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MODELLING DESIGN STAGE RISKS IN MODULAR INTEGRATED CONSTRUCTION PROJECTS IN SRI LANKA

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ABSTRACT

Modular integrated Construction (MiC) as a promising construction method has instigated significant advancements in the construction industry, especially in developed countries. However, the MiC has been becoming popular in developing countries such as Sri Lanka given its potential to improve construction efficiency, reduce cost and waste, and enhance quality. The design stage is considered critical in MiC since design errors can propagate to manufacturing and assembly issues and entire project failure. Further, as the Sri Lankan construction industry is in the preliminary stages of MiC implementation, the most risk-exposing stage is the design stage. Therefore, it is essential to explore the design stage risks (DSRs) affecting MiC in Sri Lanka to enable timely decision-making to withstand the potential risks in its implementation. Under these circumstances, this study proposed and developed a Social Network Analysis (SNA) model to identify the most critical DSRs and their co-relational impacts by probing and assessing the data collected through an industry expert survey. The findings revealed that the inaccuracy of design information, inadequate planning for design and unclear design specifications are the most critical DSRs in MiC initiation in Sri Lanka among the identified 14 total risks. Further, three significant risk categories were determined, and the co-relational impact of each risk was assessed as depicted in the SNA model. Moreover, the study findings would motivate industry professionals to appreciate and address the critical DSRs in the context of the three respective categories and thereby develop adequate measures to successfully withstand them to boost industrial performance.

Keywords: *Construction Industry; Design-Stage Risks (DSRs); Modular Integrated Construction (MiC); Social Network Analysis (SNA); Sri Lanka.*

1. INTRODUCTION

Modular integrated construction (MiC) is a distinctive offsite construction method that enables hitherto unattained innovations in highly efficient, safe, speedy, optimised, clean and advanced construction methods with reduced environmental impact in the construction industry (Chourasia et al., 2023; Ekanayake et al., 2021). Given these merits, MiC is widely applied in countries with advanced construction developments such as the

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United Kingdom, United States of America, Singapore, Hong Kong, Japan, Germany and China. Sri Lanka, which is a developing economy, is in its infancy stage of modular construction due to the shortages of expertise and experience, high initial cost, and lack of technological support (Sandamini & Waidyasekara, 2022). However, successful implementation of MiC in the construction industry would facilitate an optimal solution for the prevailing economic crisis in Sri Lanka by addressing the issues of resource scarcity, higher prices of construction materials and labour, and higher demand for lands in capital cities while facilitating many construction employment opportunities (Sandamini & Waidyasekara, 2022). That may be the reason why the leading construction companies in Sri Lanka have now started planning and initiating MiC projects.

MiC process involves designing and manufacturing the prefabricated modules in a controlled factory environment, transporting them to the site, and assembling or installation of the modules on-site (Subramanya et al., 2020). Compared to the initial generations of prefabrication, 3-dimensional volumetric units are manufactured and installed in the modular construction process and thus the entire supply chain process (manufacturing, logistics and assembly) has become much more challenging and riskier. If these challenges or so-called risks are not managed effectively and efficiently, from the beginning, i.e., the designing stage, the associated benefits realised from adopting MiC will undoubtedly wither away (Ekanayake et al., 2021). Hence, effective risk management in MiC projects is essential for successful project delivery and should begin with the identification of critical risks in MiC projects.

As the Sri Lankan construction industry is in the preliminary stages of MiC implementation, the most risk-exposing stage is the design stage. Therefore, it is vital to pay specific attention to ‘design risk management’ instead of following a holistic risk management strategy. Further, the design risks; known as ‘wicked problems’ are complex in nature, ill-defined most of the time and difficult to detect and address (Wuni et al., 2023; Buchanan, 1992). Besides, wicked problems need urgent attention in implementing MiC projects, especially in Sri Lanka as the industry is attempting to initiate the projects in the near future. Apart from the study of Wuni et al. (2023) (which attempted to identify design risk factors in MiC generally), there is no known study that attempted to explore the critical Design Stage Risks (DSRs) and their co-relational impacts in MiC in Sri Lankan context.

Given the abovementioned industry imperatives and the lack of theoretical underpinnings to explore MiC DSRs, this study was inspired and motivated to investigate and model the most critical DSRs and their co-relational impact on MiC implementation in the Sri Lankan construction industry from the viewpoint of academic and industry experts and the practitioners in Sri Lanka. By focusing on the critical DSRs identified in this study, it is expected that the MiC industry professionals will be far better informed on the appropriate DSR mitigation methods to boost industrial performance. The forthcoming sections of this paper present the research background, methods used, results and consequential discussions, practical research implications, and conclusions, including research limitations and suggested ways forward.

