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Modeling Profitability-Influencing Risk Factors for Construction Projects: A System Dynamics Approach

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Abstract: This study addressed the complexity involved in integrating the causative risk factors influencing construction profitability. Most of the existing studies cover the individual effects of profitability influencing factors. Very few focus on the systematic impact without incorporating the complexity and associated dynamics, presenting a gap targeted by the current study. The current study aimed to assess causative interrelations and interdependencies between profitability influencing risk factors (PIRF), through systems thinking (ST) and system dynamics (SD) modeling. The SD approach was used to evaluate the integrated impacts on profitability-influencing risk categories (PIRC) in construction projects. The causative influencing factors affecting construction profitability were identified through a comprehensive literature review. These were ranked using content analysis, and categorized into significant issues. Through 250 structured surveys and 15 expert opinion meetings, the path for quantitative and qualitative evaluations was prepared. Following these investigations, a causal loop diagram (CLD) was established using the ST technique, and the integrated effect was quantified using SD modeling. The study finds the rising cost of material, supply chain process, payment issues, planning and scheduling problems, financial difficulties, and effective control of manpower and equipment resources as the most critical PIRFs. The integrated effects of PIRFs on PIRC were quantified using SD modeling. This study helps field professionals with profitability-influencing factors, diagnosing issues, and integrating impacts regarding decision-making and policy formulation. For researchers, it presents a list of factors that can be investigated in detail, and the holistic interrelationships established.

Keywords: causal loop diagram; profitability-influencing risk factors; profitability-influencing risk categories; system dynamics; systems thinking

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1. Introduction and Background

The construction industry is highly complicated, due to the unique nature of projects and the involvement of multiple stakeholders [1]. It becomes more challenging when the engaged stakeholders demand different profit levels to keep them in the construction business. In addition, these stakeholders are the sources of multiple risk factors [2]. Therefore, multiple challenges exist in assessing the profit, due to various risk factors encountered during the execution stages of construction projects. Generally, construction projects fail to achieve good profitability, due to issues related to time, cost, and scope [3]. This is more evident in developing countries that struggle to meet the project objectives, due to multiple constraints. Profitability is one of the most important goals, and an essential element of satisfaction for the construction project stakeholders. This is more evident in the case of stakeholders involved in the construction business, and may not be true for public sector organizations. The aim in the latter case is the development of projects for public benefits where profitability may not be the key concern, and other social reasons may be prioritized. Nevertheless, profitability is a key goal for most private construction organizations. Therefore, it is important to highlight the profitability-influencing risk factors (PIRFs) and issues resulting in project complexity, increasing the impacts, and ultimately reducing profitability [4].

The impact assessment of PIRFs on profitability becomes a critical requirement and is significant to every stakeholder [1] because a reasonable profit level is needed to maintain and enhance their business relationships. Moreover, well-defined and time-based impact assessment of profitability during the construction phases reduces the chances of failure, and improves project performance [5]. The causes, effects, interrelationship, and interdependency of the PIRFs are essential, and need particular focus while integrating them into the construction feedback-based system. These PIRFs exhibit complicated and causal relationships. Accordingly, there is a need to understand the involvement of complexity in the systematic integration of the causative risk factors and categories concerned with profitability [6].

Further, comprehensive and in-depth knowledge of the complexity and the integration of PIRFs is needed to analyze the dynamic effects on profitability-influencing risk categories (PIRC). Such assessment of PIRFs, and their categorization into PIRCs, is crucial for the survival of construction firms engaged in construction businesses [7,8]. This approach provides a unique angle, with critical insights into the factors influencing construction profitability and the associated risks. The link between risk to profitability is rarely addressed in the literature. The risk-based profitability model is a way to explore the causation of various issues in construction projects. Accordingly, it becomes important for construction firms to review failures in terms of encountered risks in the past, taking corrective measures, and focusing on future profitability [9]. This is pivotal to the organizational continuous improvements and growth in the era of globalization.

Due to the complexities involved in PIRFs' assessment, the ST technique may be used to assess issues in which the impact of individual components is considered in the context of the whole system [10]. Causal loop diagrams (CLDs) are used in this technique to discover key processes for gathering input, and their impact on project goals [11]. In a complex system, ST manages several variables at the same time, and highlights connections and interdependencies between them. For example, in the construction industry, PIRF and PIRC are two dimensions with inherent complexities and dynamics. Accordingly, ST is an acceptable technique for this research to identify and evaluate the causal feedback impacts and links between profitability factors.

The PIRFs in construction projects are interdependent. However, the existing studies are conducted in isolation, focusing on individual factors. Previous studies show their impacts on profitability without understanding the complexities involved while integrating their causal interdependencies. There is a limited understanding of the dynamic risks faced in construction projects. Accordingly, the effect of the influencing factors on profitability needs investigation. Further, there is a need to explore the causal relationships between PIRFs of the construction projects, and the assessment of causal interrelations between key influencing factors. As previously discussed, ST and associated system dynamics (SD) are widely used for establishing and assessing such causal relationships. Therefore, this study presented the modeling of the key PIRFs and the holistic integration and evaluation of their combined effects on PIRCs using ST and SD. Further, the current study proposed management strategies for handling issues about crucial PIRFs, in order for construction projects to enhance profit.

The current study is a novel approach to PIRF and PIRC assessment, integration, and quantification. Profitability is crucial in construction projects. There is limited understanding of construction profitability risks, complexity, and dynamics. The assessment of interdependencies between the key PIRFs remains a key issue in the literature, that, to date, is not well explored. This study addressed the complexity involved while integrating the causative PIRFs influencing construction profitability using SD. The complexity was addressed by formulating the causative CLDs (reinforcing and balancing loops) to show the qualitative impact. Afterward, SD modeling and simulation were used for the assessment of the quantitative impact within the system.

In terms of the knowledge gap, most of the studies in this field identify the individual effects of PIRFs. Very few focus specifically on the systematic impact of PIRFs and PIRCs; however, these studies do not integrate and incorporate the associated complexity. Further, so far, the SD approach has not been used for PIRF and PIRC assessment in construction projects. The current study targeted these gaps, and presented an SD approach for establishing the relationships between PIRFs and PIRCs, assessing and integrating them, and their quantifications, into construction projects.

To achieve the holistic goals, the current study has the following objectives:

(1) To explore PIRFs and the corresponding issues in construction projects;
(2) To establish and assess causative interrelations and interdependencies between PIRFs through ST;
(3) To evaluate the integrated impacts on PIRC through SD modeling and simulation.

To achieve the objectives, this research involved the formulation of qualitative reinforcing, balancing causal feedback loops, and a quantitative SD model of PIRFs. The overall aim was to understand their integrated influence on construction profitability. It specifically addressed the complexity, reinforcing and balancing causal impacts, and dynamics within the construction system related to profitability, which is rarely addressed in other studies. The expected contribution of the study is the system-based learning of the impacts of risks on profitability in construction projects.

This study helps the field professionals learn about PIRFs, the causal relations, and their importance in construction projects. Using the current study, professionals can diagnose profitability issues, and assess their impacts for improved decision-making, in order to manage risks and enhance profitability.

The rest of the paper is organized as follows. Section 2 presents the pertinent literature. Section 3 presents and discusses the method and data collection approaches adopted in the current study. Section 4 presents and discusses the study results, including the CLDs and related SD analyses. Finally, Section 5 concludes the study and presents the key takeaways, limitations, and future directions for expanding upon the current study.

2. Literature Review

Risk is an uncertain event that, if it occurs, has an impact on a project's objectives. There are inherent risks in construction work that impact and reduce the overall profitability of construction projects during the execution phases. The likelihood of an actual risk event, or a combination of risk events, during the whole construction process concerns the stakeholders [12]. PIRFs involve many variables, and it is often difficult to determine cause and effect, interdependencies, and correlations. These PIRFs play a significant role in decision-making and performance. In addition, these PIRFs affect other construction dimensions such as supply chains [13], cash flows [14], contingency [15], and project complexity [16].

Multiple factors are involved in various industries that influence profit margins [2]. Business failure is closely related to such profitability-impacting variables. Any firm can improve its financial benefits by exploring and suggesting preventive measures regarding profit-influencing variables [17]. The profitability levels of construction projects vary due to their complexities and challenging objectives, often constrained by time and money. The political, economic, cultural, and legal aspects can negatively impact the level of profitability of construction projects [18]. The performance of construction firms can be measured using profitability analysis. It involves a systematic approach to defining, analyzing, and evaluating various profit-influencing variables in construction projects [19].

