have identified factors affecting construction projects scheduling, for example, Nouban and Ghaboun (2017) identified the financial situation, resources, weather, change orders, understanding of project scope, communication, prices escalation, payment delays and staff experience. The factors may be in-control or out-of-control of an organization.

Based on the literature review most of the scheduling techniques either in context to the construction industry, manufacturing industry or any other sector are all about preparing the project schedule based on 2 main assumptions, static environment, and full resources availability. Also, in most of the scheduling techniques, it is assumed that the actual physical work duration will stay the same and activities will run on a predefined track during the execution and lack the involvement of real-time events. These techniques are not practical to apply in a road construction project. In a real-world project, managers and planners need better project schedule tools to counter these real-time events (e.g., daily weather, machinery breakdown, community events and geological data). None of the present and past project scheduling techniques accommodates these real-time events in road construction project scheduling. This paper attempts to identify and link the in-control and out-of-control environment (weather, disaster, and geotechnical), resources (labour, material, equipment) and surroundings (events and pandemic) factors to dynamic scheduling.

3. Research methodology

The research adopted a Narrative inquiry methodology under constructivist epistemology, idealism ontological position and interpretivism theoretical framework. Based on Creswell and Creswell (2017), the narrative inquiry methodology is followed where the researchers relied on participants' views to construct the DS system dynamic model for the road construction industry. The process steps are shown in Figure 1**.** The first step is the research problem which includes identifying the problem, the importance of the research, identifying objectives and organisation of the research plan. Once the research problem is identified, the next step of this research is the SLR, which included international studies and literature related to the scheduling factors in the construction industry. The review included relevant materials from textbooks, professional journals, research papers, and reports developing the framework for the aim of the study. This review led to the preparation of vital information to develop the SSI with local field experts.

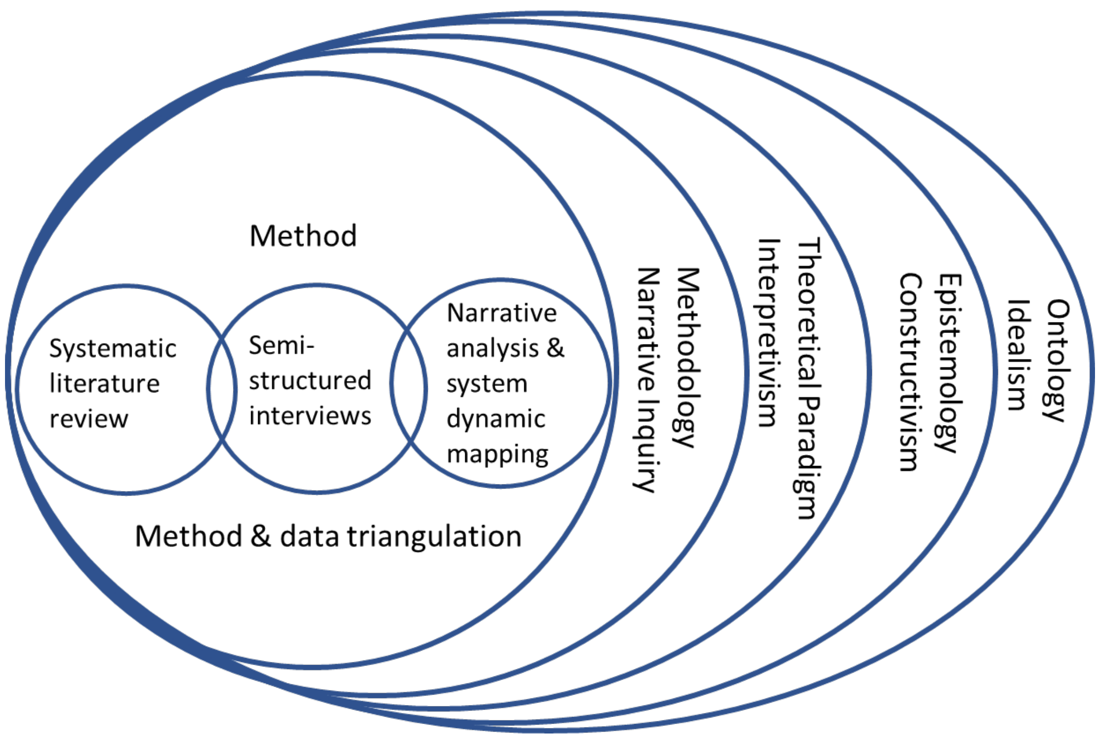

Figure 1 The research methodology framework

The SLR was conducted on articles spanned over 18 years. A total of 502 articles were shortlisted based on the keyword search and 165 articles were relevant to identify the Delay factors. The steps in the SLR are shown in Table 1 below. The method of research, the span of articles, and the percentage contribution of articles based on the country is shown in Figure 2 below.

Table 1: Steps of the SLR.

Process		Individual steps	Analysis resulting	No. of articles
Search process and data collection	1	Identification of keywords: (Road Construction; Construction; Dynamic Scheduling, scheduling, Project scheduling)	Previous research and reviews	-
	2	Development of exclusion and inclusion criteria, methodology	Quality of the article and limitations	12
	3	Specification of relevant search engines and execution of the search (5 engines: GOOGLE SCHOLAR, A WEB OF SCIENCE, EMERALD, ELSEVIER, SCIENCE DIRECT, SCOPUS)	Title and abstracts (automated based on keywords)	152,711
	4	Development of A-, B-, and C-list:		
		C-list	Keywords (dynamic scheduling, project scheduling, scheduling, road work scheduling) w.r.t civil and road construction search	18,502
		B-list	Title and abstracts that referred to construction-related scheduling	502
		A-list	Full text (strong focus construction-scheduling factors)	165
		Narrative inclusions in this article	Full text	89
Descriptive and thematic analysis	5	Descriptive categories (e.g., journals covered, methodologies applied)	Scheduling in construction	94
	6	Deductive and inductive categories to identify central themes and interpret results	Definition of schedule, its influence on construction phases, and correlation of critical factors that affect road construction	94

