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DYNAMIC SCHEDULING: INFLUENTIAL AND INFLUENCED FACTORS AND THEIR INTERRELATIONSHIPS IN THE NEW ZEALAND CONSTRUCTION INDUSTRY

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DYNAMIC SCHEDULING: INFLUENTIAL AND INFLUENCED FACTORS AND THEIR INTERRELATIONSHIPS IN THE NEW ZEALAND CONSTRUCTION INDUSTRY

Abstract:
Purpose: The research aims to investigate and analyse various complex interrelationships of positive and negative factors that significantly impact Dynamic Scheduling (DS) in the New Zealand construction industry and rank them for improved project outcomes.
Design/methodology/approach: The study used a combination of research methods, including a systematic literature review using PRISMA guidelines and expert consultations. The analysis included pairwise comparison (with steps within the Analytical Hierarchy Process) and Degree of Centrality calculation to rank the factors affecting DS in the New Zealand construction industry.
Findings: For the first time, this study identifies the five most prominent strategic and operational-level factors interacting with others. The study's findings indicate that Poor planning, Incomplete drawings and specifications/project information, Material unavailability/prefabricated product availability, Inclement weather, and lack of work permits are the primary negative factors that affect DS operationally. On the other hand, Cultural heritage diversity, Climate change mitigation and adaptation, and Cultural heritage management have a positive effect. Climate change and Resource unavailability/instability are among the top five factors that negatively impact DS strategically. Poor planning is the most influential factor at the operational level, with 6 out of degrees. At the same time, material availability and incomplete drawings and specifications / incomplete project information were most influenced by 3 degrees each. Climate change mitigation and adaptation are the most influential factors at the strategic level, and diverse cultural heritage is the most influential factor. Additionally, this paper stands out for its clear distinction between the positive and negative 176 factors within 11 distinct categories, visual representation of 61 formerly identified interrelationships from SLR, and 14 previously unidentified interactions from industry consultation that impact DS within the construction industry.
Research limitations/implications: The research centres around studying English language literature. Using specific databases such as Scopus, EBSCO, and Science Direct and searching after 2017 may potentially narrow the scope of global viewpoints. We acknowledge that there are limitations in terms of New Zealand industry consultation. Further studies should encompass non-English sources and incorporate empirical approaches to confirm the detected correlations and implications for DS customised to a specific viewpoint or country.
Practical implications: This study provides insights for academics and industries by focusing on interrelationships and identifying top strategic and operation-level factors affecting DS. It aids project managers and industry professionals create tailored baseline scheduling, risk assessment, and project controls. The study also benefits policymakers seeking to improve construction project efficiency, sustainability, and dispute resolution through informed DS practices. The DS factors polarity, interrelationships, CLD, and ranking based on DC add to the body of knowledge.
Originality/value: Numerous literary works have explored the various factors that impact Dynamic Scheduling (DS), each being analysed for its impact through expert evaluations and surveys. However, they have not considered that the factors act in conjunction with others and their interrelations have a significant impact. This paper takes a unique approach by examining the interrelationships, their network (displayed in the causal loop diagram) and the degree of centrality among these factors. The originality of this study is the distinct categorisation of positive and negative factors that impact DS in the construction industry. The paper's novelty lies in the rankings based on the interrelations and degree of centrality between these factors. This is significant since the factors often work together instead of in isolation.

KEYWORDS: Dynamic Scheduling, scheduling, construction, construction scheduling, factors, interlinks.

1. Introduction

Complex construction projects are affected by delays (Kermanshachi et al., 2023). Many factors influence construction project delays, such as hierarchy, bureaucracy and inflexible procedures that block communication, delay and initiate defects in the construction industry (Purushothaman & Seadon, 2024). Additionally, methodologies play a significant part, especially those associated with planning, scheduling, and coordination (Purushotham et al., 2024). Construction delays can have severe economic and developmental impacts (Alfakhri et al., 2018). Multiple studies have highlighted the significant impact of construction delays, including time and cost overruns, wasted resources, project abandonment, contract termination, a hindrance to economic development, reduced economic activity, reduced government revenue, and difficulty securing foreign loans

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(Javed et al., 2022; Ullah et al., 2018). These delays require efficient management due to the interdependent nature of task execution, resource allocation, and stakeholder engagement and require planning, reliability and control of dynamic project aspects (Sheikhkhoshkar et al., 2023; Sheikhkhoshkar et al., 2024). The construction industry initially relied on static planning techniques like the Project Evaluation and Review Technique and Critical Path Method (Lermen et al., 2016) to overcome project delays. However, these models had limited capabilities in predicting future results when faced with changing and growing complexities in real-time, leading to more innovative approaches like dynamic scheduling (DS) (Habibi et al., 2018). Nwadigo et al. (2022) state that DS is a widely adopted innovative, real-time digital technology-based strategy for solving real-world problems in many business systems.

DS can be defined as an established, adaptable procedure for updating, checking, and revising the schedule in real-time (Fahmy et al.,2020). DS is a strategic approach for reacting to unanticipated events (Herrmann, 2006). Dynamic scheduling defines the methods for creating the initial baseline and reacting to current events (Fahmy et al., 2014a). DS combines initial scheduling, risk assessment, and project controls (Vanhoucke, 2013). Under the constraint of time, DS would efficiently resolve the issue of resource organising connection and direct the shared scheduling procedure between various areas (He et al., 2021). Directly assigning tasks to resources based on predetermined sequencing rules defines DS (Kalinowski et al.,2013). DS automatically updates the schedule based on the most efficient measures by incorporating the impact of immediate occurrences and evaluating the present state of a timeline (Fahmy et al., 2014c). Real-time updating of project information and recording changes can provide dynamic risk identification at all project stages that could be acted upon quickly (Moshtaghian et al.,2020). DS is a more advanced approach to scheduling that can be employed to execute construction projects, provided that relevant contributing factors have been thoroughly analysed (Purushothaman & Kumar, 2022). DS is aligned with complex surroundings and allows for responding to real-time data while rescheduling and adjusting after unavoidable emergencies (Ding et al., 2022).

Nwadigo et al. (2022) highlighted the importance of practical planning and scheduling in reducing the effects of unexpected changes in construction projects. Ding et al. (2022) emphasised that DS is designed for complicated environments, allows for immediate response and adaptations in the face of unforeseen situations, and efficiently manages real-time events and schedule disruptions (Fahmy et al., 2020). DS is a highly sophisticated scheduling strategy that warrants a comprehensive analysis of its associated contributing factors (Purushothaman and Kumar, 2022). However, there is a lack of research regarding DS in construction projects (Fahmy et al., 2020; Purushothaman and Kumar, 2022; Undozerov, 2023). DS has significant optimisation challenges with various real-world applications. (Đurasević et al., 2022). The quality of all subsequent factors determines DS's overall solution quality, each connected to the previous by the transferred backlog and the timeline of the present predictable factors (Branke & Mattfeld, 2005). This implies the importance of the interrelations of the factors.

Previous literature analysing factors treated their impact as standalone and did not consider the conjunction effects. Hence, it ranked the factors based on scales such as occurrence, frequency, and importance as perceived by the construction professionals. The knowledge gap is that the interrelations of factors affecting DS have not been studied yet. Addressing this gap through factors affecting DS has substantial academic and practical benefits for the future of construction projects. Various disciplines have examined connections using Network Analysis (NA) to illustrate relationships between factors and to study the structures that arise from the repetition of these connections. However, DS in construction has not had such studies. This study serves as a pilot, identifying positive and negative factors and their interrelations that impact DS. The theoretical contributions of the study offer enhanced knowledge of DS, scheduling, and related issues that share significant perspectives with scholars, researchers, industry professionals, and policymakers who aim to enhance efficiency, sustainability, and conflict resolution in construction projects through knowledgeable decision-support practices. Positive factors will likely enhance project outcomes, negative ones may lead to scheduling and construction delays, and the interrelations define the compounding effect. For the first time, this study aims to identify the key factors and their interactions that contribute to the DS in the NZ construction industry and rank them based on their interconnectivity. This research expands upon existing literature and offers important insights into the domain of DS, emphasising the intricate relationships within the field. By providing theoretical frameworks with essential knowledge regarding critical operational and strategic aspects rooted in these interconnections, the study can improve the efficiency of construction projects, foster sustainability, and facilitate effective dispute resolution by adopting these informed practices within DS. The question for this study is

"What are the significant positive and negative interacting factors and their ranking that influence Dynamic Scheduling in New Zealand construction?"

2. Contextual background

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The construction industry has significantly contributed to NZ's economic state. Radman et al. (2021) claim that the construction sector surpasses wholesale trade-off in the five highest contributors to GDP, accounting for 19% of GDP growth. According to the Stats NZ (2023b) report, the total value of building work was $9.10 billion in March 2023. Additionally, employment statistics demonstrate the sector's magnitude, with skilled trades and consulting ranking fifth in total employment (MBIE, 2023; Stats NZ, 2023a). However, the construction industry in NZ faces a unique set of challenges. The lack of proximity to a large trading partner or consumer market makes it even more difficult for NZ to directly adopt foreign goods transport models due to its geographic isolation, dependence on imports, small market size, and unique regulatory challenges (Dhawan et al., 2022; Kahiya, 2020). The argument indicates that the importation of construction materials has the potential to increase costs and prolong construction timelines within the country. This is one of the added layers of complexity involved in building construction.

Since most real-world environments present various unforeseen challenges and continually force reconsideration and revision of established schedules, DS techniques have begun generating several research studies from the late 20th century (Ouelhadj & Petrovic, 2009). According to Kim et al. (2021), construction projects may demonstrate technical and organisational complexity. As a result, there was a noticeable transition from static to dynamic construction, necessitating a scheduling system that could adjust to real-time changes. DS offers substantial benefits, including improved utilisation of labour and cost-efficiency, optimisation of resource management, reduction of waste, and achieving optimal material procurement (Fahmy et al., 2020). On the contrary, DS has challenges, such as scalability and multi-agent reinforcement learning technological advancement (Dai et al., 2022). Moreover, De Jong (2012) contends that DS lacks "exact solutions" because the usefulness of a proposed schedule depends on an unforeseen future. Yu et al. (2021) confirm that there is a need for improvement and innovation of construction DS to accommodate uncertain circumstances. Despite the challenges associated with DS, such as its dependency on advanced technological tools and the requirement for real-time data interpretation, several studies have been made on its application in construction projects worldwide (Hao et al., 2010; Purushothaman & Kumar, 2022). Furthermore, the importance of DS was highlighted by Xie et al. (2023) since it can respond quickly to unpredictable disruptions during construction.

Dynamic Scheduling (DS) can also be referred to as "Dynamic Planning" (DP) (Fahmy et al., 2014a). Further exploring the classifications of DS, three categories define DS: completely reactive scheduling, predictive reactive scheduling, and robust, proactive scheduling (Ouelhadj & Petrovic, 2009). However, Aissani et al. (2009) introduced the concept of predictive scheduling as an additional classification within the context of DS. Predictive scheduling creates a predetermined schedule assuming a deterministic environment (Csáji & Monostori, 2006). This type of schedule assumes an ideal resource availability (Sarin & Salgame, 1990). However, due to the unpredictable environment, there are some situations where the data will only be available after the solution is implemented. Predictive-reactive scheduling updates the schedule in response to disruptions to minimise the effect on the scheduling system's performance (Tang & Wang, 2008). Alternatively, Mohan et al. (2019) describe a reactive scheduling strategy where a new schedule is generated in response to stochastic events that occurred in the field. In highly and frequently disturbed dynamic environments, reactive scheduling is used to quickly and optimally decide which changes to make based on the type of disturbance after an uncertain event, ensuring timely and cost-effective responses without relying on pre-scheduling (Zhang et al., 2021; Zhiliang & Xiaojiang, 2016). Finally, Bukkur et al. (2018) claim that robust-proactive scheduling involves developing predictive schedules by analysing and incorporating the primary causes of disruptions, allowing adaptability in dynamic environments.

Based on the literature review, despite extensive discussion of the benefits and applications of DS, there still needs to be a greater understanding concerning the specific factors and interrelations that affect its efficiency when applied to building construction. Despite some research into these influencing factors in road construction by Purushothaman and Kumar (2022), building construction projects present their challenges and complexities. Building projects' technological, logistical, and resource requirements are complex, emphasising the importance of identifying these factors for an efficient DS to meet those demands. Fahmy et al. (2014b) highlighted that any new DS system must comprehend the planners' daily scheduling challenges and research the characteristics of the problem. Hao et al. (2010) also claimed that schedule updates must maintain pace with the changing environment for a schedule to become of significant use to applications within the industry. Therefore, the building construction industry only realises its full potential by thoroughly identifying and understanding the interactions of factors affecting DS.

3. Research methodology

3.1 Research Design

The research team conducted a systematic literature review (SLR) adhering to the PRISMA guidelines to

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understand the factors and interrelations affecting DS in construction projects. First, a problem statement and research questions were developed based on their initial literature search, observations, and collegial insights. The research team worked iteratively to refine their problem statement and research questions. Then, an SLR was conducted to identify factors and their polarity and interrelations that affect DS in the construction industry. Five industry experts' consultations followed this. The data collected were analysed using themes and Degree of Centrality (DC). The results are presented through a pairwise interrelationship table, degree of centrality table, and a Causal loop diagram (CLD) and then ranked to find the most influenced and influential factors.

3.2 Systematic literature review and PRISMA statement

SLRs report how article data are identified and help reduce researcher biases (Cooper et al., 2018). Authors must outline their search strategy for identifying relevant literature, including the databases searched, search terms and keywords used, and the practical and methodological screening and exclusion criteria (Fisch and Block, 2018). The initial stage of the literature search involved applying designated search strings within the Scopus, EBSCO, and Science Direct databases. Each database was searched using two strings. This step was essential in identifying relevant literature to the research objective and ensuring it aligned with the study's theme. Table 1 *Research Search Strings and Exclusions Criteria* (The authors collected data on December 15th, 2023) details the search strings, inclusion and exclusion criteria for this study, and the databases and keywords used. The articles were collected from 2017 to ensure recency of knowledge.

Table 1 Research Search Strings and Exclusions Criteria

Database	Keywords Search	Inclusion Criteria	Exclusion criteria
Scopus	(TITLE-ABS-KEY ("Dynamic Scheduling*" OR "Dynamic Planning*" OR "Adaptive Scheduling*" OR "Flexible Scheduling*") **AND** TITLE-ABS-KEY (building* OR housing* "Building Construct*" OR "Residential Construct*" OR "Commercial Construct*" OR "High-rise Construction" OR "Low-rise Construct*" OR "Industrial Construct*" OR "Vertical Construct*" OR "Tall Building*" OR skyscraper*) **AND** TITLE-ABS-KEY (factor* OR variable* OR impact* OR cause* OR effect* OR reason* OR fail* OR challenge*)) **AND** PUBYEAR > 2017 **AND** PUBYEAR < 2023 (TITLE-ABS-KEY ("Dynamic Scheduling*" OR "Dynamic Planning*" OR "Adaptive Scheduling*" OR "Flexible Scheduling*") **AND** TITLE-ABS-KEY (construction*) **AND** TITLE-ABS-KEY (factor* OR variable* OR impact* OR cause* OR effect* OR reason* OR fail* OR challenge*)) **AND** PUBYEAR > 2017 **AND** PUBYEAR < 2024 **AND** (LIMIT-TO (LANGUAGE, "English")) **AND** (LIMIT-TO (SUBJAREA, "ENGI") OR LIMIT-TO (SUBJAREA, "ENVI") OR LIMIT-TO (SUBJAREA, "SOCI"))	Dynamic Planning and Scheduling, Flexible Scheduling, Adaptive Scheduling. Construction. Factors or similar words. English language articles. From the year 2017. From Engineering, environmental and social fields.	Not in English. Before 2017. Not from construction. Systematic, critical, and literature reviews
EBSCO	("Dynamic Scheduling*" OR "Dynamic Planning*" OR "Adaptive Scheduling*" OR "Flexible Scheduling*") **AND** (building* OR housing* "Building Construct*" OR "Residential Construct*" OR "Commercial Construct*" OR "High-rise Construction" OR "Low-rise Construct*" OR "Industrial Construct*" OR "Vertical Construct*" OR "Tall Building*" OR Skyscraper*) **AND** ((factor* OR variable* OR impact* OR cause* OR effect* OR reason* OR fail* OR challenge*) N20 (impact* OR barrier* OR delay* OR interruption* OR challenge* OR impediment* OR barricade* OR disadvantage* OR hindrance* OR conflict* OR affect* OR influence* OR effect* OR cause* OR reason* OR source* OR *root OR *foundation OR *trigger OR fail*)) ("Dynamic Scheduling*" OR "Dynamic Planning*" OR "Adaptive Scheduling*" OR "Flexible Scheduling*") **AND** (construction*) **AND** ((factor* OR variable* OR impact* OR cause* OR effect* OR reason* OR fail* OR challenge*) **N20** (impact* OR barrier* OR delay* OR interruption* OR challenge* OR impediment* OR barricade* OR disadvantage* OR hindrance* OR conflict* OR affect* OR influence* OR effect* OR cause* OR reason* OR source* OR *root OR *foundation OR *trigger OR fail*))		

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Database	Keywords Search	Inclusion Criteria	Exclusion criteria
Science Direct	("Dynamic Scheduling" OR "Dynamic Planning") **AND** ("Building Construction" OR "Residential Construction" OR "Commercial Construction" OR "Industrial Construction") **AND** (factor OR variable OR delay) ("Dynamic Scheduling" OR "Dynamic Planning") **AND** (construction) **AND** (factor OR variable OR impact OR influence OR delay OR challenge)		

PRISMA 2020 framework helps identify, select, appraise, and synthesise SLR articles (Page et al., 2021). The PRISMA framework features exclusion criteria, and the rationale behind each exclusion is meticulously documented, enhancing the study's repeatability (Page et al., 2021). Robinson and Lowe's (2015) editorial states that PRISMA is commonly used in SLRs with less than 50 papers, often fewer than 10, as compared to traditional literature reviews that may have over 150 papers. However, ten seems less useful for analysing factors, and numbers closer to 50 will benefit, provided their quality is good and helps to attain saturation. In this case, the overall quality of the papers was respectable (refer to Table 2), and the results yielded 176 factors within 11 distinct categories that were reasonably saturated (refer to Annexure 3). The process for gathering literature using the step-by-step procedure of the PRISMA framework for this study is illustrated in

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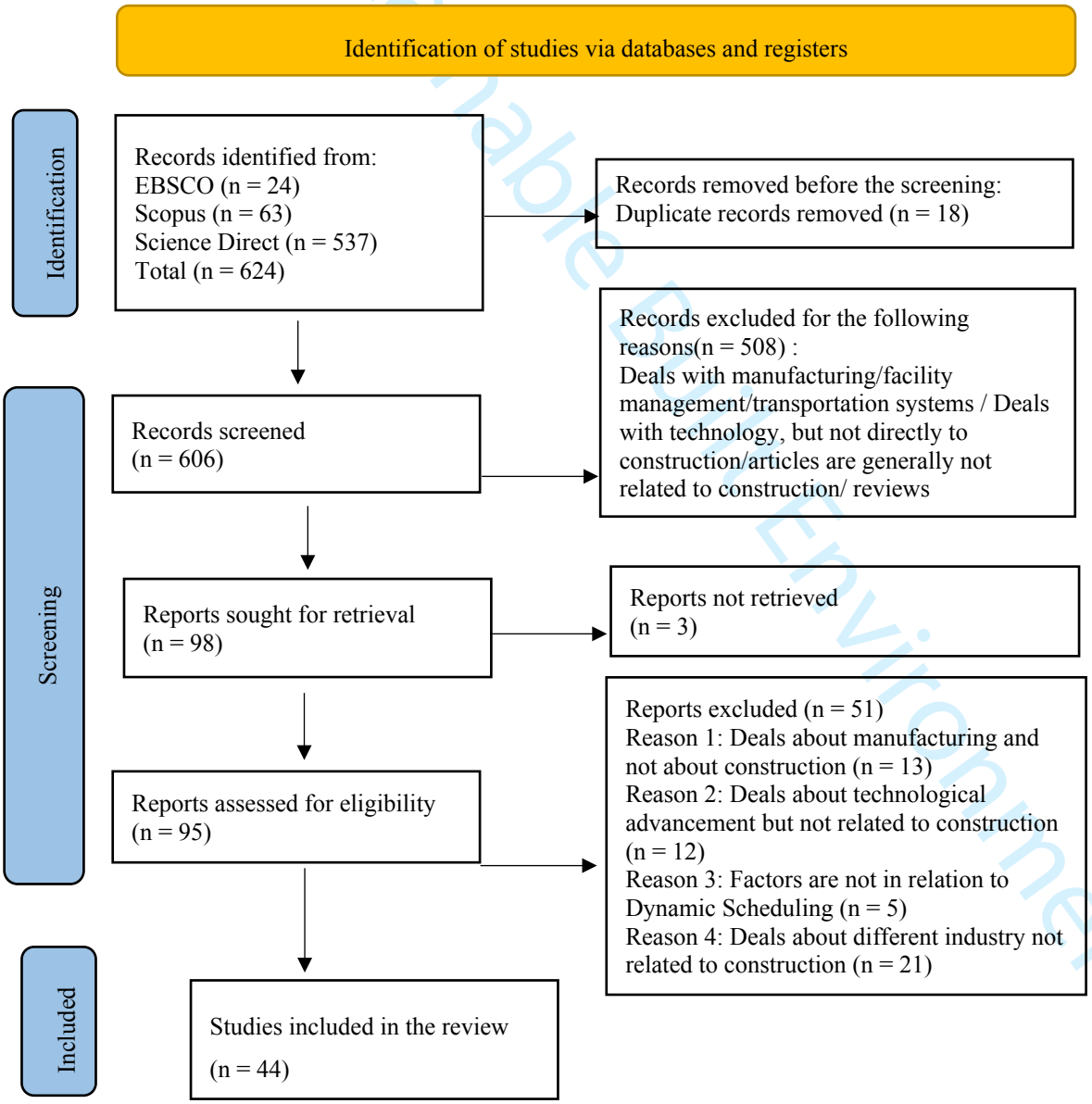

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Figure 1 PRISMA Framework (Authors' own work based on the PRISMA framework).

The quality of the articles and related journals included was analysed using the h-index and Scimago Journal & Country Rank (SJR) quartiles. Table 1 *Research Search Strings and Exclusions Criteria*provides the data, showing that 81.82% of the articles chosen were from Q1 journals, and 72.72% had an h-index greater than 100. Table 2 shows 36 papers from Q1 journals, three from Q2, and one from Q3. Four papers were from reputed conferences, and two were published in high-rated proceedings. H-index analysis revealed that 32 papers were greater than 100, seven were between 60 and 92, three were greater than 20, and two were conference papers. Ten papers were focusing building, and 34 focused on general construction.

Table 2 Ranking data analysis of Journals related to articles selected in the review

SJR H-Index	SJR Quartiles	Country	Journal	General		Total
				Building	Construction	
309	Q1	UK	Journal of Cleaner Production		1	1
292	Q1	UK	Applied Energy	1		1
271	Q1	UK	Expert Systems with Applications	1		1
243	Q1	US	Journal of Environmental Management	1	1	2
242	Q1	US	IEEE Access		1	1
232	Q1	Netherlands	Energy and Buildings		1	1
205	Q1	UK	Building and Environment		1	1
176	Q1	UK	Automation in Construction		11	11
165	Q1	UK	International Journal of Electrical Power & Energy Systems		1	1
161	Q1	UK	Computers & Industrial Engineering		4	4
139	Q1	UK	Tunnelling and Underground Space Technology		1	1
137	Q1	UK	Engineering Applications of Artificial Intelligence		1	1
123	Q1	UK	Information Processing & Management		1	1
110	Q1	UK	Advanced Engineering Informatics		4	4
92	Q1	Netherlands	Journal of Building Engineering	2		2
73	Q1	UK	Engineering, Construction and Architectural Management		1	1
28	Q1	UK	Smart and Sustainable Built Environment		1	1
23	Q1	Poland	Applied Mathematics and Nonlinear Sciences		1	1
76	Q2	UK	Engineering Optimization		1	1
60	Q2	Germany	KSCE Journal of Civil Engineering	1		1

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SJR H-Index	SJR Quartiles	Country	Journal	General Building	Construction	Total
30	Q2	Switzerland	Infrastructures		1	1
92	Q3	Netherlands	IFAC-papers online	1		1
103	Proceedings	Netherlands	Procedia CIRP	1		1
69	Proceedings	Netherlands	Transportation Research Procedia	1		1
	Conference		2nd IEEE International Conference on Distributed Computing and Electrical Circuits and Electronics, ICDCECE 2023		1	1
	Conference		ISARC 2018 - 35th International Symposium on Automation and Robotics in Construction and International AEC/FM Hackathon: The Future of Building Things	1		1
			Grand Total	10	34	44

3.3 Year and country-wise Data

Figure 2 *Year & Country Contributions and Number of Articles Studied* (The authors collected data on the 15th of December, 2023) shows the year, number of articles, and countries contributing to this study. In 2021, there was a noticeable decrease in the number of articles available on DS. The COVID-19 pandemic may have played a role in this trend. Interestingly, Chinese researchers showed significant interest in DS, as their articles outnumbered those produced by any other country. Unfortunately, there was no African representation during this period, indicating a shortage of credible research. This could be attributed to factors such as the limited popularity of DS in Africa, technological barriers, and adherence to traditional scheduling.

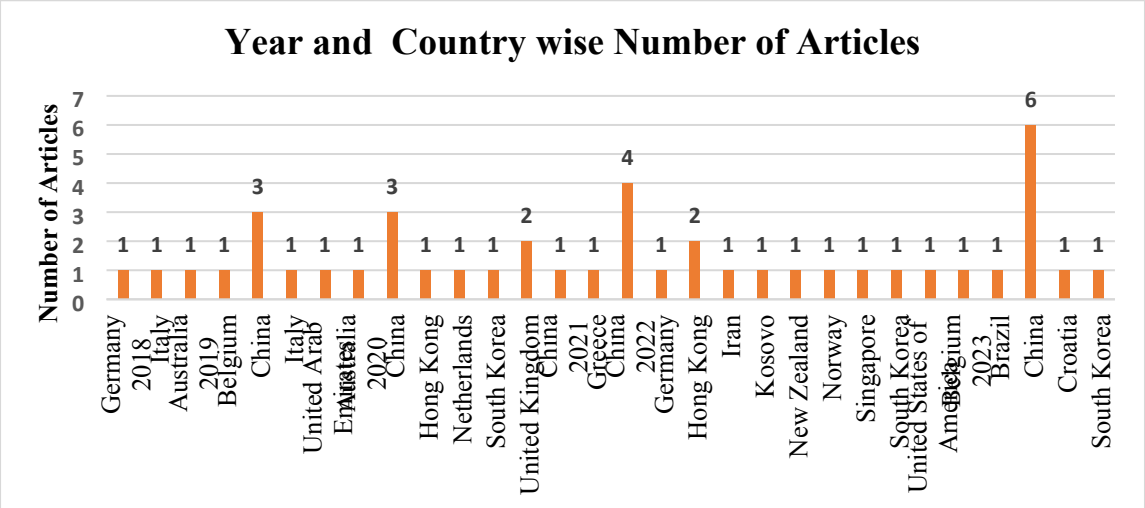

Figure 2 Year & Country Contributions and Number of Articles Studied (Author's own work)

Furthermore, VOSViewer software was employed to conduct a keyword search analysis to establish the possible interrelationships of factors mentioned in the identified literature. Figure 3 *Keyword Search Analysis* shows a graphical representation of bibliometric maps showing the connectivity between keywords used in SLR search strings.

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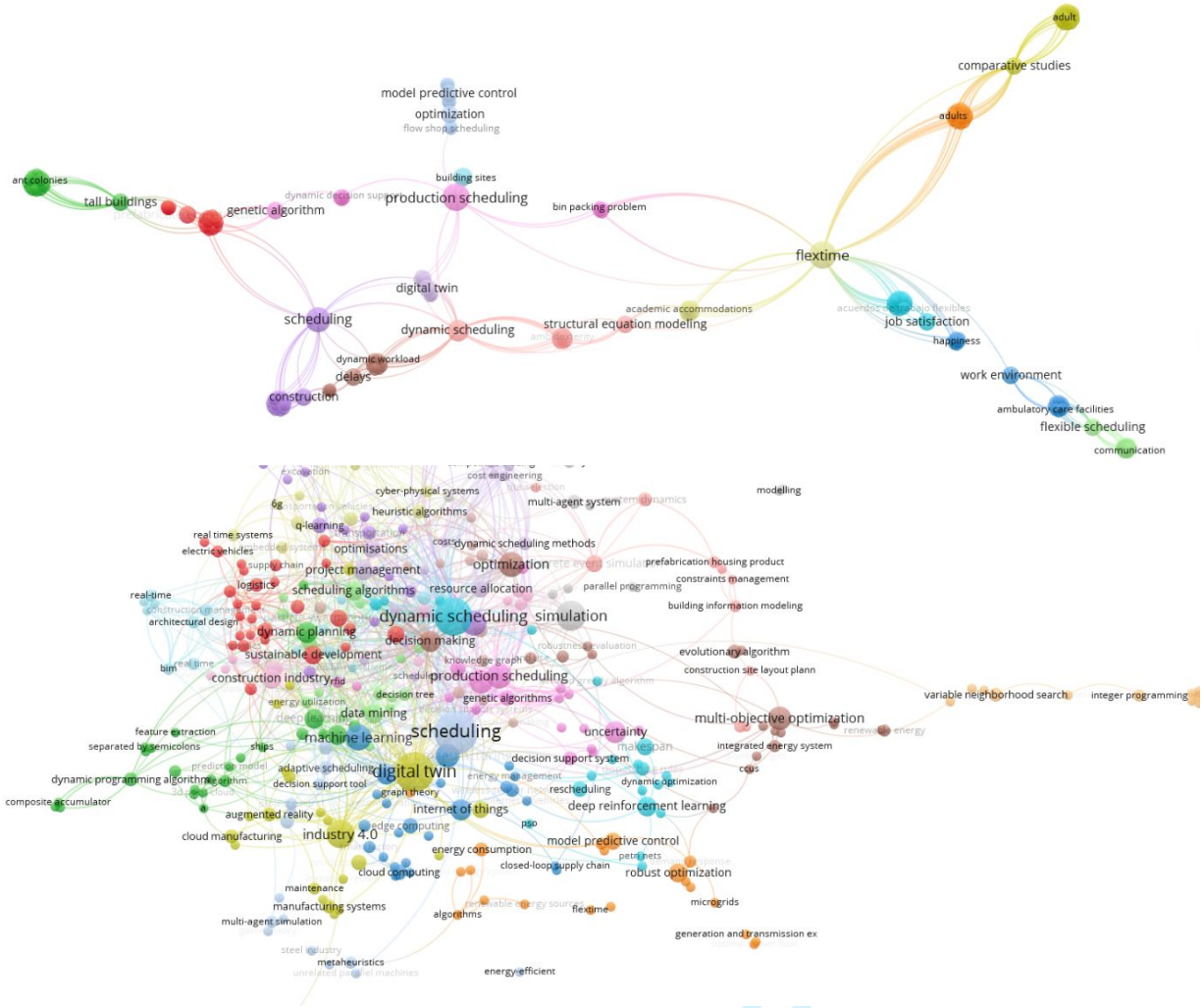

Figure 3 Keyword Search Analysis(Author's own work)

3.4 Factors and Interrelations

Vosviewer provides a graphical representation of bibliometric maps that show the keywords' relevance. However, it fails to separate and provide data on the chosen topic's factors, polarity, and interlinks. To overcome this, following Samarasekara et al. (2024), the steps within the Analytical Hierarchy Process were used to identify the interrelationship of factors affecting DS. The steps followed were:

- The problem and criteria were defined.
- The identified articles were read more than once to identify the factors, polarity, and interrelationships.
- The identified factors affecting DS and the positive and negative influences were then categorised into 11 groups, coded and tabulated (Annexure 1).
- Following Samarasekara et al. (2024), a framework for pairwise comparison using the steps within the Analytical Hierarchy Process was developed to identify the interrelationship of factors affecting DS.
- The articles were read at least twice to list the factors and their interrelations. Factors interactions and polarity were identified from SLR articles using a pairwise comparison plotted in an Excel workbook.
- The pairwise comparisons were checked for consistency before evaluating the relative factors.