2. REVIEW OF DESIGN STAGE RISKS IN MIC

The history of modular construction could be found back in 1855 and MiC was used as a solution for heightened housing demand due to the rapid immigration in California

(Thurston Group, 2018). Since then, MiC has been developed up to the recent innovation of assembling prefinished volumetric flats/building units. These volumetric units can be either 'permanent modular' or 'relocatable modular'. Relocatable modules can be hired or bought directly from the suppliers or leased for a short period and used for temporary purposes such as construction site offices, temporary communication rooms and temporary classrooms. The use of permanent modules is visible in long-lasting structures such as housing apartments, schools, high-rise buildings, and hotel constructions (Dharmendra & Thusyanth, 2021). Anyhow, the construction process of MiC comprises four main stages: design and planning, manufacturing of modular units/off-site assembly, transportation/logistics and on-site assembly of modular units (Sutrisna & Goulding, 2019). When it comes to the design stage, the total cost implication is lesser compared to the other three stages, but this stage is considered to be the most critical phase in MiC projects given its massive implication towards downstream supply chain processes (Andi & Minato, 2003). Further, the design stage of MiC is complex, and the design team faces significant challenges in line with design errors that contribute to aggravated manufacturing and assembly issues (Gao et al., 2019; Wuni et al., 2023). For instance, in MiC, unless a reasonable tolerance is provided, if a unit is designed and cast with even a 1 mm error, it becomes vulnerable to on-site assembly problems that cause considerable cost and time overrun (Ekanayake et al., 2021). Accordingly, design variations/changes are quite expensive and difficult to initiate after the design freeze and manufacturing of volumetric modular units. Besides, implementing the timely design freeze is essential in MiC to meet tighter manufacturing and assembly schedules to realise the allied time and cost savings in MiC (Wuni et al., 2023). However, managing the risks and complexities associated with the design stage of MiC is quite challenging and needs the special attention of the design team. In this regard, Wuni et al. (2023) attempted to identify the DSRs in the MiC implementation process. However, the study was not specific to the Sri Lankan context and generic risk constraints were discussed in the published papers. Therefore, after conducting a comprehensive literature search together with a desk study, the authors identified 14 DSRs (as shown in Table 1 with apposite references) as appropriate to the Sri Lankan construction industry where the MiC is at its primary stages of implementation.

Table 1: Design risk factors with references

Code	Risk Factor	References
DRF 1	Complicated supply chain links in MiC	[1]; [4]; [11]
DRF 2	Overestimation of design loads and materials	[2]; [4]; [8]
DRF 3	Inappropriate designing	[4]
DRF 4	Insufficient or lack of codes and standards	[4]; [5]
DRF 5	Poor response to the design changes	[2]; [4]; [11]; [12]; [13]
DRF 6	Inefficiency in design approval	[1]; [4]; [10]
DRF 7	Inadequate planning for design	[4]; [6]
DRF 8	Inaccuracy of design information	[4]; [7]; [15]; [16]
DRF 9	Incomplete design drawings	[1]; [4]; [8]
DRF 10	Frequent design changes in project scope	[1]; [9]
DRF 11	The design information gap between the designer and fabricator	[1]; [4]
DRF 12	Information gaps and leaks in the supply chain	[1]

Code	Risk Factor	References
DRF 13	Unclear design specifications	[2]; [3]; [14]
DRF 14	Late involvement of suppliers, fabricators, and contractors	[1]; [4]; [6]

Sources: [1] Li et al. (2016); [2] Lee and Kim (2017); [3] Rahman (2014); [4] Wuni et al. (2023); [5] Luo et al. (2015); [6] Nibbelink et al. (2017); [7] Sutrisna and Goulding (2019); [8] Mojtahedi et al. (2010); [9] Taylan et al. (2014); [10] Hossen et al. (2015); [11] Pervez et al. (2022); [12] Kamali et al. (2017); [13] Pan et al. (2007); [14] Gan et al. (2018); [15] Li et al. (2013); [16] Wu et al. (2018)

All these identified DSRs are threefold based on the root cause of each risk factor. The first category [DGRP1] includes the risks originating from information availability and human (design team) errors. Overestimation of design loads and materials (Lee & Kim, 2017), inappropriate designing (Wuni et al., 2023), incomplete design drawings (Li et al., 2016) and unclear design specifications (Lee & Kim., 2017) results in design failure that can be aggravated throughout the entire construction process if unattended. Inadequate planning for design (Sutrisna & Goulding, 2019) would be a serious cause of all these design team errors and data unavailability and hence, needs significant attention from the beginning.