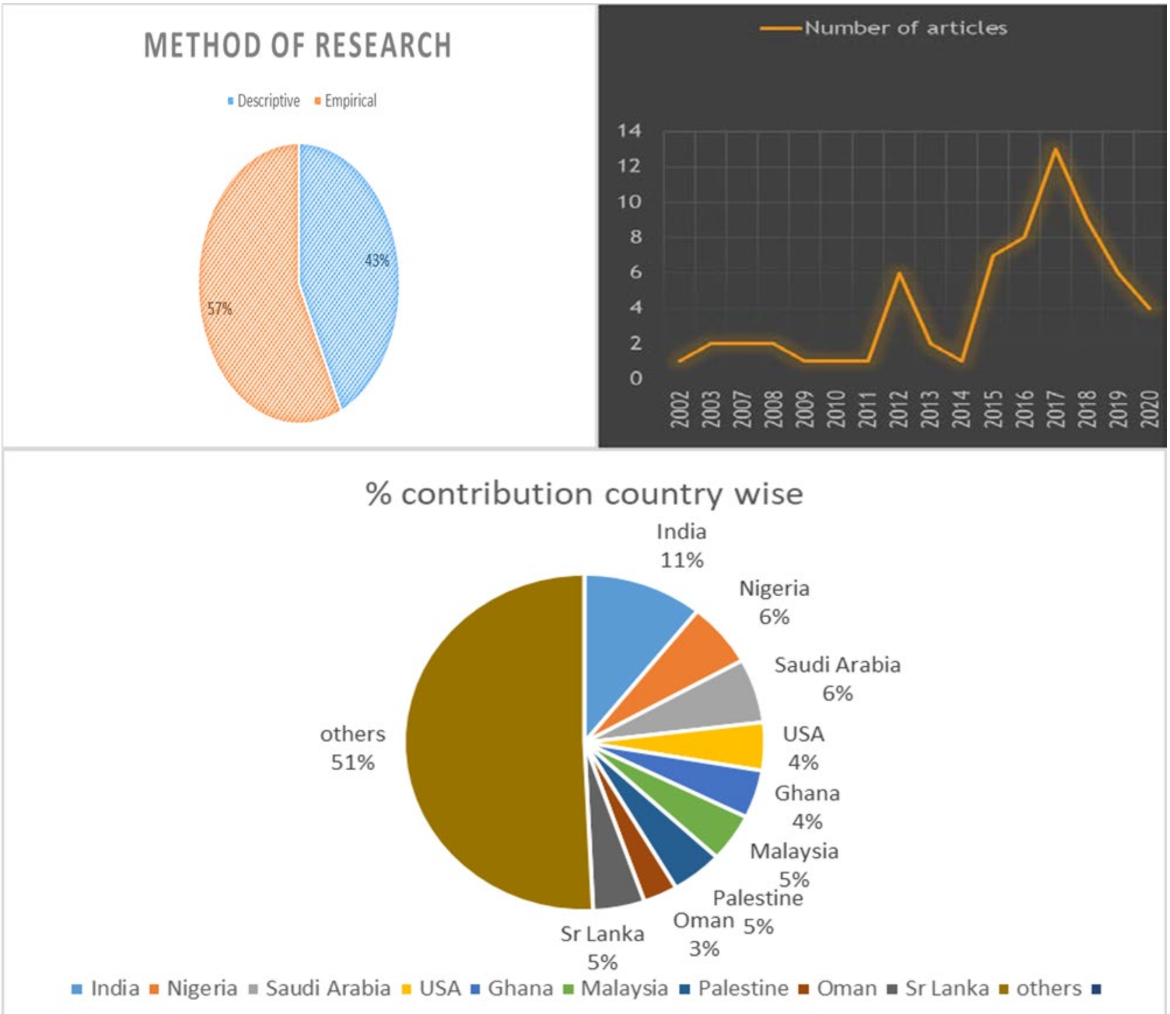

Figure 2: method, Span, and country wise percentage contribution of articles

The identified factors based on the SLR were used to frame the SSI questions to seek expert views. Based on SLR the factors such as Weather, Material, Equipment shortage, Geotechnical data, Design error, labour, Machinery breakdown, Disaster, and Events were prompted appropriately during the interview. The next step was to categorise the identified factors into critical groups based on the characteristics of the project revolves, such as critical factors (CF), critical time (CT), and critical resources (CR). The SSI was in-depth semi-structured open-ended question interactive one-on-one interviews were conducted in isolation and were recorded in interview notes. The interview questions were as below:

- What type of work are you involved in?
- How many years of experience do you have in Road construction?
- What are the factors that influence road construction scheduling in NZ?
- Can you rate the identified factors and rate based on High, Medium, and Low?
- Can you brief the reasons and your experience on the influence of the various factors on Road construction scheduling?
- Any other factors you would suggest that needs to be considered during road construction scheduling?
- Can you brief the interlink between the various factors you identified?

The fourth step in the research includes conducting SSI with representatives of three major contractors in the NZ Northern region, this followed procedures of Carter et al., (2014). The volunteers' detail is kept confidential. The selection criteria included the ability to speak English and experience in the road construction industry in New Zealand. This step helped to collect data and analyse the relevance of an SLR in context with the NZ road industry and understand the impact and interlink of each identified factor. 7 contractors were approached, and 3 contractors volunteered. The contractors interviewed during this study had a minimum of 10 years and a maximum of 25 years of work experience in the NZ road construction industry. The contractors had a combined experience of 53 years and were chosen from a particular region to gain knowledge on similar working conditions. During **SSI**, following Carter et al., (2014) open conversations were held with respondents. One-on-one in-depth interviews yield relevant knowledge on human experiences on chosen topics (Fontana and Frey, 2000).

Next, the SSI data was subjected to narrative analysis by decoding the interview notes. Thematic analysis was used for analysing the data collected during an SSI with local field experts. Following Braun and Clarke (2006), this analysis worked on the following six steps such as data familiarization, initial data, theme search, reviewing the research theme, defining, and naming themes and producing the final report. Different statistical tools were used, such as descriptive statistics–method of means and percentage to understand the correlation of the data with the research objective apart from three-point Likert scale, which labelled response relevance as high, medium, and low. 1-4 scale classed as low, 4-7 considered as a medium, and 7-10 scale considered being high, another useful tool used is the correlation analysis, which helped to study the relationship between the different variables. Using correlation analysis, system dynamic mapping was used to develop an interlink between factors based on the critical characteristics. Subsequently, following Dianat et al. (2021) a causal loop diagram was developed.
The quality of the research design is based on the concept of reliability and validity (Bakker, 2018). This research followed Dingwall et al. (1998)'s approach, the design quality was based on triangulation to achieve reliability. According to Duffy (1987), triangulation is the method to compare the results of two or more data collection methods, e.g., comparing the result of an interview with different respondents/researchers. This research used multiple methods, SLR and working field experts' opinions to achieve reliability and validity.