- A sensitivity analysis using CLD revealed interacting loops and affirmed the nodes' (factors) connectivity.
- The DC analysis using the incoming and outgoing nodes was conducted to identify the DS factors with the most interactions and rank them.
- Experts Industry consultation was obtained on DS factor interactions, and DC was calculated to compare and contrast.
- A ranking of DS factors was concluded based on SLR and industry consultation.

The interrelationship framework is depicted in On the other hand, when "Negative: CE-P02 ↓ CE-P01" is noted, it means that the impact of CE-P02 is detrimental to CE-P01, causing delays or other adverse effects. If there is no notation, it suggests no clear correlation between the variables identified.

Table 3 shows the connections between different factors that impact each other positively or negatively. The pairwise interrelationship table enables readers to recognise these links and understand how one factor can affect another (Saaty, 2012). For example, “Positive: CE-P02 ↑ CE-P01" means CE-P02 positively impacts CE-P01 and helps reduce delays due to CE-P01. On the other hand, when "Negative: CE-P02 ↓ CE-P01" is noted, it means that the impact of CE-P02 is detrimental to CE-P01, causing delays or other adverse effects. If there is no notation, it suggests no clear correlation between the variables identified.

Table 3 Pairwise Interrelationships Framework (Author's own work)

		Theme			
		Factor CE-P01	Factor CE-P02	Factor CE-P03	Factor CE-P04
Theme	Factor CE-P01	N/A	Positive: CE-P01 ↑ CE-P02 Negative: CE-P01 ↓ CE-P02 (Blank): No Relationship	Positive: CE-P01 ↑ CE-P03 Negative: CE-P01 ↓ CE-P03 (Blank): No Relationship	Positive: CE-P01 ↑ CE-P04 Negative: CE-P01 ↓ CE-P04 (Blank): No Relationship
	Factor CE-P02	Positive: CE-P02 ↑ CE-P01 Negative: CE-P02 ↓ CE-P01 (Blank): No Relationship	N/A	Positive: CE-P02 ↑ CE-P03 Negative: CE-P02 ↓ CE-P03 (Blank): No Relationship	Positive: CE-P02 ↑ CE-P04 Negative: CE-P02 ↓ CE-P04 (Blank): No Relationship
	Factor CE-P03	Positive: CE-P03 ↑ CE-P01 Negative: CE-P03 ↓ CE-P01 (Blank): No Relationship	Positive: CE-P03 ↑ CE-P02 Negative: CE-P03 ↓ CE-P02 (Blank): No Relationship	N/A	Positive: CE-P03 ↑ CE-P04 Negative: CE-P03 ↓ CE-P04 (Blank): No Relationship
	Factor CE-P04	Positive: CE-P04 ↑ CE-P01 Negative: CE-P04 ↓ CE-P01 (Blank): No Relationship	Positive: CE-P04 ↑ CE-P02 Negative: CE-P04 ↓ CE-P02 (Blank): No Relationship	Positive: CE-P04 ↑ CE-P03 Negative: CE-P04 ↓ CE-P03 (Blank): No Relationship	N/A

These tabulated data are then used to create a Causal Loop Diagram (CLD) showing the factors and their relationships influencing DS in the construction industry.

3.5 Causal Loop Diagram

CLD is a frequently used tool for addressing problems through system dynamics (Husain et al., 2020). Qualitative methods such as literature reviews and expert interviews are commonly used to create CLDs (Dhirasasna & Sahin, 2019). CLDs offer a way to easily investigate causal relationships, gain qualitative insights into the phenomena under investigation, and assist in network analysis (Uleman et al., 2021). In this study, CLDs prove critical in navigating a complex network of DS influences, distinguishing between positive

and negative factors. Following Samarasekara et al. (2024), curved lines with arrows represent each link, with blue arrows indicating positive (+) influences and red arrows representing negative (-) influences. Bold red arrows highlight the eleven major categories impacting DS. Black text indicates positive influential factors, while red text indicates negative impacts.

CLDs visually illustrate the complex interconnections and help to rank the factors based on the number of loops in which the individual factors participate. If fewer loops are identified, analysing the number of factors a particular factor "influences" or gets "influenced" is helpful. However, these are one-sided rankings based on "influence" or "influenced". In such cases, the degree of centrality that considers both "influence" and "influenced" helps identify the ranking of the interrelating factors.

3.6 Degree of Centrality

In an interrelation analysis, the network and nodes (the factors) play an important role. Network analysis focuses on Real-world systems, which are complex networks of interconnected nodes. Hence, assessing the relative importance of these nodes is crucial, typically done through various centrality measures that highlight different aspects of the network (Ronqui & Travieso,2015). Network analysis can be regarded as a set of techniques with a shared methodological perspective. It allows researchers to depict relations among factors and analyse the system structures that emerge from the recurrence of these relations (Chiesi, 2015). Centrality concepts were developed in social network analysis and later adopted in many fields. Multiple methods evolved for identifying network centrality. The closeness centrality method is used for analysing connected graphs using the natural distance between all pairs of nodes, and the metric is based on the length of the shortest paths (Parand et al., 2016). The betweenness centrality measure quantifies the number of times a node occurs as a bridge along the shortest path between two other nodes (Parand et al., 2016). Eigenvector centrality can also be seen as a weighted sum of direct and indirect connections of any length (Parand et al., 2016). Degree Centrality is defined as the number of links incident upon a node. The Degree can be interpreted as the node's (factor's) opportunity to catch the flowing interactions in the network (Parand et al., 2016).

Estimating closeness and betweenness centrality requires understanding the length or duration of factors' interaction. This requires data that evolves over a period based on presumed static situations. Hence, it will not be helpful for dynamic situations that lack duration data. Eigenvector centrality links indirect interactions and multiple iterations, complicating the calculations and possibly creating trivial issues if calculations lead to null values. Hence, the Degree of Centrality measure is advantageous, as it is a straightforward calculation based on connected nodes (interrelations). Determining the degree of centrality (DC) involves counting the edges connected to a factor. This metric is especially effective because factors with high edges (degrees) often have high centrality within the network (Golbeck, 2013). The number of edges linked to a factor is a fundamental network property that describes its connections (Golbeck, 2013). In-degree is the number of edges pointing towards the factor (influenced), while out-degree is the number of edges pointing away from it (influence) (Hansen et al., 2020).

The total degree score of the factor is obtained by adding both the in-degree and the out-degree. The total degree score is then normalised into a 0-1 scale to identify the DC of a factor. DC score is achieved by dividing the total number of relationships connected to a factor (in-degree plus out-degree) by the highest total degree factor in the network (Golbeck, 2013). The factor with the highest degree will have a DC score of 1, while every other factor's centrality will be a fraction of its degree (Golbeck, 2013). DC scores are plotted in a table and sorted in ascending order to determine the ranking of the factors. The pairwise comparison table was used to determine the number of indegree and out-degree factors and calculate each factor's DC score. Following Purushothaman et al. (2024), the Pairwise Interrelationships matrix determines the in-degree, out-degree, and Degree of Centrality.

3.7 Industry Consultation

The factors and interrelations affecting DS were further subjected to industry experts' consultation. The industry consultants were chosen based on various employment segments, roles, positions, fields, and years of experience. A web-based search was used to scan public-facing profiles to identify 12 industry experts across New Zealand (purposive sampling), and then scoping expert meetings with five individuals were carried out to capture their specific, insider and diverse perspectives on DS topics. The segments invited included contractors, government, consultants, and client organisations, ensuring a diverse pool of expertise. Contractors included direct contractors to the government and large subcontractors. The role criteria included experience working with DS. The position criteria were fixed managers and above to obtain a realistic view of DS factors and strategies. The field criteria included buildings and other construction. The years of experience were set at a minimum of 5 years to get a reasonable outcome. Table 4 shows the details of the industry consultation of five

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construction professionals in New Zealand. Their experience ranged from 6 to 25 years, and they were from different employment segments and covered most types of buildings. The consultations lasted between 53 minutes and 1 hour 17 minutes. The discussions were noted, recorded and transcribed. Following Purushothaman et al. (2021), the narrative analysis method used notes and transcriptions to determine themes (Factors Category), factors, and pairwise interrelationships. The interrelationships were then tabulated, and DC was calculated. The results were compared and contrasted.

Table 4 Industry consultation (Author's own work)

Industry expert code	Employment segment	Current Role	Years of Experience	Experience Category
IP1	Contractor	Business Development Manager	12	Housing, Communal Non-Residential, and Commercial Buildings
IP2	Contractor	Project Engineer cum Project Manager	8	Communal Non-Residential, and Commercial Buildings
IP3	Government	Project Manager	6	Communal Non-Residential, and Commercial Buildings
IP4	Consultant	Senior Project Manager	25	Housing, Industrial Buildings, and Other Construction
IP5	Client	Project Manager	10	Commercial Buildings and Industrial Buildings

3.8 Research reliability and validity

Reliability is achieved through organised data and ideas (Walliman, 2017). Factors enhancing reliability in qualitative research include ethics, large sample sizes, multiple sites, triangulation, data from large organisations, careful sampling, and rigorous coding (Walliman, 2017).

For this research, the following were taken to ensure reliability:

- The research design ensured the confidentiality of the participant and the organisation; participation was voluntary, and people were protected from any risk;
- The research was conducted with a large number of article reviews; 44 were studied in depth;
- Methods (SLR and consultation, author frequency and DC analysis), theory (interrelationships and factors), and data (SLR and Consultation) triangulation methods were used to collect the data that assured reliability.
- Emphasis was placed on the quality of industry participants, who were English-speaking employees in the real workplace, allowing the data to be analysed based on the participants' experiences to attain generalizability and enhance knowledge and
- The data were analysed to set themes and codes that ensured reliability.

Validity in research refers to the degree to which the outcomes of an experiment can be legitimately generalized (Walliman, 2017). The validity of the research depends on the robust ethical design carried out in everyday life settings that provided data representativeness of influence on sought variables (Denzin, 1978). John & Dana (2000) and Carter et al. (2014) argued that triangulation is a strategy to achieve validity. John & Dana (2000) state establishing credibility in a study is to describe in detail the setting, the participants, and the themes of the study. The validity was ensured by:

- Ensuring the same consultation protocol was developed and used for five industry participants;
- The robust ethical design of research aided in obtaining data that genuinely reflected the influences of the variables (factors on DS);
- Methods, environment, theory, and data triangulation methods used to collect and analyse the data;
- Confirmability: The research generalised theory through the DC analysis of SLR from high-quality journals, conferences, and Industry experts, confirming its practical application;
- Credibility: Credibility was ensured by gathering and analysing high-quality data from mostly reputable journals (refer to Table 2) and industry experts with DS experience.

- Transferability: The consultation was conducted in typical work settings with high ethical practices to

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ensure transferability.

The current research, conducted with the utmost care and thoroughness, adopted ethical practices and reviewed 44 articles from high-quality journals and conferences in depth. Industry consultation with the same protocol and triangulation aided in obtaining comprehensive data that genuinely reflected the influences of the factors on DS. The high-quality data from SLR and Industry experts combined with the DC analysis on the network interrelations reflected the real-life system dynamics of DS, ensuring the current research's reliability and validity. Figure 4 shows the overall research design.

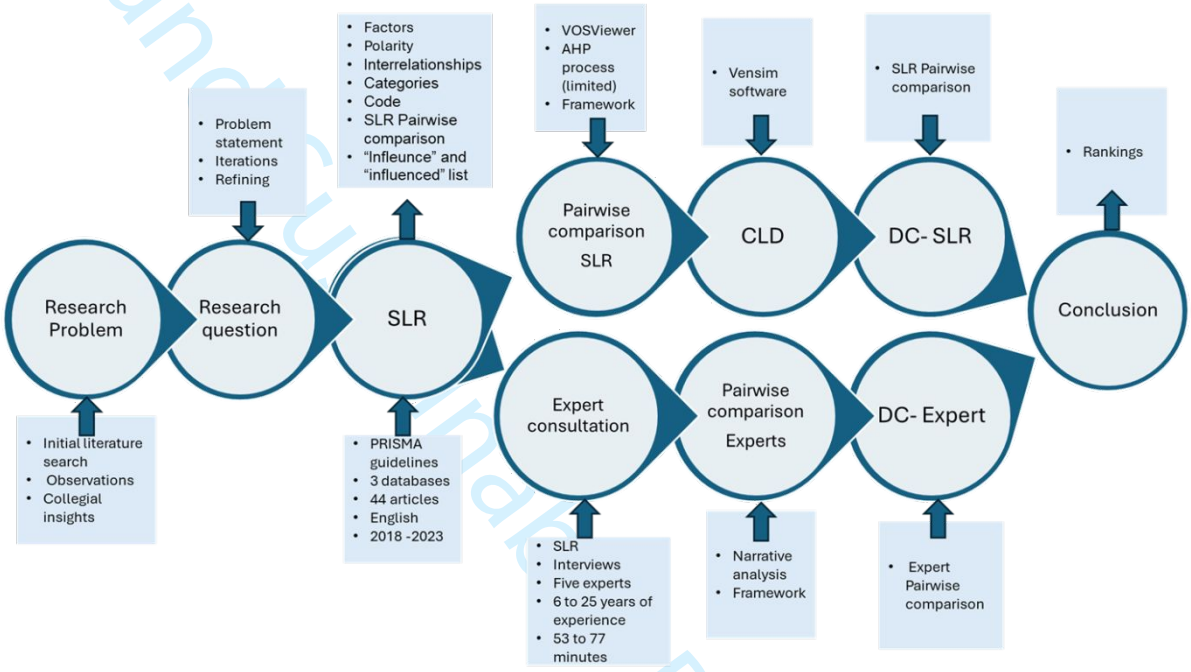

Figure 4 Research design (Author's own work)

4. RESULTS AND DISCUSSION

4.1 Systematic Literature Review Results

The SLR's summary differentiates factors influencing DS into 11 categories: cultural, design, economic/legal, environment, management, planning/scheduling, resources, safety, social, technology, and weather/climate. A total of 176 factors were identified, reviewing 44 articles published between 2018 and 2023 covering 19 countries from 5 continents. Furthermore, these factors are coded according to the positive or negative impact of DS (Annexure 1). The Author factor matrix is shown in Annexure 2. Subsequent analysis identified frequently mentioned top 3 positive and the top four negative factors; refer to *Table 5* below.

Table 5 Top Factors Influencing Dynamic Scheduling based on author count (Author's own work)

Rank	Factors Category	Code	Polarity	Author Count
1	**Technology**	TY-P01	Positive	10
2 - 3	**Technology**	TY-P02	Positive	7
	Resources	RC-N01	Negative	7
4 - 6	**Environment**	ET-P01	Positive	5
	Environment	ET-N01	Negative	5
	Weather / Climate	WR-N01	Negative	5

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Rank	Factors Category	Code	Polarity	Author Count
7 - 9	**Environment**	ET-N02	Negative	3
	Resources	RC-N02	Negative	3
	Resources	RC-N03	Negative	3
10 - 16	**Design**	DN-N01	Negative	2
	Economic / Legal	EC-N01	Negative	2
	Environment	ET-N03	Negative	2
	Environment	ET-N04	Negative	2
	Environment	ET-N05	Negative	2
	Environment	ET-N06	Negative	2
	Weather / Climate	WR-N02	Negative	2

TY-P01 10, TY-P02 7, and ET-P01, with 10, 7, and 5 articles mentioning it, respectively, were the top three positive factors that impact DS based on author count. RC-N01, ET-N01 and WR-N01, with 7, 5, and 5 articles mentioning it, respectively, were the top three negative factors that impact DS based on author count. The top-ranked positive factor based on author count, BIM (TYP-01), has been mentioned as a valuable tool for improving DS. Zavari et al. (2022) and Deng et al. (2022) emphasised that BIM provides essential intensive data for DS implementation through optimal site spatial modelling and arrangement. The second highest factor is Shapes Constraint Language (TYP-02). Soman et al. (2020) that TYP-02 is effective as it promotes a method to ascertain logical linkage between construction activities to address complex DS challenges. The third most significant positive influence is spatial development or the availability of spatial information (ET-P01) in construction. The strategic use of workspace on construction sites highlights potential productivity improvements. For instance, Jiang et al. (2020) affirmed the use of real-time 3D spatial data as a critical factor in providing opportunities to improve the effectiveness of DS in construction sites.

The most significant negative factors based on author count were resource constraints and unavailability (RC-N01). Optimistic estimates of activity durations and resource availability frequently fail to reflect the realities encountered on the project site that directly impact DS's application and efficiency (Isah and Kim, 2021). Site space, limited workspace, and accessibility issues (ET-N01) were among the top three negative factors influencing DS. Li et al. (2019a) findings emphasised the difficulties associated with rehandling due to poorly planned site space leading to potential delays. Interestingly, ET-N01 is the reverse of ET-P01, which different authors had captured. Next, bad or inclement weather conditions (WR-N01) appeared in the top three negative factors influencing DS. This finding agreed with Hsu et al. (2020), who highlighted that poor weather significantly impacts material delivery and site work stoppage, resulting in project schedule deviations. While the existing global literature focuses on identifying delay causes in the construction industry, investigating causal relationships between the factors is critical for enhancing DS effectiveness and broadening understanding of potential project outcomes.

4.2 Pairwise Interrelationships Results, Causal Loop Diagram and Degree of Centrality

The study carefully examined each article to uncover the connections between various factors. The analysis revealed 61 factors with relationships. Of these, 53 positively impacted other factors, while eight negatively impacted. **Error! Reference source not found.** provides an overview of the connections between each factor, indicating whether the relationship is positive or negative and the author's reference number. Notably, these interrelationships were identified from 44 articles (refer to Annexure 2 SLR Pairwise Interrelationship Summary and Annexure 3 for the chronological order of articles from 2018 to 2023). The analysis of pairwise interrelationships (Annexure 2) revealed significant influencing and influenced factors. Figure 5 shows the top influential and influenced factors based on the pairwise comparison of the SLR.

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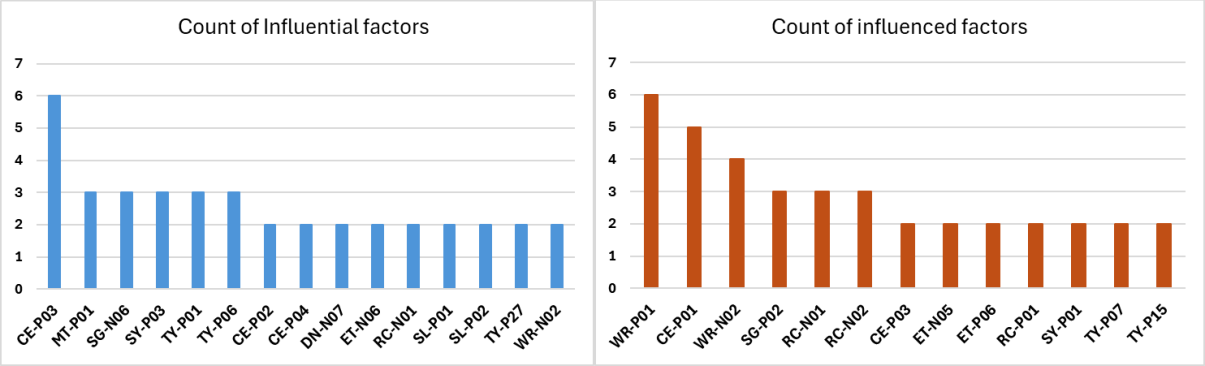

Figure 5 The leading influential and influenced factors in SLR pairwise comparison (Author's own work)

"Diverse cultural heritage" (CE-P03) emerged as the most significant influential factor, with six total counts. According to Fatorić and Egberts (2020), understanding this factor can help policymakers create effective climate action strategies. Many countries protect heritage structures to preserve cultural legacies and reduce construction projects' carbon footprint. Furthermore, heritage has an essential effect on cultural identity, strengthens community bonds, and promotes a stronger sense of communal solidarity (Fatorić and Egberts, 2020)Five factors each influenced three other factors: construction site layout (MT-P01), poor planning (SG-N06), noise barriers (SY-P03), BIM (TY-P01), and the Multi-stage stochastic programming model for optimal supply chain configuration (TY-P06). Choi et al. (2022) highlighted that effective MT-P01 improves worker productivity and safety by reducing material handling and strategic material storage, all of which improve DS effectiveness. Petroutsatou et al. (2021) highlighted that SG-N06 could result in higher transportation costs, resource inefficiencies, and increased downtime, adversely affecting DS. Choi et al. (2022) highlighted that SY-P03 affects costs, productivity, and safety and disturbs nearby residents, negatively influencing construction productivity and DS. TY-P01 appeared in the top influential factors based on pairwise comparison of the SLR and in the top influential factors based on author count. Hsu et al. (2020) highlighted that TY-P06 addresses the construction site's unpredictable and complex logistical challenges by optimising production, transportation, and inventory strategies to resolve logistics issues.

On the other hand, Climate Change Mitigation and Adaptation (WR-P01), Cultural Heritage Management (CE-P01), and Climate Change (WR-N02) emerged as the factors most influenced, with six, five and four factors influencing them, respectively. Fatorić and Egberts (2020) emphasised that cultural heritage management practices, which avoid unnecessary delays due to cultural perspectives, positively influence DS. Further, Fatorić and Egberts (2020) emphasised integrating WR-P01 strategies as necessary for promoting sustainable and eco-friendly projects. Purushothaman and Kumar (2022) highlighted that WR-N02 relies on historical data-based predictions, which may not be accurate and significantly impact construction. Three other factors influenced the use of Resource-Constrained Project Scheduling (SG-P02), Resource Unavailability / Resource Constraints / Unstable Resource Availability (RC-N01), and material Availability / Unavailability of Prefabricated Products / Material Availability (RC-N02). Chakrabortty et al. (2020) highlighted construction complexities such as stochastic activity durations, resource unavailability, and varying resource demands impact SG-P02. These challenges cause instability in the DS, which reduces its effectiveness. Purushothaman and Kumar (2022) highlighted that errors in design and unanticipated events can disrupt RC-N01. Events include changes in weather, the availability of skilled personnel, access to raw materials, equipment failures, local community events, traffic management issues, and geological uncertainty. On the other hand, Lin et al. (2022) proposed a solution that combines optimisation and network scheduling to effectively address static and dynamic resource-constrained situations, positively impacting RC-N01. Purushothaman and Kumar (2022) discussed how the design, event-related disruptions, and adverse weather conditions contribute to material shortages (RC-N02). Notably, the discussion on influencing and influenced factors does not provide the overall inter-relationship spectrum.

CLD, shown in Figure 6, helps to visualise the spectrum of factors and their effects, which provides an enhanced understanding of the interrelations of factors affecting DS. The CLD places DS at the centre of the diagram, followed by its 11 primary categories. These categories are connected to the 176 factors; 95 positive influence factors are shown with blue arrows, and 81 negative influences are indicated with red arrows. Furthermore, the CLD illustrates 61 factors of interdependent relationships, with blue arrows indicating positive and red arrows indicating negative influence. The CLD illustrated a more apparent separation between the positive and negative factors than in a tabular form. The CLD further revealed one reinforcing loop of CE-P03 and WR-N02. No other loops were deducted in the CLD.

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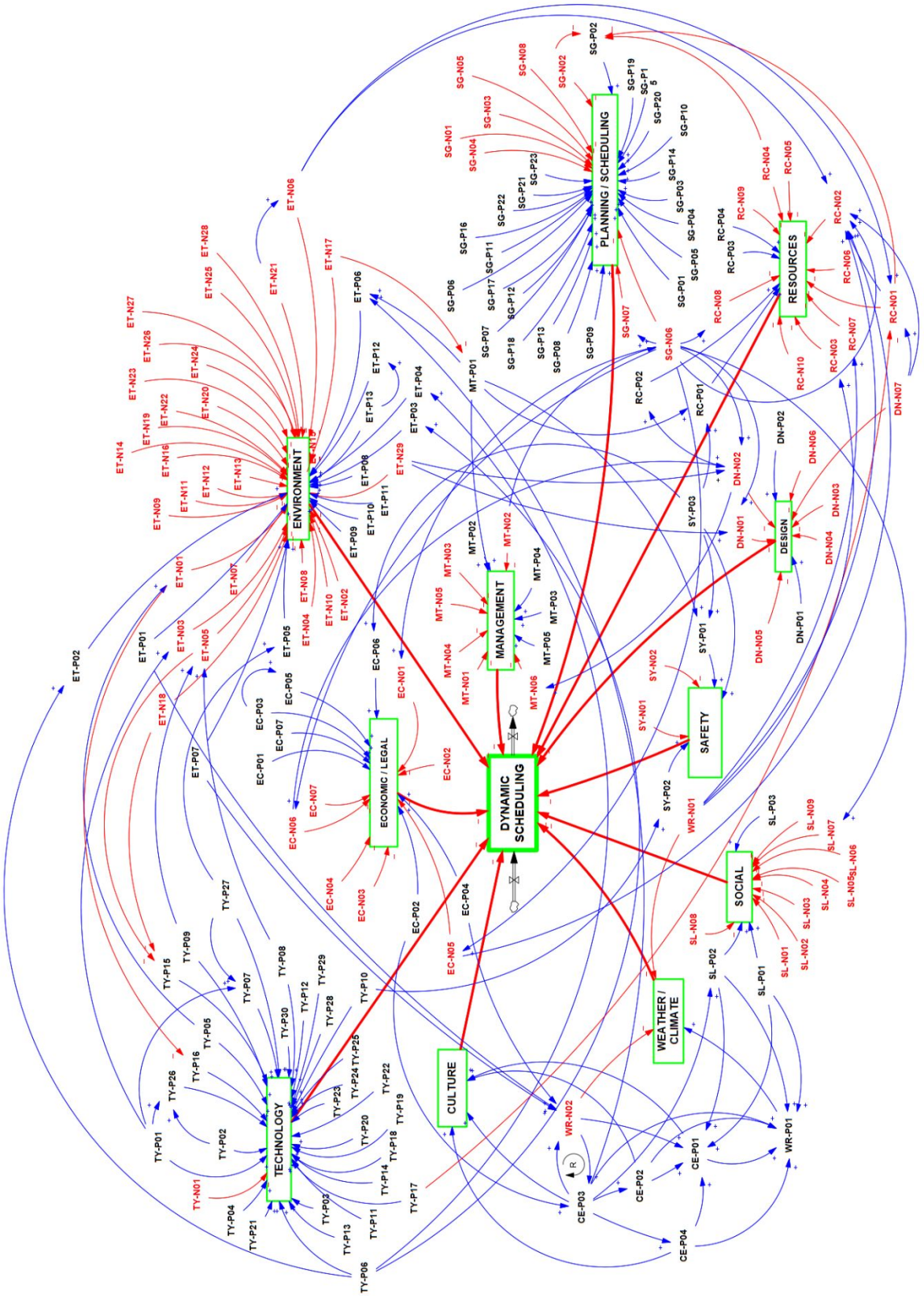

Figure 6 Causal Loop Diagram (Author's own work)

Though the CLD did not reveal more than one loop, it reveals the number of edges linked to a factor as a fundamental network property that describes its positive and negative interconnections. The more edges a factor has, the more critical and central it is to the network (Golbeck, 2013). DC is one such measure that uses the

number of edges to prioritise the focus (Golbeck, 2013). Table *6* shows the in, out and total degrees and the DC based on SLR. The top 5 factors based on SLR DC are CE-P03, WR-P01, CE-P01, WR-N02, and RC-N01.

