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The Application of System Dynamics in Claim Management of Hospital Projects: Scenario Analysis and Simulation

Reza Zandi Doulabi[1], Ehsan Asnaashari[2], Davood Sedaghat Shaygan[1], Aliasghar Amirkardoost[1]

Department of Civil Engineering, RO.C., Islamic Azad University, Roudehen, Iran[1]
School of Architecture Design and the Built Environment, Nottingham Trent University, Nottingham, UK[2]

Abstract

This paper explores the use of system dynamics in claim management for hospital projects, which face challenges like delays, design changes, financial issues, and legal disputes. Eight scenarios, including delays in manpower, legal disputes, environmental claims, and frequent design changes, are simulated. Results show how changes in one factor can trigger cascading effects on others. Reduced funding and quality increase claims and delays, while improved quality and resource management reduce them. System dynamics is a valuable tool for predicting problems and improving decision-making, particularly in complex hospital projects.

Keywords: System Dynamics, Claim Management, Hospital Projects, Project Delays, Simulation.

1. Introduction

Hospital construction projects, due to their inherent complexities, specific technical requirements, and high healthcare standards, constantly face numerous challenges. These projects demand particularly high levels of precision in planning, scheduling, and budgeting. In Iran, despite having 1,100 hospitals and 160,000 active beds, there remains a significant demand for more healthcare infrastructure. To address this need, over 270 hospital projects are currently under development, aimed at adding 40,000 new hospital beds to the healthcare system. This large volume of projects requires professional and meticulous management, as frequent design changes, project execution issues, and financial constraints can lead to contractor claims, the proper management of which plays a crucial role in the success of these projects. Contractor claims in hospital projects typically arise from sudden design changes, execution delays, and funding shortages. These claims not only impose additional costs on the projects but also severely impact project timelines. Given the time-sensitive and quality-driven nature of hospital projects, any change or delay can adversely affect the quality of the final healthcare services. For example, studies indicate that inefficient claim management can lead to significant cost overruns and delays in hospital project delivery (Ardestani & Ramesht, 2023). These conditions not only reduce the efficiency of the projects but also exert substantial pressure on financial and human resources. In such circumstances, effective claim management can not only help reduce additional costs but also prevent unnecessary delays and enhance project productivity (Yazdanpanah Lamuki & Fallahian, n.d.). In hospital projects, which are impacted by technical and organizational complexities, utilizing modern claim management methods is crucial. Among these methods, system dynamics (SD) has emerged as a powerful tool for modelling and analysing complex processes, and it can play a key role in claim management. This method allows project managers to simulate the interactions among various project factors and identify feedback loops, enabling them to uncover the root causes of claims and make better decisions (Khanzadi & Pakizeh, 2024), (Zandi et al., 2024a, b).

System dynamics, by providing accurate models of project behaviour under various conditions, can help identify and analyze the causal relationships leading to claims. This method proves to be especially useful in hospital projects, which experience frequent changes and complex requirements, offering a robust tool to improve claim

management. By using this method, project managers can mitigate risks, reduce delays, and avoid additional costs (Seyed Ebrahimi & Kasnavi, 2023). Ultimately, given that hospital projects in Iran face significant challenges such as design changes, delays, and budgetary constraints, the use of system dynamics can be an effective approach to managing and controlling claims. This paper aims to provide solutions for improving the performance of hospital projects through modern claim management techniques and the application of system dynamics, ultimately achieving cost reductions, improved scheduling, and increased productivity (Ardestani & Ramesht, 2023).