4. Result and analysis

The SLR is presented in Table 2 below. The identified factors from the SLR are grouped into the following categories:

i. Weather

ii. Material shortage
iii. Geotechnical data errors
iv. Skilled labour shortage
v. Events
vi. Equipment shortage
vii. Breakdowns
viii. Design errors

Table 2: factors affecting construction scheduling

Sl.no.	**Author**	**Weather**	**Material Shortage**	**Geotechnical**	**Labour**	**Events**	**Equipment Shortage**	**Breakdowns**	**Design Errors**
1	Alfakhri, A.Y.Y et al. (2017)	✓	✓			✓	✓	✓	✓
2	Thapanont, T. et al. (2018)	✓	✓		✓		✓	✓	✓
3	Ahmed, S. M. et al. (2003)	✓	✓	✓	✓	✓	✓		✓
4	Aibinu, A., & Jagboro, G. (2002)	✓	✓		✓		✓	✓	
5	Akinsiku, O. E., & Akinsulire, A. (2012)	✓	✓	✓	✓	✓	✓		✓
6	Al Hadithi, B. I. (2018).	✓	✓	✓	✓	✓	✓	✓	
7	Alaghbari, W. et al. (2007)	✓	✓				✓	✓	✓
8	Hasmori, M.F. et al. (2018)	✓	✓		✓		✓	✓	✓
9	Al-Hazim, N., & Abusalem, Z. (2015)	✓	✓		✓		✓		✓
10	Alotaibi, N. et al. (2015).	✓	✓				✓	✓	✓
11	Amoatey, C. T., & Ankrah, A. N. (2017).			✓	✓				✓
12	Atibu Seboru, M. (2015).	✓	✓	✓	✓	✓	✓	✓	✓
13	Aziz, R. F., & Abdel-Hakam, A. A. (2016).		✓		✓	✓	✓	✓	✓
14	Baharum, Z. et al. (2020)	✓	✓						
15	Bordoli, D. W., & Baldwin, A. N. (1998)		✓	✓	✓		✓		✓
16	Bustan, B. et al. (2015)				✓				✓
17	Multashi, A.T., & Salgude, R.R. (2015)			✓	✓		✓	✓	✓
18	Doloi, H. et al. (2012)		✓	✓	✓		✓		✓
19	Edison, J., & Singla, H. K. (2020)	✓	✓		✓				✓

Sl.no.	Author	Weather	Material Shortage	Geotechnical	Labour	Events	Equipment Shortage	Breakdowns	Design Errors
20	Egila, A. E. et al. (2020)	✓	✓			✓	✓	✓	✓
21	Ekanayake, E., & Perera, B. (2016).	✓			✓		✓		✓
22	Elawi, G. S. et al. (2016)		✓		✓				✓
23	Shahsavand, P. et al. (2018)	✓	✓	✓	✓	✓	✓	✓	✓
24	Fahmy, A. et al. (2020)				✓				✓
25	Frimpong, Y., & Oluwoye, J. (2003)	✓	✓	✓	✓	✓	✓	✓	
26	Hakami, W. G., & Yousif, M. I. (2014)	✓	✓		✓		✓	✓	✓
27	Hossen, M. M. et al. (2015)	✓	✓	✓	✓	✓	✓		✓
28	Islam, M. S., & Trigunarsyah, B. (2017)	✓	✓	✓	✓	✓	✓	✓	✓
29	Ismail, A. et al. (2018)	✓	✓				✓		✓
30	Jeyakanthan, J., & Jayawardane, A. K. (2012).	✓	✓	✓	✓				✓
31	Kaliba, C. et al. (2009)	✓	✓	✓		✓	✓		
32	Khair, K. et al. (2017)	✓	✓	✓	✓	✓	✓	✓	✓
33	Khan, R. A., & Gul, W. (2017)	✓			✓		✓	✓	✓
34	Kikwasi, G. (2013)	✓	✓		✓		✓		✓
35	Kog, Y. C. (2017)		✓				✓	✓	✓
36	Obodoh, D.A., & Obodoh, C. (2016)	✓	✓	✓	✓	✓	✓	✓	✓
37	Lessing, B. et al. (2017)	✓	✓	✓	✓		✓	✓	✓
38	Mahamid (2011)		✓		✓		✓		
39	Mahamid (2013)	✓	✓	✓	✓	✓	✓		✓
40	Mahamid (2017)	✓	✓	✓	✓				✓
41	Mahamid (2017)	✓	✓		✓	✓			✓
42	Mahamidet al. (2012)	✓	✓	✓	✓	✓	✓		✓
43	Marteye et al. (2018)				✓		✓		✓
44	Motaleb, O.H., & Kishk, M. (2015)	✓	✓		✓		✓		✓
45	Oshungade, O. O., & Kruger, D. (2017)	✓	✓	✓	✓	✓	✓	✓	✓

Sl.no.	Author	Weather	Material Shortage	Geotechnical	Labour	Events	Equipment Shortage	Breakdowns	Design Errors
46	Pathiranage, Y., & Halwatura, R. U. (2010)	✓	✓	✓	✓	✓	✓		✓
47	Pourrostam, T., & Ismail, A. (2012)	✓	✓		✓		✓		✓
48	Roumeissa, S. et al. (2018)				✓				
49	Samarghandi, H. et al. (2016)	✓	✓		✓		✓		✓
50	Santoso, D. S& Soeng, S. (2016)		✓		✓		✓		✓
51	Senouci, A. et al. (2016)				✓				✓
52	Sharma, M. (2019)	✓	✓		✓	✓	✓		✓
53	Hosaini, S.B., & Singla, S. (2019)		✓		✓		✓		✓
54	Singh, J. et al. (2012)	✓	✓	✓	✓		✓		✓
55	Sohu, S. et al. (2019)	✓	✓	✓	✓	✓	✓	✓	✓
56	Soliman, E. (2017)	✓	✓		✓		✓	✓	✓
57	Stoian, M. M., & Dicu, M. (2017)		✓				✓		✓
58	Suleiman Al Maktoumi, I. et al. (2020)		✓		✓		✓		✓
59	Sweis, G. et al. (2008)	✓	✓	✓	✓		✓		✓
60	Tafazzoli, M., & Shrestha, P. (2017)				✓		✓		✓
61	Thapanont, P. et al. (2018)	✓	✓		✓		✓		✓
62	Toor, S., & Ogunlana, S. (2008)	✓	✓		✓	✓	✓		✓
62	Umar, T. (2018)	✓	✓		✓	✓			✓
64	Venkateswaran, C. B., & Murugasan, R. (2017)	✓	✓		✓		✓		✓
65	Viles, E. et al. (2019)	✓	✓		✓		✓	✓	✓
	Total	49	55	26	57	23	53	25	58
	% Publication	**75**	**85**	**40**	**88**	**35**	**82**	**38**	**89**

Based on identified factors SSI questionnaire was framed and NZ expert opinion on the factors relating to road construction was obtained. The narrative analysis revealed that according to contractor A, material shortage, skilled labour shortage, incorrect Geotechnical data, machinery breakdown, weather, disaster, pandemic, and events are considered high-impact factors. However, equipment shortage and design errors are considered low-impact factors. There is no factor in the medium impact range as per contractor A. According to contractor B, material shortage incorrect geotechnical data, machinery breakdown, weather, disaster, and a pandemic are high-impact factors. Labour shortage, equipment shortage, design errors and events are low impact factors. According to contractor C, material shortage, equipment shortage, geotechnical data, weather, disaster, pandemic, they consider events to be high-impact factors while labour, design errors, and machinery breakdown are considered being low-impact factors. The results are tabulated in Table 3.