The second category of DSRs [DGRP2] emerged from statutory and planning bodies that are responsible for MiC project implementation. The inefficiency of design approvals (Li et al., 2016) from municipal and respective city councils creates delays and causes significant impacts towards project delivery. Also, the lack of codes and standards to maintain the design quality is another challenging consideration as it generates serious negative impacts on the quality of the final product and the satisfaction of the clients.

Considering the third category of supply chain-related DSRs [DGRP3], information gaps and leaks in MiC supply chains result in serious design errors (Nibbelink et al., 2017). This is why contractors pay for additional quality inspectors assigned to oversee the component design and manufacturing at factories to avoid information gaps and design errors (Ekanayake et al., 2021). Further, it helps to eradicate the design information gap between the designer and fabricator. In addition, the contractors who use their own manufacturing plants can control their design quality better through BIM which enables a collaborative communication platform and a smooth flow of information (Ekanayake et al., 2021). Having such a collaborative communication platform would be further beneficial to enable timely decision-making as the late involvement of suppliers, fabricators, and contractors also generates a greater risk of inaccurate and late design (Nibbelink et al., 2017). Frequent design changes (Li et al., 2016) and poor responses to design changes (Lee & Kim, 2017) are two other DSRs that result in extended design completion time. Although there can be several reasons behind the late design changes, the major cause would be the information gap and the late involvement of supply chain members in design freezing and decision-making. Moreover, the complicated supply chains in MiC projects considerably affect the upstream and downstream supply chain links and make the construction process riskier (Li et al., 2016).

Although these DSRs greatly affect the overall performance of the MiC projects even in Sri Lanka, the criticality of each risk factor and their co-relational impacts have not been investigated in previous research and attempts were not focused on developing strategies to better manage them. Given the existing gap in research and the importance of proper implementation of MiC in the Sri Lankan construction industry, this study aimed to identify and model the critical DSRs and their co-relational impacts by employing an empirical research approach explicated in detail in the following section.

3. RESEARCH METHODS

A deductive quantitative research approach was mainly adopted in this study based on the positivist research philosophy as the study aimed at investigating the criticality of DSRs in MiC implementation and their co-relational impacts. Figure 1 depicts the research methods, their flow, and interactions in this study.