Table 6 Degree of Centrality based on SLR (Author's own work)

Factor	Out-Degree	In-degree	Total Degree	Degree of Centrality
CE-P03	3	6	9	1
WR-P01	6		6	0.67
CE-P01	5	1	6	0.67
WR-N02	4	2	6	0.67
RC-N01	3	2	5	0.56
MT-P01	1	3	4	0.44
SG-P02	3		3	0.33
RC-N02	3		3	0.33
ET-N05	2	1	3	0.33
SL-P02	1	2	3	0.33
ET-N06	1	2	3	0.33
CE-P02	1	2	3	0.33
CE-P04	1	2	3	0.33
TY-P01		3	3	0.33
SY-P03		3	3	0.33
SG-N06		3	3	0.33
TY-P06		3	3	0.33
TY-P26	2		2	0.22
TY-P15	2		2	0.22
SY-P01	2		2	0.22
RC-P01	2		2	0.22
ET-P06	2		2	0.22
ET-N01	1	1	2	0.22
TY-P27		2	2	0.22
SL-P01		2	2	0.22
DN-N07		2	2	0.22
TY-P16	1		1	0.11
SY-P02	1		1	0.11
SG-N07	1		1	0.11
RC-P02	1		1	0.11
RC-N08	1		1	0.11
RC-N03	1		1	0.11
ET-P12	1		1	0.11
ET-P05	1		1	0.11
ET-P04	1		1	0.11

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Factor	Out-Degree	In-degree	Total Degree	Degree of Centrality
ET-P03	1		1	0.11
ET-P02	1		1	0.11
ET-N03	1		1	0.11
EC-P06	1		1	0.11
EC-P05	1		1	0.11
EC-N01	1		1	0.11
SG-N02		1	1	0.11
RC-N04		1	1	0.11
WR-N01		1	1	0.11
TY-P17		1	1	0.11
TY-P10		1	1	0.11
TY-P09		1	1	0.11
TY-P08		1	1	0.11
TY-P05		1	1	0.11
TY-P02		1	1	0.11
ET-P13		1	1	0.11
ET-P07		1	1	0.11
ET-P01		1	1	0.11
ET-N21		1	1	0.11
ET-N18		1	1	0.11
ET-N17		1	1	0.11
EC-P04		1	1	0.11
EC-P03		1	1	0.11
EC-P02		1	1	0.11
DN-N02		1	1	0.11

4.3 Industry Consultation Pairwise Interrelationships Results and Degree of Centrality

Table 7 below shows the pairwise interrelations stated by five construction industry professionals in New Zealand. The industry experts confirmed only a few interrelations compared to the SLR, but all were previously unidentified. A note of caution is that these interrelations may have been identified before 2017 or other databases, which this study excluded. These interrelations are also shown in *Figure 6*.

Table 7 Pairwise interrelations stated by Industry professionals (Author's own work)

Primary Factor	Polarity	Influenced Factor
DN-N02	Positive	MT-N06
EC-N05	Positive	RC-N02
EC-N06	Positive	DN-N02
ET-N29	Positive	DN-N02 and DN-N01
MT-N02	Positive	SG-N06
SG-N06	Positive	SL-N07, RC-N02, DN-N02, DN-N01, EC-N06 and EC-N05

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Primary Factor	Polarity	Influenced Factor
WR-N01	Positive	RC-N07 and RC-N02

Table 8 shows the degree of centrality for factors affecting DS based on Industry consultation. SG-N06 tops the list, followed by DN-N02, RC-N02, WR-N01, and EC-N06. Interestingly, the top 5 factors, CE-P03, WR-P01, CE-P01, WR-N02, and RC-N01, did not appear in the degree of centrality based on Industry consultation.

Table 8 Degree of centrality based on Industry consultation (Author's own work)

Factor	Out-Degree	In-degree	Total Degree	Degree of Centrality
SG-N06	6	1	7	1.00
DN-N02	1	3	4	0.57
RC-N02		3	3	0.43
WR-N01	2		2	0.29
EC-N06	1	1	2	0.29
EC-N05	1	1	2	0.29
ET-N29		2	2	0.29
DN-N01		2	2	0.29
RC-N07		1	1	0.14
MT-N06		1	1	0.14
SL-N07		1	1	0.14
MT-N02	1		1	0.14

Amongst all the critical factors, CE-P03 had the maximum degree of centrality, ranking it as the top factor among those identified by the SLR. WR-P01, CE-P01, WR-N02, and RC-N01 were ranked next (*Table 6*). WR-N02 and RC-N02 negatively affect DS, while CE-P03, WR-P01, and CE-P01 have positive impacts. The DS must consider these critical factors to avoid multiple or repelling effects. A point to consider is that these are higher-level strategic decision factors that affect DS, as identified by the global literature, considering all types of projects. In contrast, the degree of centrality for factors affecting DS based on industry consultation yielded different results. SG-N06 tops the list, followed by DN-N02, RC-N02, WR-N01, and EC-N06 (Table 8). Interestingly, the top 5 factors, CE-P03, WR-P01, CE-P01, WR-N02, and RC-N01, did not appear in the degree of centrality based on Industry consultation. However, SG-N06 appeared third in the top influential list, and DN-N02 appeared last in DC based on the SLR list (Table *6*), and one author (Al Hawarneh et al., 2019) out of 44 had identified this factor. The industry consultants were critical of this factor, which probably affects the site and building construction phase operations.

RC-N02, unavailability of materials/unavailability of prefabricated products / Material availability ranked 7-9 in the author count list (Table 5), eighth in the DC based on SLR (Though the CLD did not reveal more than one loop, it reveals the number of edges linked to a factor as a fundamental network property that describes its positive and negative interconnections. The more edges a factor has, the more critical and central it is to the network (Golbeck, 2013). DC is one such measure that uses the number of edges to prioritise the focus (Golbeck, 2013). Table *6* shows the in, out and total degrees and the DC based on SLR. The top 5 factors based on SLR DC are CE-P03, WR-P01, CE-P01, WR-N02, and RC-N01.

Table 6) and appeared as the most influenced factor (*Table 7*). Five authors identified WR-N01 as having a negative influence on DS; it was ranked between 4-6 in *Table 5*. It aligned with the ranking based on industry consultation DC (*Table 8*). EC-N06, lack of work permits, the next critical factor identified by Industry consultants, did not appear in pairwise comparison and DC based on SLR. However, Li et al. (2019b) were the only authors out of 44 who identified this factor in the SLR (Annexure 3). Though this research identified the relationship of EC-N06 for the first time, it must be interpreted cautiously. It is important to note that industry consultants are working professionals focused on problems on building construction sites rather than having a project perspective. Hence, EC-N06 should be treated as a critical factor influencing the buildings' DS at the operational level. Summarising, SG-N06, DN-N02, RC-N02, WR-N01, and EC-N06 are crucial factors affecting DS and operational level, while CE-P03, WR-P01, CE-P01, WR-N02, and RC-N01 are the top 5

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factors influencing DS at the strategic level.

4.4 Discussions

The pairwise comparison results of SLR and Industry Consultation differed, indicating differences in strategic and operational level issues. Petroutsatou et al. (2021) state that SG-N06 (Poor planning) negatively impacts on-site installation, increasing transport costs, inefficient resource use, and decreased productivity. However, New Zealand experts link it to an increase in DN-N02 (incomplete project information) and DN-N01 (complexity of construction site layouts) as real-time updating would differ from planned progress. They further link SG-N06 to RC-N02 (Material availability) as planning is critical to receiving and storing materials in time and adequately storing them in a space-constrained environment. Experts pointed out that work permits are applied in phases in large projects, and poor planning would increase EC-N06 (lack of work permits). Further, they mentioned SG-N06 would delay payment (EC-N05) as dynamic cash flow calculations are based on planning and scheduling, affecting the decision-making of clients and project owners (SL-N07) as the planning and scheduling document is the basis and centre of project progress. Through the interrelationship-based DC analysis, this article ranks SG-N06 as the top factor affecting the DS in New Zealand at the operation level.

Al Hawarneh et al. (2019) have proposed dynamic planning as an option for the construction site layout design process, where facilities are relocated between the stages for optimisation and safety. Though not explicitly stated, this points out that DN-N02 (Incomplete drawings, specifications, and project information) could be adverse if not updated in real-time, a scenario that New Zealand experts strongly agree with. The New Zealand experts further reveal that the problems caused by DN-N02 could adversely affect the actual construction process in terms of scheduling errors, delay, safety, cost and reworks. X. Li et al. (2019) state that proactive constraints management can enhance the reliability of Prefabricated house production schedules; restricting factors include incomplete drawings DN-N02, and specifications and a lack of work permits (EC-N06). Experts point out that most construction works in New Zealand can be executed only after approvals, and EC-N06 can affect the schedule directly. EC-N06 affects DN-N02, as most organisations spend the workforce to fine-tune and correct errors only on projects that get approvals from authorities. However, the work commences at the earliest, overlooking DN-N02 when approvals are obtained, only to find later errors that cause delays and affect planning, scheduling, and, in turn, the project. This article affirms the importance of DN-N02 and EC-N06 at an operation level through interrelationship analysis.

X. Li et al. (2019) and Purushothaman & Kumar (2022) state that RC-N02 (Material unavailability) is a critical factor that affects DS. New Zealand experts affirm that delays in payment (EC-N05), SG-N06 (Poor planning), and adverse weather (WR-N01) are causes of RC-N02's effects on DS. Experts opined that payment delays mean a lack of trust in the client, and in situations where the construction sector faces a downturn and surge in insolvency, the suppliers tend to be more cautious and refuse supplies because of payment delays, a factor significantly influenced by the sector's economic conditions. Experts state that in countries like New Zealand, where a high percentage of materials are imported, adverse weather delays in transportation are increasingly playing a role in delays in supplies from both inland and overseas. This article uses an interrelationship-based DC analysis to rank RC-N02 as a critical factor affecting the DS in New Zealand at the operation level.

Peng et al. (2023), (Petroutsatou et al. (2021), X. Li et al. (2019), Purushothaman & Kumar (2022), Hsu et al. (2020), and (Ahmeti, 2022) state that WR-N01(Adverse Weather) impacts DS. New Zealand experts affirm the effect of WR-N01 and further link it to RC-N07 (project productivity issue) in the construction stages as it delays project progress and RC-N02 (material availability) as it affects transportation. This article employs a DC analysis based on interrelationships to classify WR-N01 as a key element influencing the DS at the operational level in New Zealand.

The Netherlands adopts dynamic planning and decision-making, along with the National Environmental Planning Strategy, which enhances integrated cultural heritage and environmental management (Fatorić & Egberts, 2020). In addition, the country's proactive approach, aiming for climate-proof and water-resilient socio-economic sectors by 2050, recognises the unique perspective of their cultural heritage in managing water-related hazards and climate adaptation (Fatorić & Egberts, 2020). This emphasis on cultural heritage sets the Netherlands apart in its environmental planning strategies. With more structures around the globe set to attain heritage status, protecting and learning from them would be beneficial. Especially for young countries like New Zealand, where heritage status buildings are on the rise, protecting Heritage buildings from adverse weather and earthquakes and reasoning their long existence in such conditions could lead to more knowledge that could be used for future buildings. Authors such as Fatorić and Egberts (2020) have acknowledged the role of CE-P03 and CE-P01. However, unlike this article, which included them in the critical list at a strategic level, they have not stamped the importance of CE-P03 and CE-P01.

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SLR interrelationships highlighted that RC-N01 (Resource constraints) are critical. Seven authors have identified this as a critical issue (refer to Annexure 2). However, the New Zealand experts have not identified these factors at the operational level. This is probably because, in countries like New Zealand, resource availability for construction in an uptrend is a traditional concern, and it remains abundant during an economic downtrend. The experts may not have highlighted it because of the current economic situation in New Zealand. However, resource constraints such as project managers, site forepersons, and surveyors are long-term issues in the New Zealand Immigration Long-term Skills Shortage List (NZ Immigration, 2024). Governments and policymakers address them through various initiatives. This article included RC-N01 in the critical list at a strategic level, based on the SLR interrelationships DC analysis.

Purushothaman & Kumar (2022) and Yuan et al.(2023) stated WR-N02 (Climate change), and Fatorić & Egberts (2020) stated WR-P01(Climate change mitigation and adaptation) as factors affecting DS. The authors acknowledge the profound impact that WR-N02 has on DS in construction. At the same time, WR-P01 emphasises the critical importance of efforts toward climate change mitigation and adaptation, reflecting responsibility. New Zealand experts state that these factors need solutions from the strategic level involving global communities. New Zealand experts have not particularly emphasised that these factors influence the DS because they are complex and require strategic solutions from the worldwide community. Aligning these factors with the United Nations Goals and Targets, such as Target 11.b for an inclusive, resource-efficient, and climate-resilient urban landscape and Target 13.b for effective climate change-related planning and management, underscores the need for thoughtful and strategic action (UN, n.d). Hence, this article included WR-P01 and WR-N02 in the critical list at a strategic level, based on the SLR interrelationships DC analysis and the nature of the issues.

DS has long been studied to understand how individual factors could impact its performance. In the past, when studying DS, literature tended to focus on the particular factors that could impact their performance. Attempts were made to mitigate these factors by considering them as isolated entities. However, in practice, these factors do not operate in isolation. Instead, they often interact in complex ways, creating loops and compounding their effects. Understanding the interplay between different factors is crucial for effective decision-making. For the first time, this study delves into the complex interrelationships involved in DS delay mitigation, which could enhance the existing DS literature and provide further insights for academics to investigate. The study's findings showed that differences between SLR and local consultation could be of great value for industry professionals, as they can assist them in gaining a deeper understanding of the complex interrelationships involved in DS. When understood and acted upon, they would help mitigate construction delays. It is worth noting that this article provides a ranking-based or operations and strategic perspective that would help middle and top-level managers focus.

Furthermore, the study separated strategic and operational level factors that can provide valuable insights for managers in developing effective strategies to tackle these interactions of factors affecting DS and construction delays and enhance the overall efficiency of their operations. The research has adopted an efficient approach of a combination of SLR, SSI, DC, and CLD that can benefit academics, project managers, planners, and construction experts. By leveraging this approach, they can create a comprehensive framework for baseline scheduling, effectively evaluate risks, and implement project controls tailored to their specific projects. This can help them achieve greater precision and efficiency in project execution, leading to better outcomes and increased success. The results of the research can serve as a valuable resource to guide decision-making procedures and enhance the efficacy of DS in diverse settings. Additionally, the ranking of segmenting and identifying key strategic level factors that affect DS in this study holds significant theoretical value for experts and policymakers in the construction industry who aim to optimise construction project productivity, sustainability, and conflict resolution through informed DS practices. Further, the strategic-level issues are of greater importance for top management, policymakers, and governments to focus on to achieve a sustainable future. The strategic level issues such as climate and resources highlighted in this article help policymakers align the construction industry perspective with the UN sustainability goal and targets 11.b, 13.b and 9.4 focus. Further, this research categorises operational and strategic-level criticalities to the existing knowledge of delay mitigation in construction by opening the interrelations of factors affecting DS that form a base for academics in future research to quantify the impacts and suggest novel mitigation strategies. This study adds knowledge to existing literature and provides valuable insights into the DS, highlighting the complex interrelationships within the field and encouraging further research. Equipping theory with critical knowledge on operational and strategic-level criticalities based on interrelations, the research can enhance the efficiency of construction projects, encourage sustainability, and enable effective dispute resolution by implementing these informed practices in DS.

5. CONCLUSION

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This study revealed that DS within the construction sector is significantly impacted by positive and negative interrelationships, which ultimately affect project timelines. This research extends beyond the conventional focus on individual factor challenges to DS. What sets this study apart is its holistic approach, examining 176 factors within 11 categories, including Cultural, Design, Economic/Legal, Environmental, Management, Planning/Scheduling, Resources, Safety, Social, Technology, and Weather/Climate, and analysing their complex interrelationships. Moreover, the study highlights the positive and negative influences of these 176 factors (Annexure 1) from SLR. The identified factor's interrelationships from SLR and industry consultation are given in the Pairwise Interrelationships table (**Error! Reference source not found.**Annexure 2 and *Table 7*) and CLD (Figure 6) to help provide a deeper, holistic understanding of DS in the construction industry. Incorporating these factors into DS calculations and contract clauses can significantly reduce project delays, cost overruns, and contractual disputes in New Zealand and globally.

Concluding based on interrelationships and DC (*Table 6* and *Table 8*),

- SG-N06, DN-N02, RC-N02, WR-N01, and EC-N06 are critical factors affecting DS and operational level.
- CE-P03, WR-P01, CE-P01, WR-N02, and RC-N01 are the top five factors influencing DS strategically.
- At the operational level, SG-N06 is the most influential factor with six out degrees, while DN-N02 and RC-N02 were most influenced with three in-degrees each.
- At the strategic level, WR-P01 is the most influential factor with six out degrees, and CE-P03 is the most influenced factor with six in-degrees.

5.1 Originality

Previous research has contributed to identifying the factors that impact DS. Many studies have ranked these factors based on expert opinions, surveys, and their individual effects. In practical situations, most factors often interact with others, compounding the effect. Many authors recognised the relationships between the factors. However, previous research has overlooked the compounding effect of these DS factors when interacting with others. This paper presents a novel approach to considering the interrelations and combined effect of DS factors.

The study uniquely employed several research methods combinations to investigate and rank the factors that affect DS. These methods included SLR, expert consultations, Pairwise Comparison (with steps within the Analytical Hierarchy Process), CLD, and DC Calculations. By using a combination of these methods, the researchers were able to gain a comprehensive understanding of the various factors involved in DS and how they contribute to the overall outcome.

This study breaks new ground by ranking DS factors based on their interrelations and centrality (*Table 6* and *Table 8*), as these factors often combine to act. The study highlights 61 formerly identified interrelationships from SLR and 14 previously unidentified interrelationships through industrial consultations (**Error! Reference source not found.** and *Table 7*). It identifies the top five strategic and operation-level factors influencing DS in the construction industry, providing valuable insights for academics and industry professionals. Additionally, this paper presents a unique approach by separating 176 positive and negative factors (Annexure 1), visualising their interactions (*Figure 6*), and categorising them into 11 distinct categories (Annexure 1).

5.2 Practical and theoretical implications

This study yields significant insights for academics by illuminating the intricate interrelationships in the existing DS literature. By underscoring these connections, the research inspires further scholarly exploration in this evolving field and lays the groundwork for a deeper understanding of the complexities involved. For industry practitioners, the study enriches the comprehension of how various DS factors interplay, ultimately guiding the creation of robust strategies to mitigate project delays. Its practical implications provide project managers, planners, and industry professionals with essential insights to consider when developing baseline schedules, performing thorough risk assessments, and implementing tailored project controls. This tailored approach is crucial for addressing the unique challenges inherent to diverse projects. Moreover, the findings from this study hold the potential to significantly enhance decision-making processes, thereby elevating the effectiveness of delay management across a myriad of contexts. On a theoretical level, the contributions of this research are invaluable to academics, researchers, industry practitioners, and policymakers alike. By equipping them with critical knowledge, the study aims to bolster construction project efficiency, promote sustainability, and facilitate effective dispute resolution, all through adopting informed practices in DS.

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5.3 Limitations and Future Research

5.3.1 Limitations:

This study assessed only English-published literature, excluding potentially valuable insights from non-English sources. Furthermore, the study used only sources from the Scopus, EBSCO, and Science Direct databases. Other databases could add more factors and interrelationships. However, following the Prisma framework for the SLR reduces the effects of the limitations. The h-index and SJR quartile analysis show that the articles were from reputed journals, which further reduces the effects of the limitations. The industry consultation was limited to five experts in the New Zealand building segment within the construction industry. This and the limitations of interviews and subsequent analysis are acknowledged. However, the industry consultation yielded insights on previously unidentified and valuable interrelationships of factors affecting DS. A note of caution is that these interrelations may also have been identified before 2017, which this study excluded. The limitations due to the exclusion of articles before 2017 are acknowledged.

5.3.2 Future Research

In any situation, a single factor rarely creates issues without combining with other factors. This underscores the need for a comprehensive understanding of the combinational factors and their interrelationships. Whether single or multiple factors cause problems, a chain reaction is most likely to occur. This further emphasises the need to understand and quantify the effects of the interrelationships. Future research should focus on these factors' interrelationships rather than analysing factors in silos and perform network analysis with real-world data to quantify the impacts that would benefit the industry and academia. This article would be a base for identifying critical interrelations and node analysis. Further, specific relationships may bond more than others and work closely in most situations. Such interrelationships require special attention and consideration. Due to their combined effect, these relationships may prove critical in scheduling and planning. A more in-depth investigation of the specific relationships between the identified factors in future may quantify the effects and unveil additional knowledge in the field. Further, interviewing subject matter experts from other construction segments may improve the applicability of the research findings to specific countries or sectors. Furthermore, research could describe specific measures and practices tailored to New Zealand to deal with the problems on DS interrelations.

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Annexure 1: Factors affecting Dynamic scheduling, code, polarity and author count (Author's own work).

S/N	Factors Category	Code	Factors Influencing Dynamic Scheduling	Effect on DS	Authors Count
1	Cultural	CE-P01	Cultural heritage management	Positive	1
2		CE-P02	Cultural identity and togetherness	Positive	1
3		CE-P03	Diverse cultural heritage	Positive	1
4		CE-P04	Place attachment	Positive	1
5	Design	DN-N01	complexity of construction site layouts	Negative	2
6		DN-N02	Incomplete drawings and specifications / incomplete project information	Negative	1
7		DN-N03	design parameters	Negative	1
8		DN-N04	canyon aspect ratio	Negative	1
9		DN-N05	window properties	Negative	1
10		DN-N06	albedo	Negative	1
11		DN-N07	Design error	Negative	1
12		DN-P01	Computational design	Positive	1
13		DN-P02	construction site layout design	Positive	1
14	Economic / Legal	EC-N01	increased transport costs	Negative	2
15		EC-N02	Shortage of construction materials in the market	Negative	1
16		EC-N03	Changes in government regulations/laws	Negative	1
17		EC-N04	Legal disputes between various parties	Negative	1
18		EC-N05	Delay in payment by the owner	Negative	1
19		EC-N06	lack of work permits	Negative	1
20		EC-N07	dynamic economic emission dispatch problems	Negative	1
21		EC-P01	Climate adaptation policy	Positive	1
22		EC-P02	Climate policy	Positive	1
23		EC-P03	Economic benefits	Positive	1
24		EC-P04	Economic diversification	Positive	1
25		EC-P05	National cultural heritage policy	Positive	1
26		EC-P06	construction cost	Positive	1
27		EC-P07	construction investment	Positive	1
28	Environment	ET-N01	Inaccessibility of site / Required accessible workspaces / Indoor space of building / limited site space / limited workspace	Negative	5
29		ET-N02	Effect of subsurface conditions (water table, hard rock) / Geotechnical data issues / natural geological conditions	Negative	3
30		ET-N03	Dynamic changes of the internal space of a building	Negative	2

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S/N	Factors Category	Code	Factors Influencing Dynamic Scheduling	Effect on DS	Authors Count
			in the operation and maintenance stage/changes in spatial state on construction sites		
31		ET-N04	temporary facilities allocation / inconvenient location of the storage area	Negative	2
32		ET-N05	topographic changes over time / Construction site steep slopes	Negative	2
33		ET-N06	Events issues / different dynamic disturbance events	Negative	2
34		ET-N07	Ambient conditions	Negative	1
35		ET-N08	Generation and allocation of workspaces	Negative	1
36		ET-N09	Keeping enough cool air in the plenums	Negative	1
37		ET-N10	Lack of explicit feedback of airflow and temperatures	Negative	1
38		ET-N11	Site congestions identification	Negative	1
39		ET-N12	Strict space pressure control	Negative	1
40		ET-N13	Traffic congestion	Negative	1
41		ET-N14	Unavailability of utilities at site (water, electricity)	Negative	1
42		ET-N15	Curse-of-dimensionality for large-scale instances	Negative	1
43		ET-N16	Detection of physical conflicts between the site workspaces	Negative	1
44		ET-N17	construction noise	Negative	1
45		ET-N18	limitation of autonomous excavators' movement in a construction site	Negative	1
46		ET-N19	uncontrolled environmental conditions	Negative	1
47		ET-N20	Disaster issues	Negative	1
48		ET-N21	Pandemic issues	Negative	1
49		ET-N22	Crowded environment	Negative	1
50		ET-N23	greenhouse gas (GHG) emissions	Negative	1
51		ET-N24	acidifying gas emissions	Negative	1
52		ET-N25	construction sector emissions	Negative	1
53		ET-N26	urbanisation rate	Negative	1
54		ET-N27	pollution load	Negative	1
55		ET-N28	land-use change	Negative	1
56		ET-N29	complex and changeable environment	Negative	1
57		ET-P01	Spatial development / Assembly workspace / Logistics workspace / Production workspace / Spatial information	Positive	5
58		ET-P02	Reduced air pollution	Positive	1
59		ET-P03	Reduced noise	Positive	1

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S/N	Factors Category	Code	Factors Influencing Dynamic Scheduling	Effect on DS	Authors Count
60		ET-P04	Reduced vibration	Positive	1
61		ET-P05	Ensure that the facilities do not overlap with one another or with the buildings	Positive	1
62		ET-P06	Environmental management	Positive	1
63		ET-P07	Reducing carbon footprint by retrofitting historic buildings	Positive	1
64		ET-P08	Reusing existing materials will help to achieve decarbonisation	Positive	1
65		ET-P09	Use of renewable energy	Positive	1
66		ET-P10	sustainable utilisation of urban underground space	Positive	1
67		ET-P11	topological structure	Positive	1
68		ET-P12	appropriate site locations	Positive	1
69		ET-P13	Relocation of a construction site	Positive	1
70	Management	MT-N01	Logistics system	Negative	1
71		MT-N02	Poor interactivity	Negative	1
72		MT-N03	Poor interoperability	Negative	1
73		MT-N04	Problems in shipment and site inventory	Negative	1
74		MT-N05	untimely and inaccurate transportation	Negative	1
75		MT-N06	uncompleted quality control	Negative	1
76		MT-P01	Construction site layout	Positive	1
77		MT-P02	ensemble construction methods	Positive	1
78		MT-P03	lean solutions	Positive	1
79		MT-P04	act fast on decision-making and collaborative working using available information and knowledge	Positive	1
80		MT-P05	Modular Construction	Positive	1
81	Planning / Scheduling	SG-N01	Detection of schedule conflict, which means the detection of a temporal overlap between tasks	Negative	1
82		SG-N02	stochastic activity durations	Negative	1
83		SG-N03	schedule changes of other related operations	Negative	1
84		SG-N04	uncertain time of land acquisition	Negative	1
85		SG-N05	Job Scheduling Problem	Negative	1
86		SG-N06	Poor planning	Negative	1
87		SG-N07	increase in non-productive time	Negative	1
88		SG-N08	resource-constrained project scheduling problem (RCPSP)	Negative	1
89		SG-P01	maximum slack priority rule (shortest latest start time)	Positive	1

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S/N	Factors Category	Code	Factors Influencing Dynamic Scheduling	Effect on DS	Authors Count
90		SG-P02	Applications of resource-constrained project scheduling	Positive	1
91		SG-P03	Hoisting facility layout planning	Positive	1
92		SG-P04	BIM-based construction schedules	Positive	1
93		SG-P05	baseline schedule	Positive	1
94		SG-P06	periodic progress data	Positive	1
95		SG-P07	top-down control methodology	Positive	1
96		SG-P08	risk analysis	Positive	1
97		SG-P09	project control	Positive	1
98		SG-P10	Top-down Control Strategy	Positive	1
99		SG-P11	Bottom-up Control Strategy	Positive	1
100		SG-P12	Crashing Corrective actions	Positive	1
101		SG-P13	Variability Corrective actions	Positive	1
102		SG-P14	Fast-tracking Corrective actions	Positive	1
103		SG-P15	Sensitive Activity selection	Positive	1
104		SG-P16	Critical Activity selection	Positive	1
105		SG-P17	Analytical Sensitivity	Positive	1
106		SG-P18	Simulation Sensitivity	Positive	1
107		SG-P19	Analysis Sensitivity	Positive	1
108		SG-P20	Threshold Methodology	Positive	1
109		SG-P21	Set Methodology	Positive	1
110		SG-P22	serial/parallel indicator Network Topology	Positive	1
111		SG-P23	spatial planning	Positive	1
112	Resources	RC-N01	Resource unavailability/resource constraints / unstable resource availability	Negative	7
113		RC-N02	Unavailability of materials/unavailability of prefabricated products / Material availability	Negative	2
114		RC-N03	Unavailability of equipment and tools / Equipment breakdown / Equipment shortage	Negative	3
115		RC-N04	time-varying resource demands	Negative	1
116		RC-N05	shortage of temporary structures	Negative	1
117		RC-N06	unskilled operators	Negative	1
118		RC-N07	Project productivity issue	Negative	1
119		RC-N08	inefficient use of resources	Negative	1
120		RC-N09	spatial variability of human activities	Negative	1
121		RC-N10	equipment assembly process	Negative	1

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S/N	Factors Category	Code	Factors Influencing Dynamic Scheduling	Effect on DS	Authors Count
122		RC-P01	efficient construction productivity	Positive	1
123		RC-P02	dynamic facilities allocation	Positive	1
124		RC-P03	cross-domain knowledge	Positive	1
125		RC-P04	dynamic distribution of labour resources	Positive	1
126	Safety	SY-N01	Accidents during construction	Negative	1
127		SY-N02	unidentified safety and hazard issues	Negative	1
128		SY-P01	construction safety	Positive	1
129		SY-P02	enhancing safety in the pre-construction phase	Positive	1
130		SY-P03	noise barriers	Positive	1
131	Social and Human	SL-N01	Deficiency for interior personnel to understand the indoor layout	Negative	1
132		SL-N02	Delay in giving instructions	Negative	1
133		SL-N03	Human factors	Negative	1
134		SL-N04	Inadequate experience of consultant	Negative	1
135		SL-N05	Poor communication of owner with contractor	Negative	1
136		SL-N06	Risk aversion in the delivery and operation of buildings	Negative	1
137		SL-N07	Slow decision-making by the owner	Negative	1
138		SL-N08	Stakeholder's loss aversion	Negative	1
139		SL-N09	Suspension of work by owner	Negative	1
140		SL-P01	Social benefits	Positive	1
141		SL-P02	Social cohesion and integrity	Positive	1
142		SL-P03	parallel rule collaboration (PRC)	Positive	1
143	Technology	TY-N01	incomplete BIM models	Negative	1
144		TY-P01	Building information modelling (BIM) / Building Information Modelling (BIM) 5D construction duration-cost optimisation model / BIM-based integrated scheduling methodology for building projects under resource constraints / BIM-based rule-checking systems / Linked-data and constraint-checking / Linked-data based constraint-checking architecture / Ontology for linked-data based dynamic constraint-checking	Positive	10
145		TY-P02	Modelling scheduling constraints using Shapes Constraint Language (SHACL) / Prototype web application / Processing web application / Storage / Data / Prototype evaluation / automatic progress tracking technology	Positive	7
146		TY-P03	optimisation of robot motion path planning / Multi-construction robots / Tracking tasks/robot kinematic	Positive	1