Table 3: Factors identified by NZ road contractors

Factors		Literature response	Industry Response		
			Contractor A	Contractor B	Contractor C
CR	Material	55	H	H	H
	Labour	57	H	L	L
	Equipment shortage	53	L	L	H
CF	Geotechnical data	26	H	H	H
	Design error	58	L	L	L
	Machinery breakdown	25	H	H	L
CT	Weather	49	H	H	H
	Disaster	-	H	H	H
	Pandemic	-	H	H	H
	Events	23	H	L	H

Based on Table 3, the scheduling model (refer to figure 3) was developed to understand the influence of each factor. In Figure 3, the "negative" sign shows that factors harm the project schedule, whereas the "positive" sign shows that factors are contributing to achieving the project timeline. The factors that influence the project delay in the NZ road construction industry are classified in two ways. First, CR (material, Labour, and equipment shortage represented in blue circle), CF (design error, geotechnical, breakdown, and events represented in black circle) and CT (weather, disaster, and pandemic represented in red circle) as shown in Figure 3. Second, Environment (weather, disaster and geotechnical represented in the green shade), resources (equipment, material, and labour represented in brown shade) and surroundings (events and pandemic are represented in the yellow shade) as shown in figure 3. The in-control factors of an organization are shown in circles and out-of-control factors of an organization are represented in dashed circles in figure 3. Some factors are interlinked, for example, material shortage, labour shortage and equipment shortage are classified under CF.

Under CT, three factors have a negative contribution to the uncertainty in project duration. First, the pandemic, which harms the critical sealing window and contributes positively to the factors of the event. The second factor under CT is the disaster has a negative impact on the project schedule and positively contribute to the labour shortage. The third factor under CT is the weather, which contributes negatively to the project schedule and contributes positively to events (change of date or extension) and equipment breakdowns.

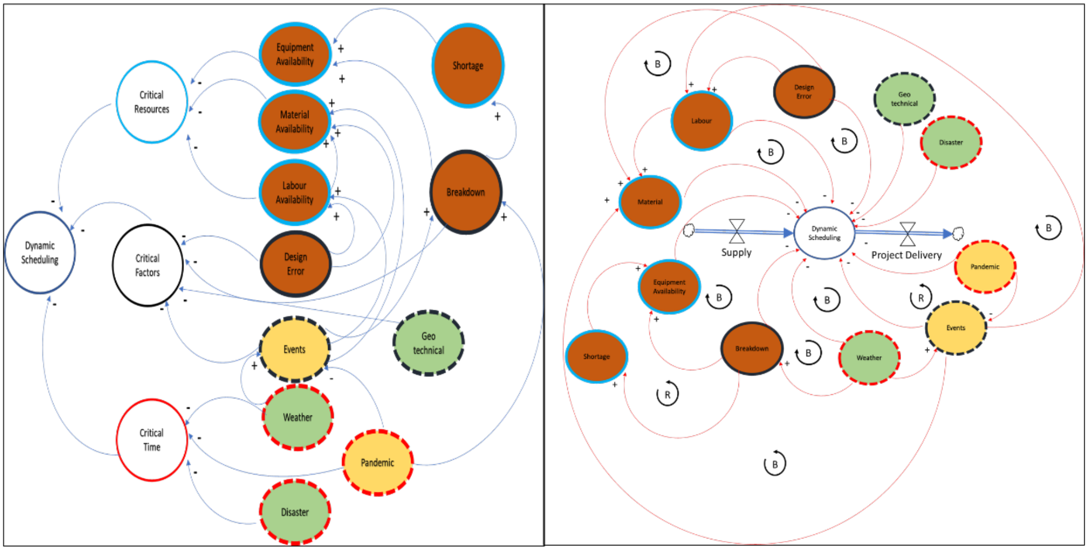

Figure 3: System dynamic model for Dynamic scheduling in road construction industry.

The second major contributing factor in scheduling is CF, a combination of four major factors such as equipment breakdown, events, design errors, and incorrect geotechnical investigation. Geotechnical events have a direct negative impact on the project schedule. Equipment breakdown contributes to the equipment shortage, events can contribute to labour, breakdown, and material availability issue, and design error can lead to a shortage of labour and material availability.

The third major factor is CR such as equipment shortage, labour shortage, and material availability. The material shortage affects the project schedule directly, but labour shortage can negatively affect the schedule directly and/or indirectly by negatively influencing the material. The labour factor can also contribute to negatively material availability.

Figure 3 shows the connectivity between delay factors and the CR, CF, and CT that are influenced by the environment, resources, and surrounding factors along with their positive (+) and negative (-) impacts, which reveal that all these factors affect the project and during initial schedule planning a planner has to consider these factors and provide an appropriate buffer to deal with these uncertainties during the execution time. The loops identified are also shown in Figure 3. The symbol "B" represents the balancing loop (change in one direction will change in opposite direction) and the symbol "R" represents the reinforcing loop (change in one direction will compound more change).

5. Discussion

As discussed in section one, the road construction sector plays an important role in NZ economic growth. The focus of the study was to identify the factors and develop the system dynamic mapping of dynamic scheduling for the road construction project. The study broadly classified the factors such as CF, CT, and CR and linked environmental, resource and surrounding subfactors to them concerning road project scheduling. The study identified weather, pandemic, material, geotechnical, disaster, equipment shortage, breakdown, design error, labour and event as the factors affecting dynamic scheduling that aids on-time project delivery by reducing the project delay in the NZ road construction industry. The pandemic and disaster are new additions to the existing literature.

The study for the first time classified factors into Environment, Resource, and Surrounding categories for a better understanding of in-control and out-of-control factors. The environment (weather, disaster, and geotechnical) and surroundings (events and pandemic) factors are dependent on natural and social phenomena respectively, which are out of control of any organisation that undertakes road construction. The organisations must align with these factors in real-time and adjust the project schedules dynamically. At the same time, the organization needs to include these out-of-control factors in the force majeure clause in the contract to accommodate the change in schedules. On the other hand, resources are in-control factors (labour, material, equipment) and that needs to be effectively managed. Based on previous experiences and data these factors abnormalities need to be factored in dynamic scheduling. The subset of resources such as equipment breakdown, equipment shortage and design error is in-control factors that need to be factored in dynamic scheduling based on data and previous experience.

Comparing the SLR and SSI result, the weather factor was confirmed by 49 authors in SLR out of 65 pieces of literature and all the field experts confirmed this factor as high impact. This could be probably since NZ has frequently changing weather conditions. Road constructions must be expedited during dry days to achieve quality, weather theme includes wet days, cloudy periods, heavy rain, high wind, cold days, and high humidity has a negative impact on the project performance. 55 authors in SLR affirmed the material shortage and material quality factor out of 65 articles, which all three experts in the road construction industry rated as high impact. All three contractors marked this factor as high impact this was due to constraints around the material availability in NZ and site locations. Probably this is due to the fact NZ imports most materials and is subject to various factors that affect quality, logistics and availability. 26 authors in SLR confirmed the geotechnical factor out of 65 articles and all three experts rated this as a high-impact factor. During the SSI, it was noted that most of the roading projects were always based on the historical geotechnical assumption which often led to unknown assumptions. The fact that most of NZ is volcanic soil could be the probable reason experts agreed to this factor.