It is observed that construction profitability depends on multiple variables, and there are numerous criteria to assess a firm's profitability [20]. There is a multi-criteria approach for construction project profitability analysis and predictions. Overall, the success of a project is linked with profitability and its influencing variables. Accordingly, the relationship is established, keeping in view the profitability-influencing factors at different levels. During the execution phase, investigating the construction process helps avoid profit failure as unpredictable and complicated scenarios occur [19]. It is necessary to highlight and discuss such failure-related factors (or in other words, the PIRFs), to enhance the success and performance of construction projects in terms of profitability.

Construction projects come across complicated and unpredictable challenges during the execution phase [17]. Construction organizations developed some tools and procedures to decrease the possible losses, and make their projects more profitable. These tools and strategies adopted by firms are based on the experience and knowledge of the firm's engineers [21]. These profitability-influencing variables are concerned with the initiation, bidding, contracting, execution, and closing stages of construction projects. However, the holistic assessment of the negative factors, or PIRFs, is rarely reported in published literature.

The construction supply chain has four significant participants: client, main contractor, consultant, and subcontractor. The main contractor drives the construction supply chain. The main loop of the construction supply chain is between the client and the main contractor [22]. A study was carried out to identify the factors influencing the relationship between these participants, and their effect on the overall project performance and profits [23,24]. The main objective of the research was to identify the factors affecting the supply chain environment of a construction project, either directly or indirectly, causing significant variation in the project profits and performance parameters. It is concluded that the project team could control and develop factors over time, such as trust, risk management, and joint working, in order to improve profit margin.

There is profitability variation for different types of projects across the construction industry, due to various factors, such as unpredictable and complicated scenarios [17]. It is essential to evaluate these situations in construction operations, to reduce losses and increase profits. Profit projection is difficult due to the nature of construction operations, intricate procedures, tough environment, organizational structure, and several other factors. As a result, construction projects are often delayed and go over budget, especially in developing countries [25]. Furthermore, the construction sector is complicated by the presence of many specialist contractors, resulting in fragmented construction projects.

Construction companies have long sought to anticipate project cash flow at the outset of a project, which is intimately linked to payment terms and financing schedules. Diverse variables impacting project cash flow for the realm of international construction projects often vary, due to a variety of external and internal risks, reducing profit margins. Financial and project-specific variables influence cash flow soundness [26]. Changes to the original design, variations to the works, production goal slippage, delays in deciding on variation/day works, and claims settlement delays are all significant contributors to loss in profits. Based on these characteristics, and the periodic variability readings, multiple linear regression models were created and applied in construction projects. The established models offer construction contractors essential information about the expected effects of key factors on cost flow baseline forecasting at various construction phases, allowing them to take proactive measures and avoid losses [27].

A project's contingency cost is calculated depending on the degree of unanticipated circumstances. Breaking down the project into major work packages is one way to do this. Then, for each work package, independent factor analysis is performed, treating them as discrete projects to secure profitability at the activity level. Potential sources are discovered by a factor analysis, based on the views of experienced project workers. Consequently, each work package's risk-adjusted target cost is determined. The contingency amount necessary to finish the work package is calculated using this goal and base cost estimate in the relevant study [28].

In underground construction works, it is imperative to identify the factors involved at the starting phases of the project [29]. As underground constructions are comparatively more complex, they contain unpredictable and variable subsurface conditions. Many uncertain variables encountered in project implementation dynamically affect the project's duration, and affect the project profit [30]. The contracting parties, such as owners, designers, contractors, subcontractors, suppliers, etc., also add to these projects' complexity. Therefore, assessment of the profitability-influencing factors is not easy and straightforward. Instead, it is complicated, tricky, and involves establishing multiple linear and nonlinear relationships.

2.1. Systems Thinking and Complexity

Systems thinking (ST) aims to understand a system's fundamental structure by confidently deducing its behavior [11]. Ullah and Sepasgozar [31] state that the interaction between a system's components is fundamental to ST. The ST method helps analyze the feedback behavior of each variable, and its influence on other variables, since variables in a system have intricate interactions among themselves. Accordingly, this approach is favored for investigating the systems with complex relationships, such as the construction PIRFs. This technique, however, focuses on the whole system, rather than a limited project perspective, when determining these linkages. As a result, a practical and efficient strategy for comprehending and addressing system complexity is needed [20]. This limitation is usually addressed in the next stage of ST applications, i.e., the SD modeling.

2.2. System Dynamics

The theory of nonlinear dynamics and feedback control established in mathematics, physics, and engineering forms the foundation of SD [11]. SD techniques are used to study human and technical system behaviors. To answer key real-world issues, SD relies on cognitive and social psychology, organizational theory, economics, and other social sciences [32]. The SD technique may be used to create 'micro worlds' that explain real-world situations in a clear, practical, organized, and accessible way [33]. The ability to deconstruct complicated systems into easily understandable subsystems is a key strength of the SD process. SD is a nonlinear feedback system that handles complexity and process linkages [34,35]. Thus, it is suited for assessing the complicated relations of PIRFs in this study.

3. Methodology

The research study focused on the causal impact of PIRFs and PIRCs on construction projects. A mixed method was adopted in this study: qualitative and quantitative. A qualitative approach was used to evaluate the causal interconnection, interdependencies, and impacts of such PIRFs and PIRCs on construction projects. Further, the qualitative integrated effects of causative influencing factors were assessed using ST feedback loops. The quantitative assessment was conducted using the SD approach, in line with relevant studies [36,37]. The processes involved in the methodology are shown in Figure 1.

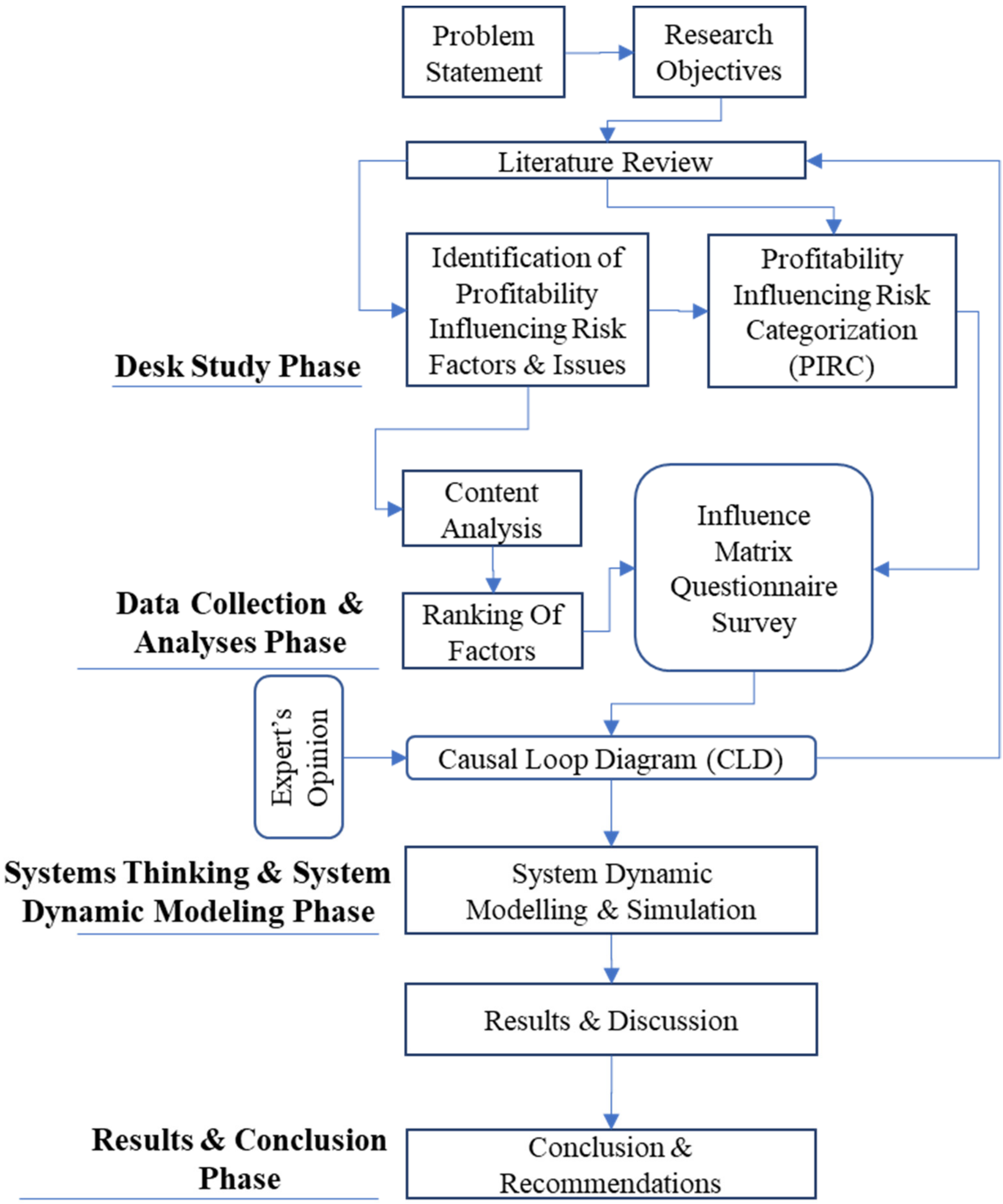

Figure 1. Schematic demonstration of methodology.

