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LEAN ICEBERG MODEL FOR POST DISASTER RECONSTRUCTION PROJECTS

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ABSTRACT

Post Disaster Reconstruction (PDR) projects are currently facing many issues. The highly demanding construction process of PDR projects that involves a number of different and well-coordinated courses of action can be simplified through integrating lean construction. Hence, Lean Iceberg Model (LIM) implementation for PDR projects will eventually minimise the issues in PDR projects. However, there is lack of research on implementation of lean construction to PDR projects. Therefore, this study aims to develop a framework to minimise PDR issues through LIM. This research adopted interpretivism stance and uses the qualitative survey strategy. Semi-structured interviews were conducted with ten experts, selected based on purposive sampling. The code-based content analysis was used to data analysis, which was supported by NVivo12. The findings of the study revealed that lack of quality, lack of budget and delays as the main issues in PDR projects. The essential part, therefore, was to identify invisible elements which were most of the times neglected rather than the visible elements of LIM. Finally, a framework was developed by systematically mapping the identified PDR issues for both visible and invisible elements of the LIM. In addition, the "LIM for PDR" mobile application has been developed as part of the framework which deals with educating and guiding users on a successful implementation of lean in a PDR project through LIM. The results of this research contribute to overcome the PDR issues which can be derived from the LIM. Hence, industry practitioners can use the outcomes to successfully implement lean in PDR projects.

Keywords: *Lean Construction; Lean Iceberg Model; Post Disaster Reconstruction; Sri Lanka.*

1. INTRODUCTION

The world is increasingly vulnerable by the influences of disasters, which are followed by a susceptible combination of both climatic and non-climatic associated risks (Wamsler and Johannssen, 2019). During 2001-2015, 341 climate-related disasters have been recorded worldwide, which is a 50% increment comparing to the previous 15 years. Ahmad and Ma (2019) stated that, during 1994 to 2013, floods alone have accounted for 43% of global natural disasters, causing 2.5 billion people affected at a 160,000-death toll and economic losses amounted to US $ 115 billion. Furthermore, Ahmad and Ma (2019) stated that 95% of people affected by foods each year in Asia and Africa, accounted for 73% of total direct economic losses. In Sri Lanka, the total number of people affected by

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floods, landslides, strong winds, fires, and lightning in 2017 was approximately 946,176, while the number of partially damaged and destroyed houses have increased significantly compared to 2016 (Disaster Management Center, 2017). Therefore, Ismail, et al. (2014) stated that, PDR projects are complex and highly demanding process that involves a number of different and well-coordinated courses of action. In addition, PDR Projects encountered difficulties in provisioning, scheduled transportation, aviation clearances, custom clearances, and delivery of materials to target communities without any delay while ensuring the expected quality, allocated budget limit and timely completion of the projects (Enshassi, et al., 2019; Matsumaru, et al., 2012; Barakat, 2003). Therefore, it is vital that these complex activities are well planned, subject to thorough consultation with process improvement methodologies (Ismail, et al., 2014).

Lean construction is well acknowledged in the construction industry for achieving value of the project through proper planning and continuous improvement (Tezel, Koskela and Aziz, 2018). Therefore, implementation of lean construction will improve the value of PDR project. Hines (2008) developed the "Lean iceberg model (LIM)" to provide an accurate definition by grouping technology, tools, techniques, process management, strategy, alignment, leadership, behaviour, and engagement into five organizational components in terms of cultural and technical elements for successful lean implementation. Many researchers in United Kingdom (Tezel, et al., 2018), Sweden (Eriksson, 2010), Malaysia (Marhani, et al., 2013), Sri Lanka (Hettiaarachchige, et al., 2022: Ranadewa, et al., 2021) and Turkey (Polat and Ballard, 2004) had successfully applied the lean construction in projects and achieved the benefits. However, there is a lack of research in incorporating lean to PDR projects. Therefore, the aim of this study is to develop a framework to minimise the issues in PDR projects through LIM. This paper begins with a review on issues in PDR projects and the significance of lean construction for PDR projects. The next section discusses the methodology used in this study. The findings of the research are presented by mapping the suitable elements of LIM to the issues of PDR projects. Finally, a framework for LIM along with the mobile application is presented in this paper.