2. Literature Review

In reviewing the literature, attention to previous studies and their findings is crucial for a better understanding of scientific topics. Research related to claim management in construction projects has always been a focus for researchers due to the complexities involved in these projects. Various studies have examined the causes of claims, their impact on project scheduling and costs, as well as management strategies to mitigate their negative effects. Notably, research has shown that effective risk management, contract administration, and delay analysis play key roles in reducing the number of claims and improving project performance. In recent years, modern technologies such as Building Information Modelling (BIM) and advanced project management systems have emerged as effective tools for claim management. This section reviews previous studies in the area of contractor claims and the role of technologies and management methods in optimizing these processes. International collaboration networks between countries are a key aspect of scientific research, as reflected in co-occurrence maps of different nations. These maps show the extent and breadth of scientific collaborations across various research fields. In the presented map, the United States and the People's Republic of China stand out as two central countries in the international scientific collaboration network. The large size of these countries represents the high number of international collaborations they engage in (Web of Science, 2024). The United States, as one of the largest nodes on this map, collaborates with a wide range of countries, including Canada, Germany, the United Kingdom, France, and many others. This highlights the pivotal role of the U.S. in knowledge production and the co-publication of scientific papers with other nations. The thick lines between the U.S. and other countries indicate the high number of collaborations and the large volume of jointly published scientific papers. These collaborations occur in various scientific fields, including management, engineering, medical sciences, and other disciplines. In contrast, China has also emerged as one of the key players in the global scientific network. The country has extensive collaborations with nations such as Iran, Australia, Malaysia, Indonesia, and India. These widespread scientific connections have turned China into one of the main contributors to global knowledge production. The thick lines between China and these countries indicate the strong scientific interactions China maintains with many Asian and Oceania nations. Another important country on this map is the United Kingdom, which plays a pivotal role in international scientific collaborations. The U.K. has significant scientific partnerships with countries such as Germany, France, the Netherlands, and Scotland. Known as a major hub for scientific and research activities, the U.K. conducts a substantial amount of international research with various nations.

Additionally, countries like Germany, Australia, France, and Canada are also prominent nodes in this scientific collaboration network. These nations play a vital role in international scientific collaborations due to their strong research infrastructures and focus on global research initiatives. For example, Germany not only collaborates with other European countries but also maintains extensive scientific partnerships with the U.S. and Canada. One interesting observation from this map is the wide-ranging scientific collaboration between Asian countries such as Iran and China. Iran, in particular, has notable scientific interactions with countries such as China, Malaysia, and Indonesia, reflecting the scientific and research growth of these nations on the global stage. Countries like Canada, Australia, and Germany also maintain extensive scientific collaborations with Asian countries, underscoring their commitment to advancing international research. This map also effectively illustrates the scientific interactions between different countries. The nations are grouped into distinct clusters, which highlight the focus of scientific collaborations among specific groups of countries. For example, the cluster that includes the U.S., Canada, and European countries indicates that these nations frequently collaborate on numerous projects and scientific publications. The cluster of China and other Asian countries also shows that scientific collaborations in this region are more internal and regional. These international scientific collaboration networks are vital for

global knowledge production. Through such interactions and partnerships, countries can leverage each other's resources and expertise to accelerate their scientific growth. Leading countries in these collaboration networks typically have strong research and scientific infrastructures, and these partnerships often result in higher-quality research and the development of scientific innovations. Ultimately, this map of international scientific collaborations clearly illustrates how different nations contribute to global knowledge production and play significant roles in advancing international research. The larger, more prominent countries tend to play a more central role in these interactions, contributing to scientific growth and development through their extensive collaborations with other countries.