3.1. Desk Study Phase

A detailed review of relevant published research articles was carried out in the desk study phase. Accordingly, the problem statement and the research objectives were developed. Relevant literature was synthesized to recognize the PIRFs and related issues concerned with the profitability of construction projects. An extensive literature study was undertaken using these aims as a guide. Research articles and conference proceedings were searched using the keywords "construction profitability," "profit in construction projects," "construction profitability impacting factors," "profit influencing factors," and "construction profit performance" on relevant literary databases. A number of scholarly research platforms, including Google Scholar, Scopus, Emerald Insight, Taylor and Francis, American Society of Civil Engineers, Elsevier-Science Direct, Springer, MDPI, and SAGE, were consulted and utilized during this process, following recent articles [37–39]. As a result, as indicated in Table 1, 60 relevant publications were collected to identify major causal elements impacting the profitability of construction projects.

Table 1. Identification of profitability-influencing risk factors (PIRF).

Sr. No.	Significant Causative Impacting Factors of Construction Profitability	References
1	Additional work and rework due to faulty execution	[40]
2	Changes in specifications	[41]
3	Communication issues among stakeholders	[1]
4	The competitive bidding process causes competitive pressure	[42]
5	Contract issues in contract management	[12,43]
6	Complicated coordination and collaboration among contracting parties	[44]
7	Cost escalation	[26]
8	High degree of construction risk	[16]
9	Delays of activities on the critical path	[23]
10	Dependency on suppliers	[45]
11	Design errors and mistakes	[46]
12	Complication of contract attract different profitability levels	[47]
13	Ineffective control of the manpower and equipment resources	[48]
14	Inefficiency and ineffectiveness in activity duration and cost	[42]
15	Fluctuating exchange rate	[41]
16	Financial difficulties due to cash flow problems	[26]
17	Improper investigation of geotechnical and underground conditions	[26]
18	Inaccurate measurements and estimation	[42]
19	Inclement weather conditions	[41]
20	Incompetency of project team	[2]
21	Increase in project durations	[42]
22	Ineffective information sharing and use of information technology	[11]
23	Insufficient and poor technology	[49]
24	Fluctuating interest rate	[26]
25	Lack and shortage of funds and finances	[41]
26	Lack of material availability	[50]
27	Higher level of difficulty due to the degree of complexity	[47]
28	Material deliveries bottlenecks during supply	[41]
29	Material supply network risks	[49,51]
30	Payment issues (timely and delay payments)	[2,43]
31	Planning and schedule issues	[16]
32	Price fluctuations	[52]
33	Unsuitable resource delivery conditions during construction	[26]
34	The rising cost of materials due to market fluctuation	[42]
35	Rising inflation levels	[53]
36	Scope variations and scope changes	[2,43]
37	Poor site management and supervision	[47]
38	Interrupted supply chain process	[39]
39	Unexpected situations during project execution	[52]
40	Unstable market conditions (supply and demand, competition)	[12,43]

The significant problems related to the PIRFs (listed in Table 1) in construction projects are listed in Table 2. The problems were observed due to controlling factors' impacts, and enhancing or reducing the construction profits.

The PIRFs are causative risk factors that significantly impact profitability [4] in a construction project, especially in the execution stages [12]. These were extracted through a literature review in this study, as listed in Table 1. The causes help to diagnose profitability issues and their impact. These further help in improved decision-making, in terms of causal significance, in order to reduce the native effects and enhance profitability [2].

Since there is no standard classification of risk, several methods regarding risk classification are reported in published literature, with the most common type based on the nature of risk [54]. Keeping in view the identified causative influencing factors, and related issues from the set of selected literature, the PIRCs in this study were derived mainly considering supply chain [13], cash flow [14], contingency [15], and project complexity [16], as shown in Table 2. The PIRFs have specific natures and causes, whereas the PIRCs have combinations of different factors, and their corresponding issues, under larger categories. This study analyzes the causal interdependencies of PIRFs on the PIRCs in construction projects.

Table 2. Profitability-influencing risk categories (PIRC) and issues.

Sr. No.	Profitability-Influencing Risk Categories (PIRC)	Significant Issues Faced in Construction Profitability	References
1	Supply chain	Material supply disruptions Reduction in supply chain performance Delays in project delivery	[50] [55] [51]
2	Cash flow	Poor cost and financial controls Material cost rises and disturbs forecasted cash flow Slows down construction activities	[56] [2] [26]
3	Contingency	Project cost variation Improper utilization of contingencies Disturb construction planning	[57] [47] [58]
4	Project complexity	Obstacle increase complexity and reduces construction performance Contract issues Increase in expenses and decrease in profit	[59] [14] [12]

A content analysis was carried out on the PIRF (causes only), which included a two-part literature review, based on relevant publications, and a preliminary pilot survey in computing and assigning literature and industry scores to factors following recent approaches [37]. The frequency of occurrence of each PIRF was noted and compiled in the first portion of the literature study, giving the frequency scores. Then, on a five-point Likert scale (1 = very low, 2 = low, 3 = medium, 4 = high, and 5 = very high), the different authors (of reviewed papers) assigned a qualitative score to the PIRFs in the second section, to mark their contextual significance [36]. Finally, each component was given a combined score by multiplying its collected frequency and qualitative scores. The literature ratings were adjusted before ranking them in decreasing order.

In addition, to establish the connection to the local context, a preliminary survey was conducted to identify the PIRFs influencing construction profitability in developing countries. The primary survey was conducted to target (50) construction industry professionals appointed at various levels in construction projects. These include project managers (11), construction managers (8), project directors (7), project/site engineers (10), design team leaders (9), and contract engineers (5).

The key questions inquired about each respondent's level of understanding of the topic, knowledge of risk-based digital tools, and the implementation of risk management systems in their respective organization for managing profitability. As a result, 30% of the respondents respond with moderate understanding, and 55% respond with an advanced understanding of the topic. Further, 40% have average knowledge of risk tools, and 45% have good knowledge of tools regarding implementation, which corroborates the data quality of the current study.

Most of the field specialists were associated with contractors (24), consultants (14), and clients (12). The average experience of the group of 50 respondents was more than 15 years. Further, the distribution is 5–10 years (15), 11–15 years (12), 16–20 years (13), and over 20 years (10). Most of the responses were from the respondents associated with large-size organizations engaged with the construction of hydropower, road, and building projects. The numbers and nature of risk observed by the specialists of the organizations dealing with projects were reported as medium to high. Based on expert feedback, normalized industry scores were calculated using mode values against all responses obtained from the survey. These were subsequently ranked in descending order [36].

Overall, three surveys were conducted in this study. The first survey was carried out for ranking PIRFs, using weighted normalized and cumulative scoring of literature/industry. The second survey was carried out to assess the interrelationship and impact of PIRFs and PIRCs, in order to compute the relative importance index (RII) of responses. Finally, a third survey was carried out to confirm the linkages and polarities for the development of CLD, speed and strength of influences, and loop prioritization, in line with the recent studies [36,37].

3.2. Data Collection and Analysis Phase

During the analysis phase, factors of lower values were screened out using a simple additive weighting procedure, and the critical factors were ranked appropriately [36,60]. First, the components were given cumulative scores based on alternative weighting distributions (literature/industry), such as 30/70, 40/60, and 50/50. These were determined using the literature and industry scores as previously discussed. Then, using additional weighting distributions, a statistical check (one-way ANOVA) was run to examine whether there was a statistically significant change between the rankings of different variables. A p-value of 0.85 indicates that there is no statistically significant difference, prompting industry experts to speculate. As a result, 15 key PIRFs of construction profitability were ranked, as indicated in Table 3. These were chosen based on a 60% commutative score to include maximal effect, employing a 40/60 weighting distribution.