2. LITERATURE REVIEW

2.1 ISSUES IN POST DISASTER RECONSTRUCTION PROJECTS

PDR projects are known to be dynamic, complex, and chaotic in nature, which in turn represents many failures as they are different from traditional construction. Hidayat and Egbu (2010) mentioned that management of the construction procedure of PDR is similar to traditional construction, only with more emphasis on inadequate resource, quality, and coordination. Some of the issues are controllable although some of the issues are uncontrollable. Following Table 1 presents the most common issues identified with regard to PDR projects.

Table 1: Issues in post disaster reconstruction projects

PDR Issue	References
1. Budget	[2] [3] [4] [5] [8] [10] [11]
2. Policies	[3] [4] [10] [13]
3. Limited Time	[5 [6] [7] [8] [13] [16] [18]

PDR Issue	References
4. Lack of Resources	[1] [2] [4] [8] [11] [13] [18]
5. Political Pressure	[2] [3] [4] [8] [13] [15]
6. Procuring Resources	[3] [4] [8]
7. Community Participation	[8] [10] [13] [15]
8. Communication and Coordination	[1] [2] [10] [15] [20]
9. Inappropriate Assessment	[6] [13] [19]
10. Unproductive Design	[6] [14] [19]
11. Government Support	[10] [13] [15]
12. Transportation	[9] [14]
13. Social Pressure	[7] [8] [13] [15]
14. Poor Quality	[2] [5] [8] [11]
15. Delays	[3] [4] [5] [7] [8] [10] [16] [17]

1.Chang, et al. (2011), 2. Hidayat and Egbu (2010), 3. Nissanka, et al. (2008), 4. Kulatunga (2011), 5. Norling (2013), 6. Alexander (2014), 7. Ismail, et al. (2014), 8. Barakat (2003), 9. Matsumaru, et al. (2012), 10. Enshassi, et al. (2019) 11. Ye and Okada (2002), 12. Freeman (2004), 13. Sadiqi, et al. (2015), 14. Ika, et al. (2012), 15. Dikmen (2005), 16. Steinberg (2007), 17. Moloney (2014) 18. Arain (2015), 19. Kennedy, et al. 2008), 20. Chang, et al. (2010)

Many authors have identified funding and resourcing as the most common PDR issues which will ultimately result in cost and time overruns. Therefore, the efficiency of PDR projects depends mainly on the accessibility and availability of resources such as, labour, materials, plant, and equipment as the lack of resources might lead to a delay in reconstruction works and increased costs (Kulatunga, 2011). According to Kulatunga (2011), although the background may be different from one project to another, if a PDR project is to be completed effectively, these identified challenges need to be overcome through a successful process improvement methodology. Consequently, Mojtahedi and Oo (2012) indicated the possibility of improving the construction process and labour productivity of PDR projects through lean implementation.

2.2 LEAN CONSTRUCTION

Koskela (2020) identified lean construction as a continuous waste eliminating process that meets the needs of customers, focuses on the entire value stream, and pursues excellence in the execution of a construction project. Value creation in design and building projects has an especially strong position in the lean construction (Koskela, et al. 2002). Lean construction has been used with significant benefits in countries such as United Kingdom (Koskela, 2020; Mossman, 2009), Singapore (Dulaimi and Tanamas, 2001), Brazil (Silva and Cardoso, 1999), Chile (Alarcon and Diethelm 2001), The Netherlands (Johansen, et al., 2002), South Africa (Emuze and Smallwood, 2012), Turkey (Polat and Ballard, 2004), USA (Nahmens and Ikuma, 2009), Sri Lanka (Ranadewa, et al., 2019; Ranadewa, et al., 2021) and in many other countries.

Organizational culture has been identified as a crucial element in the implementation of lean construction (Ranadewa, et al., 2021; Hettiarachchige et al., 2022). '*Lean Culture*' allows all workers to contribute ideas, responds rapidly to new ideas for change, offers a collaborative learning atmosphere, aims for excellence in its goods, services and

processes and enjoys the clear support of all employees and leaders (Koskela, 2020; Hines, et al., 2008). Findings of Waduwawala, et al. (2019) showed that companies believe that lean improvements are very short-lived and complained that lean does not help them to achieve their long-term objectives. This is due to the use of lean only as a toolkit where there is no change in the culture of employees, the management of the development process and the development of leaders (Ahmed, 2013). Therefore, cultural barriers (Ranadewa, et al., 2021) and change (Singh, 2019) of an organization are the most critical obstacles for lean implementation. Unfortunately, the over-focus on tools, resources and fast solutions are unlikely to work if the fundamental concepts of lean have been overlooked (Womack, 2007). Therefore, there needs to be a strategic vision and a culture (Hines, 2010). As a result of that, LIM was developed by Hines in 2008. There are several models such as Liker model, Toyota Production System (TPS) and Shingo model. However, out of these models, many researchers have highlighted the applicability of LIM for construction industry.