57 authors in SLR confirmed the shortage of labour and skilled labour factor out of 65 articles, while one expert confirmed this factor as high and the other two confirmed low impact. The reason for varied responses could be because of quality education and training as well as a large sector of labour in road laying has low skill requirements. 23 authors in SLR confirmed the event factor out of 65 articles and two experts rated it as high impact while one rated it as low impact. This may be probably since NZ is a country that has many scheduled events running throughout the year and the scheduled approach could systematically delay or provide scope for rescheduling road construction. Event factors identified to have a positive impact on equipment shortage. 53 authors in SLR confirmed the equipment shortage factor out of 65 articles and two experts rated it as low impact while one rated it as high impact. The low impact may be because the equipment is made available in NZ predicting largescale construction drive based on government policies and high impact may be due to relying on equipment hire and due to constant equipment breakdowns. 25 authors in SLR confirmed the breakdown factor out of 65 articles, while 2 experts confirmed as high, and one confirmed as low. This may be because NZ has low expert maintenance personnel concerning heavy equipment and awareness of equipment maintenance is high. The design error factor is cited in 58 out of 65 articles, while all three field experts confirmed it as low impact. This may be due to standard procedures/designs used in NZ. The disaster and pandemic

were rated high impact by the three experts and none of the literature stated it as factors. This may be since NZ is affected by earthquakes, storms, and heavy rains more than other countries given the landmass and inhabited area.

The records and data shown by experts confirmed the disaster and pandemic, weather, material, and geotechnical were the most influential in NZ road construction projects. While labour, event, equipment shortage, breakdown, and design error had mixed impacts in NZ road construction projects. The study revealed pandemic and disaster influence on road construction for the first time and affirmed events create major issues for scheduling and road project delivery. Based on the SSI conducted with field experts, the road construction projects experience time overrun which can vary any way between 20-40%, based on the project size. This is probably due to the interlink between various factors shown in Figure 3 that could trigger a chain reaction. This study can help in incorporating the new factors affecting the dynamic scheduling in road construction projects and minimise their effects.

6. Conclusion.

This study concludes that weather, pandemic, material, geotechnical, and disaster factors highly influence the dynamic scheduling and in turn the project delay, while other factors such as equipment shortage, breakdown, design error, labour and event had mixed impact on dynamic scheduling that aids on-time project delivery by reducing the project delay. Though there is a significant body of knowledge on barriers to dynamic scheduling, this research considered system-wide environment, resource and surroundings factors and their relationships. The environment and surroundings are out-of-control and need to be dynamically scheduled in real-time. These factors are to be suitably incorporated in the force majeure clause of the contracts. The in-control resources factors need to be managed effectively and dynamic scheduling to be based on data and experience. The novelty in the paper is that it included ERS factors specifically events, disasters, and pandemics' influence on Dynamic scheduling that aids on-time project delivery by reducing the project delay in the NZ road construction industry for the first time. The new factors identified and modelled would help in further analysing and incorporating in dynamic scheduling calculations of the road construction industry which would enable planners to predict more accurate delivery time. The including of these factors in force majeure clauses will bring an understanding between contracting parties and in turn reduce disputes and delays. The practical implications include understanding factors that affect dynamic scheduling and if these factors are incorporated in scheduling calculations and contracts, it will help reduce the delays, cost overrun and contractual disputes in NZ and the global road construction industry.

7. **Limitation** and **future research**

This study was conducted by surveying literature in English and experts were those people who could speak fluently in English. The limitation of factors appearing in articles other than English must be acknowledged. The limitations of constructivist, narrative inquiry methodology and qualitative research are acknowledged. The small sample of experts is also acknowledged as a limitation of this research. This research forms the basis and future studies on the influence of the study of events, disasters, and pandemics and their effects on Dynamic scheduling in the NZ road construction industry would be helpful.

References

Ahmed, S.M., Azhar, S., Kappagantula, P. and Gollapudi, D. (2003). Delays in Construction: A Brief Study of the Florida Construction Industry.[online] Ascweb.org. Available at: http://ascpro0.ascweb.org/archives/cd/2003/2003pro/2003/Ahmed03.htm.

Aibinu, A., & Jagboro, G. (2002). The effects of construction delays on project delivery in Nigerian construction industry. International Journal of Project Management, 20(8), 593-599. https://doi.org/10.1016/s0263-7863(02)00028-5

Akinsiku, O. E., & Akinsulire, A. (2012). Stakeholders' perception of the causes and effects of construction delays on project delivery. Journal of Construction Engineering and Project Management, 2(4), 25-31. https://doi.org/10.6106/jcepm.2012.2.4.025

Al Hadithi, B. I. (2018). An investigation into factors causing delays in highway construction projects in Iraq. MATEC Web of Conferences, 162, 02035. https://doi.org/10.1051/matecconf/201816202035

Alaghbari, W., Razali A. Kadir, M., Salim, A., & Ernawati. (2007). The significant factors causing delay of building construction projects in Malaysia. Engineering, Construction and Architectural Management, 14(2), 192-206. https://doi.org/10.1108/09699980710731308

Alfakhri, A. Y., Ismail, A., & Khoiry, M. A. (2018). The effects of delays in road construction projects in Tripoli, Libya. International Journal of Technology, 9(4), 766. https://doi.org/10.14716/ijtech.v9i4.2219

Al-Hazim, N., & Abusalem, Z. (2015). Delay and cost overrun in road construction projects in Jordan. International Journal of Engineering & Technology, 4(2), 288. https://doi.org/10.14419/ijet.v4i2.4409

Alotaibi, N., Sutrisna, M., & Chong, H. (2015). Managing critical factors causing delays in public construction projects in Kingdom of Saudi Arabia. Proceedings of the 2015 (6th) International Conference on Engineering, Project, and Production Management. https://doi.org/10.32738/ceppm.201509.0013

Amoatey, C. T., & Ankrah, A. N. (2017). Exploring critical road project delay factors in Ghana. Journal of Facilities Management, 15(2), 110-127. https://doi.org/10.1108/jfm-09-2016-0036

Atibu Seboru, M. (2015). An investigation into factors causing delays in road construction projects in Kenya. American Journal of Civil Engineering, 3(3), 51. https://doi.org/10.11648/j.ajce.20150303.11

Aziz, R. F., & Abdel-Hakam, A. A. (2016). Exploring delay causes of road construction projects in Egypt. Alexandria Engineering Journal, 55(2), 1515-1539. https://doi.org/10.1016/j.aej.2016.03.006