Table 3. Significant profitability-influencing factors risk (PIRF).

Sr. No.	Description of Factor	Normalized Score	Cumulative Score	Rank
1	Rising cost of material due to market fluctuation	0.0662	0.0662	1
2	Interrupted supply chain process	0.0513	0.1175	2
3	Ineffective control of the manpower and equipment resources	0.0508	0.1683	3
4	Payment issues (timely and delay payments)	0.0483	0.2166	4
5	Planning and schedule issues	0.0432	0.2598	5
6	Financial difficulties due to cash flow problems	0.0407	0.3005	6
7	Unexpected situations during project execution	0.0407	0.3411	7
8	Increase in project durations	0.0431	0.3842	8
9	Scope variations and scope changes	0.0381	0.4223	9
10	Inclement weather conditions	0.0355	0.4578	10
11	Ineffective information sharing and use of information technology	0.0355	0.4933	11
12	Price fluctuations	0.0340	0.5273	12
13	Unstable market conditions (supply and demand, competition)	0.0330	0.5603	13
14	Poor site management and supervision	0.0309	0.5912	14
15	Lack of material availability	0.0309	0.6222	15

As content analysis was based on secondary data, primary data gathering was required to enhance the reliability and establish the context for the current study. To guarantee and enhance the credibility and efficacy of this study, an international survey was conducted, which included additional analysis and data collection from developing countries. The World Economic Forum's Inclusive Development Index (IDI), which assesses each country's development, was used to choose these nations (2018).

To begin the data gathering process, a structured impact matrix questionnaire was created using Google Docs. It was divided into two sections: the first section asked respondents for personal information, such as their country of origin, educational background, work experience, and organizational role, and the second section asked them to rate the impact of each causative factor on construction profitability using a three-point Likert scale (1 = low, 3 = medium, and 5 = high).

To assure a representative sample, a sample size of 96 or more was needed, as highlighted in a similar study [61]. By examining their profiles on research network sites for research, such as Research Gate, and social media, including Facebook, Twitter, and LinkedIn, 305 construction management field specialists were contacted to provide relevant data. These specialists represent the four primary internal stakeholder categories: client, contractor, consultant, and designer, and come from both multinational and local (Pakistan) construction organizations [62].

A valid response rate of 82 percent was obtained via an online survey, which yielded 250 valid replies. The reliability, consistency, and normalcy of these replies were checked using IBM SPSS Statistics. The RII approach was used to rank the derived relationships based on the importance assigned by respondents. In construction projects, the data gathering through questionnaires identified 60 influencing linkages between PIRFs and PIRCs. The RII was used to calculate importance indices for each relationship [63] and to identify the most immediate causative variables and PIRC in construction projects. Equation (1) was used for this purpose.

$$Relative\ Importance\ Index = \frac{\sum W}{A \times N} \tag{1}$$

where W = weights assigned on the Likert scale;

A = the maximum assigned weight;

N = total number of respondents.

The minimum and maximum values of RII are 0 and 1, respectively. It is vital to remember that evaluating all impacts, rather than direct causes, does not accurately portray the system's structure [10].

To classify the replies according to significance levels, a criterion similar to Rooshdi, et al. [64] was used, which defined RII scores ranging from 0 to 0.2 as "Very Low," 0.2 to 0.4 as "Low-Medium," and 0.4 to 0.6 as "High." "Medium" is defined as score between 0.4–0.6, "Medium-High" is defined as 0.6–0.8, and "Very High" is defined as 0.8–1.

To restrict the data to a smaller collection of summary variables, relations with RII values of less than 0.8 were regarded as most important or most urgent, as shown in Table 4, and, therefore, evaluated for further analysis using ST.

Table 4. Scrutiny of immediate PIRFs based on RII.

PIRCs in Construction	PIRFs	Weighted RII Score
Supply chain	Price fluctuations	0.907
	Market conditions	0.814
	The rising cost of material	0.810
	Interrupted supply chain process	0.814
Contingency	Financial difficulties due to cash flow problems	0.810
	Unexpected situations during project execution	0.806
	Project complexity	0.802
Cash flow	Financial difficulties due to cash flow problems	0.895
	Payment delay	0.887
Project complexity	Project durations	0.875
	Inclement weather conditions	0.867
	Planning and schedule issues	0.842
	Ineffective resources management	0.846
	Scope variations and scope changes	0.834
	Lack of material availability	0.822
	Poor site management and supervision	0.818
	Ineffective information sharing and use of information technology	0.846

3.3. Demographics of Survey Respondents

In the third survey conducted in this study, several construction field practitioners and professionals were engaged. These respondents were appointed at various levels in in their organizations, occupying various roles and responsibilities. Additionally, they have considerable experience in executing complex construction projects. Further, these respondents belong to different developing countries of the world. The international responses were around 54%, and the remaining 46% were from the Pakistan construction industry. Qualification-wise, 66% of respondents have master's degrees, and 6% have a PhD/D.Eng. This indicates that 72% of replies are from highly qualified professionals. A repuTable 28% of responses come from B.Eng./BS degree holders. The experience and higher qualifications of the professionals responding to the current questionnaire survey highlight the responses' credibility.

The survey results show that 15% of respondents are field professionals with more than 15 years of experience in different types of construction projects. This demonstrates that the responses are from extraordinarily knowledgeable and practiced professionals. A total of 35% of respondents have 10–15 years of experience, and 32% of respondents have an experience between 5–10 years. This means a total of 82% of the respondents have more than five years of experience. The remaining 18% have less than 5 years of construction experience. Considering the organizations, most of the respondents are from multinational organizations (48%). Likewise, 27% are from government departments, and 25% are from semi-government and other organizations.

3.4. Systems Thinking and System Dynamics Modeling Phase

In this phase, various CLDs were created, and ST and SD analyses were conducted accordingly. In order to create a CLD, the data is gathered in the form of expert opinions. Interviews with industry professionals, with an average of over 20 years of experience, were performed during the first phase. These respondents were working for client, contractor, designer, and consultant companies, each with their own tasks and responsibilities. There were project team leaders (4), contract and procurement experts (2), construction managers (3), planning engineers (2), and site engineers (4), among the most important positions. This step aimed to recognize linkages between variables and give polarity to relationships between the most direct causal links in chronological order, following relevant studies [37]. Using this information, a CLD was created that revealed six major loops.

CLDs represent the causal interdependencies in the form of links and loops within the system, to visually represent the causal relationships. In CLD, there are two types of loops, i.e., reinforcing and balancing loops. In the CLDs, "R" denotes the reinforcing loop and "B" denotes the balancing loop. Arrows are used to connect the factors in the diagram, indicating their directional influence. Each arrowhead is given a polarity to represent the link between the two variables. A negative polarity (−) suggests an inversely proportional connection, while a positive (+) indicates a directly proportional link. CLDs are created through Vensim software, to analyze the impact of the causal relationships, keeping in view the negative (−) and positive (+) polarities in the system.

As a result, a stock and flow diagram was created in this study to assess the combined effect of each influencing element on the profitability risk categories, including cash flow, supply chain, contingency, and project complexity. For the created system of construction profitability, many simulations were run to provide dynamic and integrated causal effects of elements on one another and the profitability risk categories. Finally, conclusions were drawn based on the project goals and analyses.

In the second phase, the same experts involved in CLD preparation were asked to characterize each feedback loop according to its intensity and speed of effect. Using this loop-based categorization method, the system's most essential loops were determined [65]. For the interviews, the sample size was determined using the notion of sample saturation [66]. To achieve data saturation, many interviews are necessary. However, by the 15th interview, sample saturation was attained, demonstrating that the replies were consistent, and confirming the validity of the data.

4. Results, Analyses, and Discussions

4.1. Impacts of Influencing Factors on Construction Profitability

The interdependencies between important aspects of construction profitability and the associated PIRFs and PIRCs necessitated mixed analyses: qualitative and quantitative. As a result, the assessment was conducted using the CLDs (Figure 2), which aid in a better understanding of how construction project profitability is driven inside a dynamic system. This also helped visualize the influence of various PIRFs and PIRCs in construction projects.