2.3 LEAN ICEBERG MODEL

Hines, et al. (2008) likened the lean transition process to the iceberg, the visible part includes technology, tools, and techniques as well as process management; the invisible part includes internal features that endorse lean and should be applied to all levels of the organization, including strategy and alignment; leadership; behaviour and engagement as present in the following Figure 1.

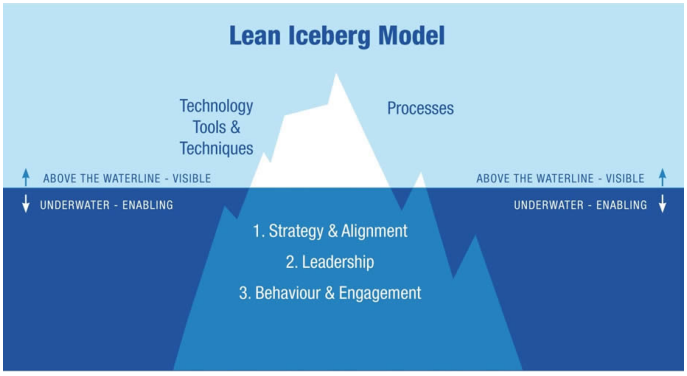

Figure 1: Lean iceberg model

Source: Hines, et al. (2008))

LIM is the graphical representation of the underlying causality of successful implementation (Pearce and Pons, 2017). Similarly, the LIM is an analogy for the two elements of a lean organization, the visible and the invisible (Hines, et al., 2008). The visible elements are those above the waterline and the invisible ones below the waterline. It is easy to identify the Lean process as an iceberg. However, the bulk of the iceberg is below the surface and invisible, and this allows the anchoring mass to render the iceberg a strong force (Hines and Lethbridge, 2008). At the top of the iceberg model are the visible elements which are easily identifiable namely technology, tools and techniques and processes, deposited and substantially described in literature, yet the most essential elements, namely strategy and alignment, leadership and behaviour and engagement are located below the waterline and need to be considered prior to the application of lean tools and techniques (Damrath, 2012). However, there is lack of studies to investigate the

applicability of LIM for PDR projects. Therefore, there is a need to empirically investigate the possibility of mapping the LIM elements to the issues of PDR projects.

3. METHODOLOGY

A literature review was carried out to explore the theoretical understanding. There is a need to ascertain different views of the experts with regards to PDR issues and LIM in Sri Lankan context. Therefore, the research adopted the interpretivism stance. The research strategy followed by the study is 'qualitative survey strategy'. The empirical data collection technique adopted is semi-structured interviews with experts in Sri Lanka selected through purposive sampling. Employing semi-structured interview method is preferred in qualitative approach since the respondents have a structured flow to ask questions from interviewees. The identified 15 number of issues from the literature were further questioned during the expert interviews. The number of experts was limited to 10 as there is a lack of experts, who are having experiences both in PDR projects and lean implementation. Table 2 gives the profile of the experts of the study.

Table 2: Profile of the experts

Respondent	Discipline	Industry Experience	Experience in		Awareness in	
			PDR	LC	PDR	LC
R1	Quantity Surveyor	12	High	High	Well Aware	Well Aware
R2	Quantity Surveyor	12	High	High	Well Aware	Well Aware
R3	Professor	20	Medium	Medium	Well Aware	Aware
R4	Project Manager	16	Low	High	Well Aware	Well Aware
R5	Contracts Manager	16	High	High	Well Aware	Well Aware
R6	Researcher	18	High	Medium	Well Aware	Aware
R7	Town and Country Planner	12	High	Medium	Well Aware	Aware
R8	Architect	34	High	Medium	Well Aware	Aware
R9	Civil Engineer	11	High	High	Well Aware	Well Aware
R10	Quantity Surveyor	13	High	Medium	Well Aware	Well Aware

The interviews had to be conducted through 'Zoom' platform due to the implications caused by global pandemic. The content analysis method was used to analyse the qualitative data and NVivo 12 computer software tool was used for the analysis.