Baharum, Z., Jamil, F., Hairulnizam, M., & Yacob, A. (2020). Simulation-based development for uncertainty in environmental factors on project delay. Journal of critical reviews, 7(08), 59-64. https://doi.org/10.31838/jcr.07.08.12

Bakker, A. (2018). Research quality in design research. Design Research in Education, pp.87–95. https://doi.org/10.4324/9780203701010-8

Ballesteros Perez, P. (2017). M-PERT: Manual Project-Duration Estimation Technique for Teaching Scheduling Basics. Journal of Construction Engineering and Management, 143(9), p.04017063. https://doi.org/10.1061/(asce)co.1943-7862.0001358

Bordoli, D. W., & Baldwin, A. N. (1998). A methodology for assessing construction project delays. Construction Management and Economics, 16(3), 327-337. https://doi.org/10.1080/014461998372358

Braun, V. and Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), pp.77–101. https://doi.org/10.1191/1478088706qp063oa

Bustan, B., Ramli, I., Sammang, L., & Ali, N. (2015). Risk level assessment on road construction S contractors using cultural professionalism-based approach. Third International Conference on Advances in Civil, Structural and

Mechanical Engineering - ACSM 2015. https://doi.org/10.15224/978-1-63248-083-5-94

Carter, N., Bryant-Lukosius, D., DiCenso, A., Blythe, J., & Neville, A. J. (2014). The use of triangulation in qualitative research Symposium conducted at the meeting of the Oncology nursing forum https://doi.org/10.1188/14.ONF.545-547

Coughlan, T. (2020). Government announces billions of infrastructure spending, with roads the big winner. [online] Stuff. Available at: https://www.stuff.co.nz/national/119105125/government-announces-billions-of-spending- with-roads-the-big-winner [Accessed 18 Mar. 2020].

Creswell, J. W. & Creswell, J. D. 2017. Research design: Qualitative, quantitative, and mixed methods approaches, Thousand Oaks, CA, USA, Sage publications.

Dianat, H., Wilkinson, S., Williams, P., & Khatibi, H. (2021). Planning the resilient city: Investigations into using “causal loop diagram” in combination with “UNISDR scorecard” for making cities more resilient. International Journal of Disaster Risk Reduction, 65, 102561. https://doi.org/10.1016/j.ijdrr.2021.102561 .

Ding, C., Wang, H., Zhang, M., Gao, C. & Jing, Y. (2004)Dynamic scheduling of road construction machines based on multi-agent system. In: SHAO, X. Y. & DENG, C., eds. International Conference on Manufacturing Automation: Advanced Design and Manufacturing in Global Competition, 2004 Wuhan, People's Republic of China. Professional Engineering Publishing Limited, UK, 303.

Dingwall, R., Murphy, E., Watson, P., Greatbatch, D. and Parker, S. (1998). Catching Goldfish: Quality in Qualitative Research. Journal of Health Services Research & Policy, 3(3), pp.167–172. https://doi.org/10.1177/135581969800300308

Doloi, H., Sawhney, A., & Iyer, K. (2012). Structural equation model for investigating factors affecting delay in Indian construction projects. Construction Management and Economics, 30(10), 869-884. https://doi.org/10.1080/01446193.2012.717705

Duffy, M.E. (1987). Methodological Triangulation: A Vehicle for Merging Quantitative and Qualitative Research Methods. Image: The Journal of Nursing Scholarship, 19(3), pp.130–133. https://doi.org/10.1111/j.1547-5069.1987.tb00609.x

East E William (2015). Critical path method tutor for construction planning and scheduling. New York,USA: McGraw-Hill Education.

Edison, J., & Singla, H. K. (2020). Development of a scale for factors causing delays in infrastructure projects in India. Construction Economics and Building, 20(1). https://doi.org/10.5130/ajceb.v20i1.6750

Egila, A. E., Balogun, O. A., & Yusuf, S. O. (2020). Assessment of delay and cost-overrun in federal road construction project in Abuja. Independent Journal of Management & Production, 11(4), 1184. https://doi.org/10.14807/ijmp.v11i4.1065

Ekanayake, E., & Perera, B. (2016). Appropriate delay analysis techniques to analyse delays in road construction projects in Sri Lanka. Built Environment Project and Asset Management, 6(5), 521-534. https://doi.org/10.1108/bepam-08-2015-0039

Elawi, G. S., Algahtany, M., & Kashiwagi, D. (2016). Owners’ perspective of factors contributing to project delay: Case studies of road and bridge projects in Saudi Arabia. Procedia Engineering, 145, 1402-1409. https://doi.org/10.1016/j.proeng.2016.04.176

Fahmy, A., Hassan, T., Bassioni, H., & McCaffer, R. (2020). Dynamic scheduling model for the construction industry. Built Environment Project and Asset Management, 10(3), 313-330. https://doi.org/10.1108/bepam-02-2019-0021

Fallon, V. (2020). Kāpiti expressway repairs delayed, 10km still to go in multi-million dollar fix up. [online] Stuff.

Available at: https://www.stuff.co.nz/motoring/119126079/kpiti-expressway-repairs-delayed-10km-still-to-go- in-multimillion-dollar-fix-up [Accessed 10 Apr. 2020].

Fontana, A. & Frey, J. H. (2000). The interview: From structured questions to negotiated text. In: S, L. Y. & Denzin, N. K. (eds.) Handbook of qualitative research. 2 nd ed. Thousand Oaks, CA, USA: Sage.

Frimpong, Y., & Oluwoye, J. (2003). Significant factors causing delay and cost overruns in construction of groundwater projects in Ghana. Journal of Construction Research, 04(02), 175-187. https://doi.org/10.1142/s1609945103000418

Guerriero, A., Kubicki, S., Berroir, F. & Lemaire, C. (2017) BIM-enhanced collaborative smart technologies for LEAN construction processes. 2017 International Conference on Engineering, Technology and Innovation (ICE/ITMC), 27-29 June 2017 2017. 1023-1030.