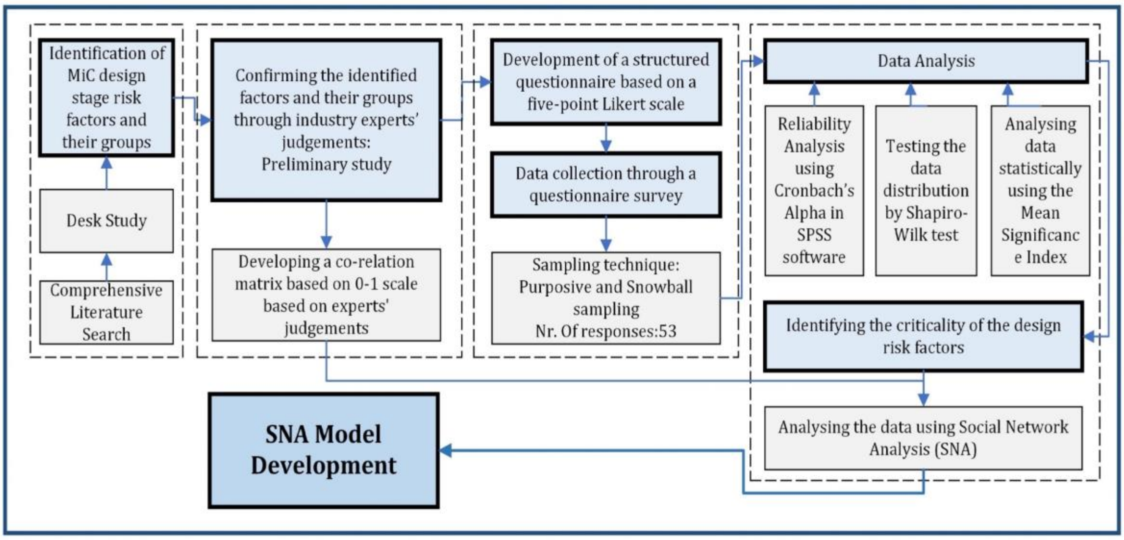

Figure 1: Research data collection, analysis and flow of this study

Accordingly, a set of 14 design stage MiC risks were first determined from a broad literature search followed by a desk study as explicated above. Then, a pilot study was conducted with a group of seven industry experts who are currently involved in modular construction projects in Sri Lanka to test the significance, applicability, and comprehensiveness of the identified DSRs in order to proceed with the main data collection through a questionnaire survey. These industry experts were from designing, engineering, architectural and quantity surveying (helps to determine economical risks in design) backgrounds and possess vast relevant knowledge and industry experience in the Sri Lankan construction industry. Further to the preliminary testing of the risk factors, the industry experts were asked to confirm the grouping of the factors and to identify each factor's significance within the respective groups and their overall significance on a 0-1 scale. The collected data was used to identify and model the degree of co-relationships of each factor towards its own group and other factor groups.

After agreeing upon the identified 14 DSRs and groupings, a structured questionnaire was designed by including the DSRs. A five-point Likert scale (5 - highest criticality, 4 - moderate criticality, 3 - slight criticality, 2 - least criticality and 1 - not at all) was used in the questionnaire to rank the risk factors based on their level of criticality in the design stage of MiC projects. A questionnaire survey was then conducted to collect the relevant data for analysis in this study. The time horizon used was cross-sectional and a purposive sampling approach was employed to arrive at the selection of suitable respondents for data collection (Ekanayake et al., 2021). In selecting the respondents, it was considered that the respondents should have adequate knowledge, industry experience or research experience and/or be involved in MiC planning or implementation. Following the purposive expert sampling, the snowball sampling technique was then used to expand the respondent 'catchment area' for this study. The questionnaire was sent to the selected professionals in the construction industry in Sri Lanka through personalised emails. A total of 53 (over 137) complete responses (with a 38.6% response rate) were received. Although the samples size was slightly small, it was considered adequate because (a) the lower number of professionals full fill the used respondents' selection criteria in Sri Lanka; (b) the number of responses exceeds the minimum requirement of the central limit theorem for valid statistical analysis (Ott & Longnecker, 2016); and (c) the responses were adequate to derive meaningful conclusions as appropriate to this study.

The data collected from the questionnaire survey was first tested for reliability and validity using Cronbach's Alpha in SPSS software (Brown, 2002) and for the data distribution type using the Shapiro-Wilk test (Razali & Wah, 2011). After that, the subsequent statistical analysis was conducted using the Mean Significance Index to identify the criticality of the DSRs (Ott & Longnecker, 2016; Wuni et al., 2023). Then, the data received from the pilot study were analysed using Social Network Analysis (SNA) to determine and model the degree of co-relational impact among the risk factors and their respective risk categories because SNA is established as an effective method to explore the influence of risk factors in construction supply chains (Gong et al., 2019) and it facilitates effective decisional and interactional analysis with a limited sample size (Tichy et al., 1979).

4. RESULTS AND DISCUSSION

4.1 PRE-TEST ANALYSIS

The result of Cronbach's Alpha Test was 0.703 and indicated that the selected MiC DSRs are internally reliable and consistent (Brown, 2002). Also, the results of the Shapiro-Wilk test indicated that the data in this study are nonnormally distributed as the test value was lesser than the stipulated p-value, at a standard significance level of 0.05 (Razali & Wah, 2011). Therefore, the study then proceeded with the statistical analysis.

4.2 SURVEY RESULTS

Accordingly, primary statistical techniques of the Mean Significance Index and the Weight Index (respectively presented in Equation 1 & Equation 2) were used to determine the most critical MiC DSRs in the Sri Lankan construction industry.

$$\mu_i = \frac{(E \times F)}{N} \qquad (Eq...1)$$

$$W_i = \frac{\mu_i}{\sum_{i=1}^{n} \mu_i} \qquad (Eq...2)$$

Where:

E = the number of point scale (1 - 5) for the Design Risk Factor (DRF),
F = the scores assigned to a DRF by the experts ranging from 1 to 5,
N = the total number of responses obtained by a DRF,
Wi = the weight of a DRF,
Σμi = the summation of the mean significance indices of all DRFs for MiC projects in Sri Lanka

Table 2 presents the results generated from this primary statistical analysis including the ranking of the DSRs based on their criticality.