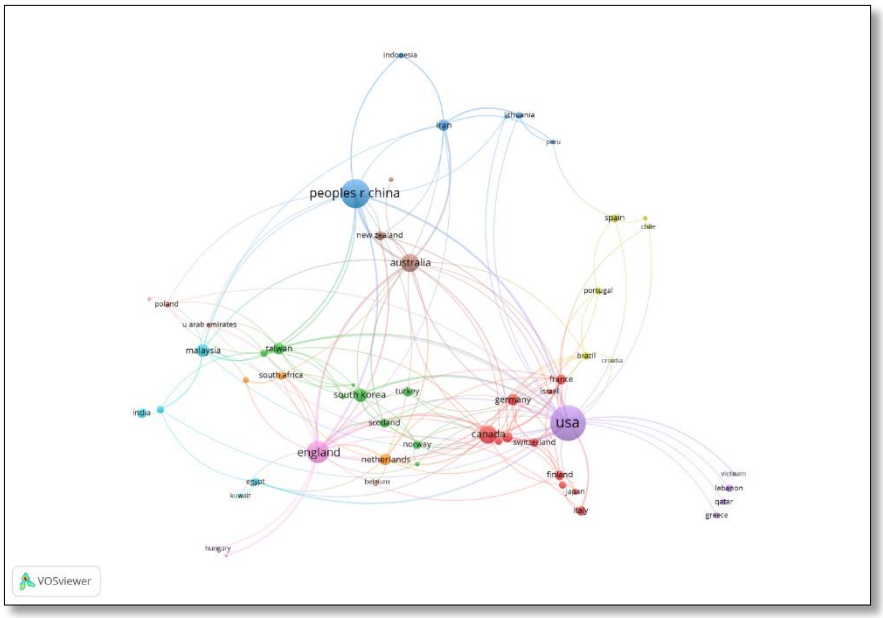

Figure 1: Researcher Countries (Web of Science, 2024)

The keyword map, generated using VOSviewer software, illustrates the co-occurrence and connections between different keywords in a specific research field. This map demonstrates how various scientific topics are related to one another and used together in academic papers. In this map, Management is positioned as the central keyword, having the highest number of connections with other topics. The large size of this node signifies the high number of papers that utilize this keyword. Management, especially in the context of construction projects, risk management, and information systems, holds significant importance.

Other key terms, such as Claims and Construction Projects, are also highlighted as crucial topics on this map. Claims in construction projects are linked to topics such as risk management, delay analysis, and contract management. These issues commonly arise due to changes in project design and execution, as well as financial difficulties and the delays caused by them. The analysis and management of claims, particularly in large-scale construction projects, are critical for preventing delays and additional costs.

The keyword map is divided into various clusters, each represented by a different color. These clusters indicate groups of keywords that are frequently used together in research papers. The green cluster focuses on topics related to claims and risk management in construction projects. This cluster underscores the fact that managing claims and risks is one of the heavily researched areas in this field. In contrast, the red cluster deals with topics related to Politics, Identity, and Governance, which point to the political and managerial aspects of projects and organizations.

The blue cluster addresses issues related to Health and Safety in workplace environments and projects, highlighting that these subjects are also significant in construction project management. The lines connecting the

nodes or keywords represent their co-occurrence or simultaneous use in scientific papers. The thickness of these lines indicates the frequency of their joint appearance. The thick line between Claims and Construction Projects shows that these two concepts are frequently used together in research papers, highlighting the importance of claims in construction projects. Additionally, the lines between different color clusters reflect the interaction and overlap between various topics.

The interaction between the green and red clusters might indicate a connection between project management and policies in the management of large projects. The keyword map plays a significant role in analyzing research trends and identifying key and frequently discussed areas of research. Such maps help researchers identify critical and debated topics and analyze research trends. For instance, observing a cluster like BIM (Building Information Modeling) or Artificial Intelligence signifies the growing interest in new technologies in project management. Moreover, these maps can highlight research gaps and deficiencies; if keywords related to a particular topic appear infrequently or have weak connections with other subjects, it may indicate the need for further research in that area.