4. ANALYSIS

The interviewees were asked about the PDR issues, lean construction, and LIM. The interviewees were asked to explain how the issues in PDR can be overcome using the five elements of LIM. Ultimately, the PDR issues identified from the literature were further verified during the expert interviews. The findings lead to map the relationships between the issues of PDR to the elements of LIM as described in detail below.

4.1 BUDGET

During the interview, R5 stated that "*mainly it was the frequent change of the scopes. Works which were not included at the award of the tender were inserted at the latter part*

of the project. Hence, time overruns and cost overruns had occurred. So, the contractor had to compromise the quality of the works." Therefore, budget links with all five elements of the LIM namely, technology, tools and techniques, process management, leadership, strategy and alignment and behaviour and engagement. Hence, all respondents suggested that the budgetary issues can be resolved addressing both the visible and invisible elements of LIM.

4.2 POLICIES

R6 mentioned that "*the customary tender procedure was time consuming. The designs that were made at the initial stages, had become outdated when the construction had been started after a lengthy tender procedure. By the time a second wave might have hit the affected region as well. New requirements will be generated by the time of getting approvals. And it caused budgetary constraints*." Policies enacted by the government, statutory, legal body or any other institution / organization deals with process management, leadership, and behaviour and engagement only. It only associates with the invisible elements of the LIM. Hence, the policy issues can only be overcome addressing the above-mentioned invisible elements.

4.3 LIMITED TIME

The improper planning leads to limited amount of time for the completion of a project. Limited time issue relates to all five elements of the LIM. Consequently, it suggests that the limited time issues can be resolved addressing both the visible and invisible elements of LIM.

4.4 LACK OF RESOURCES

This is the most common issue that any PDR projects face nowadays. This issue relates with entire five elements of the LIM. Thus, both the visible and invisible elements of LIM need to be addressed to minimise the lack of resources issue.

4.5 POLITICAL PRESSURE

R2 stated that "*Employees are not personally affected from these issues or challenges. But they might end up in a dilemma due to political interventions. The professionals were thinking that their expertise was neglected and overridden by political authority. So, they lost the motivation towards the project. Other than thinking of the profession itself, most of the professionals had a genuine interest towards the construction and it seemed to be damaged by the political authorities*". Political pressure issues are widely generated in government aided or funded projects. Due to the intervention of local politicians in areas, most of the projects have been suspended or cancelled. Hence, this issue can only be overcome addressing the invisible elements in LIM.

4.6 PROCURING RESOURCES

R6 highlighted that since number of parties are involved and interested of PDR, especially the public, government, and funding agencies, they seek the transparency of the work. Therefore, transparency in procuring resources was vital for the success of the project. In addition, it was further mentioned that the proper documentation and granting approval of the relevant authorities and bodies consumed more time and needed to be avoided as

it was an emergency. In order to overcome an issue relating to procuring of resources, significant consideration must be given to all of the elements.

4.7 COMMUNITY PARTICIPATION

R5 said that "*Community participation should not always be by supplying labour, but also providing and sharing their ideas, views, interests, knowledge, and requirements. This is called "Participatory Reconstruction". When participatory reconstruction is not used and the community's authority of making decisions is withdrawn, there would be deficiencies of the constructions and make an avenue for issues*". Community participation issue deals with all elements of LIM except, technology. The invisible elements hold a substantial role in overcoming and facing the issue/s.

4.8 COMMUNICATION AND COORDINATION

R7 said "*the disaster victims did like to move to new places due to changes in cultural aspects and difficulties*." Therefore, effective communication is a must to ensure that the victims' trust is gained, and the risks and impacts need to be communicated properly to the victims. Hence, this issue is directly relating to all elements in LIM.

4.9 INAPPROPRIATE ASSESSMENT

Inappropriate assessments issues are related to process management, leadership and behaviour and engagement elements. R6 added that *'during 2004 post-tsunami reconstructions, few politicians were influencing the officials as to repair roads which were not damaged from the disaster. Politicians tried to favour their political bases making influences. As a result of that, there was a conflict of interests as what should be constructed and what really is needed to be constructed*'. Hence, two third of linked elements are invisible elements of the LIM.

4.10 UNPRODUCTIVE DESIGN

R9 noted that '*project team suffered from the time constraints as they had to prepare project charters within a short period of time. The rush caused errors when defining the scope, coming up with productive designs and not waiting for final designs*.' Unproductive design issue relates to all five elements of the LIM. Consequently, it defines the need of addressing both the visible and invisible elements of LIM.