Table 2: Table of descriptive statistics of the identified DSRs

Risk Factor	**Risk Category**	**Standard Deviation**	**Mean**	**Weight**	**Rank**	**Score % for SNA**	**Co-relation matrix**		
							DG RP1	**DG RP2**	**DG RP3**
DRF2	Category 1 [DGRP1]	0.98	3.92	0.07	8	7.04	1.00	0.00	0.00
DRF3		0.97	3.91	0.07	9	7.02	1.00	0.00	0.50
DRF7		0.82	4.28	0.08	2	7.68	1.00	0.30	0.30
DRF8		0.84	4.40	0.08	1	7.90	1.00	0.20	0.20
DRF9		0.70	4.08	0.07	5	7.32	1.00	0.20	0.20
DRF13		0.71	4.19	0.08	3	7.52	1.00	0.00	0.00
DRF4	Category 2 [DGRP2]	0.86	3.85	0.07	10	6.91	0.40	1.00	0.00
DRF6		0.84	3.79	0.07	12	6.80	0.50	1.00	0.50
DRF1	Category 3 [DGRP3]	0.82	4.09	0.07	4	7.34	0.00	0.00	1.00
DRF5		0.84	4.06	0.07	6	7.29	0.00	0.50	1.00
DRF10		0.81	3.96	0.07	7	7.11	0.65	0.15	1.00
DRF11		0.89	3.83	0.07	11	6.88	0.00	0.00	1.00
DRF12		0.84	3.57	0.06	14	6.41	0.00	0.00	1.00
DRF14		0.82	3.77	0.07	13	6.77	0.00	0.00	1.00

4.3 SNA MODELLING

After the primary statistical analysis, the data collected through the industry experts survey were incorporated to develop a social network analysis model as illustrated above in the research methods section. The score values and matrix values used to develop the model are shown in Table 2. As identified in the pilot study, each factor's significance within the respective groups and their overall significance on a 0-1 scale was used to create the SNA matrix. The appropriate percentage values shown in Table 2 are the total scores received for each DRF over the summation of scores received for all the DRF groups. All those values were imported into the Netminer 4 software, and a two-mode network analysis was conducted to derive the results depicted in Figure 2. The node shapes on the SNA model denote the types of DSRs (circles) and their categories (squares), respectively, whereas the arrow (link) thickness reflects the degree of influence between the nodes. In this context, this study adopted SNA to determine and model the co-relationships between DSRs and their own risk categories.

The node size reflects the level of criticality of each design risk factor. Further, 'degree' as one of the key measures in SNA was used to explain the results. By examining the immediate characteristics of node connections, this metric identifies the extent of connections to other actors within the network (Tichy et al. 1979). Hence, the measure of 'degree' enabled identifying the most critical DSRs, considering the highest degree values they received.

4.4 DISCUSSION OF THE RESULTS

As presented in Table 2, the questionnaire respondents have ranked all the risk factors as significant and more or less critical given their Mean Significance Index exceeds 3.5. The most critical DSRs are the inaccuracy of design information, inadequate planning for design and unclear design specifications. All these critical risks belonged to Category 1 and originated from the unavailability of information and human (design team) errors. As the MiC is in its preliminary stage of implementation in Sri Lanka (Sandamini & Waidayasekara, 2022), the lack of hands-on experience would be the cause behind these human and information-based risk factors. However, these risk factors could be properly managed by paying due care and attention (Luo et al., 2015). Also, the lessons learnt from other jurisdiction-based industry advancements would be greatly helpful in this respect. Besides, the results are in line with the study conducted by Wuni et al. (2023) as the most critical risk factor in general MiC implementation is the unsuitability of the design. Therefore, it is visible that even developed industries still struggle with design management in MiC.