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S/N	Factors Category	Code	Factors Influencing Dynamic Scheduling	Effect on DS	Authors Count
			optimisation principle / mobile platform planning/path control strategy		
147		TY-P04	Dynamic scheduling coordination technology	Positive	1
148		TY-P05	Mobile robots	Positive	1
149		TY-P06	The multi-stage stochastic programming model for identifying the optimal supply chain configuration	Positive	1
150		TY-P07	Navigating spatial data dynamically	Positive	1
151		TY-P08	reinforcement learning model	Positive	1
152		TY-P09	earthwork allocation planning	Positive	1
153		TY-P10	ant colony optimisation	Positive	1
154		TY-P11	network's reliability	Positive	1
155		TY-P12	Dynamic programming algorithm	Positive	1
156		TY-P13	Genetic algorithm for assembly sequence planning in precast concrete buildings	Positive	1
157		TY-P14	dynamic planning model (DPM) using Digital Twin	Positive	1
158		TY-P15	optimisation of the task planning algorithm	Positive	1
159		TY-P16	dynamic planning optimisation model using a Genetic Algorithm	Positive	1
160		TY-P17	input-adaptive particle swarm optimisation (iRC-APSO) algorithm	Positive	1
161		TY-P18	heuristic algorithms	Positive	1
162		TY-P19	intelligent algorithms	Positive	1
163		TY-P20	graph-based model	Positive	1
164		TY-P21	Binary Pareto-Optimal Particle Swarm Optimisation (BP-PSO) algorithm	Positive	1
165		TY-P22	Holonic Management System (HMS)	Positive	1
166		TY-P23	Discrete event simulation	Positive	1
167		TY-P24	system dynamics	Positive	1
168		TY-P25	on-line planning	Positive	1
169		TY-P26	linked-data-based constraint-checking (LDCC) method	Positive	1
170		TY-P27	Geospatial information system (GIS)	Positive	1
171		TY-P28	Data mining (DM)	Positive	1
172		TY-P29	genetic algorithm (GA)	Positive	1
173		TY-P30	new intelligent environmental evaluation method to optimally and dynamically schedule the resource, production and inventory activities	Positive	1
174	Weather /	WR-N01	Adverse weather condition	Negative	5

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S/N	Factors Category	Code	Factors Influencing Dynamic Scheduling	Effect on DS	Authors Count
175	Climate	WR-N02	Climate change	Negative	2
176		WR-P01	Climate change mitigation and adaptation	Positive	1

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Annexure 2: Table 5 SLR Pairwise Interrelationship Summary (Author's own work)

PF	P, IFN 1, AN	P, IFN 2, AN	P, IFN 3, AN	P, IFN 4, AN	P, IFN 5, AN	P, IFN 6, AN
CE-P03	+, CE-P02, 11	+, CE-P04, 11	+, ET-P06, 11	+, SL-P02,11	+, WR-N02,11	+, WR-P01, 11
TY-P01	+, ET-N03, 25	+, TY-P07, 34	+, TY-P26, 16			
MT-P01	+, ET-P06, 24	+, RC-P01, 24	+, SY-P01, 24			
SY-P03	+, EC-P06, 24	+, RC-P01, 24	+, SY-P01, 24			
SG-N06	+,EC-N01, 20	+, SG-N07, 20	+, RC-N08, 20			
TY-P06	+, ET-P02, 12	+, ET-P03, 12	+, ET-P04, 12			
CE-P02	+, CE-P01, 11	+, WR-P01, 11				
CE-P04	+, CE-P01, 11	+, WR-P01, 11				
SL-P01	+, CE-P01, 11	+, WR-P01, 11				
SL-P02	+, CE-P01, 11	+, WR-P01, 11				
TY-P27	+, ET-P05, 34	+, TY-P07, 34				
DN-N07	+,RC-N01, 32	+, RC-N02, 32				
ET-N06	+,RC-N01, 32	+, RC-N02, 32				
RC-N01	-, SG-P02, 10	+, RC-N02, 32				
WR-02	+, CE-P01, 11	+,CE-P03, 11				
CE-P01	+,WR-P01, 11					
DN-N02	+, RC-P02, 3					
EC-P02	+, CE-P03, 11					
EC-P03	+, EC-P05,11					
EC-P04	+,WR-N02,11					
ET-N01	-, TY-P16, 5					
ET-N05	-, TY-P15, 14					
ET-N17	-, MT-P01, 24					
ET-N18	-, TY-P15, 14					
ET-N21	+, ET-N06,32					
ET-P01	+,WR-N02,11					
ET-P07	+,WR-N02,11					
ET-P13	+, ET-P12, 20					
SG-N02	-, SG-P02, 10					
RC-N04	-, SG-P02, 10					
TY-P02	+, TY-P26, 16					
TY-P05	+, ET-N01, 28					
TY-P08	+, ET-N05, 35					

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PF	P, IFN 1, AN	P, IFN 2, AN	P, IFN 3, AN	P, IFN 4, AN	P, IFN 5, AN	P, IFN 6, AN
TY-P09	+, ET-N05, 35					
TY-P10	+, SY-P02, 24					
TY-P17	-, RC-N01, 30					
WRN01	+,RC-N03, 32					

Note: PF = Primary Factor, P = Polarity, + = Positive, - = Negative, IFN = Influenced Factor Number, AN = Author Number stated in Annexure 3.

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Annexure 3: Author factor matrix (Author's own work).

| | | CULTURE | | | | DESIGN | | | | | | | | | | ECONOMIC / LEGAL | | | | | | | | | |

DYNAMIC SCHEDULING: INFLUENTIAL AND INFLUENCED FACTORS AND THEIR INTERRELATIONSHIPS IN THE NEW ZEALAND CONSTRUCTION INDUSTRY

Abstract:

Purpose: The research aims to investigate and analyse various complex interrelationships of positive and negative factors that significantly impact Dynamic Scheduling (DS) in the New Zealand construction industry and rank them for improved project outcomes.

Design/methodology/approach: The study used a combination of research methods, including a systematic literature review using PRISMA guidelines and expert consultations. The analysis included pairwise comparison (with steps within the Analytical Hierarchy Process) and Degree of Centrality calculation to rank the factors affecting DS in the New Zealand construction industry.

Findings: For the first time, this ~~pilot~~ study identifies the five most prominent strategic and operational-level factors interacting with others. The study's findings indicate that Poor planning, Incomplete drawings and specifications/project information, Material unavailability/prefabricated product availability, Inclement weather, and lack of work permits are the primary negative factors that affect DS operationally. On the other hand, Cultural heritage diversity, Climate change mitigation and adaptation, and Cultural heritage management have a positive effect. Climate change and Resource unavailability/instability are among the top five factors that negatively impact DS strategically. Poor planning is the most influential factor at the operational level, with 6 out of degrees. At the same time, material availability and incomplete drawings and specifications / incomplete project information were most influenced by 3 degrees each. Climate change mitigation and adaptation are the most influential factors at the strategic level, and diverse cultural heritage is the most influential factor. Additionally, this paper stands out for its clear distinction between the positive and negative ~~176 factors~~176 factors within 11 distinct categories, visual representation of 61 formerly identified interrelationships from SLR, and 14 previously unidentified interactions from industry consultation that impact DS within the construction industry.

Research limitations/implications: The research centres around studying English language literature~~, and using specific databases such as Scopus, EBSCO, and Science Direct and search~~. Using specific databases such as Scopus, EBSCO, and Science Direct and searching after 2017 may potentially narrow the scope of global viewpoints. We acknowledge that there are limitations in terms of New Zealand industry consultation. Further studies should encompass non-English sources and incorporate empirical approaches to confirm the detected correlations and implications for DS customised to a specific viewpoint or country.

Practical implications: This ~~pilot~~ study provides insights for academics and industries by focusing on interrelationships and identifying top strategic and operation-level factors affecting DS. It aids project managers and industry professionals ~~in creating~~create tailored baseline scheduling, risk assessment, and project controls. The study also benefits policymakers seeking to improve construction project efficiency, sustainability, and dispute resolution through informed DS practices. The DS factors polarity, interrelationships, CLD, and ranking based on DC add to the body of knowledge.

Originality/value: Numerous literary works have explored the various factors that impact Dynamic Scheduling (DS), each being analysed for its impact through expert evaluations and surveys. However, they have not considered that the factors act in conjunction with others and their interrelations have a significant impact. This paper takes a unique approach by examining the interrelationships, their network (displayed in the causal loop diagram) and the degree of centrality among these factors. The originality of this study is the distinct categorisation of positive and negative factors that impact ~~DS in~~DS in the construction industry. The paper's novelty lies in the rankings based on the interrelations and degree of centrality between these factors. This is significant since the factors often work together instead of in isolation.

KEYWORDS: Dynamic Scheduling, scheduling, construction, construction scheduling, factors, interlinks.

1. Introduction

Complex construction projects are affected by delays (Kermanshachi et al., 2023). Many factors influence construction project delays, such as hierarchy, bureaucracy and inflexible procedures that block communication, delay and initiate defects in the construction industry (Purushothaman ~~and~~ & ~~Seadon, 2024~~Seadon, 2024). Additionally, methodologies play a significant part, especially those associated with planning, scheduling, and ~~coordination (~~coordination (Purushotham et al., 2024). Construction delays can have severe economic and developmental impacts (Alfakhri et al., 2018). Multiple studies have highlighted the significant impact of

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construction delays, including time and cost overruns, wasted resources, project abandonment, contract termination, a hindrance to economic development, reduced economic activity, reduced government revenue, and difficulty securing foreign loans (Javed et al., 2022~~,~~; Ullah et al., 2018). These delays require efficient management due to the interdependent nature of task execution, resource allocation, and stakeholder engagement and require planning, reliability and control of dynamic project aspects (Sheikhkhoshkar et al., 2023; Sheikhkhoshkar et al., 2024). The construction industry initially relied on static planning techniques like the Project Evaluation and Review Technique and Critical Path Method (Lermen et al., 2016) to overcome project delays. However, these models had limited capabilities in predicting future results when faced with changing and growing complexities in real-time, leading to more innovative approaches like dynamic scheduling (DS) (Habibi et al., 2018). Nwadigo et al. (2022) state that DS is a widely adopted innovative, real-time digital technology-based strategy for solving real-world problems in many business systems.

DS can be defined as an established, adaptable procedure for updating, checking, and revising the schedule in real-time (Fahmy et al.,2020). DS is a strategic approach for reacting to unanticipated events (Herrmann, 2006). Dynamic scheduling defines the methods for creating the initial baseline and reacting to current events (Fahmy et al., 2014a). DS combines initial scheduling, risk assessment, and project controls (Vanhoucke, 2013). Under the constraint of time, DS would efficiently resolve the issue of resource organising connection and direct the shared scheduling procedure between various areas (He et al., 2021). Directly assigning tasks to resources based on predetermined sequencing rules defines DS (Kalinowski et al.,2013). DS automatically updates the schedule based on the most efficient measures by incorporating the impact of immediate occurrences and evaluating the present state of a timeline (Fahmy et al., 2014c). Real-time updating of project information and recording changes can provide dynamic risk identification at all project stages that could be acted upon quickly (Moshtaghian et al.,2020). DS is a more advanced approach to scheduling that can be employed to execute construction projects, provided that relevant contributing factors have been thoroughly analysed (Purushothaman & Kumar, 2022). DS is aligned with complex surroundings and allows for responding to real-time data while rescheduling and adjusting after unavoidable emergencies (Ding et al., 2022).

Nwadigo et al. (2022) highlighted the importance of practical planning and scheduling in reducing the effects of unexpected changes in construction projects. Ding et al. (2022) emphasised that DS is designed for complicated environments, allows for immediate response and adaptations in the face of unforeseen situations, and efficiently manages real-time events and schedule disruptions (Fahmy et al., 2020). DS is a highly sophisticated scheduling strategy that warrants a comprehensive analysis of its associated contributing factors (Purushothaman and Kumar, 2022). However, there is a lack of research regarding DS in construction projects (Fahmy et al., 2020; Purushothaman and Kumar, 2022; Undozerov, 2023). DS has significant optimisation challenges with various real-world applications. (Đurasević et al., 2022). The quality of all subsequent factors determines DS's overall solution quality, each connected to the previous by the transferred backlog and the timeline of the present predictable factors (Branke & Mattfeld, 2005). This implies the importance of the interrelations of the factors.

Previous literature analysing factors treated their impact as standalone and did not consider the conjunction effects. Hence, it ranked the factors based on scales such as occurrence, frequency, and importance as perceived by the construction professionals. The knowledge gap is that the interrelations of factors affecting DS have not been studied yet. Addressing this gap through factors affecting DS has substantial academic and practical benefits for the future of construction projects. Various disciplines have examined connections using Network Analysis (NA) to illustrate relationships between factors and to study the structures that arise from the repetition of these connections. However, DS in construction has not had such studies. This study serves as a pilot, identifying positive and negative factors and their interrelations that impact DS. The theoretical contributions of the study offer enhanced knowledge of DS, scheduling, and related issues that share significant perspectives with scholars, researchers, industry professionals, and policymakers who aim to enhance efficiency, sustainability, and conflict resolution in construction projects through knowledgeable decision-support practices. Positive factors will likely enhance project outcomes, negative ones may lead to scheduling and construction delays, and the interrelations define the compounding effect. For the first time, this study aims to identify the key factors and their interactions that contribute to the DS in the NZ construction industry and rank them based on their interconnectivity. This research expands upon existing literature and offers important insights into the domain of DS, emphasising the intricate relationships within the field. By providing theoretical frameworks with essential knowledge regarding critical operational and strategic aspects rooted in these interconnections, the study can improve the efficiency of construction projects, foster sustainability, and facilitate effective dispute resolution by adopting these informed practices within DS. The question for this study is

"What are the significant positive and negative interacting factors and their ranking that influence Dynamic Scheduling ~~in New~~in New Zealand ~~construction ?~~construction?"

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2. Contextual background

The construction industry has significantly contributed to NZ's economic state. Radman et al. (2021) claim that the construction sector surpasses wholesale trade-off in the five highest contributors to GDP, accounting for 19% of GDP growth. According to the Stats NZ (2023b) report, the total value of building work was $9.10 billion in March 2023. Additionally, employment statistics demonstrate the sector's magnitude, with skilled trades and consulting ranking fifth in total employment (MBIE, 2023; Stats NZ, 2023a). However, the construction industry in NZ faces a unique set of challenges. The lack of proximity to a large trading partner or consumer market makes it even more difficult for NZ to directly adopt foreign goods transport models due to its geographic isolation, dependence on imports, small market size, and unique regulatory challenges (Dhawan et al., 2022; Kahiya, 2020). The argument indicates that the importation of construction materials has the potential to increase costs and prolong construction timelines within the country. This is one of the added layers of complexity involved in building construction.

Since most real-world environments present various unforeseen challenges and continually force reconsideration and revision of established schedules, DS techniques have begun generating several research studies from the late 20th century (Ouelhadj & Petrovic, 2009). According to Kim et al. (2021), construction projects may demonstrate technical and organisational complexity. As a result, there was a noticeable transition from static to dynamic construction, necessitating a scheduling system that could adjust to real-time changes. DS offers substantial benefits, including improved utilisation of labour and cost-efficiency, optimisation of resource management, reduction of waste, and achieving optimal material procurement (Fahmy et al., 2020). On the contrary, DS has challenges, such as scalability and multi-agent reinforcement learning technological advancement (Dai et al., 2022). Moreover, De Jong (2012) contends ~~that DS~~that DS lacks "exact solutions" because the usefulness of a proposed schedule depends on an unforeseen future. Yu et al. (2021) confirm that there is a need for improvement and innovation of construction DS to accommodate uncertain circumstances. Despite the challenges associated with DS, such as its dependency on advanced technological tools and the requirement for real-time data interpretation, several studies have been made on its application in construction projects worldwide ~~(Hao~~(Hao et al., 2010; Purushothaman & Kumar, 2022). Furthermore, the importance of DS was highlighted by Xie et al. (2023) since it can respond quickly to unpredictable disruptions during construction.

Dynamic Scheduling (DS) can also be referred to as "Dynamic Planning" (DP) (Fahmy et al., 2014a). Further exploring the classifications of DS, three categories define DS: completely reactive scheduling, predictive reactive scheduling, and robust, proactive scheduling (Ouelhadj & Petrovic, 2009). However, Aissani et al. (2009) introduced the concept of predictive scheduling as an additional classification within the context of DS. Predictive scheduling creates a predetermined schedule assuming a deterministic environment (Csáji & Monostori, 2006). This type of schedule assumes an ideal resource availability (Sarin & Salgame, 1990). However, due to the unpredictable environment, there are some situations where the data will only be available after the solution is implemented. Predictive-reactive scheduling updates the schedule in response to disruptions ~~in order to~~to minimise the effect on the scheduling system's performance (Tang & Wang, 2008). Alternatively, Mohan et al. (2019) describe a reactive scheduling strategy where a new schedule is generated in response to stochastic events that occurred in the field. In highly and frequently disturbed dynamic environments, reactive scheduling is used to quickly and optimally decide which changes to make based on the type of disturbance after an uncertain event, ensuring timely and cost-effective responses without relying on pre-scheduling (Zhang et al., 2021; Zhiliang & Xiaojiang, 2016). Finally, Bukkur et al. (2018) claim that robust-proactive scheduling involves developing predictive schedules by analysing and incorporating the primary causes of disruptions, allowing adaptability in dynamic environments.

Based on the literature review, despite extensive discussion of the benefits and applications of DS, there still needs to be a greater understanding concerning the specific factors and interrelations that affect its efficiency when applied to building construction. Despite some research into these influencing factors in road construction by Purushothaman and Kumar (2022), building construction projects present their challenges and complexities. Building projects' technological, logistical, and resource requirements are complex, emphasising the importance of identifying these factors for an efficient DS to meet those demands. Fahmy et al. (2014b) highlighted that any new DS system must comprehend the planners' daily scheduling challenges and research the characteristics of the problem. Hao et al. (2010) also claimed that schedule updates must maintain pace with the changing environment for a schedule to become of significant use to applications within the industry. Therefore, the building construction industry only realises its full potential by thoroughly identifying and understanding the interactions of factors affecting DS.

3. Research methodology

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3.1 Research Design

The research team conducted a systematic literature review (SLR) adhering to the PRISMA guidelines to understand the factors and interrelations affecting DS in construction projects. First, a problem statement and research questions were developed based on their initial literature search, observations, and collegial insights. The research team worked iteratively to refine their problem statement and research questions. Then, an SLR was conducted to identify factors and their polarity and interrelations that affect DS in the construction industry. Five industry experts' consultations followed this. The data collected were analysed using themes and Degree of Centrality (DC). The results are presented through a pairwise interrelationship table, degree of centrality table ~~and,~~ and a Causal loop diagram (CLD) and then ranked to find the most influenced and influential factors.

3.2 Systematic literature review and ~~prisma~~ PRISMA statement

SLRs report how article data are identified and help reduce researcher biases (Cooper et al., 2018). Authors must outline their search strategy for identifying relevant literature, including the databases searched, search terms and keywords used, and the practical and methodological screening and exclusion criteria (Fisch and Block, 2018). The initial stage of the literature search involved applying designated search strings within the Scopus, EBSCO, and Science Direct databases. Each database was searched using two strings. This step was essential in identifying relevant literature to the research objective and ensuring it aligned with the study's theme. Table 1 *Research Search Strings and Exclusions Criteria* (The authors collected data on December 15th, 2023) details the search strings, inclusion and exclusion criteria for this study, and the databases and keywords used. The articles were collected from 2017 to ensure recency of knowledge.

Table 1 Research Search Strings and Exclusions Criteria

Database	Keywords Search	Inclusion Criteria	Exclusion criteria
Scopus	(TITLE-ABS-KEY ("Dynamic Scheduling*" OR "Dynamic Planning*" OR "Adaptive Scheduling*" OR "Flexible Scheduling*") **AND** TITLE-ABS-KEY (building* OR housing* "Building Construct*" OR "Residential Construct*" OR "Commercial Construct*" OR "High-rise Construction" OR "Low-rise Construct*" OR "Industrial Construct*" OR "Vertical Construct*" OR "Tall Building*" OR skyscraper*) **AND** TITLE-ABS-KEY (factor* OR variable* OR impact* OR cause* OR effect* OR reason* OR fail* OR challenge*)) **AND** PUBYEAR > 2017 **AND** PUBYEAR < 2023 (TITLE-ABS-KEY ("Dynamic Scheduling*" OR "Dynamic Planning*" OR "Adaptive Scheduling*" OR "Flexible Scheduling*") **AND** TITLE-ABS-KEY (construction*) **AND** TITLE-ABS-KEY (factor* OR variable* OR impact* OR cause* OR effect* OR reason* OR fail* OR challenge*)) **AND** PUBYEAR > 2017 **AND** PUBYEAR < 2024 **AND** (LIMIT-TO (LANGUAGE, "English")) **AND** (LIMIT-TO (SUBJAREA, "ENGI") OR LIMIT-TO (SUBJAREA, "ENVI") OR LIMIT-TO (SUBJAREA, "SOCI"))	Dynamic Planning and Scheduling, Flexible Scheduling, Adaptive Scheduling. Construction. Factors or similar	Not in English. Before 2017. Not from construction. Systematic, critical, and literature reviews

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Database	Keywords Search	Inclusion Criteria	Exclusion criteria
EBSCO	("Dynamic Scheduling*" OR "Dynamic Planning*" OR "Adaptive Scheduling*" OR "Flexible Scheduling*") **AND** (building* OR housing* "Building Construct*" OR "Residential Construct*" OR "Commercial Construct*" OR "High-rise Construction" OR "Low-rise Construct*" OR "Industrial Construct*" OR "Vertical Construct*" OR "Tall Building*" OR Skyscraper*) **AND** ((factor* OR variable* OR impact* OR cause* OR effect* OR reason* OR fail* OR challenge*) N20 (impact* OR barrier* OR delay* OR interruption* OR challenge* OR impediment* OR barricade* OR disadvantage* OR hindrance* OR conflict* OR affect* OR influence* OR effect* OR cause* OR reason* OR source* OR *root OR *foundation OR *trigger OR fail*)) ("Dynamic Scheduling*" OR "Dynamic Planning*" OR "Adaptive Scheduling*" OR "Flexible Scheduling*") **AND** (construction*) **AND** ((factor* OR variable* OR impact* OR cause* OR effect* OR reason* OR fail* OR challenge*) **N20** (impact* OR barrier* OR delay* OR interruption* OR challenge* OR impediment* OR barricade* OR disadvantage* OR hindrance* OR conflict* OR affect* OR influence* OR effect* OR cause* OR reason* OR source* OR *root OR *foundation OR *trigger OR fail*))	words. English language articles. From the year 2017. From Engineering, environmental and social fields.	
Science Direct	("Dynamic Scheduling" OR "Dynamic Planning") **AND** ("Building Construction" OR "Residential Construction" OR "Commercial Construction" OR "Industrial Construction") **AND** (factor OR variable OR delay) ("Dynamic Scheduling" OR "Dynamic Planning") **AND** (construction) **AND** (factor OR variable OR impact OR influence OR delay OR challenge)		

PRISMA 2020 framework helps identify, select, appraise, and synthesise SLR articles (Page et al., 2021). The PRISMA framework features exclusion criteria, and the rationale behind each exclusion is meticulously documented, enhancing the study's repeatability (Page et al., 2021). Robinson and Lowe's (2015) editorial states that PRISMA is commonly used in SLRs with less than 50 papers, often fewer than 10, as compared to traditional literature reviews that may have over 150 papers. However, ten seems less useful for analysing factors, and numbers closer to 50 will benefit, provided their quality is good and helps to ~~atain~~ attain saturation. In this case, the overall quality of the papers ~~were~~ was respectable (refer to Table 2) ~~and the results yelided 176 factors within 11 distinct categories and~~, and the results yielded 176 factors within 11 distinct categories that were reasonably saturated (refer to Annexure 3). The process for gathering literature using the step-by-step procedure of the PRISMA framework for this study is illustrated in

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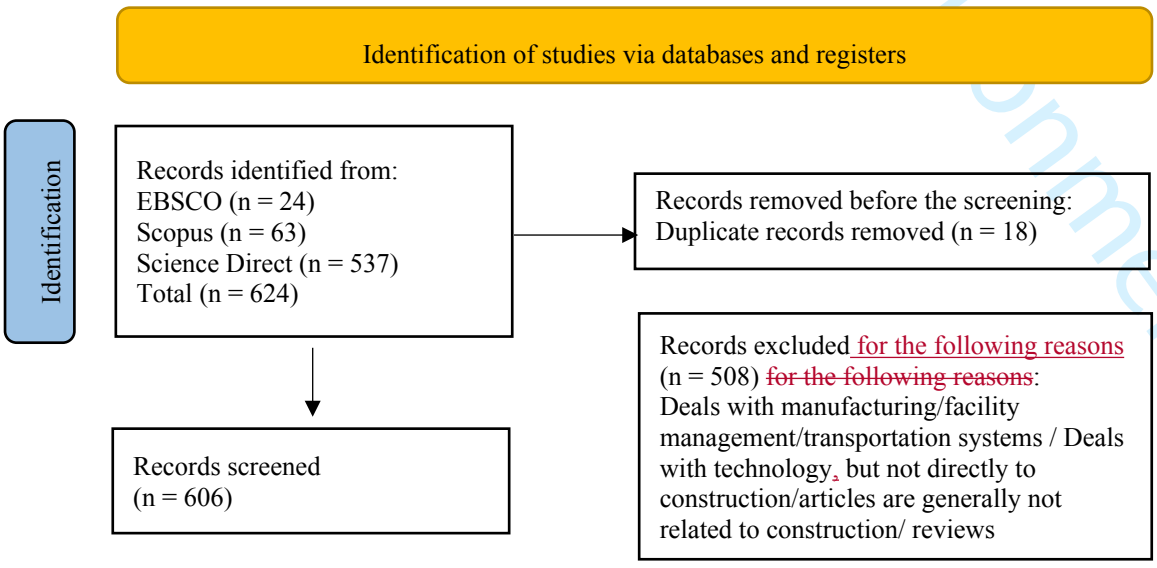

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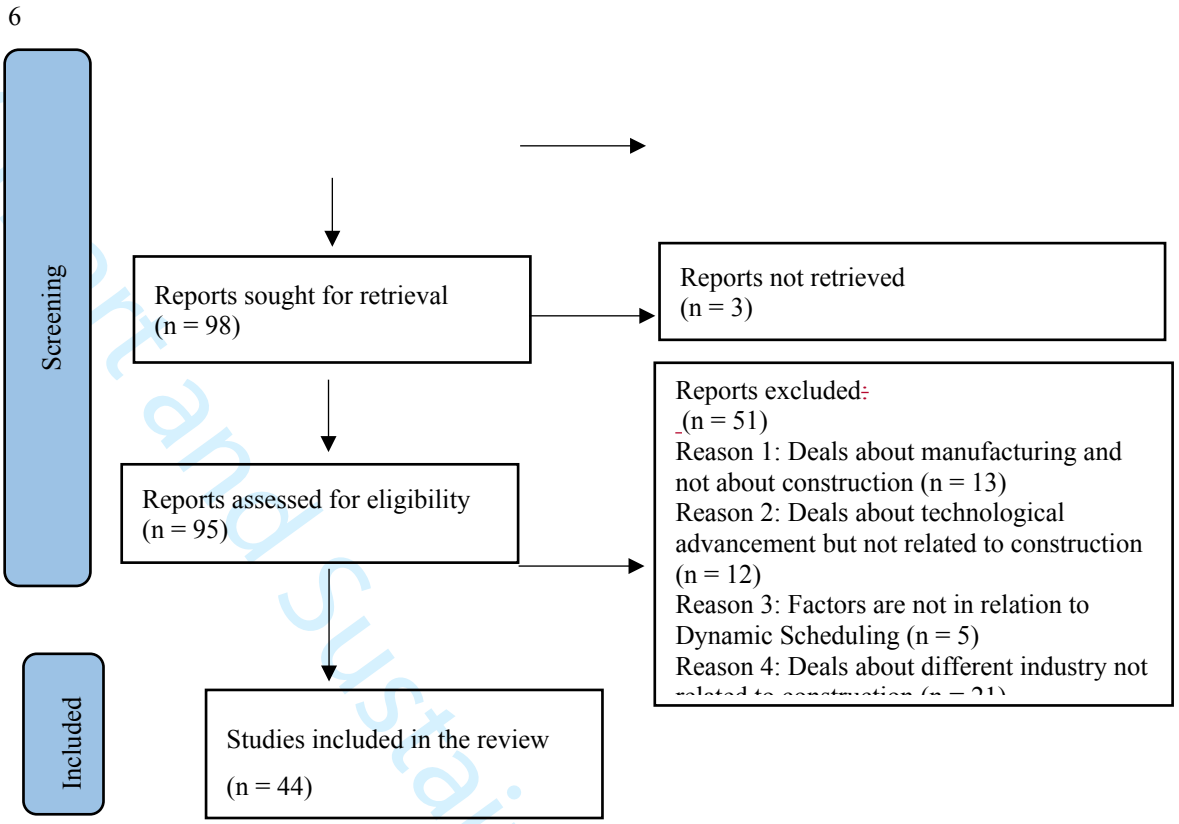

Figure 1 PRISMA Framework (Authors' own work based on the PRISMA framework).

The quality of the articles and related journals included was analysed using the h-index and Scimago Journal & Country Rank (SJR) quartiles. Table 1 *Research Search Strings and Exclusions Criteria*provides the data, showing that 81.82% of the articles chosen were from Q1 journals, and 72.72% had an h-index greater than 100. Table 2 ~~shows 36~~shows 36 papers from Q1 journals, three from Q2, and one from Q3. Four papers were from reputed conferences, and two were published in high-rated proceedings. H-index analysis revealed ~~that 32~~that 32 papers were greater than 100, seven were between 60 and 92, three were greater than 20, and two were conference papers. Ten papers were focusing building, and 34 focused on general construction.