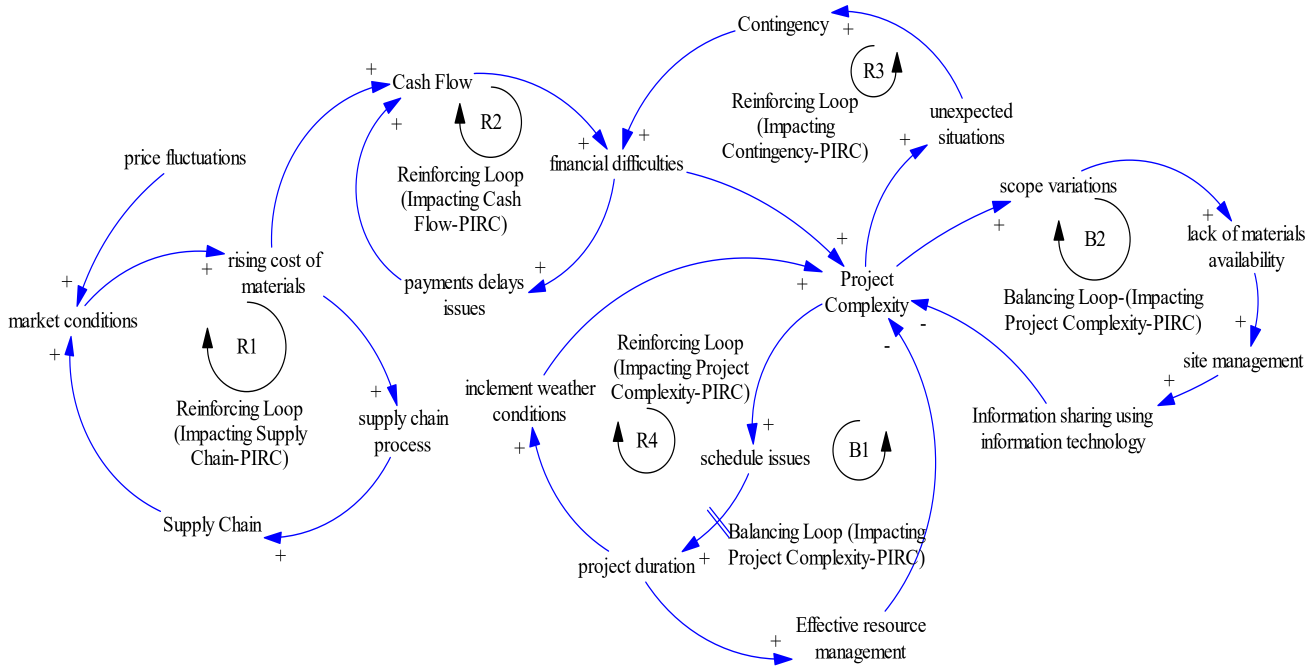

Figure 2. Causal loop diagram based on systems thinking of balancing and reinforcing loops.

The CLD constructed in this study has six important loops, representing the causality of PIRFs affecting one of the PIRCs. It is made up of four reinforcing, or positive, loops that cause a change in the same direction (growing or decreasing), represented by the symbol "R". On the other hand, it has two balancing, or negative, loops that move variables in the opposite direction (i.e., oppose the change in every cycle), marked by the letter "B". The loops are all recognized and discussed in the following sections.

4.2. Reinforcing Loop-R1 (Impacting Supply Chain-PIRC)

Figure 3 shows that the abrupt disturbance in the market conditions is due to frequent fluctuations in price. As a result, the supply of the materials cannot be provided at a constant price rate, leading to the rising cost of construction materials. The disturbance in the supply chain process is observed due to the increasing cost of construction materials, which finally impacts the overall construction project supply cost and time. This reduces the estimated profit of the construction project.

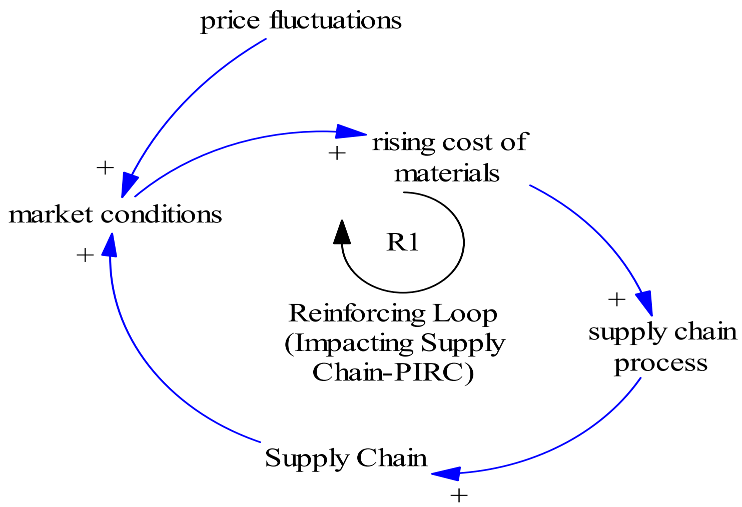

Figure 3. Impact on profitability risk category–supply chain (reinforcing loop-R1).

4.3. Reinforcing Loop-R2 (Impacting Cash Flow-PIRC)

Figure 4 shows that the supply of the materials cannot be provided at a constant price rate, due to the rise in the cost of construction materials. As a result, the construction contractor spends more money procuring materials than the planned and forecasted cash flow reserved for purchasing. The disturbance in the cash flow leads to an increase in the construction contractor's financial difficulties. Accordingly, the contractor cannot fulfill the payment agreement to all concerned payment-receiving stakeholders. Finally, the loop variables impact construction projects' overall cash flow behavior.

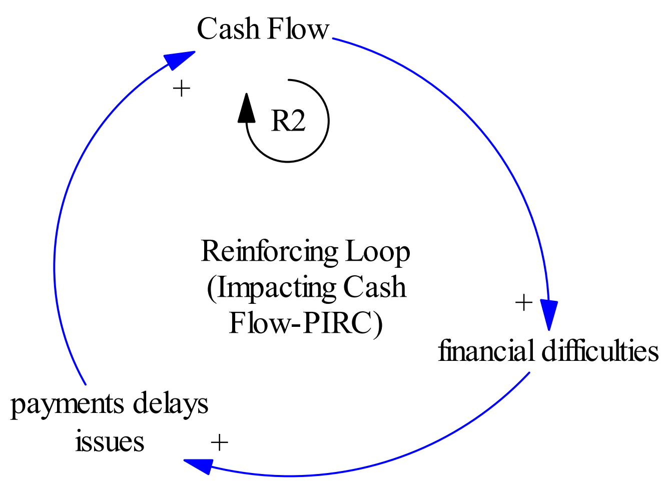

Figure 4. Impact on profitability risk category–cash flow (reinforcing loop-R2).

4.4. Reinforcing Loop-R3 (Impacting Contingency-PIRC)

Figure 5 shows that the risk factor "financial difficulties", from the previously derived loop, create issues such as cost overruns, time delays, scarifying quality, and, sometimes, scope variations. The economic challenges are also responsible for the ineffectiveness and inefficiency of executing critical activities in construction projects. In addition, the cost, time, quality, and scope increase the overall project complexity in different directions and stages. This further exacerbates the unexpected risks/situations for the contracting parties. As in other construction projects, time contingency and cost contingency are used to encounter uncertain problems. Finally, the loop variables impact the overall construction project time and cost contingency.

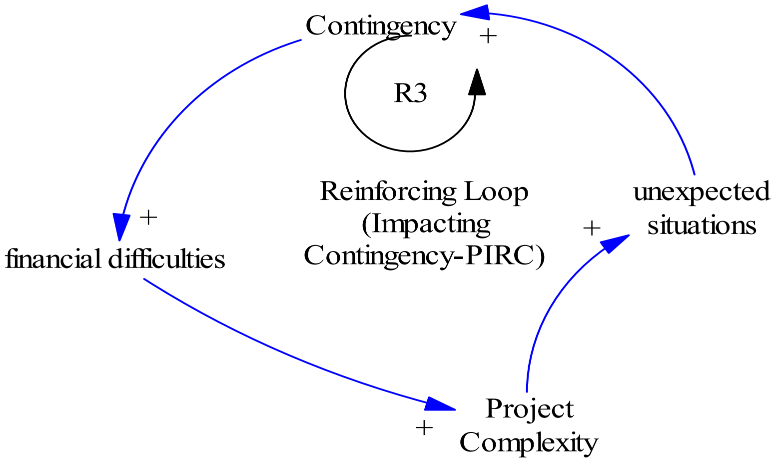

Figure 5. Impact on profitability risk category–contingency (reinforcing loop-R3).