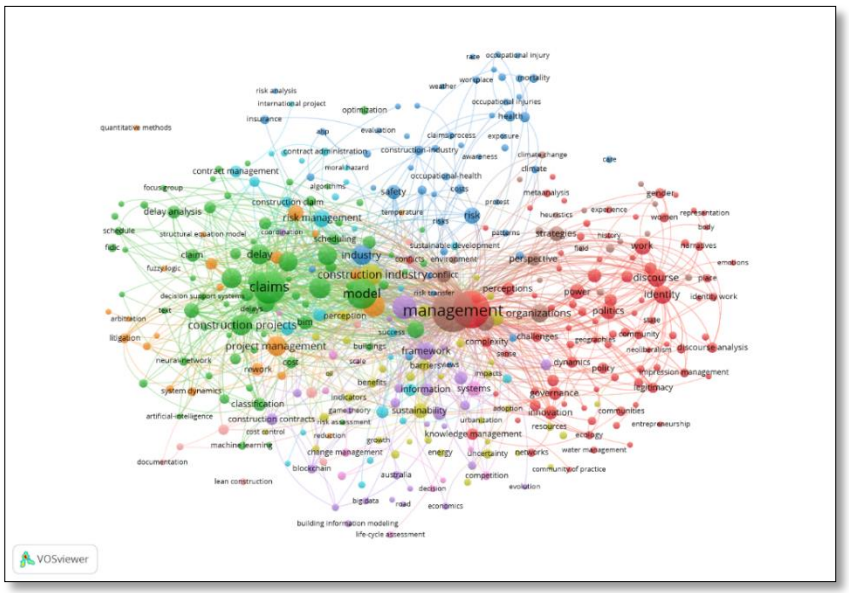

Figure 2: Keyword Map (Web of Science, 2024)

3. Research Methodology

This research methodology employs unstructured interviews and system dynamics as the primary tools for data collection and analysis. It is specifically designed to better understand and examine claims in construction projects.

Unstructured Interviews

Objective: The aim of these interviews is to gather qualitative data from construction project stakeholders (contractors, project managers, legal consultants, and other stakeholders) regarding the challenges of claims, their root causes, and how they are managed.

Method: In unstructured interviews, open-ended questions are used to allow interviewees to freely share their experiences and perspectives on various topics. This approach enables the researcher to explore the hidden and more complex aspects of claims and their management.

Data Analysis: The data gathered from the interviews will be qualitatively analyzed to identify patterns, recurring themes, and the root causes of claims in projects. This unstructured data will serve as input for the modeling phase that follows.

System Dynamics

Objective: The purpose of using system dynamics is to model and simulate the interactions between various factors that contribute to the occurrence and management of claims in construction projects.

Method: After collecting qualitative data from the interviews, key factors and the causal relationships between them will be identified using the system dynamics approach. A dynamic model will then be developed, simulating the relationships and feedback loops between various factors (such as delays, contract changes, risks, etc.).

Data Analysis: This model will help project managers simulate different scenarios and predict the impact of their decisions on the occurrence or reduction of claims. Furthermore, the system dynamics model will provide optimized solutions for better claim management and risk reduction.

This research methodology, by combining unstructured interviews and system dynamics modeling, provides a deeper understanding of issues related to claims in construction projects. The interviews help uncover the perspectives and experiences of stakeholders, while system dynamics modeling offers a more comprehensive analysis of the complex relationships between various factors and proposes improvements in claim management practices.

4. Data Collection and Analysis

Claims in hospital construction projects refer to specific compensation requests made by contractors or other stakeholders due to changes, delays, or unforeseen circumstances. Given the high complexity, technical requirements, and direct impact on healthcare services, hospital projects are more prone to contractor claims than other types of construction projects. The most significant claims in hospital projects are:

Delay-Related Claims

Claims Related to Scheduling and Timelines

Scope Change Claims

Contractual Change Claims

Unforeseen Condition Claims

Claims Related to Quality and Standards

Resource Supply Claims

Claims Related to Funding Delays

Contractual Dispute Claims

Medical Equipment Supply Claims

Site Access Claims

Safety and Health Claims

Environmental Claims

Technology and Innovation Claims

Subcontractor Contract Claims

Social and Cultural Claims

Energy and Infrastructure Supply Claims

To use system dynamics in the analysis of claims in hospital projects, we must first identify the key elements of the system and then visualize the relationships between them in the form of causal and feedback models. System dynamics helps us understand the interactions between various factors and how changes in one part of the system can affect the entire project.