Hakami, W. G., & Yousif, M. I. (2014). The critical factors of project management in sudanese construction projects. Journal of Construction Engineering and Project Management, 4(1), 1-7. https://doi.org/10.6106/jcepm.2014.4.1.001

Hasmori, M.F., Said, I., Deraman, R., Abas, N.H., Nagpan, S., Ismail, M.H., Khalid, F.S., &Roslan, A.F. (2018). Significant Factors of Construction Delays Among Contractors in Klang Valley and its Mitigation. International journal of integrated engineering, 10(2), 32-36. https://doi.org/10.30880/ijie.2018.10.02.007

Herroelen, W., Leus, R. and Demeulemeester (2002)Critical chain project scheduling: Do not oversimplify. Project Management Journal, 33(4), 48-60. https://doi.org/10.1177/875697280203300406

Hosaini, S.B., & Singla, S. (2019). Significant factors of delay in construction projects in Afghanistan. International Journal of Innovative Technology and Exploring Engineering, 8(9S), 1060-1069. https://doi.org/10.35940/ijitee.i1170.0789s19

Hosseininasab, S.-M., Shetab-Boushehri, S.-N., Hejazi, S. R. & Karimi, H. (2018). A multi-objective integrated model for selecting, scheduling, and budgeting road construction projects. European Journal of Operational Research, 271, 262-277. https://doi.org/10.1016/j.ejor.2018.04.051

Hossen, M. M., Kang, S., & Kim, J. (2015). Construction schedule delay risk assessment by using combined AHP-RII methodology for an international NPP project. Nuclear Engineering and Technology, 47(3), 362-379. https://doi.org/10.1016/j.net.2014.12.019

Islam, M. S., & Trigunarsyah, B. (2017). Construction delays in developing countries: A review. Journal of Construction Engineering and Project Management, 7(1), 1-12. https://doi.org/10.6106/jcepm.2017.3.30.001

Ismail, A., Y. Y. Alfakhri, A., Azry Khoiry, M., M Abdelsalam, H., & Elhub, B. (2018). Investigating delays in Libyan road construction projects using structural equation modelling (SEM). International Journal of Engineering & Technology, 7(2.29), 858. https://doi.org/10.14419/ijet.v7i2.29.14272

Jeyakanthan, J., & Jayawardane, A. K. (2012). Mitigating delays in donor funded road projects in Sri Lanka. Engineer: Journal of the Institution of Engineers, Sri Lanka, 45(1), 65. https://doi.org/10.4038/engineer.v45i1.6950

Kaliba, C., Muya, M., & Mumba, K. (2009). Cost escalation and schedule delays in road construction projects in Zambia. International Journal of Project Management, 27(5), 522-531. https://doi.org/10.1016/j.ijproman.2008.07.003

Kerkhove, L.-P. & Vanhoucke, M. (2017). Optimised scheduling for weather sensitive offshore construction projects. Omega, 66, 58-78. https://doi.org/10.1016/j.omega.2016.01.011

Khair, K., Mohamed, Z., Mohammad, R., Farouk, H., & Ahmed, M. E. (2017). A management framework to reduce delays in road construction projects in Sudan. Arabian Journal for Science and Engineering, 43(4), 1925-1940.

https://doi.org/10.1007/s13369-017-2806-6

Khan, R. A., & Gul, W. (2017). Emperical study of critical risk factors causing delays in construction projects. 2017 9th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications (IDAACS). https://doi.org/10.1109/idaacs.2017.8095217

Kikwasi, G. (2013). Causes and effects of delays and disruptions in construction projects in Tanzania. Australasian Journal of Construction Economics and Building - Conference Series, 1(2), 52. https://doi.org/10.5130/ajceb-cs.v1i2.3166

Kimura, O. and Terada, H. (1981). Desiǵn and analysis of pull system, a method of multi-staǵe production control. International Journal of Production Research, 19(3), 241-253. https://doi.org/10.1080/00207548108956651

Kog, Y. C. (2017). Major delay factors for construction projects in Nigeria. International Journal of Architecture, Engineering and Construction, 6(2). https://doi.org/10.7492/ijaec.2017.011

Kumar, P.P. (2005). Kumar, P. P. (2005). Effective use of Gantt chart for managing large scale projects. Cost engineering, 47(7), pp.14–21.

Lessing, B., Thurnell, D., & Durdyev, S. (2017). Main factors causing delays in large construction projects: Evidence from New Zealand. Journal of Management, Economics, and Industrial Organization, 63-82. https://doi.org/10.31039/jomeino.2017.1.2.5

Mahamid, I. (2011). Risk matrix for factors affecting time delay in road construction projects: Consultants' perspective. Applied Mechanics and Materials, 147, 244-248. https://doi.org/10.4028/www.scientific.net/amm.147.244

Mahamid, I. (2013). Common risks affecting time overrun in road construction projects in Palestine: Contractors' perspective. Construction Economics and Building, 13(2), 45-53. https://doi.org/10.5130/ajceb.v13i2.3194

Mahamid, I. (2017). Analysis of schedule deviations in road construction projects and the effects of project physical characteristics. Journal of Financial Management of Property and Construction, 22(2), 192-210. https://doi.org/10.1108/jfmpc-07-2016-0031

Mahamid, I. (2017). Schedule delay in Saudi Arabia road construction projects: Size, estimate, determinants and effects. International Journal of Architecture, Engineering and Construction, 6(3). https://doi.org/10.7492/ijaec.2017.017

Mahamid, I., Bruland, A., & Dmaidi, N. (2012). Causes of delay in road construction projects. Journal of Management in Engineering, 28(3), 300-310. https://doi.org/10.1061/(asce)me.1943-5479.0000096

Marteye, N., Kissi, E., Yamoah, D., & Samuel, A. (2018). Exploring challenges facing road contractors in execution of government of Ghana (GOG) funded projects. Road and Rail Infrastructure V. https://doi.org/10.5592/co/cetra.2018.654

Maxwell, J. (2020). NZTA wipes $16,000-a-day late fines for late Transmission Gully project. [online] Stuff. Available at: https://www.stuff.co.nz/dominion-post/news/119696051/nzta-wipes-16000aday-late-fines-for-late- transmission-gully-project [Accessed 11 Apr. 2020].

MBIE -Ministry of Business, Innovation & Employment - (2013). Construction the New Zealand Sectors Report 2013. [online] Available at: https://www.mbie.govt.nz/assets/77439ddc45/Construction-report-2013.pdf.

MBIE- Ministry of Business, Innovation & Employment (2016). Road infrastructure. [online] MBIE. Available at: https://www.mbie.govt.nz/assets/5f96bf780c/road-infrastructure.pdf.