4.5. Reinforcing Loop-R4 (Impacting Project Complexity-PIRC)

Figure 6 shows that the risk factor "financial difficulties" creates complexities for the construction project in terms of cost overruns, time delays, scarifying quality, and scope variations. The complexities in the execution stage of the project are responsible for the increase in schedule risks and associated issues. Moreover, the scheduling issues increase the chance of time overruns and the overall project duration. The inclement weather cycle becomes prominent in the construction project, due to such time overruns and increased project durations. The impact of the inclement weather cycle increases the project complexities and the duration. Finally, the loop variables show an integrating impact that reinforces the project complexity.

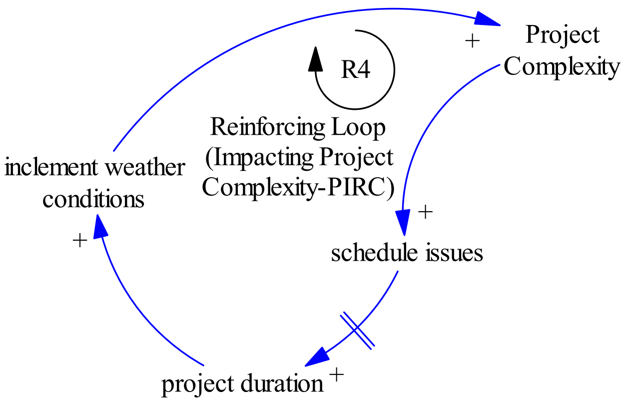

Figure 6. Impact on profitability risk category–complexity (reinforcing loop-R4).

4.6. Balancing Loop-B1 (Impacting Project Complexity-PIRC)

Figure 7 shows that the risk factor "project complexity" negatively impacts the schedule and project duration, and creates multiple problems related to time overruns. In a construction project, time is money for the construction contractors. Thus, when encountering an increase in the project duration, the contractor has to manage the human resources and equipment resources efficiently. Therefore, effective resources management becomes necessary to deliver the project within the specified contract period. Additionally, adequate resources management, including effective time management, helps reduce the complexities involved during the execution stage of the project. Accordingly, loop B1 shows a balancing impact on project complexity.

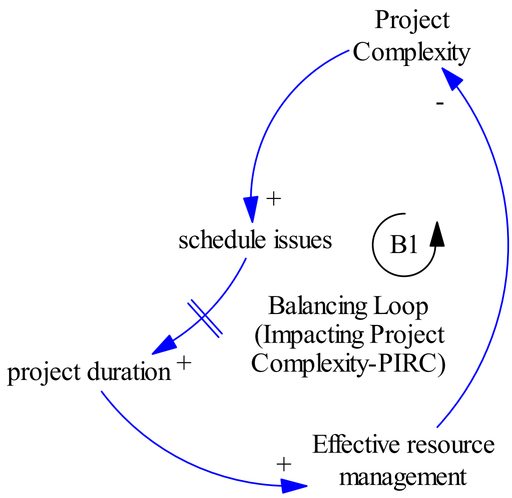

Figure 7. Impact on profitability risk category–complexity (balancing loop-B1).

4.7. Balancing Loop-B2 (Impacting Project Complexity-PIRC)

Figure 8 shows that the scope variations in the construction projects are responsible for the changes in the specification, which leads to a lack of material availability. As a result, the stakeholders must spend more money on material management. Construction site management becomes difficult due to the lack of material availability, which usually delays the execution of the construction activities, causing cost and time overruns. Poor site management demands more sharing of information. Therefore, effective information sharing, and management through information technology, becomes necessary. It helps reduce complexities in the execution stage of the project and aids effective time management for the construction activities. Accordingly, loop B2 also shows a balancing impact on project complexity.

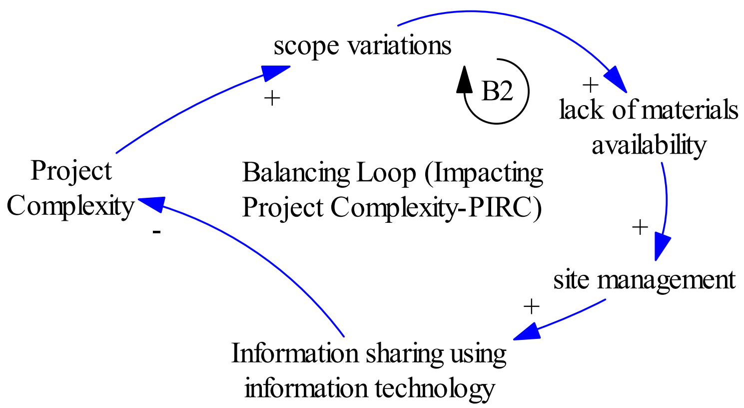

Figure 8. Impact on profitability risk category–complexity (balancing loop-B2).

4.8. Loop Analysis and Validation

The speed and degree of effect of system outputs provide thorough criteria for loop classification. This category serves as a filter, making it easier to prioritize important tasks. The following order is used to prioritize the influence of all loops in the CLD: fast–strong, fast–weak, slow–strong, and slow–weak, in line with the recent studies [65]. For each feedback loop, Table 5 summarizes the findings. Reinforcing loops have a long-lasting resonant effect, while balancing loops have a fading effect that shifts with time.

Table 5. Loop analyses results.

Loop ID	PIRC				Loop Prioritization		
	Cash Flow	Project Complexity	Supply Chain	Contingency	Speed of Influence	Strength of Influence	Nature of Influence
R1			√		Fast	Strong	Reinforcing
R2	√				Fast	Strong	Reinforcing
R3				√	Fast	Strong	Reinforcing
R4		√			Fast	Strong	Reinforcing
B1		√			Fast	Strong	Self-balancing
B2		√			Slow	Strong	Self-balancing

As loop R2 has such a powerful, quick, and reinforcing impact, it is deemed crucial in the current study. R1, R3, R4, B1, and B2, are less important loops. Before moving on to SD modeling and the conclusion of the research, the member-checking approach, also known as responder validation, was used to confirm the reliability of the data and validate the CLD [67]. The CLD was returned to the participants involved in the expert opinion session to verify whether the dependencies still hold. Accordingly, each participant interpreted the data. They confirmed the correlations as they saw them during the first interviews, adding to the findings' credibility.

4.9. System Dynamic Modeling and Simulations

The developed CLD was converted into a stock and flow diagram to predict the behavior of the variables within the system over time. The pictorial view of SD modeling is shown in Figure 9. Figure 9 includes key causative PIRFs and the PIRC in the developed construction profitability system. PIRCs, i.e., supply chain, cash flow, contingency, and project complexity, serve as the leading stocks in SD modeling. The price fluctuation acts as an exogenous variable, and is subjected to different input values. These values range from 0–100%, depending on the economic conditions faced by the construction projects. Many simulations were conducted to judge the impact on the PIRCs, due to the system integration and nonlinear dynamic relationships among the interdependent variables (PIRFs).