Table 2 Ranking data analysis of Journals related to articles selected in the review

SJR H-Index	SJR Quartiles	Country	Journal	General Building	Construction	Total
309	Q1	UK	Journal of Cleaner Production		1	1
292	Q1	UK	Applied Energy	1		1
271	Q1	UK	Expert Systems with Applications	1		1
243	Q1	US	Journal of Environmental Management	1	1	2
242	Q1	US	IEEE Access		1	1

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SJR H-Index	SJR Quartiles	Country	Journal	General Building Construction	Total
232	Q1	Netherlands	Energy and Buildings	1	1
205	Q1	UK	Building and Environment	1	1
176	Q1	UK	Automation in Construction	11	11
165	Q1	UK	International Journal of Electrical Power & Energy Systems	1	1
161	Q1	UK	Computers & Industrial Engineering	4	4
139	Q1	UK	Tunnelling and Underground Space Technology	1	1
137	Q1	UK	Engineering Applications of Artificial Intelligence	1	1
123	Q1	UK	Information Processing & Management	1	1
110	Q1	UK	Advanced Engineering Informatics	4	4
92	Q1	Netherlands	Journal of Building Engineering	2	2
73	Q1	UK	Engineering, Construction and Architectural Management	1	1
28	Q1	UK	Smart and Sustainable Built Environment	1	1
23	Q1	Poland	Applied Mathematics and Nonlinear Sciences	1	1
76	Q2	UK	Engineering Optimization	1	1
60	Q2	Germany	KSCE Journal of Civil Engineering	1	1
30	Q2	Switzerland	Infrastructures	1	1
92	Q3	Netherlands	IFAC-papers online	1	1
103	Proceedings	Netherlands	Procedia CIRP	1	1
69	Proceedings	Netherlands	Transportation Research Procedia	1	1
	Conference		2nd IEEE International Conference on Distributed Computing and Electrical Circuits and Electronics, ICDCECE 2023	1	1
	Conference		ISARC 2018 - 35th International Symposium on Automation and Robotics in Construction and International AEC/FM Hackathon: The Future of Building Things	1	1
			Grand Total	10 34	44

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3.3 Year and country-wise Data

Figure 2 *Year & Country Contributions and Number of Articles Studied* (The authors collected data on the 15th of ~~December,~~December, 2023) shows the year, number of articles, and countries contributing to this study. ~~In 2021~~In 2021, there was a noticeable decrease in the number of articles available on DS. The COVID-19 pandemic may have played a role in this trend. Interestingly, Chinese researchers showed significant interest in DS, as their articles outnumbered those produced by any other country. Unfortunately, there was no African representation during this period, indicating a shortage of credible research. This could be attributed to factors such as the limited popularity of DS in Africa, technological barriers, and adherence to traditional scheduling.

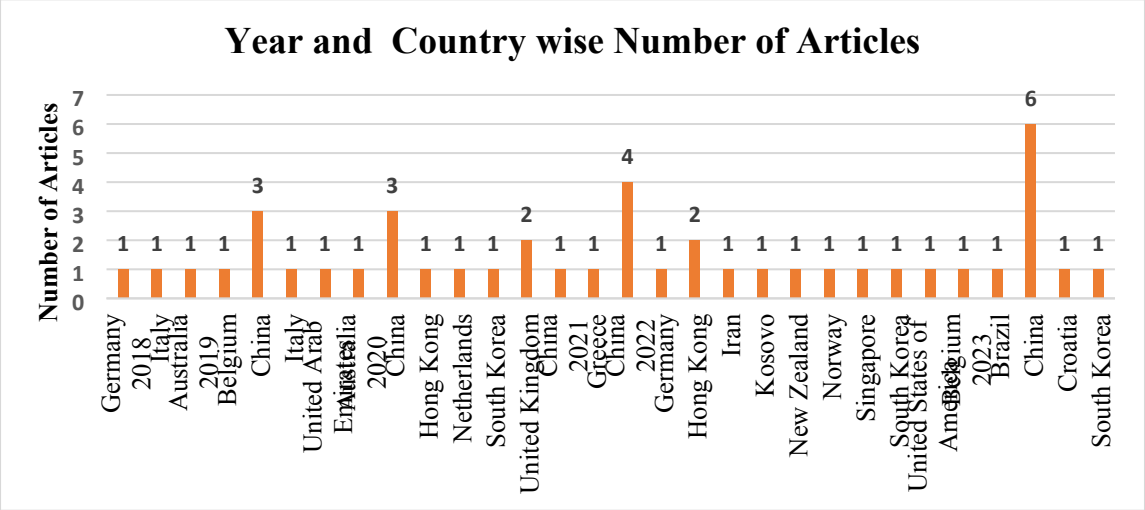

Figure 2 Year & Country Contributions and Number of Articles Studied (Author's own work)

Furthermore, VOSViewer software was employed to conduct a keyword search analysis to establish the possible interrelationships of factors mentioned in the identified literature. Figure 3 *Keyword Search Analysis* shows a graphical representation of bibliometric maps showing the connectivity between keywords used in SLR search strings.

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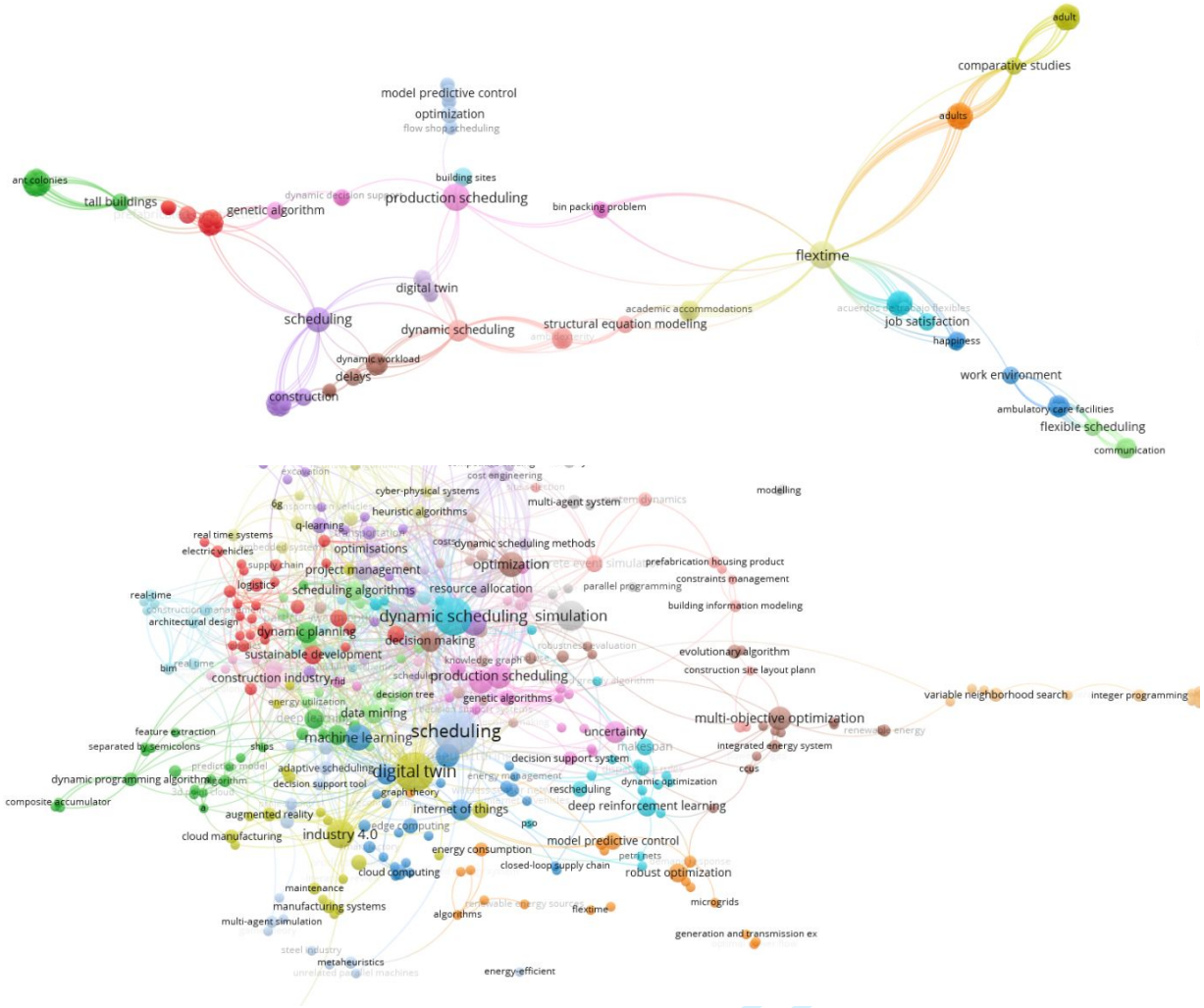

Figure 3 Keyword Search Analysis(Author's own work)

3.4 Factors and Interrelations

Vosviewer provides a graphical representation of bibliometric maps that show the keywords' relevance. However, it fails to separate and provide data on the chosen topic's factors, polarity, and interlinks. To overcome this, following Samarasekara et al. (2024), the steps within the Analytical Hierarchy Process were used to identify the interrelationship of factors affecting DS. The steps followed were:

- The problem and criteria were defined.
- The identified articles were read more than once to identify the factors, polarity, and interrelationships.
- The identified factors affecting DS and the positive and negative influences were then categorised into 11 groups, coded and tabulated (Annexure 1).
- Following Samarasekara et al. (2024), a framework for pairwise comparison using the steps within the Analytical Hierarchy Process was developed to identify the interrelationship of factors affecting DS.
- The articles were read at least twice to list the factors and their interrelations. Factors interactions and polarity were identified from SLR articles using a pairwise comparison plotted in an Excel workbook.
- The pairwise comparisons were checked for consistency before evaluating the relative factors.

- A sensitivity analysis using CLD revealed interacting loops and affirmed the nodes' (factors) connectivity.
- The DC analysis using the incoming and outgoing nodes was conducted to identify the DS factors with the most interactions and rank them.
- Experts Industry consultation was obtained on DS factor interactions, and DC was calculated to compare and contrast.
- A ranking of DS factors was concluded based on SLR and industry consultation.

The interrelationship framework is depicted in On the other hand, when "Negative: CE-P02 ↓ CE-P01" is noted, it means that the impact of CE-P02 is detrimental to CE-P01, causing delays or other adverse effects. If there is no notation, it suggests no clear correlation between the variables identified.

Table 3 shows the connections between different factors that impact each other positively or negatively. The pairwise interrelationship table enables readers to recognise these links and understand how one factor can affect another (Saaty, 2012). For ~~example, "~~example, "Positive: CE-P02 ↑ CE-P01" means CE-P02 positively impacts CE-P01 and helps reduce delays due to CE-P01. On the other hand, when "Negative: CE-P02 ↓ CE-P01" is noted, it means that the impact of CE-P02 is detrimental to CE-P01, causing delays or other adverse effects. If there is no notation, it suggests no clear correlation between the variables identified.

Table 3 Pairwise Interrelationships Framework (Author's own work)

		Theme			
		Factor CE-P01	Factor CE-P02	Factor CE-P03	Factor CE-P04
Theme	Factor CE-P01	N/A	Positive: CE-P01 ↑ CE-P02 Negative: CE-P01 ↓ CE-P02 (Blank): No Relationship	Positive: CE-P01 ↑ CE-P03 Negative: CE-P01 ↓ CE-P03 (Blank): No Relationship	Positive: CE-P01 ↑ CE-P04 Negative: CE-P01 ↓ CE-P04 (Blank): No Relationship
	Factor CE-P02	Positive: CE-P02 ↑ CE-P01 Negative: CE-P02 ↓ CE-P01 (Blank): No Relationship	N/A	Positive: CE-P02 ↑ CE-P03 Negative: CE-P02 ↓ CE-P03 (Blank): No Relationship	Positive: CE-P02 ↑ CE-P04 Negative: CE-P02 ↓ CE-P04 (Blank): No Relationship
	Factor CE-P03	Positive: CE-P03 ↑ CE-P01 Negative: CE-P03 ↓ CE-P01 (Blank): No Relationship	Positive: CE-P03 ↑ CE-P02 Negative: CE-P03 ↓ CE-P02 (Blank): No Relationship	N/A	Positive: CE-P03 ↑ CE-P04 Negative: CE-P03 ↓ CE-P04 (Blank): No Relationship
	Factor CE-P04	Positive: CE-P04 ↑ CE-P01 Negative: CE-P04 ↓ CE-P01 (Blank): No Relationship	Positive: CE-P04 ↑ CE-P02 Negative: CE-P04 ↓ CE-P02 (Blank): No Relationship	Positive: CE-P04 ↑ CE-P03 Negative: CE-P04 ↓ CE-P03 (Blank): No Relationship	N/A

These tabulated data are then used to create a Causal Loop Diagram (CLD) showing the factors and their relationships influencing DS in the construction industry.

3.5 Causal Loop Diagram

CLD is a frequently used tool for addressing problems through system dynamics (Husain et al., 2020). Qualitative methods such as literature reviews and expert interviews are commonly used to create CLDs (Dhirasasna & Sahin, 2019). CLDs offer a way to easily investigate causal relationships, gain qualitative insights into the phenomena under investigation, and assist in network analysis (Uleman et al., 2021). In this study, CLDs prove critical in navigating a complex network of DS influences, distinguishing between positive

and negative factors. Following Samarasekara et al. (2024), curved lines with arrows represent each link, with blue arrows indicating positive (+) influences and red arrows representing negative (-) influences. Bold red arrows highlight the eleven major categories impacting DS. Black text indicates positive influential factors, while red text indicates negative impacts.

CLDs visually illustrate the complex interconnections and help to rank the factors based on the number of loops in which the individual factors participate. If fewer loops are identified, analysing the number of factors a particular factor "influences" or gets "influenced" is helpful. However, these are one-sided rankings based on "influence" or "influenced". In such cases, the degree of centrality that considers both "influence" and "influenced" helps identify the ranking of the interrelating factors.

3.6 Degree of Centrality

In an interrelation analysis, the network and nodes (the factors) play an important role. Network analysis focuses on Real-world systems, which are complex networks of interconnected nodes. Hence, assessing the relative importance of these nodes is crucial, typically done through various centrality measures that highlight different aspects of the network (Ronqui & Travieso,2015). Network analysis can be regarded as a set of techniques with a shared methodological perspective. It allows researchers to depict relations among factors and analyse the system structures that emerge from the recurrence of these relations (Chiesi, 2015). Centrality concepts were developed in social network analysis and later adopted in many fields. Multiple methods evolved for identifying network centrality. The closeness centrality method is used for analysing connected graphs using the natural distance between all pairs of nodes, and the metric is based on the length of the shortest paths (Parand et al., 2016). The betweenness centrality measure quantifies the number of times a node occurs as a bridge along the shortest path between two other nodes (Parand et al., 2016). Eigenvector centrality can also be seen as a weighted sum of direct and indirect connections of any length (Parand et al., 2016). Degree Centrality is defined as the number of links incident upon a node. The Degree can be interpreted as the node's (factor's) opportunity to catch the flowing interactions in the network (Parand et al., 2016).

Estimating closeness and betweenness centrality requires understanding the length or duration of factors' interaction. This requires data that evolves over a period based on presumed static situations. Hence, it will not be helpful for dynamic situations that lack duration data. Eigenvector centrality links indirect interactions and multiple iterations, complicating the calculations and possibly creating trivial issues if calculations lead to null values. Hence, the Degree of Centrality measure is advantageous, as it is a straightforward calculation based on connected nodes (interrelations). Determining the degree of centrality (DC) involves counting the edges connected to a factor. This metric is especially effective because factors with high edges (degrees) often have high centrality within the network (Golbeck, 2013). The number of edges linked to a factor is a fundamental network property that describes its connections (Golbeck, 2013). In-degree is the number of edges pointing towards the factor (influenced), while out-degree is the number of edges pointing away from it (influence) (Hansen et al., 2020).

The total degree score of the factor is obtained by adding both ~~in-degree and~~ the in-degree and the out-degree. The total degree score is then normalised into a 0-1 scale to identify the DC of a factor. DC score is achieved by dividing the total number of relationships connected to a factor (in-degree plus out-degree) by the highest total degree factor in the network (Golbeck, 2013). The factor with the highest degree will have a DC score of 1, while every other factor's centrality will be a fraction of its degree (Golbeck, 2013). DC scores are plotted in a table and sorted in ascending order to determine the ranking of the factors. The pairwise comparison table was used to determine the number of indegree and out-degree factors and calculate each factor's DC score. Following ~~Purushothamanet~~ Purushothaman et al. (2024), ~~the two types of degrees, in-degree and out-degree, are determined from the Pairwise Interrelationships matrix~~the Pairwise Interrelationships matrix determines the in-degree, out-degree, and Degree of Centrality.

3.7 Industry Consultation

The factors and interrelations affecting DS were further subjected to industry experts' consultation. The industry consultants were chosen based on various employment segments, roles, positions, fields, and years of experience. A web-based search was used to scan public-facing profiles to identify 12 industry experts across New Zealand (purposive sampling~~), and~~), and then scoping expert meetings with five individuals were carried out to capture their specific, insider and diverse perspectives on DS topics. The segments invited included contractors, government, consultants, and client organisations, ensuring a diverse pool of expertise. Contractors included direct contractors to the government and large subcontractors. The role criteria included experience working with DS. The position criteria were fixed managers and above to obtain a realistic view of DS factors and strategies. The field criteria included buildings and other construction. The years of experience were set at a

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minimum of 5 years to get a reasonable outcome. Table 4 shows the details of the industry consultation of five construction professionals in New Zealand. Their experience ranged from 6 to 25 years, and they were from different employment segments and covered most types of buildings. The consultations lasted between 53 minutes ~~to~~ and 1 hour 17 minutes. The discussions were noted, recorded and transcribed. Following Purushothaman et al. (2021), the narrative analysis method used notes and transcriptions to determine themes (Factors Category), factors, and pairwise interrelationships. The interrelationships were then tabulated, and DC was calculated. The results were compared and contrasted.

Table 4 Industry consultation (Author's own work)

Industry expert code	Employment segment	Current Role	Years of Experience	Experience Category
IP1	Contractor	Business Development Manager	12	Housing, Communal Non-Residential, and Commercial Buildings
IP2	Contractor	Project Engineer cum Project Manager	8	Communal Non-Residential, and Commercial Buildings
IP3	Government	Project Manager	6	Communal Non-Residential, and Commercial Buildings
IP4	Consultant	Senior Project Manager	25	Housing, Industrial Buildings, and Other Construction
IP5	Client	Project Manager	10	Commercial Buildings and Industrial Buildings

3.8 Research reliability and validity

Reliability is achieved through ~~organized~~ organised data and ideas (Walliman, 2017). Factors enhancing reliability in qualitative research include ethics, large sample sizes, multiple sites, triangulation, data from large ~~organizations~~organisations, careful sampling, and rigorous coding (Walliman, 2017).

For this research, the following were taken to ensure reliability:

- ~~The research~~The research design ensured the confidentiality of the participant and the organisation; participation was voluntary, and people were protected from any risk;
- The research was conducted with a large number of article reviews; 44 were studied in depth;
- Methods ~~(SLR~~(SLR and consultation, author frequency and DC analysis~~), theory~~), theory (interrelationships and factors), and data (SLR and Consultation) triangulation methods were used to collect the data that assured reliability.
- Emphasis was placed on the quality of industry participants, who were English-speaking employees in the real workplace, allowing the data to be ~~analyzed~~analysed based on the participants' experiences to attain generalizability and enhance knowledge and
- The data were analysed to set themes and codes that ensured reliability.

Validity in research refers to the degree to which the outcomes of an experiment can be legitimately generalized (Walliman, 2017). The validity of the research depends on the robust ethical design carried out in everyday life settings that provided data representativeness of influence on sought variables (Denzin, 1978). John & Dana (2000) and Carter et al. (2014) argued that triangulation is a strategy to achieve validity. ~~John &~~John & Dana (2000) state establishing credibility in a study is to describe in detail the setting, the participants, and the themes of the study. The validity was ensured by:

- Ensuring the same consultation protocol was developed and used for five industry participants;
- The robust ethical design of research aided in obtaining data that genuinely reflected the influences of the variables (factors on DS);
- Methods, environment, theory, and data triangulation methods used to ~~collect and~~collect and analyse the data;
- Confirmability: The research generalised theory through the DC analysis of SLR from high-quality journals, conferences, and Industry experts, confirming its practical application;
- Credibility: Credibility was ensured by gathering and analysing high-quality data from mostly

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reputable journals ~~(refer~~(refer to Table 2) and industry experts with DS experience.

Transferability: The consultation was conducted in typical work settings with high ethical practices to ensure transferability.

The current research, conducted with the utmost care and thoroughness, adopted ethical practices and reviewed 44 articles from high-quality journals and conferences in depth ~~44 articles in depth from high-quality journals and conferences~~. Industry consultation with the same protocol and triangulation aided in obtaining comprehensive data that genuinely reflected the influences of the factors on DS. The high-quality data from SLR and Industry experts combined with the DC analysis on the network interrelations reflected the real-life system dynamics of DS, ensuring the current research's reliability and validity. Figure 4 shows the overall research design.

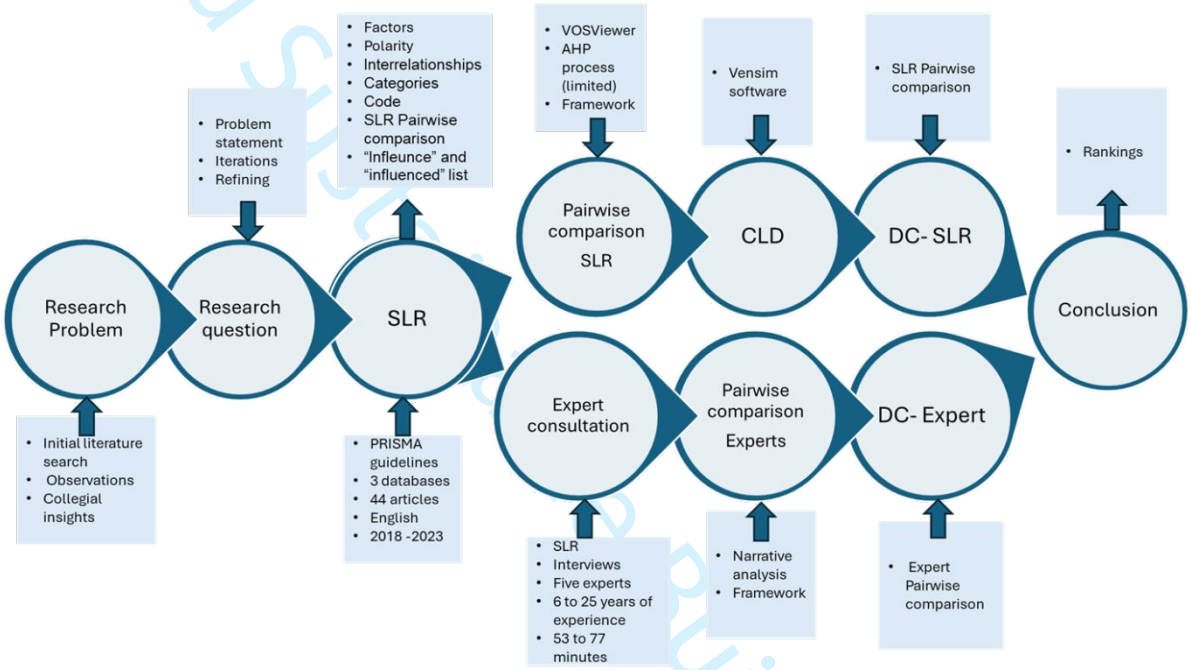

Figure 4 Research design (Author's own work)

4. RESULTS AND DISCUSSION

4.1 Systematic Literature Review Results

The SLR's summary differentiates factors influencing DS into 11 categories: cultural, design, economic/legal, environment, management, planning/scheduling, resources, safety, social, technology, and weather/climate. A total of 176 factors were identified, reviewing 44 articles published between 2018 and 2023 covering 19 countries from 5 continents. Furthermore, these factors are coded according to the positive or negative impact of DS (Annexure 1). The Author factor matrix is shown in Annexure 2. Subsequent analysis identified frequently mentioned top 3 positive and the top four negative factors; refer to *Table 5* below.

Table 5 Top Factors Influencing Dynamic Scheduling based on author count (Author's own work)

Rank	Factors Category	Code	Polarity	Author Count
1	**Technology**	TY-P01	Positive	10
2 - 3	**Technology**	TY-P02	Positive	7
	Resources	RC-N01	Negative	7
4 - 6	**Environment**	ET-P01	Positive	5

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Rank	Factors Category	Code	Polarity	Author Count
7 - 9	**Environment**	ET-N01	Negative	5
	Weather / Climate	WR-N01	Negative	5
	Environment	ET-N02	Negative	3
	Resources	RC-N02	Negative	3
	Resources	RC-N03	Negative	3
10 - 16	**Design**	DN-N01	Negative	2
	Economic / Legal	EC-N01	Negative	2
	Environment	ET-N03	Negative	2
	Environment	ET-N04	Negative	2
	Environment	ET-N05	Negative	2
	Environment	ET-N06	Negative	2
	Weather / Climate	WR-N02	Negative	2

TY-P01 10, TY-P02 7, and ET-P01, with 10, 7, and 5 articles mentioning it, respectively, were the top three positive factors that impact DS based on author count. RC-N01, ET-N01 and WR-N01, with 7, 5, and 5 articles mentioning it, respectively, were the top three negative factors that impact DS based on author count. The top-ranked positive factor based on author count, BIM (TYP-01), has been mentioned as a valuable tool for improving DS. Zavari et al. (2022) and Deng et al. (2022) emphasised that BIM provides essential intensive data for DS implementation through optimal site spatial modelling and arrangement. The second highest factor is Shapes Constraint Language (TYP-02). Soman et al. (2020) that TYP-02 is effective as it promotes a method to ascertain logical linkage between construction activities to address complex DS challenges. The third most significant positive influence is spatial development or the availability of spatial information (ET-P01) in construction. The strategic use of workspace on construction sites highlights potential productivity improvements. For instance, Jiang et al. (2020) affirmed the use of real-time 3D spatial data as a critical factor in providing opportunities to improve the effectiveness of DS in construction sites.

The most significant negative factors based on author count were resource constraints and unavailability (RC-N01). Optimistic estimates of activity durations and resource availability frequently fail to reflect the realities encountered on the project site that directly impact DS's application and efficiency (Isah and Kim, 2021). Site space, limited workspace, and accessibility issues (ET-N01) were among the top three negative factors influencing DS. Li et al. (2019a) findings emphasised the difficulties associated with rehandling due to poorly planned site space leading to potential delays. Interestingly, ET-N01 is the reverse of ET-P01, which different authors had captured. Next, bad or inclement weather conditions (WR-N01) appeared in the top three negative factors influencing DS. This finding agreed with Hsu et al. (2020), who highlighted that poor weather significantly impacts material delivery and site work stoppage, resulting in project schedule deviations. While the existing global literature focuses on identifying delay causes in the construction industry, investigating causal relationships between the factors is critical for enhancing DS effectiveness and broadening understanding of potential project outcomes.

4.2 Pairwise Interrelationships Results, Causal Loop Diagram and Degree of Centrality

The study carefully examined each article to uncover the connections between various factors. The analysis revealed 61 factors with relationships. Of these, 53 positively impacted other factors, while eight negatively impacted. **Error! Reference source not found.** provides an overview of the connections between each factor, indicating whether the relationship is positive or negative and the author's reference number. Notably, these interrelationships were identified from 44 ~~articles(~~articles (refer to Annexure 2 SLR Pairwise Interrelationship Summary and Annexure 3 for the chronological order of articles from 2018 to 2023). The analysis of pairwise interrelationships (Annexure 2) revealed significant influencing and influenced factors. Figure 5 shows the top influential and influenced factors based on the pairwise comparison of the SLR.

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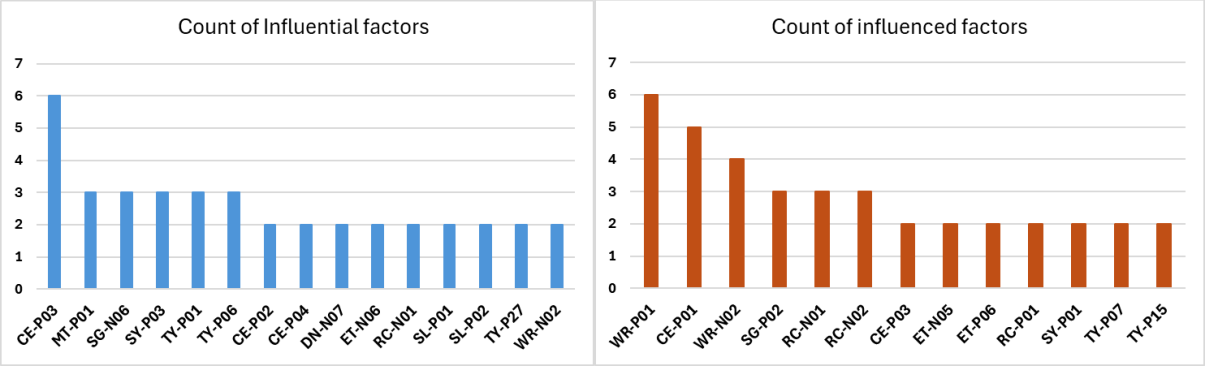

Figure 5 The leading influential and influenced factors in SLR pairwise comparison (Author's own work)

"Diverse cultural heritage" (CE-P03) emerged as the most significant influential factor, with six total counts. According to Fatorić and Egberts (2020), understanding this factor can help policymakers create effective climate action strategies. Many countries protect heritage structures to preserve cultural legacies and reduce construction projects' carbon footprint. Furthermore, heritage has an essential effect on cultural identity, strengthens community bonds, and promotes a stronger sense of communal solidarity (Fatorić and Egberts, 2020)Five factors each influenced three other factors: construction site layout (MT-P01), poor planning (SG-N06), noise barriers (SY-P03), BIM (TY-P01), and the Multi-stage stochastic programming model for optimal supply chain configuration (TY-P06). Choi et al. (2022) highlighted that effective MT-P01 improves worker productivity and safety by reducing material handling and strategic material storage, all of which improve DS effectiveness. Petroutsatou et al. (2021) highlighted that SG-N06 could result in higher transportation costs, resource inefficiencies, and increased downtime, adversely affecting DS. Choi et al. (2022) highlighted that SY-P03 affects costs, productivity, and safety and disturbs nearby residents, negatively influencing construction productivity and DS. TY-P01 appeared in the top influential ~~influenced~~ factors based on pairwise comparison of the SLR and in the top influential ~~influenced~~ factors based on author count. Hsu et al. (2020) highlighted that TY-P06 addresses the construction site's unpredictable and complex logistical challenges by optimising production, transportation, and inventory strategies to resolve logistics issues.