Mohammadi, A., Igwe, C., Amador-Jimenez, L. & Nasiri, F. (2020). Applying lean construction principles in road maintenance planning and scheduling. International Journal of Construction Management, 1-11.

https://doi.org/10.1080/15623599.2020.1788758

Motaleb, O. H., & Kishk, M. (2015). Controlling the risk of construction delay in the Middle East: State-of-the-art review. Journal of Civil Engineering and Architecture, 9, 506-516. doi: 10.17265/1934-7359/2015.05.002

Multashi, A.T., & Salgude, R.R. (2015). Delay analysis in construction project a case study - Alkut Olympic Stadium. (2016). International Journal of Science and Research (IJSR), 5(6), 822-827. https://doi.org/10.21275/v5i6.6061607

Nouban, F. & Ghaboun, N. 2017. The factors affecting the methods of construction projects scheduling: an state of the art and overview. Asian Journal of Natural & Applied Sciences Vol, 6. http://www.ajsc.leena-luna.co.jp/AJSCPDFs/Vol.6(4)/AJSC2017(6.4-13).pdf

Obodoh, D. A., & Obodoh, C. (2016). Causes and Effects of Construction Project Delays in Nigerian Construction Industry. International Journal of Innovative Science, Engineering & Technology, 3(5). http://ijiset.com/vol3/v3s5/IJISET_V3_I5_10.pdf

Oshungade, O. O., & Kruger, D. (2017). A comparative study of causes and effects of project delays and disruptions in construction projects in the South African construction industry. Journal of Construction Engineering and Project Management, 7(1), 13-25. https://doi.org/10.6106/jcepm.2017.3.30.013

Pathiranage, Y., & Halwatura, R. U. (2010). Factors influencing the duration of road construction projects in Sri Lanka. Engineer: Journal of the Institution of Engineers, Sri Lanka, 43(4), 17. https://doi.org/10.4038/engineer.v43i4.6997

Pourrostam, T., & Ismail, A. (2012). Causes and effects of delay in Iranian construction projects. International Journal of Engineering and Technology, 4(5), 598-601. https://doi.org/10.7763/ijet.2012.v4.441

Project Management Journal, 33(4), pp.48–60.

Roumeissa, S., Karima, M., & Souad, S. B. (2018). Identification of factors causing delays in construction projects in Algeria. European Journal of Engineering and Formal Sciences, 2(1), 6. https://doi.org/10.26417/ejef.v2i1.p6-11

Rouse, M. (2007). What is Gantt chart? - Definition from WhatIs.com. [online] Search Software Quality. Available at: https://searchsoftwarequality.techtarget.com/definition/Gantt-chart.

Samarghandi, H., Tabatabaei, S. M., Taabayan, P., Hashemi, A. M., & Willoughby, K. (2016). Studying the reasons for delay and cost overrun in construction projects: The case of Iran. Journal of Construction in Developing Countries, 21(1), 51-84. https://doi.org/10.21315/jcdc2016.21.1.4

Santoso, D. S., & Soeng, S. (2016). Analyzing delays of road construction projects in Cambodia: Causes and effects. Journal of Management in Engineering, 32(6), 05016020. https://doi.org/10.1061/(asce)me.1943-5479.0000467

Senouci, A., Ismail, A., & Eldin, N. (2016). Time delay and cost overrun in qatari public construction projects. Procedia Engineering, 164, 368-375. https://doi.org/10.1016/j.proeng.2016.11.632

Shahsavand, P., Akbar, M., Parchamijalal, M. (2018). Causes of delays in construction industry and comparative delay analysis techniques with SCL protocol. Engineering, construction and architecture management, 25(4). https://doi.org/10.1108/ECAM-10-2016-0220

Sharma, M. (2019). Review of delay factors and affecting the construction projects. International Journal for Research in Applied Science and Engineering Technology, 7(1), 179-181. https://doi.org/10.22214/ijraset.2019.1030

Singh, J., Raghavan, V. S., & P.H. Dadlani, P. D. (2012). Factors causing performance delays of deep foundation construction projects in vicinity of river. Paripex - Indian Journal Of Research, 3(5), 85-92. https://doi.org/10.15373/22501991/may2014/29

Sohu, S., Chandio, A. F., & Ullah, K. (2019). Identification of causes and minimization of delays in highway projects of Pakistan. January 2019, 38(1), 103-112. https://doi.org/10.22581/muet1982.1901.09

Soliman, E. (2017). Recommendations to mitigate delay causes in Kuwait construction projects. American Journal of Civil Engineering and Architecture, 5(6), 253-262. https://doi.org/10.12691/ajcea-5-6-5

Stoian, M. M., & Dicu, M. (2017). Analysis of delays and extension of execution duration of a road project. Romanian Journal of Transport Infrastructure, 6(2), 53-60. https://doi.org/10.1515/rjti-2017-0060

Strang, B. (2019). $850m Transmission Gully completion delays likely. [online] RNZ. Available at: www.rnz.co.nz /news/national/398107/850m-transmission-gully-completion-delays-likely [Accessed 25May 2020].

Suleiman Al Maktoumi, I., Rahman Khan, F., & Rashid Suwied Al Maktoumi, A. (2020). Assessing the factors causing project completion delays in the construction sector of Oman using sem-pls. Humanities & Social Sciences Reviews, 8(3), 900-912. https://doi.org/10.18510/hssr.2020.8394

Sweis, G., Sweis, R., Abu Hammad, A., & Shboul, A. (2008). Delays in construction projects: The case of Jordan. International Journal of Project Management, 26(6), 665-674. https://doi.org/10.1016/j.ijproman.2007.09.009

Tafazzoli, M., & Shrestha, P. (2017). Factor analysis of construction delays in the U.S. construction industry. International Conference on Sustainable Infrastructure 2017. https://doi.org/10.1061/9780784481196.011

Thapanont, P., Santi, C., & Pruethipong, X. (2018). Causes of delay on highway construction projects in Thailand. In MATEC Web of Conferences (Vol. 192, p. 02014). EDP Sciences. https://doi.org/10.1051/matecconf/201819202014

Toor, S., & Ogunlana, S. (2008). Problems causing delays in major construction projects in Thailand. Construction Management and Economics, 26(4), 395-408. https://doi.org/10.1080/01446190801905406

Umar, T. (2018). Causes of delay in construction projects in Oman. Middle East J. of Management, 5(2), 121. https://doi.org/10.1504/mejm.2018.10012114

Valikoniene, L. (2015). Resource Buffers in Critical Chain Project Management | Research Explorer | The University of Manchester.[online] www.research.manchester.ac.uk. Available at: https://www.research.manchester.ac.uk/portal/en/theses/resource-buffers-in-critical-chain-project-management(eb4dda85-edb3-4775-b0ef-91ee5c76ec24).html [Accessed 13 May 2020]

Vanhoucke, M. (2013). Project management using dynamic scheduling: Baseline scheduling, risk analysis and project control. The Measurable News, 2, 45-50. http://www.pmknowledgecenter.com/sites/default/files/files/Vanhoucke,%20TMN,%202013.pdf

Venkateswaran, C. B., & Murugasan, R. (2017). Time delay and cost overrun of road over bridge (ROB) construction projects in India. Journal of Construction in Developing Countries, 22(suppl. 1), 79-96. https://doi.org/10.21315/jcdc2017.22.supp1.5

Viles, E., Rudeli, N. C., & Santilli, A. (2019). Causes of delay in construction projects: A quantitative analysis. Engineering, Construction and Architectural Management, 27(4), 917-935. Doi:10.1108/ecam-01-2019-0024

Zenga, N., Yea, X., Pengb, X. & Königa, M.(2019) Applying Kanban System in Construction Logistics for Real-time Material Demand Report and Pulled Replenishment. Proceedings of the 36th International Symposium on Automation and Robotics in Construction (ISARC), 2019. 1018-1025.