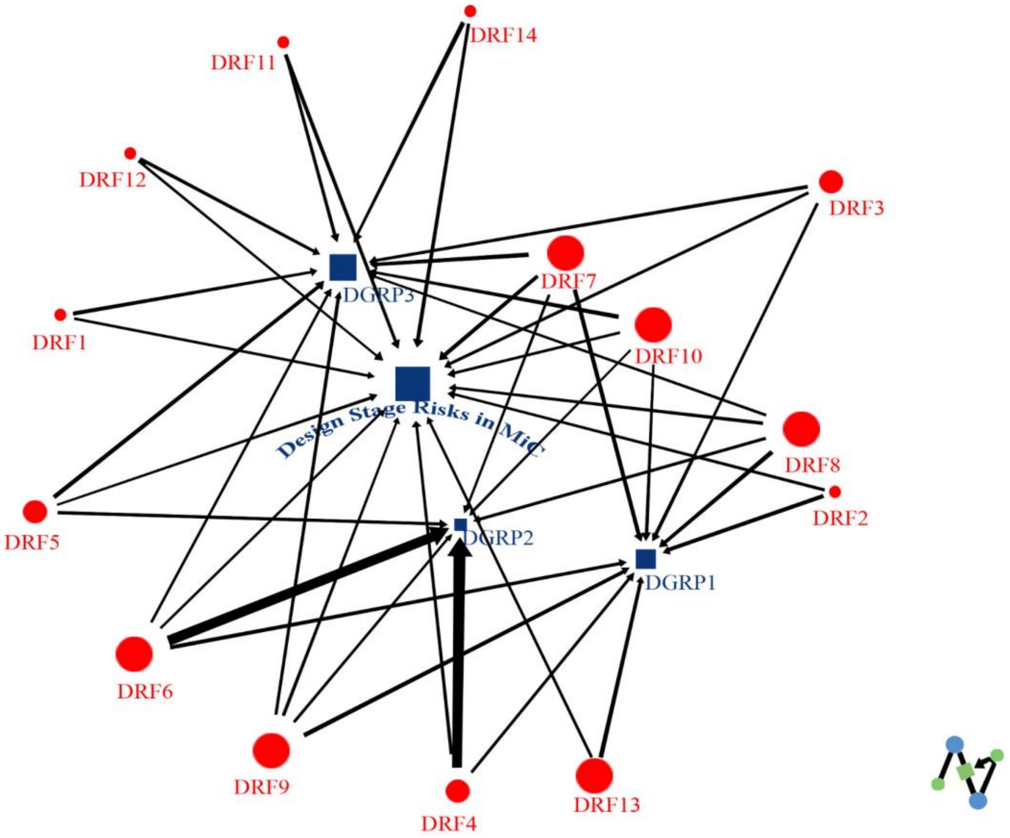

Figure 2: SNA Model for DSRs in MiC

‘Complicated supply chain links in MiC’ is ranked as the fourth critical risk factor. The pre-fabricators, architectural designers, structural engineers and contractors (both upstream and downstream supply chain links) should work together from the beginning of the design stage to avoid fabricating and assembly issues due to the design complexity of MiC projects. However, as observed in Wuni et al. (2023), project complexity is ranked as the 9th critical risk factor in global MiC implementation. The reason behind this difference can be due to the lack of technology and the shortage of expertise in MiC within the Sri Lankan construction industry when compared to other developed industries in the UK, USA, Hong Kong, Japan, and Australia. Therefore, the design complexity and inaccuracies would be quite significant and expected more in Sri Lanka compared to the industries with advanced technology and expertise.

Improved anticipation, collaboration and visibility would be effective in mitigating the DSRs due to supply chain complexities in MiC (Ekanayake et al., 2021). For instance, as practised in developed countries, assigning quality checkers (representing the contractor) to oversee the modular component design and manufacturing is vital to avoid design information issues and design errors while eradicating subsequent tolerance issues in assembly. BIM-integrated project management tools and collaborative communication platforms can help to trigger early warning signals before any disruptions (Luo et al., 2015) and facilitate early design risk mitigation and management. As model simulations are also possible with the techniques, all the models could be pre-tested to detect and manage design errors at the first instance.

The 10th-ranked DSR of this study is the lack of codes and standards for MiC implementation. Currently, in Sri Lanka, BS Codes and EU codes are used for the design purposes of modular projects because the industry is initiating small-scale projects. Therefore, still, standardisation has not become a substantial issue for MiC delivery in Sri Lanka compared to the other DSRs. However, the lack of bespoke MiC codes has been detected as one of the topmost critical DSRs in an international survey conducted by Wuni et al. (2023). As described by Nibbelink et al. (2017), the output will be greatly defective when the accuracy of the input data is poor, especially in the MiC since the early design freeze is essential for the successful delivery of the projects. Therefore, standardisation and receiving technical guidance would play key roles in this respect and gathering industry knowledge and technology would be necessitated.