On the other hand, Climate Change Mitigation and Adaptation (WR-P01), Cultural Heritage Management (CE-P01), and Climate Change (WR-N02) emerged as the factors most influenced, with six, five and four factors influencing them, respectively. Fatorić and Egberts (2020) emphasised that cultural heritage management practices, which avoid unnecessary delays due to cultural perspectives, positively influence DS. Further, Fatorić and Egberts (2020) emphasised integrating WR-P01 strategies as necessary for promoting sustainable and eco-friendly projects. Purushothaman and Kumar (2022) highlighted that WR-N02 relies on historical data-based predictions, which may not be accurate and significantly impact construction. Three other factors influenced the use of Resource-Constrained Project Scheduling (SG-P02), Resource Unavailability / Resource Constraints / Unstable Resource Availability (RC-N01), and material Availability / Unavailability of Prefabricated Products / Material Availability (RC-N02). Chakrabortty et al. (2020) highlighted construction complexities such as stochastic activity durations, resource unavailability, and varying resource demands impact SG-P02. These challenges cause instability in the DS, which reduces its effectiveness. Purushothaman and Kumar (2022) highlighted that errors in design and unanticipated events can disrupt RC-N01. Events include changes in weather, the availability of skilled personnel, access to raw materials, equipment failures, local community events, traffic management issues, and geological uncertainty. On the other hand, Lin et al. (2022) proposed a solution that combines optimisation and network scheduling to effectively address static and dynamic resource-constrained situations, positively impacting RC-N01. Purushothaman and Kumar (2022) discussed how the design, event-related disruptions, and adverse weather conditions contribute to material shortages (RC-N02). Notably, the discussion on influencing and influenced factors does not provide the overall inter-relationship spectrum.

CLD, ~~as~~ shown in Figure 6, ~~,~~ helps to visualise the spectrum of factors and their effects, which provides an enhanced understanding of the interrelations of factors affecting DS. The CLD places DS at the centre of the diagram, followed by its 11 primary categories. These categories are connected to the 176 factors; 95 positive influence factors are shown with blue arrows, and 81 negative influences are indicated with red arrows. Furthermore, the CLD illustrates 61 factors of interdependent relationships, with blue arrows indicating positive and red arrows indicating negative influence. The CLD illustrated a more apparent separation between the positive and negative factors than in a tabular form. The CLD further revealed one reinforcing loop of CE-P03 and WR-N02. No other loops were deducted in the CLD.

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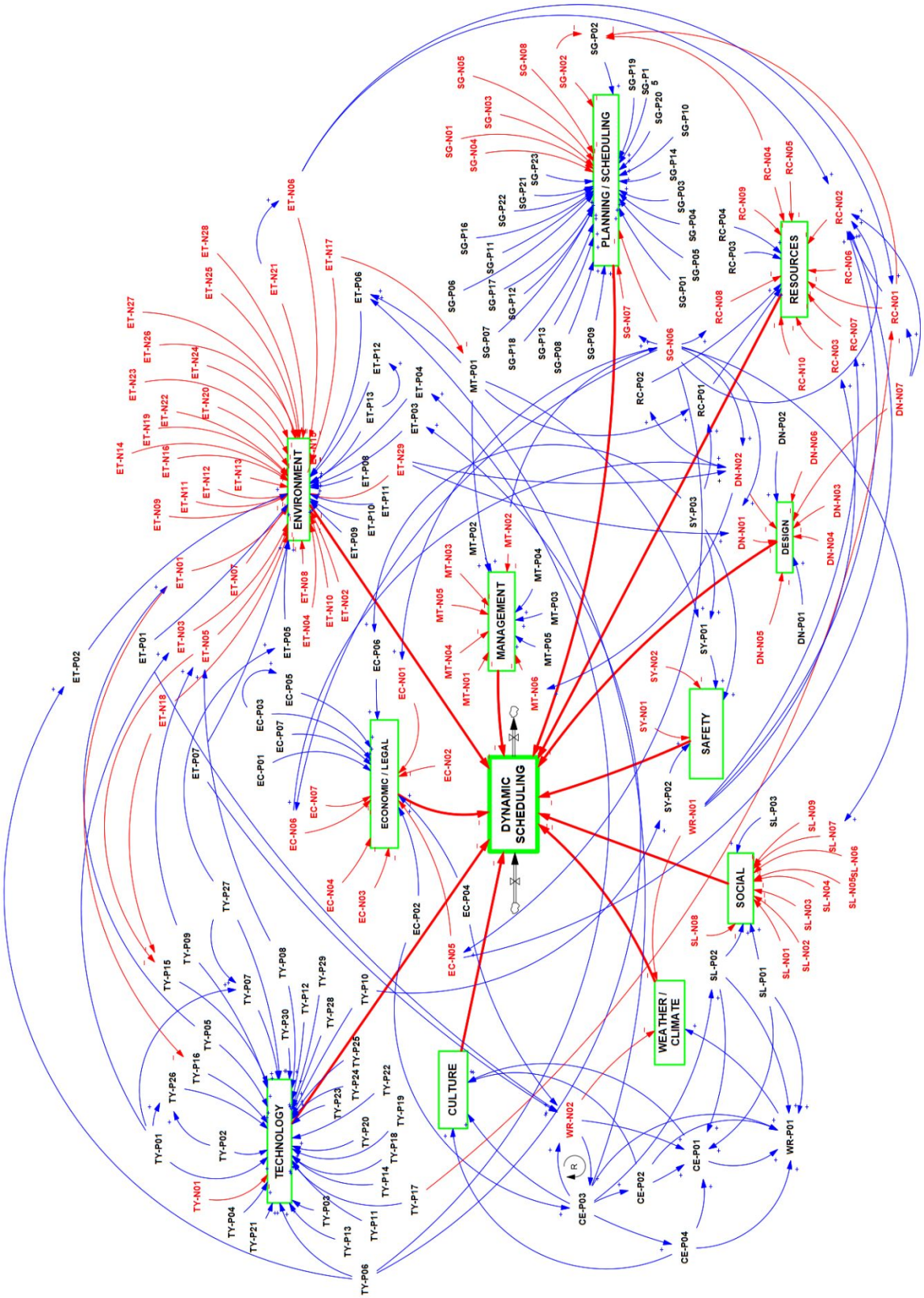

Figure 6 Causal Loop Diagram (Author's own work)

Though the CLD did not reveal more than one loop, it reveals the number of edges linked to a factor as a fundamental network property that describes its positive and negative interconnections. The more edges a factor has, the more critical and central it is to the network (Golbeck, 2013). DC is one such measure that uses the

number of edges to prioritise the focus (Golbeck, 2013). Table *6* shows the in, out and total degrees and the DC based on SLR. The top 5 factors based on SLR DC are CE-P03, WR-P01, CE-P01, WR-N02, and RC-N01.

Table 6 Degree of Centrality based on SLR (Author's own work)

Factor	Out-Degree	In-degree	Total Degree	Degree of Centrality
CE-P03	3	6	9	1
WR-P01	6		6	0.67
CE-P01	5	1	6	0.67
WR-N02	4	2	6	0.67
RC-N01	3	2	5	0.56
MT-P01	1	3	4	0.44
SG-P02	3		3	0.33
RC-N02	3		3	0.33
ET-N05	2	1	3	0.33
SL-P02	1	2	3	0.33
ET-N06	1	2	3	0.33
CE-P02	1	2	3	0.33
CE-P04	1	2	3	0.33
TY-P01		3	3	0.33
SY-P03		3	3	0.33
SG-N06		3	3	0.33
TY-P06		3	3	0.33
TY-P26	2		2	0.22
TY-P15	2		2	0.22
SY-P01	2		2	0.22
RC-P01	2		2	0.22
ET-P06	2		2	0.22
ET-N01	1	1	2	0.22
TY-P27		2	2	0.22
SL-P01		2	2	0.22
DN-N07		2	2	0.22
TY-P16	1		1	0.11
SY-P02	1		1	0.11
SG-N07	1		1	0.11
RC-P02	1		1	0.11
RC-N08	1		1	0.11
RC-N03	1		1	0.11
ET-P12	1		1	0.11
ET-P05	1		1	0.11
ET-P04	1		1	0.11

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Factor	Out-Degree	In-degree	Total Degree	Degree of Centrality
ET-P03	1		1	0.11
ET-P02	1		1	0.11
ET-N03	1		1	0.11
EC-P06	1		1	0.11
EC-P05	1		1	0.11
EC-N01	1		1	0.11
SG-N02		1	1	0.11
RC-N04		1	1	0.11
WR-N01		1	1	0.11
TY-P17		1	1	0.11
TY-P10		1	1	0.11
TY-P09		1	1	0.11
TY-P08		1	1	0.11
TY-P05		1	1	0.11
TY-P02		1	1	0.11
ET-P13		1	1	0.11
ET-P07		1	1	0.11
ET-P01		1	1	0.11
ET-N21		1	1	0.11
ET-N18		1	1	0.11
ET-N17		1	1	0.11
EC-P04		1	1	0.11
EC-P03		1	1	0.11
EC-P02		1	1	0.11
DN-N02		1	1	0.11

4.3 Industry Consultation Pairwise Interrelationships Results and Degree of Centrality

Table 7 below shows the pairwise interrelations stated by five construction industry professionals in New Zealand. The industry experts confirmed only a few interrelations compared to the SLR, but all were previously unidentified. A note of caution is that these interrelations may have been identified before 2017 or other databases, which this study excluded. These interrelations are also shown in *Figure 6*.

Table 7 Pairwise interrelations stated by Industry ~~professionals~~(professionals (Author's own work)

Primary Factor	Polarity	Influenced Factor
DN-N02	Positive	MT-N06
EC-N05	Positive	RC-N02
EC-N06	Positive	DN-N02
ET-N29	Positive	DN-N02 and DN-N01
MT-N02	Positive	SG-N06
SG-N06	Positive	SL-N07, RC-N02, DN-N02, DN-N01, EC-N06 and EC-N05

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Primary Factor	Polarity	Influenced Factor
WR-N01	Positive	RC-N07 and RC-N02

Table 8 shows the degree of centrality for factors affecting DS based on Industry consultation. SG-N06 tops the list, followed by DN-N02, RC-N02, WR-N01, and EC-N06. Interestingly, the top 5 factors, CE-P03, WR-P01, CE-P01, WR-N02, and RC-N01, did not appear in the degree of centrality based on Industry consultation.

Table 8 Degree of centrality based on Industry consultation (Author's own work)

Factor	Out-Degree	In-degree	Total Degree	Degree of Centrality
SG-N06	6	1	7	1.00
DN-N02	1	3	4	0.57
RC-N02		3	3	0.43
WR-N01	2		2	0.29
EC-N06	1	1	2	0.29
EC-N05	1	1	2	0.29
ET-N29		2	2	0.29
DN-N01		2	2	0.29
RC-N07		1	1	0.14
MT-N06		1	1	0.14
SL-N07		1	1	0.14
MT-N02	1		1	0.14

Amongst all the critical factors, CE-P03 had the maximum degree of centrality, ranking it as the top factor among those identified by the SLR. WR-P01, CE-P01, WR-N~~02, and~~02, and RC-N01 were ranked next (*Table 6*). WR-N02 and RC-N02 negatively affect DS, while CE-P03, WR-P01, and CE-P01 have positive impacts. The DS must consider these critical factors to avoid multiple or repelling effects. A point to consider is that these are higher-level strategic decision factors that affect DS, as identified by the global literature, considering all types of projects. In contrast, the degree of centrality for factors affecting DS based on industry consultation yielded different results. SG-N06 tops the list, followed by DN-N02, RC-N02, WR-N01, and EC-N06 (Table 8). Interestingly, the top 5 factors, CE-P03, WR-P01, CE-P01, WR-N02, and RC-N01, did not appear in the degree of centrality based on Industry consultation. However, SG-N06 appeared third in the top influential list, and DN-N02 appeared last in DC based on the SLR list (Table *6*), and one author (Al Hawarneh et al., 2019) out of 44 had identified this factor. The industry consultants were critical of this factor, which probably affects the site and building construction phase operations.

RC-N02, unavailability of materials/unavailability of prefabricated products / Material availability ranked 7-9 in the author count list (Table 5), eighth in the DC based on SLR (Though the CLD did not reveal more than one loop, it reveals the number of edges linked to a factor as a fundamental network property that describes its positive and negative interconnections. The more edges a factor has, the more critical and central it is to the network (Golbeck, 2013). DC is one such measure that uses the number of edges to prioritise the focus (Golbeck, 2013). Table *6* shows the in, out and total degrees and the DC based on SLR. The top 5 factors based on SLR DC are CE-P03, WR-P01, CE-P01, WR-N02, and RC-N01.

Table 6) and appeared as the most influenced factor (*Table 7*). Five authors identified WR-N01 as having a negative influence on DS; it was ranked between 4-6 in *Table 5*. It aligned with the ranking based on industry consultation DC (*Table 8*). EC-N06, lack of work permits, the next critical factor identified by Industry consultants, did not appear in pairwise comparison and DC based on SLR. However, Li et al. (2019b) were the only authors out of 44 who identified this factor in the SLR (Annexure 3). Though this research identified the relationship of EC-N06 for the first time, it must be interpreted cautiously. It is important to note that industry consultants are working professionals focused on problems on building construction sites rather than having a project perspective. Hence, EC-N06 should be treated as a critical factor influencing the buildings' DS at the operational level. Summarising, SG-N06, DN-N02, RC-N02, WR-N01, and EC-N06 are crucial factors affecting DS and operational level, while CE-P03, WR-P01, CE-P01, WR-N02, and RC-N01 are the top 5

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factors influencing DS at the strategic level.

~~4.4 Discussions~~4.4 Discussions

The pairwise comparison results of SLR and Industry Consultation differed, indicating differences in strategic and operational level issues. Petroutsatou et al. (2021) state that SG-N06 (Poor planning) negatively impacts on-site installation, increasing transport costs, inefficient resource use, and decreased productivity. However, New Zealand experts link it to an increase in DN-N02 (incomplete project information) and DN-N01 (complexity of construction site layouts) as real-time updating would differ from planned progress. They further link SG-N06 to RC-N02 (Material availability) as planning is critical to receiving and storing materials in time and adequately storing them in a space-constrained environment. Experts pointed out that work permits are applied in phases in large projects, and poor planning would increase EC-N06 (lack of work permits). Further, they mentioned SG-N06 would delay payment (EC-N05) as dynamic cash flow calculations are based on planning and scheduling, affecting the decision-making of clients and project owners (SL-N07) as the planning and scheduling document is the basis and centre of project progress. Through the interrelationship-based DC analysis, this article ranks SG-N06 as the top factor affecting the DS in New Zealand at the operation level.

Al Hawarneh et al. (2019) have proposed dynamic planning as an option for the construction site layout design process, where facilities are relocated between the stages for optimisation and safety. Though not explicitly stated, this points out that DN-N02 (Incomplete drawings, specifications, and project information) could be adverse if not updated in real-time, a scenario that New Zealand experts strongly agree with. The New Zealand experts further reveal that the problems caused by DN-N02 could adversely affect the actual construction process in terms of scheduling errors, delay, safety, cost and reworks. X. Li et al. (2019) state that proactive constraints management can enhance the reliability of Prefabricated house production schedules~~, ; and~~ restricting factors include incomplete drawings DN-~~N02~~N02, and specifications and a lack of work permits (EC-N06). Experts point out that most construction works in New Zealand can be executed only after approvals, and EC-N06 can affect the schedule directly. EC-N06 ~~affects DN~~affects DN-N02, as most organisations spend the ~~manpower~~ workforce to fine-tune and correct errors only on projects that get approvals from authorities. However, the work commences at the earliest, overlooking DN-N02 when approvals are obtained, only to find later errors that cause delays and affect planning, scheduling, and, in turn, the project. ~~Through interrelationship analysis, this article affirms the importance of DN-N02 and EC-N06 at an operation level~~This article affirms the importance of DN-N02 and EC-N06 at an operation level through interrelationship analysis.

X. Li et al. (2019) and Purushothaman & Kumar (2022) state that RC-N02 (Material unavailability) is a critical factor that affects DS. New Zealand experts affirm that delays in payment (EC-N05), SG-N06 (Poor planning), and adverse weather (WR-N01) are causes of RC-N02's effects on DS. Experts opined that payment delays mean a lack of trust in the client, and in situations where the construction sector faces a downturn and surge in insolvency, the suppliers tend to be more cautious and refuse supplies because of payment delays, a factor significantly influenced by the sector's economic conditions. Experts state that in countries like New Zealand, where a high percentage of materials are imported, adverse weather delays in transportation are increasingly playing a role in delays in supplies from both inland and overseas. This article uses an interrelationship-based DC analysis to rank RC-N02 as a critical factor affecting the DS in New Zealand at the operation level.

Peng et al. (2023), (Petroutsatou ~~et al.~~(et al. (2021), X. Li et al. (2019), Purushothaman & Kumar (2022), Hsu et al. (2020), and (Ahmeti, 2022~~) state~~) state that WR-N01(Adverse Weather) impacts DS. New Zealand experts affirm the effect ~~of WR~~of WR-N01 and further link it to RC-N07 (project productivity issue) in the construction stages as it delays project progress and RC-N02 (material availability) as it affects transportation. This article employs a DC analysis based on interrelationships to classify WR-N01 as a key element influencing the DS at the operational level in New Zealand.

The Netherlands adopts dynamic planning and decision-making, along with the National Environmental Planning Strategy, which enhances integrated cultural heritage and environmental management (Fatorić & Egberts, 2020). In addition, the country's proactive approach, aiming for climate-proof and water-resilient socio-economic sectors by 2050, ~~recognizes~~ recognises the unique perspective of their cultural heritage in managing water-related hazards and climate adaptation (Fatorić & Egberts, 2020). This emphasis on cultural heritage sets the Netherlands apart in its environmental planning strategies. With more structures around the globe set to attain heritage status, protecting and learning from them would be beneficial. Especially for young countries like New Zealand, where heritage status buildings are on the rise, protecting Heritage buildings from adverse weather and earthquakes and reasoning their long existence in such conditions could lead to more knowledge that could be used for future buildings. Authors such as Fatorić and Egberts (2020) have acknowledged the role

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of CE-P03 and CE-P01. However, unlike this article, which included them in the critical list at a strategic level, they have not stamped the importance of CE-P03 and CE-P01.

SLR interrelationships highlighted that RC-N01 (Resource constraints) are critical. Seven authors have identified this as a critical issue (refer to Annexure 2). However, the New Zealand experts have not identified these factors at the operational level. This is probably because, in countries like New Zealand, resource availability for construction in an uptrend is a traditional concern, and it remains abundant during an economic downtrend. The experts may not have highlighted it because of the current economic situation in New Zealand. However, resource constraints such as project managers, site forepersons, and surveyors are long-term issues ~~stated~~ in the New Zealand Immigration Long-term Skills Shortage List (NZ Immigration, 2024). Governments and policymakers address them through various initiatives. This article included RC-N01 in the critical list at a strategic level, based on the SLR interrelationships DC analysis.

Purushothaman & Kumar (2022) and ~~(Yuan et al.(2023) stated WR-N02 (Climate change), and (Fatorić & Egberts,~~ Yuan et al.(2023) stated WR-N02 (Climate change), and Fatorić & Egberts (2020) stated WR-P01(Climate change mitigation and adaptation) as factors affecting DS. The authors acknowledge the profound impact that WR-N02 has on DS in construction. At the same time, WR-P01 emphasises the critical importance of efforts toward climate change mitigation and adaptation, reflecting responsibility. New Zealand experts state that these factors need solutions from the strategic level involving global communities. New Zealand experts have not particularly emphasised that these factors influence the DS because they are complex and require strategic solutions from the worldwide community. Aligning these factors with the United Nations Goals and Targets, such as Target 11.b for an inclusive, resource-efficient, and climate-resilient urban landscape and Target 13.b for effective climate change-related planning and management, underscores the need for thoughtful and strategic action (UN, n.d). Hence, this article included WR-P01 and WR-N~~02 in~~02 in the critical list at a strategic level, based on the SLR interrelationships DC analysis and the nature of the issues.

DS has long been studied to understand how individual factors could impact its performance. In the past, when studying DS, literature tended to focus on the particular factors that could impact their performance. Attempts were made to mitigate these factors by considering them as isolated entities. However, in practice, these factors do not operate in isolation. Instead, they often interact in complex ways, creating loops and compounding their effects. Understanding the interplay between different factors is crucial for effective decision-making. For the first time, this ~~pilot~~ study delves into the complex interrelationships involved in DS delay mitigation, which could enhance the existing DS literature and provide further insights for academics to investigate. The study's findings showed that differences between SLR and local consultation could be of great value for industry professionals, as they can assist them in gaining a deeper understanding of the complex interrelationships involved in DS. When understood and acted upon, they would help mitigate construction delays. It is worth noting that this article provides a ranking-based or operations and strategic perspective that would help middle and top-level managers focus.

Furthermore, the study separated strategic and operational level factors that can provide valuable insights for managers in developing effective strategies to tackle these interactions of factors affecting DS and construction delays and enhance the overall efficiency of their operations. The research has adopted an efficient approach of a combination of SLR, SSI, DC, and CLD that can benefit academics, project managers, planners, and construction experts. By leveraging this approach, they can create a comprehensive framework for baseline scheduling, effectively evaluate risks, and implement project controls tailored to their specific projects. This can help them achieve greater precision and efficiency in project execution, leading to better outcomes and increased success. The results of the research can serve as a valuable resource to guide decision-making procedures and enhance the efficacy of DS in diverse settings. Additionally, the ranking of segmenting and identifying key strategic level factors that affect DS in this study holds significant theoretical value for experts and policymakers in the construction industry who aim to optimise construction project productivity, sustainability, and conflict resolution through informed DS practices. Further, the strategic-level issues are of greater importance for top management, policymakers, and governments to focus on to achieve a sustainable future. The strategic level issues such as climate and resources highlighted in this article help policymakers align the construction industry perspective with the UN sustainability goal and targets 11.b, 13.b and 9.4 focus. Further, this research categorises operational and strategic-level criticalities to the existing knowledge of delay mitigation in construction by ~~opening up~~opening the interrelations of factors affecting DS that form a base for academics in future research to quantify the impacts and suggest novel mitigation strategies. This study adds knowledge to existing literature and provides valuable insights into the DS, highlighting the complex interrelationships within the field and encouraging further research. Equipping theory with critical knowledge on operational and strategic-level criticalities based on interrelations, the research can enhance the efficiency of construction projects, encourage sustainability, and enable effective dispute resolution by implementing these

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informed practices in DS.

5. CONCLUSION

This study revealed that DS within the construction sector is significantly impacted by positive and negative interrelationships, which ultimately affect project timelines. This research extends beyond the conventional focus on individual factor challenges to DS. What sets this study apart is its holistic approach, examining 176 factors within 11 categories, including Cultural, Design, Economic/Legal, Environmental, Management, Planning/Scheduling, Resources, Safety, Social, Technology, and Weather/Climate, and analysing their complex interrelationships. Moreover, the study highlights the positive and negative influences of these 176 factors (Annexure 1) from SLR. The identified factor's interrelationships from SLR and industry consultation are given in the Pairwise Interrelationships table (**Error! Reference source not found.**Annexure 2 and *Table 7*) and CLD (Figure 6) to help provide a deeper, holistic understanding of DS in the construction industry. Incorporating these factors into DS calculations and contract clauses can significantly reduce project delays, cost overruns, and contractual disputes in New Zealand and globally.

Concluding based on interrelationships and DC (*Table 6* and *Table 8*),

- SG-N06, DN-N02, RC-N02, WR-N01, and EC-N06 are critical factors affecting DS and operational level.
- CE-P03, WR-P01, CE-P01, WR-N02, and RC-N01 are the top five factors influencing DS strategically.
- At the operational level, SG-N06 is the most influential factor with six out degrees, while DN-N02 and RC-N02 were most influenced with three in-degrees each.
- At the strategic level, WR-P01 is the most influential factor with six out degrees, and CE-P03 is the most influenced factor with six in-degrees.

5.1 Originality

Previous research has contributed to identifying the factors that impact DS. Many studies have ranked these factors based on expert opinions, surveys, and their individual effects. In practical situations, most factors often interact with others, compounding the effect. Many authors recognised the relationships between the factors. However, previous research has overlooked the compounding effect of these DS factors when interacting with others. This paper presents a novel approach to considering the interrelations and combined effect of DS factors.

The study uniquely employed several research methods combinations to investigate and rank the factors that affect DS. These methods included SLR, expert consultations, Pairwise Comparison (with steps within the Analytical Hierarchy Process), CLD, and DC Calculations. By using a combination of these methods, the researchers were able to gain a comprehensive understanding of the various factors involved in DS and how they contribute to the overall outcome.

This study breaks new ground by ranking DS factors based on their interrelations and centrality (*Table 6* and *Table 8*), as these factors often combine to act. The study highlights 61 formerly identified interrelationships from SLR and 14 previously unidentified interrelationships through industrial consultations (**Error! Reference source not found.** and *Table 7*). It identifies the top five strategic and operation-level factors influencing DS in the construction industry, providing valuable insights for academics and industry professionals. Additionally, this paper presents a unique approach by separating 176 positive and negative factors (Annexure 1), visualising their interactions (*Figure 6*), and categorising them into 11 distinct categories (Annexure 1).

5.2 Practical and theoretical implications

This study yields significant insights for academics by illuminating the intricate interrelationships in the existing DS literature. By underscoring these connections, the research inspires further scholarly exploration in this evolving field and lays the groundwork for a deeper understanding of the complexities involved. For industry practitioners, the study enriches the comprehension of how various DS factors interplay, ultimately guiding the creation of robust strategies to mitigate project delays. Its practical implications provide project managers, planners, and industry professionals with essential insights to consider when developing baseline schedules, performing thorough risk assessments, and implementing tailored project controls. This tailored approach is crucial for addressing the unique challenges inherent to diverse projects. Moreover, the findings from this study hold the potential to significantly enhance decision-making processes, thereby elevating the effectiveness of

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delay management across a myriad of contexts. On a theoretical level, the contributions of this research are invaluable to academics, researchers, industry practitioners, and policymakers alike. By equipping them with critical knowledge, the study aims to bolster construction project efficiency, promote sustainability, and facilitate effective dispute resolution, all through adopting informed practices in DS.~~This pilot study is helpful for academics as it focuses on interrelationships, which would add knowledge to the existing DS literature and help them investigate further. Further, this pilot study would benefit the industry by assisting them in understanding the interrelationships and building their DS delay mitigation. The practical approach of the research aids the project managers, planners, and industry professionals in using these factors during the creation of baseline scheduling, risk assessment, and project controls tailored to their specific projects. The study's findings can inform decision-making processes and improve the effectiveness of DS in various settings. Furthermore, the study's theoretical impact provides valuable insight for academics, researchers, industry practitioners and policymakers seeking to improve construction project efficiency, sustainability, and dispute resolution through informed DS practices.~~

5.3 Limitations and Future Research

5.3.1 Limitations:

This study assessed only English-published literature, excluding potentially valuable insights from non-English sources. Furthermore, the study used only sources from the Scopus, EBSCO, and Science Direct databases. Other databases could add more factors and interrelationships. However, following the Prisma framework for the SLR reduces the effects of the limitations. The h-index and SJR quartile analysis show that the articles were from reputed journals, which further reduces the effects of the limitations. The industry consultation was limited to five experts in the New Zealand building segment within the construction industry~~, as this was a pilot study~~. This and the limitations of interviews and subsequent analysis are acknowledged. However, the industry consultation yielded insights on previously unidentified and valuable interrelationships of factors affecting DS. A note of caution is that these interrelations may also have been identified ~~prior to~~before 2017, which this study excluded. The limitations due to the exclusion of articles before 2017 are acknowledged.

5.3.2 Future Research

In any situation, a single factor rarely creates issues without combining with other factors. This underscores the need for a comprehensive understanding of the combinational factors and their interrelationships. Whether single or multiple factors cause problems, a chain reaction is most likely to occur. This further emphasises the need to understand and quantify the effects of the interrelationships. Future research should focus on these factors' interrelationships rather than analysing factors in silos and perform network analysis with real-world data to quantify the impacts that would benefit the industry and academia. This article would be a base for identifying critical interrelations and node analysis. Further, specific relationships may bond more than others and work closely in most situations. Such interrelationships require special attention and consideration. Due to their combined effect, these relationships may prove critical in scheduling and planning. A more in-depth investigation of the specific relationships between the identified factors in future may quantify the effects and unveil additional knowledge in the field. Further, interviewing subject matter experts from other construction segments may improve the applicability of the research findings to specific countries or sectors. Furthermore, research could describe specific measures and practices tailored to New Zealand to deal with the problems on DS interrelations.

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Annexure 1: Factors affecting Dynamic scheduling, code, polarity and author count (Author's own work).