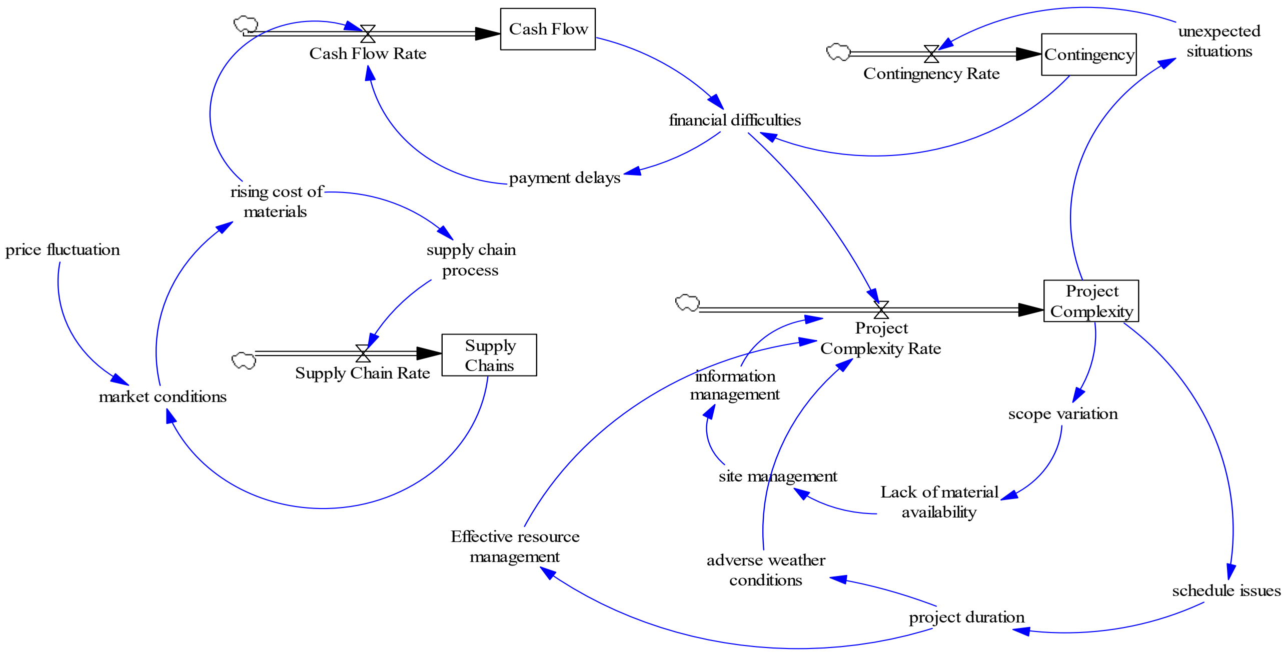

Figure 9. System dynamic modeling.

Vensim is used to conduct SD analyses. The inputs are in the form of stocks and flows using Euler's integration based on time steps: initial time and final time. It integrates the causal feedback links and loops. It creates time-based simulation results in the form of tables, graphs, and causes trees. The model uses trees, causes strip loops, and equations.

In this research, PIRCs are stocks, denoted by "C", and PIRFs are flows, denoted by "F". The governing equations, in terms of stocks and flows, are given in Equations (2)–(5).

$$\text{PIRC-C1} = (0.5 \times \text{F12} + 0.5 \times \text{F8}) \tag{2}$$

$$\text{PIRC-C2} = (0.5 \times \text{F14}) \tag{3}$$

$$\text{PIRC-C3} = (0.5 \times \text{F1} - \text{F5} + 0.5 \times \text{F2} - \text{F4}) \tag{4}$$

$$\text{PIRC-C4} = (0.5 \times \text{F6}) \tag{5}$$

where the pertinent variables include cash flow (C1), contingency (C2), project complexity (C3), and supply chain (C4) as various categories (PIRCs). The PIRFs include financial difficulties due to cash flow problems (F1), inclement weather conditions (F2), increase in project durations (F3), ineffective control of the manpower and equipment resources (F4), ineffective information sharing and use of information technology (F5), interrupted supply chain process (F6), lack of material availability (F7), payment issues (F8), planning and scheduling issues (F9), poor site management and supervision (F10), price fluctuations (F11), the rising cost of material due to market fluctuation (F12), scope variations and scope changes (F13), unexpected situations during project execution (F14), and fluctuations in market conditions (F15).

The simulation results presented in Figures 10–12 show that the causative influences of PIRFs are increasing functions. The value starts at zero, and rises exponentially over the course of a year to a maximum effect value. The causal feedback influence of other interdependent variables in the system causes this nonlinearity. Price changes of 10%, 50%, and 100% were used in the experiment (as extreme conditions).

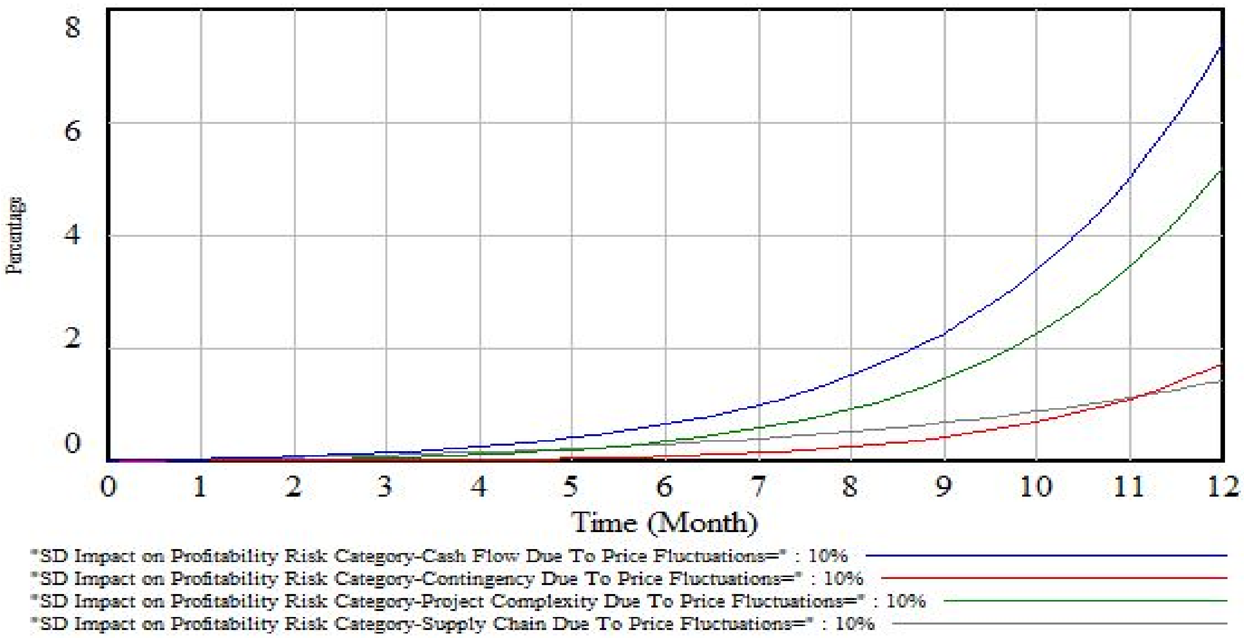

Figure 10. Dynamic integrated impacts on profitability risk categories over time (price fluctuations = 10%).

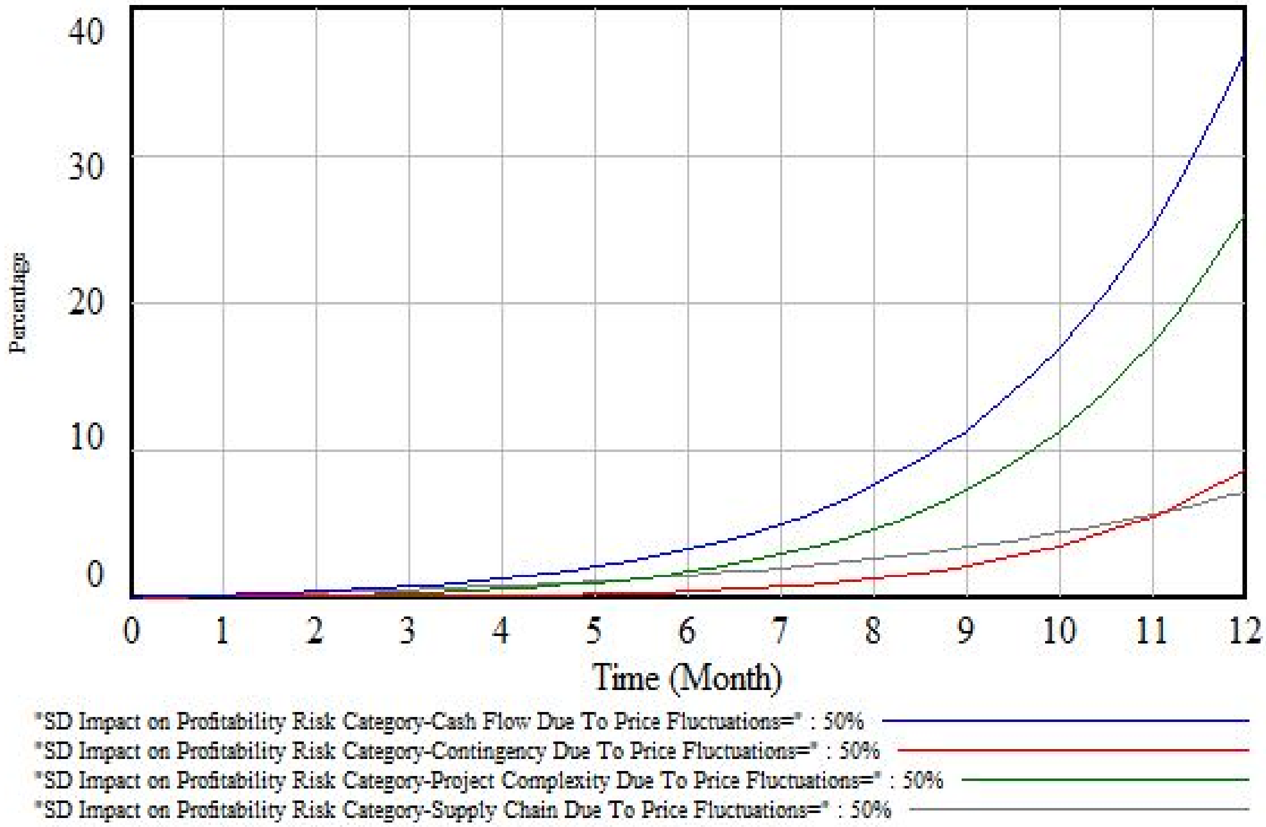

Figure 11. Dynamic integrated impacts on profitability risk categories over time (price fluctuations = 50%).