Data reported in Table 2 are confirmed to a higher extent by results achieved through the SNA model. Referring to Figure 2 released by the model, the DGRP3 category shows a higher level of direct correlational impact with different DSRs (unless DRF2, 4 and 13) in comparison to the other two categories, the same outcome is reported in Table 2 in the correlation matrix section. It is emphasising the importance of establishing efficient information workflow between different stakeholders involved in MiC from the early stages of design to avoid clashes and mistakes. Risks originating from human errors (DGRP1) demonstrated direct relation to 9 different DRFs while the level of effectiveness of each DRF in this category is almost the same (semi-similar arrow line thickness). Totally eight Risk Factors are connected directly to the DGRP2, while among them two DRF4 and DRF6 illustrated a very high level of effectiveness that both related to the lack of adequate standards and procedures defined by the government for MiC in the industry during the design stage. Based on the SNA model, every DRF suggested in this research at least has linked with two DGRP categories, while the majority of them demonstrated a connection with all DGRP groups.

The DRF6, 7, 8, 9,10 and 13 are reported with the highest level of criticality in accordance with the size of the node demonstrated in Figure 2. This agrees with values reported in Table 2 which measured the Inaccuracy of design information, Inadequate planning for the design, Incomplete design drawings, Frequent design changes in project scope and Unclear design specifications as main risk factors with a high level of effectiveness in the design stage in MiC projects. Apparently, improving mentioned factors can assist to enhance the efficiency of the design in MiC.

4.5 RESEARCH IMPLICATIONS

This research contributes to the MiC knowledge domain by first identifying the critical DSRs (within three different risk categories) affecting the MiC projects' success. And then, the study reveals the co-relational impacts of each critical risk towards the different risk categories and their overall impact towards the MiC design process. More significantly, this is the first known attempt to model DSRs in MiC implementation through the SNA approach. Besides, the model facilitates industry practitioners in Sri Lanka to determine the critical DSRs in MiC and their relational impacts while enabling them to make well-informed timely decision making to overcome these risks successfully. As the Sri Lankan construction industry is currently seeking avenues to enhance its overall performance due to the prevailing economic crisis, effective risk management is essential and inevitable to realise the expected benefits of MiC. Other developing countries will also be benefited from these research outcomes by enhancing their own practices to determine and withstand design stage risks by following the suggested research approach. Therefore, it should be noted that the novel research method employed, and the principal research outputs from this study significantly contribute to both construction research and industry development.

5. CONCLUSIONS, LIMITATIONS AND WAY FORWARD

This study revealed the critical DSRs and their co-relational impacts on MiC implementation in the Sri Lankan construction industry through an expert survey and Social Network Analysis approach. Three critical risk groups were identified based on the root cause of each risk factor including the risks originating from information unavailability and human (design team) errors, statutory and planning bodies, and supply chain-related complexities. Further, the inaccuracy of design information, inadequate planning for design and unclear design specifications were identified as the most critical DRFs among the identified 14 DSRs through the primary statistical analysis of data. Finally, an SNA model was developed by considering the criticality of the DSRs and their co-relational impacts. The developed model represents both theoretical and practical underpinnings of the DSRs' influence on MiC implementation. Hence, industry practitioners would benefit from having prior knowledge of these DSRs and their levels of criticality as well as their co-relational impacts, enabling them to prioritise addressing them, targeting successful MiC project implementation in Sri Lanka as the industry is at its primary stages of MiC initiation.

More significantly, the study unveiled that SNA is an effective method to analyse and model DSRs in construction projects by being the first known study that analyses the co-relational impacts of DSRs in MiC projects using SNA. As a way forward, the model can be further improved by reflecting 'centrality' values and more inputs from the industry to withstand these risks. Further, subsequent studies may increase the response rate for enhanced generalisation of the results. Moreover, the model could be tested through different case studies and proceed with the verification of the findings. Since these risks and their levels of criticalities are jurisdiction-specific, the developed model can be extended as appropriate to other country contexts and generalised for different industrial contexts. In addition, it is worth noting that there could be other potential risk factors that are unavoidably missed in the model development which may potentially lead to unobserved heterogeneity and biases of the estimates in the developed model. However, this novel modelling approach facilitates useful implications for construction research, and practice in the Sri Lankan construction industry given that it is high time to rethink effective measures to enhance the construction industry's performance while boosting the whole economy.

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