4.11 GOVERNMENT SUPPORT

R1 stated that the corruption in governance was an added issue which could be identified unlike in domestic conventional constructions initiated by individuals. As a result, the stakeholders did not get the support they needed. Government support is related to technology, tools and techniques, strategy and alignment and behaviour and engagement. Out of three, two linked elements are invisible elements of the LIM.

4.12 TRANSPORTATION

Transportation issue relates to all five elements of the LIM. Therefore, it defines that the issue can be resolved addressing both the visible and invisible elements of LIM.

4.13 SOCIAL PRESSURE

R3 highlighted that "*the convincing of the victims to move to newer locations was critical as they tend to move back to the disaster-prone areas as they were not satisfied with the new dwellings and settled locations*". Further, R3 added that "*managing the expectations of victims and donors was much more difficult*". In order to overcome this issue, significant consideration must be given to all of the elements.

4.14 POOR QUALITY

R3 mentioned that, due to lack of finance, quality has been. Poor quality issue relates to all five elements of the LIM and hence need to address both visible and invisible elements of LIM.

4.15 DELAYS

R5 stated that "*Variations affected the critical paths of the activities and caused time overruns. It also affected the other projects as the resources were being used by the PDR projects. The delay affected the cash flows and resource allocation.*" Delay issue links to all five elements of the LIM.

4.16 LEAN ICEBERG MODEL FOR PDR PROJECTS

By incorporating the emperical findings of the study, a model has been developed as illustrated below in Figure 2.

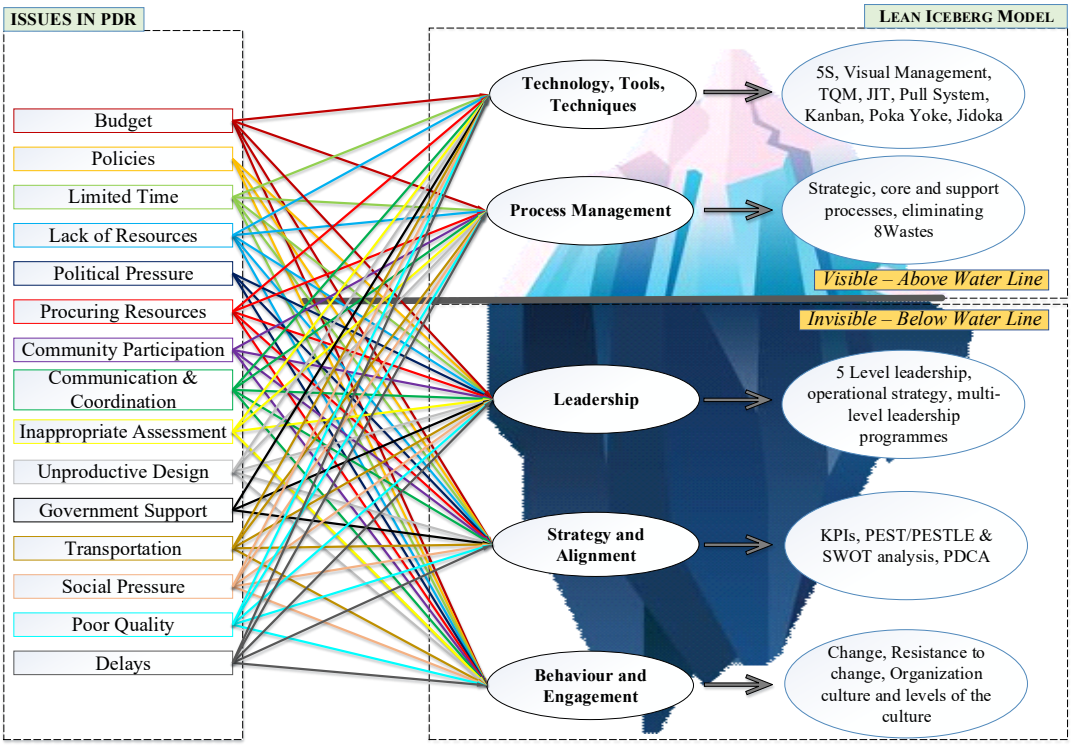

Figure 2: LIM for PDR framework

The relationships of the issues in PDR and elements of LIM had been formulated with the findings from the expert interviews. Number of authors identified budget (Hidayat and Egbu, 2010; Nissanka, et al., 2008; Kulatunga, 2011; Barakat, 2003; Sadiqi, et al.,