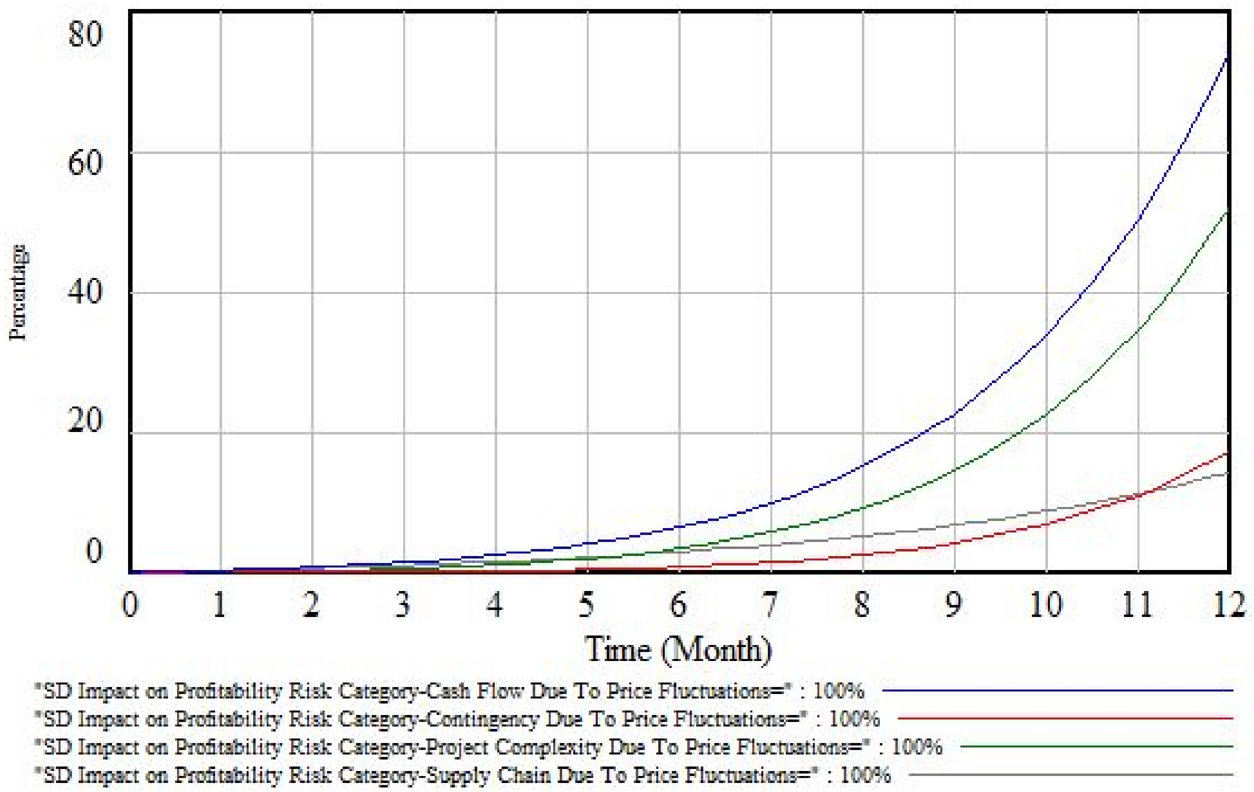

Figure 12. Dynamic integrated impacts on profitability risk categories over time (price fluctuations =100%).

The overall results concerned with SD integrated impacts on PIRCs are shown in Table 6. The maximum effects are observed for the category of cash flow (74.18%), followed by project complexity (52.26%), contingency (17.22%), and supply chain (14.21%).

Table 6. Results of system dynamic modeling and simulations.

S/n	Price Fluctuations Input Values (%)	System Dynamic Integrated Impacts on Profitability-Influencing Risk Category (PIRC)			
		Supply Chain (%)	Cash Flow (%)	Contingency (%)	Project Complexity (%)
1	10	1.42	7.42	1.73	5.23
2	25	3.55	18.55	4.30	13.06
3	50	7.11	37.09	8.61	26.13
4	75	10.66	55.64	12.91	39.20
5	100 extreme conditions	14.21	74.18	17.22	52.26

4.10. Discussion on SD Simulation

In continuation of SD simulation, it is observed that the link of PIRC–Cash Flow to financial difficulties is the most important. This is in line with other relevant studies [2,26]. The link is a key source of contractor's payment risks, and creates cash flow problems in construction projects during execution. The second important link observed is of PIRC–project complexity to unexpected situations. A similar relation is highlighted by Ortiz et al. [58]. The increase in project complexity leads to many unexpected situations during project execution. The published articles, as mentioned previously, only show qualitative impacts, and a holistic mixed assessment has yet to be reported. To address this, the current study describes causal impact in terms of qualitative and quantitative simulations and derives the relevant values. The first link, "cash flow-financial difficulties," has a simulation value of 6.8%, and the second link, "project complexity-unexpected situations," has a value of 2.9% over the period of 12 months, against the input of price fluctuations of 10%.

Similarly, the simulation values for 20% price fluctuations are 13.70% and 5.81%, respectively. In future studies, any effect in the system can be observed for any discrete period, and simulation results can be obtained and compared for specific data sets for all causal links using the developed SD model. Accordingly, all loops can be highlighted and explored to judge the causative qualitative and quantitative impact values of PIRFs and PIRCs for construction projects.

5. Conclusions

The current study's findings show that the rising cost of materials, supply chain issues, payment issues, planning and scheduling issues, financial difficulties, and ineffective control of manpower and equipment resources are the most critical PIRFs that have a causal impact on construction profitability. The interrelationships between these PIRFs, and the associated four PIRCs, are established through ST. These are iterated and quantified through SD modeling. A total of six causal feedback loops are developed here, in which four loops are reinforcing, i.e., R1 to R4, and two loops are balancing, i.e., B1 and B2. Overall, loop R2, dealing with the PIRC "cash flow," is considered critical because it has a strong, fast, and reinforcing influence. R1, R3, and R4 are the least important loops, followed by B1 and B2.

The quantification of the integrated influences of variables in causal feedback loops is achieved through the SD tool (Vensim). These are converted into stocks (PIRC) and flows (PIRF) diagrams. The SD integrated impacts of PIRFs on PIRCs follows the pattern of "cash flow (74.18%)," "project complexity (52.26%)," "contingency (17.22%)," and "supply chain (14.21%)".

ST helps managers grasp management difficulties, not through computations, but by deductions from the system's behavior. The quantitative information (impacts) of the variables in the system over a certain time period is explained by SD. However, it is important to remember that qualitative and quantitative models may only help with decision-making by enabling linkages and interdependencies to describe complicated system behavior. They advise field practitioners on particular project-related issues. In addition, the model must be combined with case-based, or expert, systems to provide real-time advice to the project team on issues that arise throughout construction projects.

This study helps field professionals learn about PIRFs, diagnose associated issues, and assess their impacts. This helps in decision-making and policy formulation based on the PIRFs and PIRCs' causal significance, reduces the dynamic effect of their integration, and enhances profitability in construction projects. This study is limited to causes only and does not consider the positive aspects (opportunities). In the future, the causal integration and interrelationships of PIRCs, i.e., supply chain, cash flow, contingency, and project complexity, can be explored. Exploring other categories, and their integration and the risks associated with these interdependencies, may be recognized, and a risk-based model can be developed as a future priority.

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