S/N	Factors Category	Code	Factors Influencing Dynamic Scheduling	Effect on DS	Authors Count
1	Cultural	CE-P01	Cultural heritage management	Positive	1
2		CE-P02	Cultural identity and togetherness	Positive	1
3		CE-P03	Diverse cultural heritage	Positive	1
4		CE-P04	Place attachment	Positive	1
5	Design	DN-N01	complexity of construction site layouts	Negative	2
6		DN-N02	Incomplete drawings and specifications / incomplete project information	Negative	1
7		DN-N03	design parameters	Negative	1
8		DN-N04	canyon aspect ratio	Negative	1
9		DN-N05	window properties	Negative	1
10		DN-N06	albedo	Negative	1
11		DN-N07	Design error	Negative	1
12		DN-P01	Computational design	Positive	1
13		DN-P02	construction site layout design	Positive	1
14	Economic / Legal	EC-N01	increased transport costs	Negative	2
15		EC-N02	Shortage of construction materials in the market	Negative	1
16		EC-N03	Changes in government regulations/laws	Negative	1
17		EC-N04	Legal disputes between various parties	Negative	1
18		EC-N05	Delay in payment by the owner	Negative	1
19		EC-N06	lack of work permits	Negative	1
20		EC-N07	dynamic economic emission dispatch problems	Negative	1
21		EC-P01	Climate adaptation policy	Positive	1
22		EC-P02	Climate policy	Positive	1
23		EC-P03	Economic benefits	Positive	1
24		EC-P04	Economic diversification	Positive	1
25		EC-P05	National cultural heritage policy	Positive	1
26		EC-P06	construction cost	Positive	1
27		EC-P07	construction investment	Positive	1
28	Environment	ET-N01	Inaccessibility of site / Required accessible workspaces / Indoor space of building / limited site space / limited workspace	Negative	5
29		ET-N02	Effect of subsurface conditions (water table, hard rock) / Geotechnical data issues / natural geological conditions	Negative	3
30		ET-N03	Dynamic changes of the internal space of a building	Negative	2

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S/N	Factors Category	Code	Factors Influencing Dynamic Scheduling	Effect on DS	Authors Count
			in the operation and maintenance stage/changes in spatial state on construction sites		
31		ET-N04	temporary facilities allocation / inconvenient location of the storage area	Negative	2
32		ET-N05	topographic changes over time / Construction site steep slopes	Negative	2
33		ET-N06	Events issues / different dynamic disturbance events	Negative	2
34		ET-N07	Ambient conditions	Negative	1
35		ET-N08	Generation and allocation of workspaces	Negative	1
36		ET-N09	Keeping enough cool air in the plenums	Negative	1
37		ET-N10	Lack of explicit feedback of airflow and temperatures	Negative	1
38		ET-N11	Site congestions identification	Negative	1
39		ET-N12	Strict space pressure control	Negative	1
40		ET-N13	Traffic congestion	Negative	1
41		ET-N14	Unavailability of utilities at site (water, electricity)	Negative	1
42		ET-N15	Curse-of-dimensionality for large-scale instances	Negative	1
43		ET-N16	Detection of physical conflicts between the site workspaces	Negative	1
44		ET-N17	construction noise	Negative	1
45		ET-N18	limitation of autonomous excavators' movement in a construction site	Negative	1
46		ET-N19	uncontrolled environmental conditions	Negative	1
47		ET-N20	Disaster issues	Negative	1
48		ET-N21	Pandemic issues	Negative	1
49		ET-N22	Crowded environment	Negative	1
50		ET-N23	greenhouse gas (GHG) emissions	Negative	1
51		ET-N24	acidifying gas emissions	Negative	1
52		ET-N25	construction sector emissions	Negative	1
53		ET-N26	urbanisation rate	Negative	1
54		ET-N27	pollution load	Negative	1
55		ET-N28	land-use change	Negative	1
56		ET-N29	complex and changeable environment	Negative	1
57		ET-P01	Spatial development / Assembly workspace / Logistics workspace / Production workspace / Spatial information	Positive	5
58		ET-P02	Reduced air pollution	Positive	1
59		ET-P03	Reduced noise	Positive	1

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S/N	Factors Category	Code	Factors Influencing Dynamic Scheduling	Effect on DS	Authors Count
60		ET-P04	Reduced vibration	Positive	1
61		ET-P05	Ensure that the facilities do not overlap with one another or with the buildings	Positive	1
62		ET-P06	Environmental management	Positive	1
63		ET-P07	Reducing carbon footprint by retrofitting historic buildings	Positive	1
64		ET-P08	Reusing existing materials will help to achieve decarbonisation	Positive	1
65		ET-P09	Use of renewable energy	Positive	1
66		ET-P10	sustainable utilisation of urban underground space	Positive	1
67		ET-P11	topological structure	Positive	1
68		ET-P12	appropriate site locations	Positive	1
69		ET-P13	Relocation of a construction site	Positive	1
70	Management	MT-N01	Logistics system	Negative	1
71		MT-N02	Poor interactivity	Negative	1
72		MT-N03	Poor interoperability	Negative	1
73		MT-N04	Problems in shipment and site inventory	Negative	1
74		MT-N05	untimely and inaccurate transportation	Negative	1
75		MT-N06	uncompleted quality control	Negative	1
76		MT-P01	Construction site layout	Positive	1
77		MT-P02	ensemble construction methods	Positive	1
78		MT-P03	lean solutions	Positive	1
79		MT-P04	act fast on decision-making and collaborative working using available information and knowledge	Positive	1
80		MT-P05	Modular Construction	Positive	1
81	Planning / Scheduling	SG-N01	Detection of schedule conflict, which means the detection of a temporal overlap between tasks	Negative	1
82		SG-N02	stochastic activity durations	Negative	1
83		SG-N03	schedule changes of other related operations	Negative	1
84		SG-N04	uncertain time of land acquisition	Negative	1
85		SG-N05	Job Scheduling Problem	Negative	1
86		SG-N06	Poor planning	Negative	1
87		SG-N07	increase in non-productive time	Negative	1
88		SG-N08	resource-constrained project scheduling problem (RCPSP)	Negative	1
89		SG-P01	maximum slack priority rule (shortest latest start time)	Positive	1

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S/N	Factors Category	Code	Factors Influencing Dynamic Scheduling	Effect on DS	Authors Count
90		SG-P02	Applications of resource-constrained project scheduling	Positive	1
91		SG-P03	Hoisting facility layout planning	Positive	1
92		SG-P04	BIM-based construction schedules	Positive	1
93		SG-P05	baseline schedule	Positive	1
94		SG-P06	periodic progress data	Positive	1
95		SG-P07	top-down control methodology	Positive	1
96		SG-P08	risk analysis	Positive	1
97		SG-P09	project control	Positive	1
98		SG-P10	Top-down Control Strategy	Positive	1
99		SG-P11	Bottom-up Control Strategy	Positive	1
100		SG-P12	Crashing Corrective actions	Positive	1
101		SG-P13	Variability Corrective actions	Positive	1
102		SG-P14	Fast-tracking Corrective actions	Positive	1
103		SG-P15	Sensitive Activity selection	Positive	1
104		SG-P16	Critical Activity selection	Positive	1
105		SG-P17	Analytical Sensitivity	Positive	1
106		SG-P18	Simulation Sensitivity	Positive	1
107		SG-P19	Analysis Sensitivity	Positive	1
108		SG-P20	Threshold Methodology	Positive	1
109		SG-P21	Set Methodology	Positive	1
110		SG-P22	serial/parallel indicator Network Topology	Positive	1
111		SG-P23	spatial planning	Positive	1
112	Resources	RC-N01	Resource unavailability/resource constraints / unstable resource availability	Negative	7
113		RC-N02	Unavailability of materials/unavailability of prefabricated products / Material availability	Negative	2
114		RC-N03	Unavailability of equipment and tools / Equipment breakdown / Equipment shortage	Negative	3
115		RC-N04	time-varying resource demands	Negative	1
116		RC-N05	shortage of temporary structures	Negative	1
117		RC-N06	unskilled operators	Negative	1
118		RC-N07	Project productivity issue	Negative	1
119		RC-N08	inefficient use of resources	Negative	1
120		RC-N09	spatial variability of human activities	Negative	1
121		RC-N10	equipment assembly process	Negative	1

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S/N	Factors Category	Code	Factors Influencing Dynamic Scheduling	Effect on DS	Authors Count
122		RC-P01	efficient construction productivity	Positive	1
123		RC-P02	dynamic facilities allocation	Positive	1
124		RC-P03	cross-domain knowledge	Positive	1
125		RC-P04	dynamic distribution of labour resources	Positive	1
126	Safety	SY-N01	Accidents during construction	Negative	1
127		SY-N02	unidentified safety and hazard issues	Negative	1
128		SY-P01	construction safety	Positive	1
129		SY-P02	enhancing safety in the pre-construction phase	Positive	1
130		SY-P03	noise barriers	Positive	1
131	Social and Human	SL-N01	Deficiency for interior personnel to understand the indoor layout	Negative	1
132		SL-N02	Delay in giving instructions	Negative	1
133		SL-N03	Human factors	Negative	1
134		SL-N04	Inadequate experience of consultant	Negative	1
135		SL-N05	Poor communication of owner with contractor	Negative	1
136		SL-N06	Risk aversion in the delivery and operation of buildings	Negative	1
137		SL-N07	Slow decision-making by the owner	Negative	1
138		SL-N08	Stakeholder's loss aversion	Negative	1
139		SL-N09	Suspension of work by owner	Negative	1
140		SL-P01	Social benefits	Positive	1
141		SL-P02	Social cohesion and integrity	Positive	1
142		SL-P03	parallel rule collaboration (PRC)	Positive	1
143	Technology	TY-N01	incomplete BIM models	Negative	1
144		TY-P01	Building information modelling (BIM) / Building Information Modelling (BIM) 5D construction duration-cost optimisation model / BIM-based integrated scheduling methodology for building projects under resource constraints / BIM-based rule-checking systems / Linked-data and constraint-checking / Linked-data based constraint-checking architecture / Ontology for linked-data based dynamic constraint-checking	Positive	10
145		TY-P02	Modelling scheduling constraints using Shapes Constraint Language (SHACL) / Prototype web application / Processing web application / Storage / Data / Prototype evaluation / automatic progress tracking technology	Positive	7
146		TY-P03	optimisation of robot motion path planning / Multi-construction robots / Tracking tasks/robot kinematic	Positive	1

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S/N	Factors Category	Code	Factors Influencing Dynamic Scheduling	Effect on DS	Authors Count
			optimisation principle / mobile platform planning/path control strategy		
147		TY-P04	Dynamic scheduling coordination technology	Positive	1
148		TY-P05	Mobile robots	Positive	1
149		TY-P06	The multi-stage stochastic programming model for identifying the optimal supply chain configuration	Positive	1
150		TY-P07	Navigating spatial data dynamically	Positive	1
151		TY-P08	reinforcement learning model	Positive	1
152		TY-P09	earthwork allocation planning	Positive	1
153		TY-P10	ant colony optimisation	Positive	1
154		TY-P11	network's reliability	Positive	1
155		TY-P12	Dynamic programming algorithm	Positive	1
156		TY-P13	Genetic algorithm for assembly sequence planning in precast concrete buildings	Positive	1
157		TY-P14	dynamic planning model (DPM) using Digital Twin	Positive	1
158		TY-P15	optimisation of the task planning algorithm	Positive	1
159		TY-P16	dynamic planning optimisation model using a Genetic Algorithm	Positive	1
160		TY-P17	input-adaptive particle swarm optimisation (iRC-APSO) algorithm	Positive	1
161		TY-P18	heuristic algorithms	Positive	1
162		TY-P19	intelligent algorithms	Positive	1
163		TY-P20	graph-based model	Positive	1
164		TY-P21	Binary Pareto-Optimal Particle Swarm Optimisation (BP-PSO) algorithm	Positive	1
165		TY-P22	Holonic Management System (HMS)	Positive	1
166		TY-P23	Discrete event simulation	Positive	1
167		TY-P24	system dynamics	Positive	1
168		TY-P25	on-line planning	Positive	1
169		TY-P26	linked-data-based constraint-checking (LDCC) method	Positive	1
170		TY-P27	Geospatial information system (GIS)	Positive	1
171		TY-P28	Data mining (DM)	Positive	1
172		TY-P29	genetic algorithm (GA)	Positive	1
173		TY-P30	new intelligent environmental evaluation method to optimally and dynamically schedule the resource, production and inventory activities	Positive	1
174	Weather /	WR-N01	Adverse weather condition	Negative	5

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S/N	Factors Category	Code	Factors Influencing Dynamic Scheduling	Effect on DS	Authors Count
175	Climate	WR-N02	Climate change	Negative	2
176		WR-P01	Climate change mitigation and adaptation	Positive	1

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Annexure 2: Table 5 SLR Pairwise Interrelationship Summary (Author's own work)

PF	P, IFN 1, AN	P, IFN 2, AN	P, IFN 3, AN	P, IFN 4, AN	P, IFN 5, AN	P, IFN 6, AN
CE-P03	+, CE-P02, 11	+, CE-P04, 11	+, ET-P06, 11	+, SL-P02,11	+, WR-N02,11	+, WR-P01, 11
TY-P01	+, ET-N03, 25	+, TY-P07, 34	+, TY-P26, 16			
MT-P01	+, ET-P06, 24	+, RC-P01, 24	+, SY-P01, 24			
SY-P03	+, EC-P06, 24	+, RC-P01, 24	+, SY-P01, 24			
SG-N06	+,EC-N01, 20	+, SG-N07, 20	+, RC-N08, 20			
TY-P06	+, ET-P02, 12	+, ET-P03, 12	+, ET-P04, 12			
CE-P02	+, CE-P01, 11	+, WR-P01, 11				
CE-P04	+, CE-P01, 11	+, WR-P01, 11				
SL-P01	+, CE-P01, 11	+, WR-P01, 11				
SL-P02	+, CE-P01, 11	+, WR-P01, 11				
TY-P27	+, ET-P05, 34	+, TY-P07, 34				
DN-N07	+,RC-N01, 32	+, RC-N02, 32				
ET-N06	+,RC-N01, 32	+, RC-N02, 32				
RC-N01	-, SG-P02, 10	+, RC-N02, 32				
WR-02	+, CE-P01, 11	+,CE-P03, 11				
CE-P01	+,WR-P01, 11					
DN-N02	+, RC-P02, 3					
EC-P02	+, CE-P03, 11					
EC-P03	+, EC-P05,11					
EC-P04	+,WR-N02,11					
ET-N01	-, TY-P16, 5					
ET-N05	-, TY-P15, 14					
ET-N17	-, MT-P01, 24					
ET-N18	-, TY-P15, 14					
ET-N21	+, ET-N06,32					
ET-P01	+,WR-N02,11					
ET-P07	+,WR-N02,11					
ET-P13	+, ET-P12, 20					
SG-N02	-, SG-P02, 10					
RC-N04	-, SG-P02, 10					
TY-P02	+, TY-P26, 16					
TY-P05	+, ET-N01, 28					
TY-P08	+, ET-N05, 35					

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PF	P, IFN 1, AN	P, IFN 2, AN	P, IFN 3, AN	P, IFN 4, AN	P, IFN 5, AN	P, IFN 6, AN
TY-P09	+, ET-N05, 35					
TY-P10	+, SY-P02, 24					
TY-P17	-, RC-N01, 30					
WRN01	+,RC-N03, 32					

Note: PF = Primary Factor, P = Polarity, + = Positive, - = Negative, IFN = Influenced Factor Number, AN = Author Number stated in ~~anexure~~ Annexure 3.

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Annexure 3: Author factor matrix (Author's own work).

| | | CULTURE | | | | DESIGN | | | | | | | | | | ECONOMIC / LEGAL | | | | | | | | | |

DYNAMIC SCHEDULING: INFLUENTIAL AND INFLUENCED FACTORS AND THEIR INTERRELATIONSHIPS IN THE NEW ZEALAND CONSTRUCTION INDUSTRY

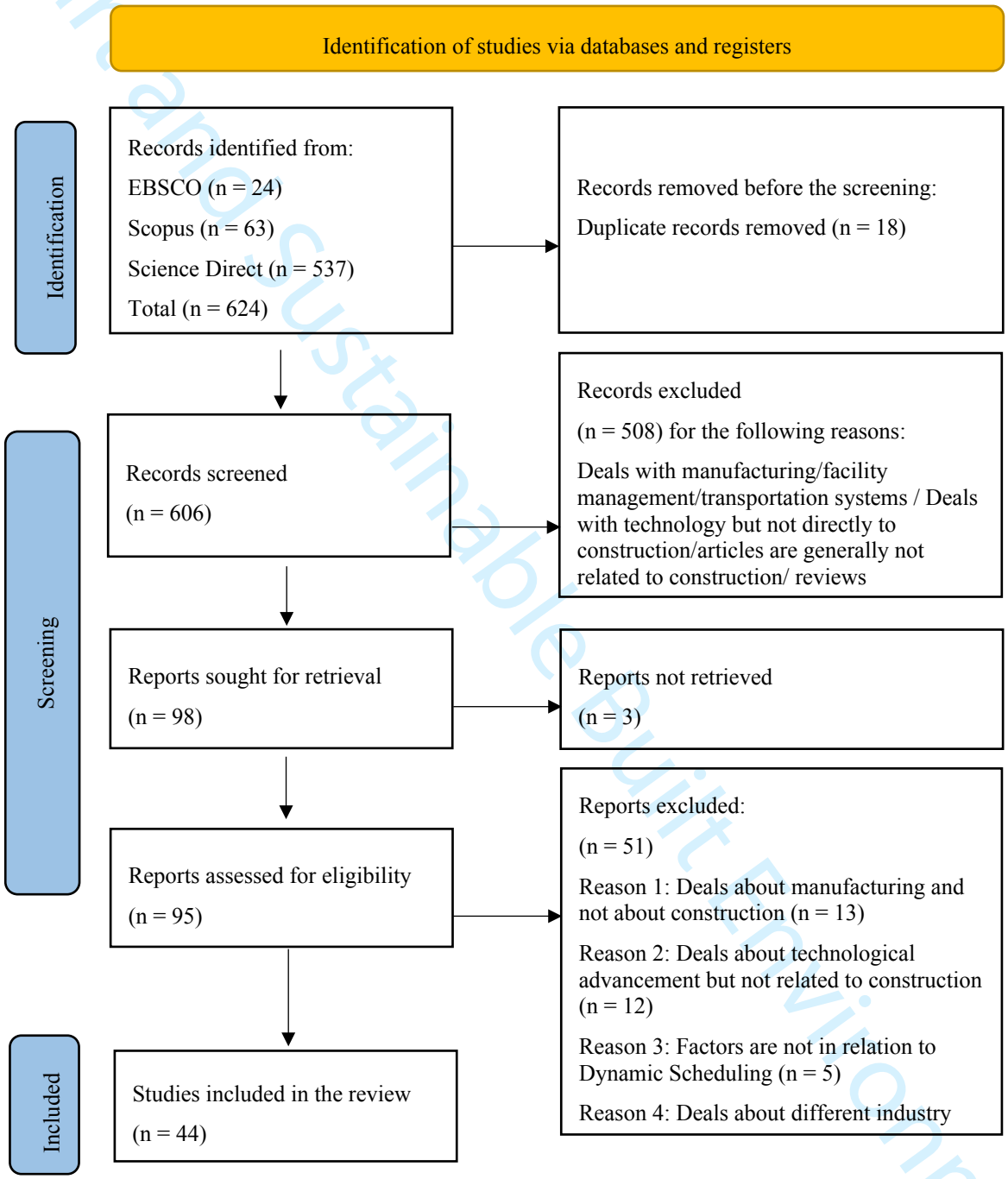

Figure 1 PRISMA Framework (Authors' own work based on the PRISMA framework).

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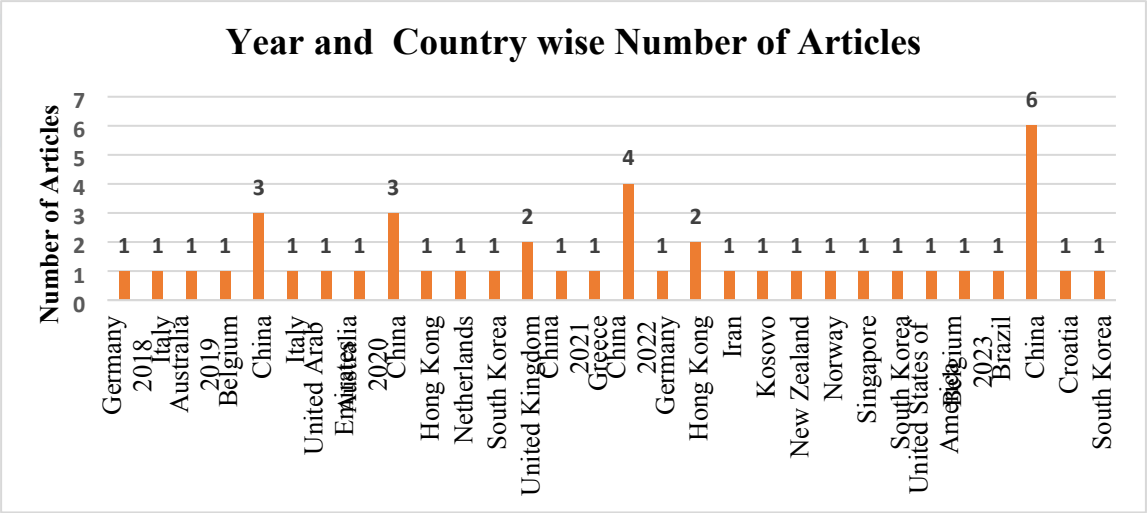

Figure 2 Year & Country Contributions and Number of Articles Studied (Author's own work)

Smart and Sustainable Built Environment

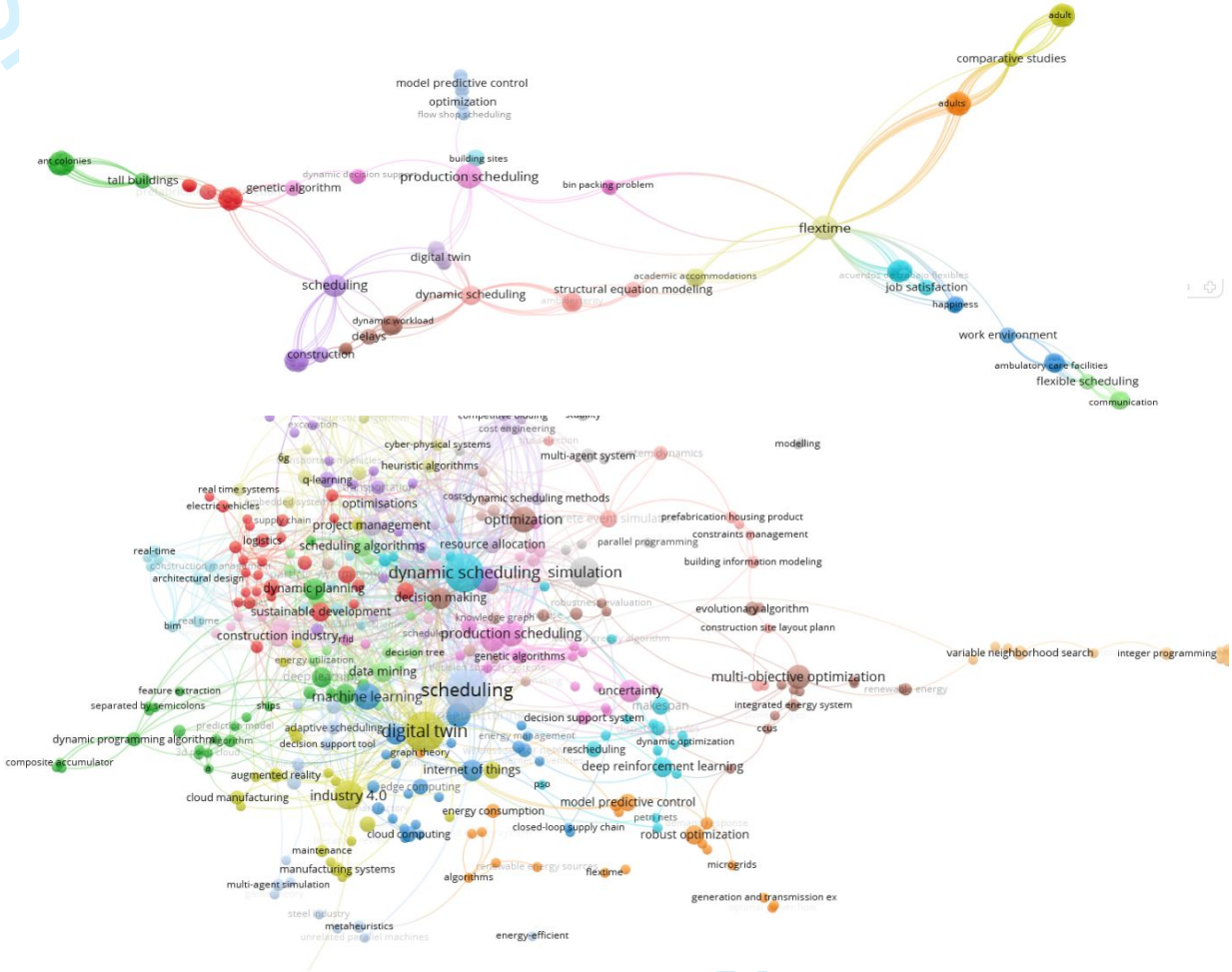

Figure 3 Keyword Search Analysis(Author's own work)

Built Environment

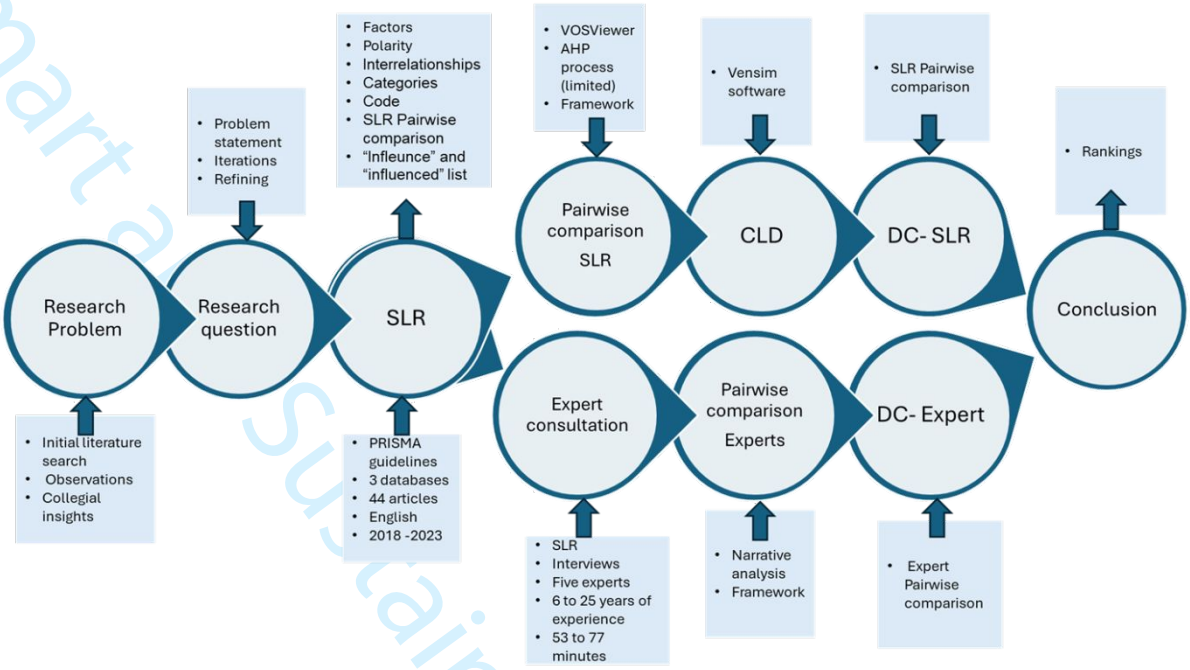

Figure 4 Research design (Author's own work)

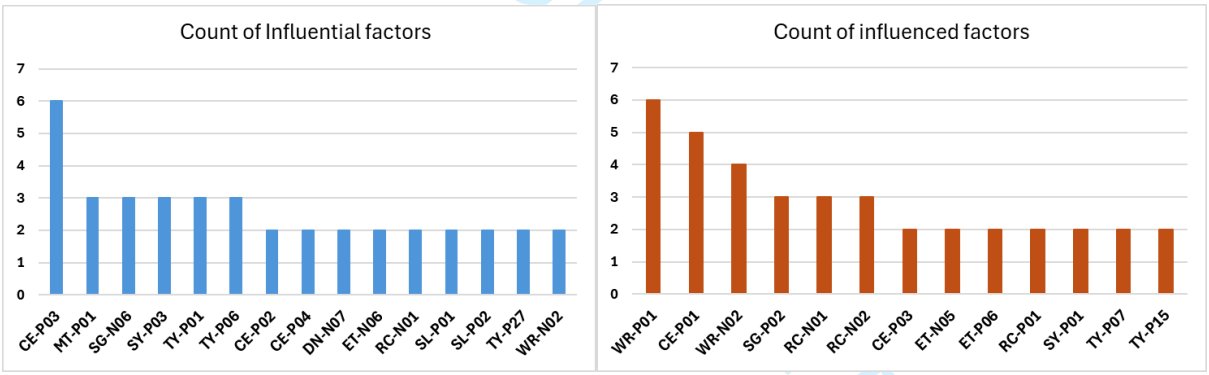

Figure 5 The leading influential and influenced factors in SLR pairwise comparison (Author's own work)

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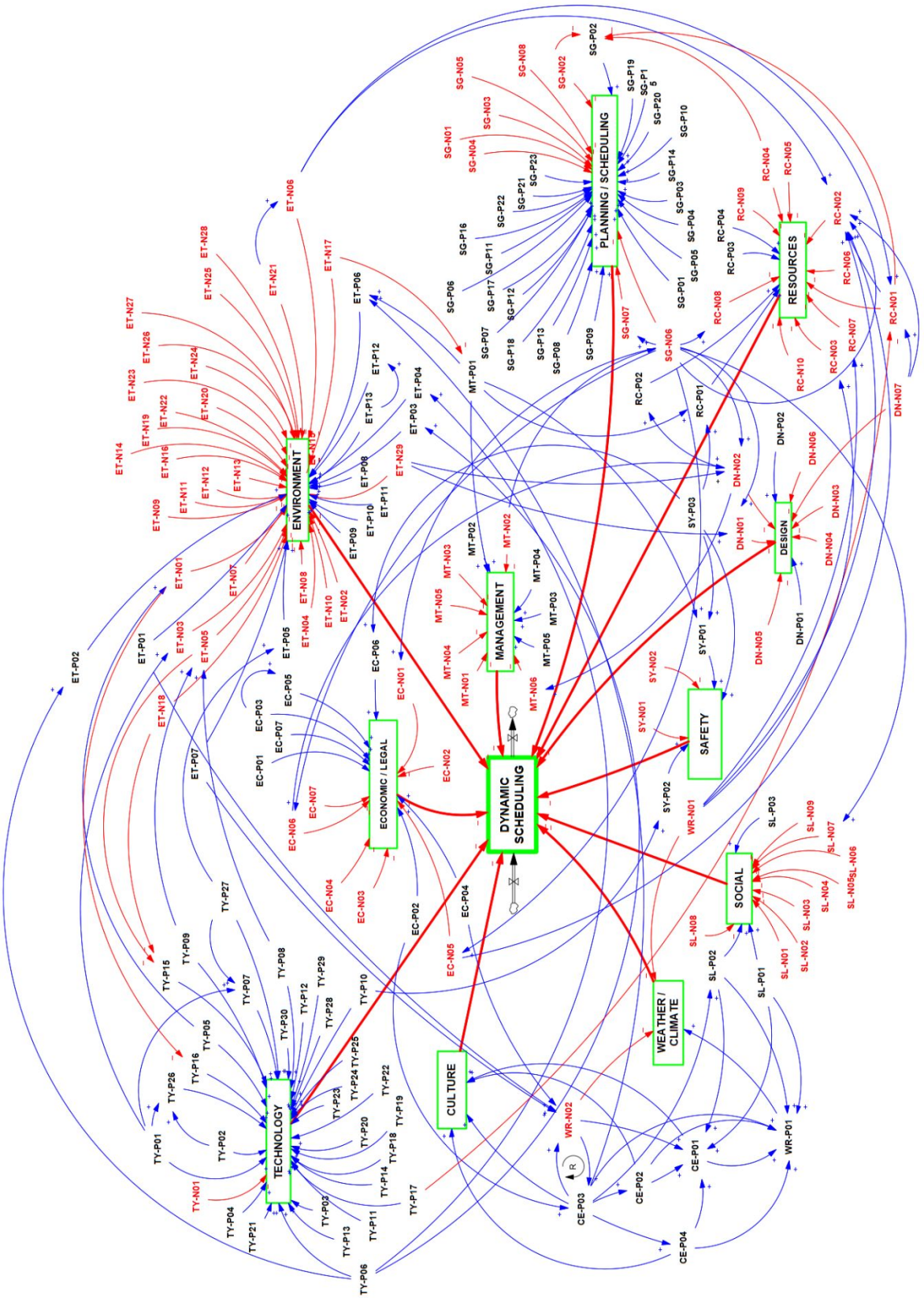