2015; Dikmen, 2005), limited time and delays (Norling, 2013; Alexander, 2014; Ismail, et al., 2014; Sadiqi, et al., 2015; Steinberg, 2007; Arain, 2015 and lack of quality (Hidayat and Egbu, 2010; Norling, 2013; Ye and Okada, 2002) as the main PDR issues. These issues linked with all the invisible elements namely, leadership, strategy and alignment and behaviour and engagement. It depicted that these PDR issues could be overcome through successful implementation of the above-mentioned LIM elements. It was also found during the analysis that the PDR issues linked with the elements of LIM placed above the waterline which were considered as visible elements and to invisible elements placed below the waterline. 22 connections were made to the visible elements while 52 connections were made to the invisible elements. It clearly suggested the significance of the invisible elements was much larger than the invisible elements. It proved that in order to achieve success, addressing only the invisible elements or visible elements were not enough. Therefore, both needed to be addressed simultaneously while more consideration should be given for invisible elements.

4.17 "LIM FOR PDR" MOBILE APPLICATION

Based on the findings, a mobile application was developed to address the issues of PDR through LIM. This has been designed to run on android operating systems using the Android Studio version 3.5. The very first interface is a splashing activity along with an animation. Next window displays an interface showing the issues in PDR. A modern User Interface has been designed with a grid view in which the images act as buttons and navigate to the corresponding page/window. Java with sdk was used for programme coding as illustrated in Figure 3.

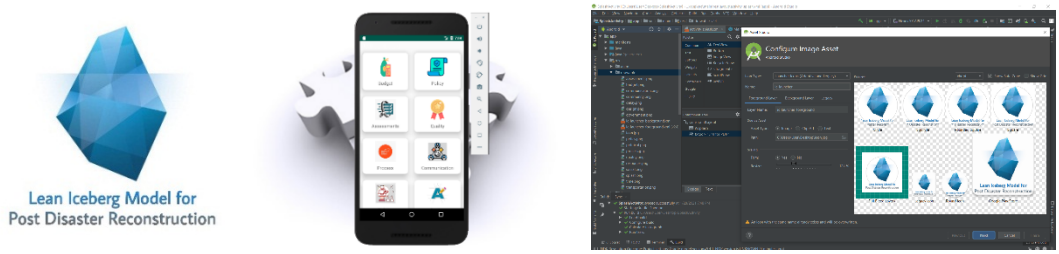

Figure 3: Developed mobile application for PDR

Files such as manifest gradle were modified to make the application more efficient and attractive. The app can be used by any personnel who are interested and enthusiastic in LIM for PDR projects. In addition, it can aid any professional or any student to identify and analyse the existing or the possible related issues of a PDR project and the best methods to overcome those issues. Major advantages of the app are the ability to access the content without having an active internet connection (Offline) and the consumption of a small volume of storage and RAM. The concise nature of the app also encourages anyone with a smartphone or a smart device to install it and use it as it frisks the use of paperwork. Most importantly, the App can be updated with newer versions carrying latest news, acts, and amendments etc. imposed by the state or relevant authorities and bodies. Therefore, the App itself would be continuously improving with time to time. 'LIM for PDR' would be cloud storage or a library of e-books/ e-documents. External links can be easily inserted into the App saving the user time spent on finding strategies for specific PDR issue.

5. CONCLUSION

The literature review of the research confirmed fifteen issues of PDR projects and the outcome was incorporated to expert interviews for further verification. The empirical findings revealed that, each PDR issue can be overcome through appropriate identification of suitable elements of LIM, even though the PDR projects are subjective in nature. The relationship of the PDR issues and elements of LIM namely, technology, tools and techniques, process management, leadership, strategy and alignment, behaviour and engagement were identified. In addition, a mobile application which runs on android OS was also developed to present the findings and at the same time to be used as a guideline for any member involved in the PDR project for successful LIM implementation. Since the rigid policies and regulations act as barriers to the construction industry and proper leadership is needed to manage and tackle the changes in legislation, the mobile App "LIM for PDR" can also be used as reference for enthusiasts and policy makers in the PDR as well as the conventional construction. The existing and upcoming laws, acts, guidelines, and protocols enacted by the state regarding the use of Lean Construction in PDR can also be updated and uploaded to the mobile App. The users can easily access the related documentation without further delay or cost. It will aid to improve the speed, flexibility of the successful practices in the construction industry.

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