Figure 6 Causal Loop Diagram (Author's own work)

DYNAMIC SCHEDULING: INFLUENTIAL AND INFLUENCED FACTORS AND THEIR INTERRELATIONSHIPS IN THE NEW ZEALAND CONSTRUCTION INDUSTRY

Table 1 Research Search Strings and Exclusions Criteria

Database	Keywords Search	Inclusion Criteria	Exclusion criteria
Scopus	(TITLE-ABS-KEY ("Dynamic Scheduling*" OR "Dynamic Planning*" OR "Adaptive Scheduling*" OR "Flexible Scheduling*") **AND** TITLE-ABS-KEY (building* OR housing* "Building Construct*" OR "Residential Construct*" OR "Commercial Construct*" OR "High-rise Construction" OR "Low-rise Construct*" OR "Industrial Construct*" OR "Vertical Construct*" OR "Tall Building*" OR skyscraper*) **AND** TITLE-ABS-KEY (factor* OR variable* OR impact* OR cause* OR effect* OR reason* OR fail* OR challenge*)) **AND** PUBYEAR > 2017 **AND** PUBYEAR < 2023 (TITLE-ABS-KEY ("Dynamic Scheduling*" OR "Dynamic Planning*" OR "Adaptive Scheduling*" OR "Flexible Scheduling*") **AND** TITLE-ABS-KEY (construction*) **AND** TITLE-ABS-KEY (factor* OR variable* OR impact* OR cause* OR effect* OR reason* OR fail* OR challenge*)) **AND** PUBYEAR > 2017 **AND** PUBYEAR < 2024 **AND** (LIMIT-TO (LANGUAGE, "English")) **AND** (LIMIT-TO (SUBJAREA, "ENGI") OR LIMIT-TO (SUBJAREA, "ENVI") OR LIMIT-TO (SUBJAREA, "SOCI"))	Dynamic Planning and Scheduling, Flexible Scheduling, Adaptive Scheduling. Construction. Factors or similar words. English language articles. From the year 2017. From Engineering, environmental and social fields.	Not in English. Before 2017. Not from construction. Systematic, critical, and literature reviews
EBSCO	("Dynamic Scheduling*" OR "Dynamic Planning*" OR "Adaptive Scheduling*" OR "Flexible Scheduling*") **AND** (building* OR housing* "Building Construct*" OR "Residential Construct*" OR "Commercial Construct*" OR "High-rise Construction" OR "Low-rise Construct*" OR "Industrial Construct*" OR "Vertical Construct*" OR "Tall Building*" OR Skyscraper*) **AND** ((factor* OR variable* OR impact* OR cause* OR effect* OR reason* OR fail* OR challenge*) N20 (impact* OR barrier* OR delay* OR interruption* OR challenge* OR impediment* OR barricade* OR disadvantage* OR hindrance* OR conflict* OR affect* OR influence* OR effect* OR cause* OR reason* OR source* OR *root OR *foundation OR *trigger OR fail*)) ("Dynamic Scheduling*" OR "Dynamic Planning*" OR "Adaptive Scheduling*" OR "Flexible Scheduling*") **AND** (construction*) **AND** ((factor* OR variable* OR impact* OR cause* OR effect* OR reason* OR fail* OR challenge*) **N20** (impact* OR barrier* OR delay* OR interruption* OR challenge* OR impediment* OR barricade* OR disadvantage* OR hindrance* OR conflict* OR affect* OR influence* OR effect* OR cause* OR reason* OR source* OR *root OR *foundation OR *trigger OR fail*))		
Science Direct	("Dynamic Scheduling" OR "Dynamic Planning") **AND** ("Building Construction" OR "Residential Construction" OR "Commercial Construction" OR "Industrial Construction") **AND** (factor OR variable OR delay) ("Dynamic Scheduling" OR "Dynamic Planning") **AND** (construction) **AND** (factor OR variable OR impact OR influence OR delay OR challenge)		

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Table 2 Ranking data analysis of Journals related to articles selected in the review

SJR H-Index	SJR Quartiles	Country	Journal	General Building	Construction	Total
309	Q1	UK	Journal of Cleaner Production		1	1
292	Q1	UK	Applied Energy	1		1
271	Q1	UK	Expert Systems with Applications	1		1
243	Q1	US	Journal of Environmental Management	1	1	2
242	Q1	US	IEEE Access		1	1
232	Q1	Netherlands	Energy and Buildings		1	1
205	Q1	UK	Building and Environment		1	1
176	Q1	UK	Automation in Construction		11	11
165	Q1	UK	International Journal of Electrical Power & Energy Systems		1	1
161	Q1	UK	Computers & Industrial Engineering		4	4
139	Q1	UK	Tunnelling and Underground Space Technology		1	1
137	Q1	UK	Engineering Applications of Artificial Intelligence		1	1
123	Q1	UK	Information Processing & Management		1	1
110	Q1	UK	Advanced Engineering Informatics		4	4
92	Q1	Netherlands	Journal of Building Engineering	2		2
73	Q1	UK	Engineering, Construction and Architectural Management		1	1
28	Q1	UK	Smart and Sustainable Built Environment		1	1
23	Q1	Poland	Applied Mathematics and Nonlinear Sciences		1	1
76	Q2	UK	Engineering Optimization		1	1
60	Q2	Germany	KSCE Journal of Civil Engineering	1		1
30	Q2	Switzerland	Infrastructures		1	1
92	Q3	Netherlands	IFAC-papers online	1		1
103	Proceedings	Netherlands	Procedia CIRP	1		1
69	Proceedings	Netherlands	Transportation Research Procedia	1		1
	Conference		2nd IEEE International Conference on Distributed Computing and Electrical Circuits and Electronics, ICDCECE 2023		1	1
	Conference		ISARC 2018 - 35th International Symposium on Automation and Robotics in Construction and International	1		1

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AEC/FM Hackathon: The Future of Building Things		
Grand Total	10	34 44

Table 3 Pairwise Interrelationships Framework (Author's own work)

		Theme			
		Factor CE-P01	Factor CE-P02	Factor CE-P03	Factor CE-P04
Theme	Factor CE-P01	N/A	Positive: CE-P01 ↑ CE-P02 Negative: CE-P01 ↓ CE-P02 (Blank): No Relationship	Positive: CE-P01 ↑ CE-P03 Negative: CE-P01 ↓ CE-P03 (Blank): No Relationship	Positive: CE-P01 ↑ CE-P04 Negative: CE-P01 ↓ CE-P04 (Blank): No Relationship
	Factor CE-P02	Positive: CE-P02 ↑ CE-P01 Negative: CE-P02 ↓ CE-P01 (Blank): No Relationship	N/A	Positive: CE-P02 ↑ CE-P03 Negative: CE-P02 ↓ CE-P03 (Blank): No Relationship	Positive: CE-P02 ↑ CE-P04 Negative: CE-P02 ↓ CE-P04 (Blank): No Relationship
	Factor CE-P03	Positive: CE-P03 ↑ CE-P01 Negative: CE-P03 ↓ CE-P01 (Blank): No Relationship	Positive: CE-P03 ↑ CE-P02 Negative: CE-P03 ↓ CE-P02 (Blank): No Relationship	N/A	Positive: CE-P03 ↑ CE-P04 Negative: CE-P03 ↓ CE-P04 (Blank): No Relationship
	Factor CE-P04	Positive: CE-P04 ↑ CE-P01 Negative: CE-P04 ↓ CE-P01 (Blank): No Relationship	Positive: CE-P04 ↑ CE-P02 Negative: CE-P04 ↓ CE-P02 (Blank): No Relationship	Positive: CE-P04 ↑ CE-P03 Negative: CE-P04 ↓ CE-P03 (Blank): No Relationship	N/A

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Table 4 Industry consultation (Author's own work)

Industry expert code	Employment segment	Current Role	Years of Experience	Experience Category
IP1	Contractor	Business Development Manager	12	Housing, Communal Non-Residential, and Commercial Buildings
IP2	Contractor	Project Engineer cum Project Manager	8	Communal Non-Residential, and Commercial Buildings
IP3	Government	Project Manager	6	Communal Non-Residential, and Commercial Buildings
IP4	Consultant	Senior Project Manager	25	Housing, Industrial Buildings, and Other construction
IP5	Client	Project Manager	10	Commercial Buildings and Industrial Buildings

Table 5 Top Factors Influencing Dynamic Scheduling based on author count (Author's own work)

Rank	Factors Category	Code	Polarity	Author Count
1	**Technology**	TY-P01	Positive	10
2 - 3	**Technology**	TY-P02	Positive	7
	Resources	RC-N01	Negative	7
4 - 6	**Environment**	ET-P01	Positive	5
	Environment	ET-N01	Negative	5
	Weather / Climate	WR-N01	Negative	5
7 - 9	**Environment**	ET-N02	Negative	3
	Resources	RC-N02	Negative	3
	Resources	RC-N03	Negative	3
10 - 16	**Design**	DN-N01	Negative	2
	Economic / Legal	EC-N01	Negative	2
	Environment	ET-N03	Negative	2
	Environment	ET-N04	Negative	2
	Environment	ET-N05	Negative	2
	Environment	ET-N06	Negative	2
	Weather / Climate	WR-N02	Negative	2

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Table 6 Degree of Centrality based on SLR (Author's own work)

Factor	Out-Degree	In-degree	Total Degree	Degree of Centrality
CE-P03	3	6	9	1
WR-P01	6		6	0.67
CE-P01	5	1	6	0.67
WR-N02	4	2	6	0.67
RC-N01	3	2	5	0.56
MT-P01	1	3	4	0.44
SG-P02	3		3	0.33
RC-N02	3		3	0.33
ET-N05	2	1	3	0.33
SL-P02	1	2	3	0.33
ET-N06	1	2	3	0.33
CE-P02	1	2	3	0.33
CE-P04	1	2	3	0.33
TY-P01		3	3	0.33
SY-P03		3	3	0.33
SG-N06		3	3	0.33
TY-P06		3	3	0.33
TY-P26	2		2	0.22
TY-P15	2		2	0.22
SY-P01	2		2	0.22
RC-P01	2		2	0.22
ET-P06	2		2	0.22
ET-N01	1	1	2	0.22
TY-P27		2	2	0.22
SL-P01		2	2	0.22
DN-N07		2	2	0.22
TY-P16	1		1	0.11
SY-P02	1		1	0.11
SG-N07	1		1	0.11
RC-P02	1		1	0.11
RC-N08	1		1	0.11
RC-N03	1		1	0.11
ET-P12	1		1	0.11

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Factor	Out-Degree	In-degree	Total Degree	Degree of Centrality
ET-P05	1		1	0.11
ET-P04	1		1	0.11
ET-P03	1		1	0.11
ET-P02	1		1	0.11
ET-N03	1		1	0.11
EC-P06	1		1	0.11
EC-P05	1		1	0.11
EC-N01	1		1	0.11
SG-N02		1	1	0.11
RC-N04		1	1	0.11
WR-N01		1	1	0.11
TY-P17		1	1	0.11
TY-P10		1	1	0.11
TY-P09		1	1	0.11
TY-P08		1	1	0.11
TY-P05		1	1	0.11
TY-P02		1	1	0.11
ET-P13		1	1	0.11
ET-P07		1	1	0.11
ET-P01		1	1	0.11
ET-N21		1	1	0.11
ET-N18		1	1	0.11
ET-N17		1	1	0.11
EC-P04		1	1	0.11
EC-P03		1	1	0.11
EC-P02		1	1	0.11
DN-N02		1	1	0.11

Table 7 Pairwise interrelations stated by Industry professionals(Author's own work)

Primary Factor	Polarity	Influenced Factor
DN-N02	Positive	MT-N06
EC-N05	Positive	RC-N02
EC-N06	Positive	DN-N02
ET-N29	Positive	DN-N02 and DN-N01
MT-N02	Positive	SG-N06
SG-N06	Positive	SL-N07, RC-N02, DN-N02, DN-N01, EC-N06 and EC-N05

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Primary Factor	Polarity	Influenced Factor
WR-N01	Positive	RC-N07 and RC-N02

Table 8 shows the degree of centrality for factors affecting DS based on Industry consultation. SG-N06 tops the list, followed by DN-N02, RC-N02, WR-N01, and EC-N06. Interestingly, the top 5 factors, CE-P03, WR-P01, CE-P01, WR-N02, and RC-N01, did not appear in the degree of centrality based on Industry consultation.

Table 8 Degree of centrality based on Industry consultation (Author's own work)

Factor	Out-Degree	In-degree	Total Degree	Degree of Centrality
SG-N06	6	1	7	1.00
DN-N02	1	3	4	0.57
RC-N02		3	3	0.43
WR-N01	2		2	0.29
EC-N06	1	1	2	0.29
EC-N05	1	1	2	0.29
ET-N29		2	2	0.29
DN-N01		2	2	0.29
RC-N07		1	1	0.14
MT-N06		1	1	0.14
SL-N07		1	1	0.14
MT-N02	1		1	0.14

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Annexure 1: Factors affecting Dynamic scheduling, code, polarity and author count (Author's own work).

S/N	Factors Category	Code	Factors Influencing Dynamic Scheduling	Effect on DS	Authors Count
1	Cultural	CE-P01	Cultural heritage management	Positive	1
2		CE-P02	Cultural identity and togetherness	Positive	1
3		CE-P03	Diverse cultural heritage	Positive	1
4		CE-P04	Place attachment	Positive	1
5	Design	DN-N01	complexity of construction site layouts	Negative	2
6		DN-N02	Incomplete drawings and specifications / incomplete project information	Negative	1
7		DN-N03	design parameters	Negative	1
8		DN-N04	canyon aspect ratio	Negative	1
9		DN-N05	window properties	Negative	1
10		DN-N06	albedo	Negative	1
11		DN-N07	Design error	Negative	1
12		DN-P01	Computational design	Positive	1
13		DN-P02	construction site layout design	Positive	1
14	Economic / Legal	EC-N01	increased transport costs	Negative	2
15		EC-N02	Shortage of construction materials in the market	Negative	1
16		EC-N03	Changes in government regulations/laws	Negative	1
17		EC-N04	Legal disputes between various parties	Negative	1
18		EC-N05	Delay in payment by the owner	Negative	1
19		EC-N06	lack of work permits	Negative	1
20		EC-N07	dynamic economic emission dispatch problems	Negative	1
21		EC-P01	Climate adaptation policy	Positive	1
22		EC-P02	Climate policy	Positive	1
23		EC-P03	Economic benefits	Positive	1
24		EC-P04	Economic diversification	Positive	1
25		EC-P05	National cultural heritage policy	Positive	1
26		EC-P06	construction cost	Positive	1
27		EC-P07	construction investment	Positive	1
28	Environment	ET-N01	Inaccessibility of site / Required accessible workspaces / Indoor space of building / limited site space / limited workspace	Negative	5
29		ET-N02	Effect of subsurface conditions (water table, hard rock) / Geotechnical data issues / natural geological conditions	Negative	3
30		ET-N03	Dynamic changes of the internal space of a building	Negative	2

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S/N	Factors Category	Code	Factors Influencing Dynamic Scheduling	Effect on DS	Authors Count
			in the operation and maintenance stage/changes in spatial state on construction sites		
31		ET-N04	temporary facilities allocation / inconvenient location of the storage area	Negative	2
32		ET-N05	topographic changes over time / Construction site steep slopes	Negative	2
33		ET-N06	Events issues / different dynamic disturbance events	Negative	2
34		ET-N07	Ambient conditions	Negative	1
35		ET-N08	Generation and allocation of workspaces	Negative	1
36		ET-N09	Keeping enough cool air in the plenums	Negative	1
37		ET-N10	Lack of explicit feedback of airflow and temperatures	Negative	1
38		ET-N11	Site congestions identification	Negative	1
39		ET-N12	Strict space pressure control	Negative	1
40		ET-N13	Traffic congestion	Negative	1
41		ET-N14	Unavailability of utilities at site (water, electricity)	Negative	1
42		ET-N15	Curse-of-dimensionality for large-scale instances	Negative	1
43		ET-N16	Detection of physical conflicts between the site workspaces	Negative	1
44		ET-N17	construction noise	Negative	1
45		ET-N18	limitation of autonomous excavators' movement in a construction site	Negative	1
46		ET-N19	uncontrolled environmental conditions	Negative	1
47		ET-N20	Disaster issues	Negative	1
48		ET-N21	Pandemic issues	Negative	1
49		ET-N22	Crowded environment	Negative	1
50		ET-N23	greenhouse gas (GHG) emissions	Negative	1
51		ET-N24	acidifying gas emissions	Negative	1
52		ET-N25	construction sector emissions	Negative	1
53		ET-N26	urbanisation rate	Negative	1
54		ET-N27	pollution load	Negative	1
55		ET-N28	land-use change	Negative	1
56		ET-N29	complex and changeable environment	Negative	1
57		ET-P01	Spatial development / Assembly workspace / Logistics workspace / Production workspace / Spatial information	Positive	5
58		ET-P02	Reduced air pollution	Positive	1
59		ET-P03	Reduced noise	Positive	1

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S/N	Factors Category	Code	Factors Influencing Dynamic Scheduling	Effect on DS	Authors Count
60		ET-P04	Reduced vibration	Positive	1
61		ET-P05	Ensure that the facilities do not overlap with one another or with the buildings	Positive	1
62		ET-P06	Environmental management	Positive	1
63		ET-P07	Reducing carbon footprint by retrofitting historic buildings	Positive	1
64		ET-P08	Reusing existing materials will help to achieve decarbonisation	Positive	1
65		ET-P09	Use of renewable energy	Positive	1
66		ET-P10	sustainable utilisation of urban underground space	Positive	1
67		ET-P11	topological structure	Positive	1
68		ET-P12	appropriate site locations	Positive	1
69		ET-P13	Relocation of a construction site	Positive	1
70	Management	MT-N01	Logistics system	Negative	1
71		MT-N02	Poor interactivity	Negative	1
72		MT-N03	Poor interoperability	Negative	1
73		MT-N04	Problems in shipment and site inventory	Negative	1
74		MT-N05	untimely and inaccurate transportation	Negative	1
75		MT-N06	uncompleted quality control	Negative	1
76		MT-P01	Construction site layout	Positive	1
77		MT-P02	ensemble construction methods	Positive	1
78		MT-P03	lean solutions	Positive	1
79		MT-P04	act fast on decision-making and collaborative working using available information and knowledge	Positive	1
80		MT-P05	Modular Construction	Positive	1
81	Planning / Scheduling	SG-N01	Detection of schedule conflict, which means the detection of a temporal overlap between tasks	Negative	1
82		SG-N02	stochastic activity durations	Negative	1
83		SG-N03	schedule changes of other related operations	Negative	1
84		SG-N04	uncertain time of land acquisition	Negative	1
85		SG-N05	Job Scheduling Problem	Negative	1
86		SG-N06	Poor planning	Negative	1
87		SG-N07	increase in non-productive time	Negative	1
88		SG-N08	resource-constrained project scheduling problem (RCPSP)	Negative	1
89		SG-P01	maximum slack priority rule (shortest latest start time)	Positive	1

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S/N	Factors Category	Code	Factors Influencing Dynamic Scheduling	Effect on DS	Authors Count
90		SG-P02	Applications of resource-constrained project scheduling	Positive	1
91		SG-P03	Hoisting facility layout planning	Positive	1
92		SG-P04	BIM-based construction schedules	Positive	1
93		SG-P05	baseline schedule	Positive	1
94		SG-P06	periodic progress data	Positive	1
95		SG-P07	top-down control methodology	Positive	1
96		SG-P08	risk analysis	Positive	1
97		SG-P09	project control	Positive	1
98		SG-P10	Top-down Control Strategy	Positive	1
99		SG-P11	Bottom-up Control Strategy	Positive	1
100		SG-P12	Crashing Corrective actions	Positive	1
101		SG-P13	Variability Corrective actions	Positive	1
102		SG-P14	Fast-tracking Corrective actions	Positive	1
103		SG-P15	Sensitive Activity selection	Positive	1
104		SG-P16	Critical Activity selection	Positive	1
105		SG-P17	Analytical Sensitivity	Positive	1
106		SG-P18	Simulation Sensitivity	Positive	1
107		SG-P19	Analysis Sensitivity	Positive	1
108		SG-P20	Threshold Methodology	Positive	1
109		SG-P21	Set Methodology	Positive	1
110		SG-P22	serial/parallel indicator Network Topology	Positive	1
111		SG-P23	spatial planning	Positive	1
112	Resources	RC-N01	Resource unavailability/resource constraints / unstable resource availability	Negative	7
113		RC-N02	Unavailability of materials/unavailability of prefabricated products / Material availability	Negative	2
114		RC-N03	Unavailability of equipment and tools / Equipment breakdown / Equipment shortage	Negative	3
115		RC-N04	time-varying resource demands	Negative	1
116		RC-N05	shortage of temporary structures	Negative	1
117		RC-N06	unskilled operators	Negative	1
118		RC-N07	Project productivity issue	Negative	1
119		RC-N08	inefficient use of resources	Negative	1
120		RC-N09	spatial variability of human activities	Negative	1
121		RC-N10	equipment assembly process	Negative	1

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S/N	Factors Category	Code	Factors Influencing Dynamic Scheduling	Effect on DS	Authors Count
122		RC-P01	efficient construction productivity	Positive	1
123		RC-P02	dynamic facilities allocation	Positive	1
124		RC-P03	cross-domain knowledge	Positive	1
125		RC-P04	dynamic distribution of labour resources	Positive	1
126	Safety	SY-N01	Accidents during construction	Negative	1
127		SY-N02	unidentified safety and hazard issues	Negative	1
128		SY-P01	construction safety	Positive	1
129		SY-P02	enhancing safety in the pre-construction phase	Positive	1
130		SY-P03	noise barriers	Positive	1
131	Social and Human	SL-N01	Deficiency for interior personnel to understand the indoor layout	Negative	1
132		SL-N02	Delay in giving instructions	Negative	1
133		SL-N03	Human factors	Negative	1
134		SL-N04	Inadequate experience of consultant	Negative	1
135		SL-N05	Poor communication of owner with contractor	Negative	1
136		SL-N06	Risk aversion in the delivery and operation of buildings	Negative	1
137		SL-N07	Slow decision-making by the owner	Negative	1
138		SL-N08	Stakeholder's loss aversion	Negative	1
139		SL-N09	Suspension of work by owner	Negative	1
140		SL-P01	Social benefits	Positive	1
141		SL-P02	Social cohesion and integrity	Positive	1
142		SL-P03	parallel rule collaboration (PRC)	Positive	1
143	Technology	TY-N01	incomplete BIM models	Negative	1
144		TY-P01	Building information modelling (BIM) / Building Information Modelling (BIM) 5D construction duration-cost optimisation model / BIM-based integrated scheduling methodology for building projects under resource constraints / BIM-based rule-checking systems / Linked-data and constraint-checking / Linked-data based constraint-checking architecture / Ontology for linked-data based dynamic constraint-checking	Positive	10
145		TY-P02	Modelling scheduling constraints using Shapes Constraint Language (SHACL) / Prototype web application / Processing web application / Storage / Data / Prototype evaluation / automatic progress tracking technology	Positive	7
146		TY-P03	optimisation of robot motion path planning / Multi-construction robots / Tracking tasks/robot kinematic	Positive	1

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S/N	Factors Category	Code	Factors Influencing Dynamic Scheduling	Effect on DS	Authors Count
			optimisation principle / mobile platform planning/path control strategy		
147		TY-P04	Dynamic scheduling coordination technology	Positive	1
148		TY-P05	Mobile robots	Positive	1
149		TY-P06	The multi-stage stochastic programming model for identifying the optimal supply chain configuration	Positive	1
150		TY-P07	Navigating spatial data dynamically	Positive	1
151		TY-P08	reinforcement learning model	Positive	1
152		TY-P09	earthwork allocation planning	Positive	1
153		TY-P10	ant colony optimisation	Positive	1
154		TY-P11	network's reliability	Positive	1
155		TY-P12	Dynamic programming algorithm	Positive	1
156		TY-P13	Genetic algorithm for assembly sequence planning in precast concrete buildings	Positive	1
157		TY-P14	dynamic planning model (DPM) using Digital Twin	Positive	1
158		TY-P15	optimisation of the task planning algorithm	Positive	1
159		TY-P16	dynamic planning optimisation model using a Genetic Algorithm	Positive	1
160		TY-P17	input-adaptive particle swarm optimisation (iRC-APSO) algorithm	Positive	1
161		TY-P18	heuristic algorithms	Positive	1
162		TY-P19	intelligent algorithms	Positive	1
163		TY-P20	graph-based model	Positive	1
164		TY-P21	Binary Pareto-Optimal Particle Swarm Optimisation (BP-PSO) algorithm	Positive	1
165		TY-P22	Holonic Management System (HMS)	Positive	1
166		TY-P23	Discrete event simulation	Positive	1
167		TY-P24	system dynamics	Positive	1
168		TY-P25	on-line planning	Positive	1
169		TY-P26	linked-data-based constraint-checking (LDCC) method	Positive	1
170		TY-P27	Geospatial information system (GIS)	Positive	1
171		TY-P28	Data mining (DM)	Positive	1
172		TY-P29	genetic algorithm (GA)	Positive	1
173		TY-P30	new intelligent environmental evaluation method to optimally and dynamically schedule the resource, production and inventory activities	Positive	1
174	Weather /	WR-N01	Adverse weather condition	Negative	5

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S/N	Factors Category	Code	Factors Influencing Dynamic Scheduling	Effect on DS	Authors Count
175	Climate	WR-N02	Climate change	Negative	2
176		WR-P01	Climate change mitigation and adaptation	Positive	1

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Annexure 2: Table 5 SLR Pairwise Interrelationship Summary (Author's own work)

PF	P, IFN 1, AN	P, IFN 2, AN	P, IFN 3, AN	P, IFN 4, AN	P, IFN 5, AN	P, IFN 6, AN
CE-P03	+, CE-P02, 11	+, CE-P04, 11	+, ET-P06, 11	+, SL-P02,11	+, WR-N02,11	+, WR-P01, 11
TY-P01	+, ET-N03, 25	+, TY-P07, 34	+, TY-P26, 16			
MT-P01	+, ET-P06, 24	+, RC-P01, 24	+, SY-P01, 24			
SY-P03	+, EC-P06, 24	+, RC-P01, 24	+, SY-P01, 24			
SG-N06	+,EC-N01, 20	+, SG-N07, 20	+, RC-N08, 20			
TY-P06	+, ET-P02, 12	+, ET-P03, 12	+, ET-P04, 12			
CE-P02	+, CE-P01, 11	+, WR-P01, 11				
CE-P04	+, CE-P01, 11	+, WR-P01, 11				
SL-P01	+, CE-P01, 11	+, WR-P01, 11				
SL-P02	+, CE-P01, 11	+, WR-P01, 11				
TY-P27	+, ET-P05, 34	+, TY-P07, 34				
DN-N07	+,RC-N01, 32	+, RC-N02, 32				
ET-N06	+,RC-N01, 32	+, RC-N02, 32				
RC-N01	-, SG-P02, 10	+, RC-N02, 32				
WR-02	+, CE-P01, 11	+,CE-P03, 11				
CE-P01	+,WR-P01, 11					
DN-N02	+, RC-P02, 3					
EC-P02	+, CE-P03, 11					
EC-P03	+, EC-P05,11					
EC-P04	+,WR-N02,11					
ET-N01	-, TY-P16, 5					
ET-N05	-, TY-P15, 14					
ET-N17	-, MT-P01, 24					
ET-N18	-, TY-P15, 14					
ET-N21	+, ET-N06,32					
ET-P01	+,WR-N02,11					
ET-P07	+,WR-N02,11					
ET-P13	+, ET-P12, 20					
SG-N02	-, SG-P02, 10					
RC-N04	-, SG-P02, 10					
TY-P02	+, TY-P26, 16					
TY-P05	+, ET-N01, 28					
TY-P08	+, ET-N05, 35					

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PF	P, IFN 1, AN	P, IFN 2, AN	P, IFN 3, AN	P, IFN 4, AN	P, IFN 5, AN	P, IFN 6, AN
TY-P09	+, ET-N05, 35					
TY-P10	+, SY-P02, 24					
TY-P17	-, RC-N01, 30					
WRN01	+,RC-N03, 32					

Note: PF = Primary Factor, P = Polarity, + = Positive, - = Negative, IFN = Influenced Factor Number, AN = Author Number stated in anexure 3.

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Annexure 3: Author factor matrix (Author's own work).

| | | CULTURE | | | | DESIGN | | | | | | | | | | ECONOMIC / LEGAL | | | | | | | | | |