Defining Key Elements and Variables in System Dynamics

In system dynamics for claim management and hospital projects, the key elements that play a crucial role in modeling and simulating the system's behaviour include various factors that interact with one another. In each scenario, these key elements experience changes that affect the final outcomes of the project, such as time, cost, quality, and claims. Below are the main key elements in the system dynamics for hospital projects:

1. **Budget**
   The budget plays a critical role in determining the availability of resources for the project. Delays in budget allocation or budget cuts directly affect the quality, delays, and number of claims.
   Budget reductions usually occur due to financial issues, legal disputes, or poor management decisions.
2. **Project Scope**
   The project scope defines the extent and volume of work and required changes. Frequent changes in project scope (such as design changes) lead to increased complexity and claims.
   Changes in scope also increase costs and impact the project schedule.
3. **Quality**
   Project execution quality is a key factor in determining the project's success. Reducing quality due to cheaper resources or budget cuts can increase the number of claims and the need for compensation due to poor quality.
   Quality is particularly critical in hospital projects, where high medical and health standards must be met.
4. **Claims**
   Claims are one of the most important outcomes of the complex interactions in the system. Claims arise from factors such as delays, changes in scope, poor quality, and contractual disputes.
   An increase in claims often leads to higher project costs and delays in final delivery.
5. **Delays**
   Delays are the direct result of various problems, such as budget delays, lack of human resources, scope changes, and poor quality. Increased delays often lead to higher costs and more claims.
   Delays are particularly critical in hospital projects as any delay in completion can directly impact the provision of healthcare services.
6. **Human Resources and Materials**
   Shortages in skilled labor or technical resources are key factors that can lead to delays and reduced project quality. A lack of access to skilled workers or technical resources increases operational challenges and claims.
   Timely procurement of resources also affects other factors, such as quality and delays.
7. **Risks and Unforeseen Conditions**
   Unanticipated risks or conditions, such as weather problems, infrastructure issues, and delays in raw material supply, can increase claims and delays.
   Risk management is essential in hospital projects due to their complexity.
8. **Legal and Contractual Disputes**
   Legal and contractual disputes are critical factors that can increase claims, delays, and project costs. These disputes often arise from differing interpretations of contract terms or a lack of coordination between project parties.
9. **Health and Medical Standards**
   In hospital projects, adhering to health and medical standards is of utmost importance. Any change or failure to meet these standards can lead to claims and delays.
   Healthcare requirements for medical equipment and hospital structures add to the complexity of the project.
10. **Equipment Supply**
    Timely equipment delivery is crucial. Any delay in delivering equipment or using non-compliant equipment can increase claims and delays.
11. **Design Changes**
    Changes in design or project scope are one of the main reasons for claims and delays. These changes

typically arise from new client needs, changes in health standards, or altered environmental conditions in the project.

Causal and Feedback Loops

Causal relationships and feedback loops are fundamental principles in system dynamics modeling. These relationships explain how variables interact with each other and how changes in one variable can affect others. Feedback loops can be positive or negative and play a decisive role in the system's dynamics. Causal relationships refer to the direct impact of one variable on others. In hospital projects, these relationships clearly demonstrate the influence of variables like budget, scheduling, and quality on claims and delays.

- Budget → Quality: A reduction in budget leads to the use of cheaper materials and a decline in quality.
- Quality → Claims: A decline in quality increases claims, as contractors seek compensation for defects.
- Design Changes → Claims: Any changes in design lead to changes in project scope, resulting in an increase in claims.
- Claims → Project Delays: An increase in claims extends the time needed for review and resolution, leading to project delays.

Feedback Loops

Feedback loops can be either positive or negative and are crucial in system dynamics. These loops can create reinforcing or balancing processes within the system.

a. Positive Feedback Loop

In positive feedback loops, a change in one variable reinforces that change over time. These loops typically lead to exponential growth or increased problems.

- Project Delays → Increased Claims → More Delays: Delays in the project lead to more claims, and the review of these claims causes further delays. This positive feedback loop continuously amplifies the issues and delays.

b. Negative Feedback Loop

Negative feedback loops occur when a change in the system triggers a process that neutralizes or mitigates that change. These loops promote system stability or moderation.

- Increased Quality → Fewer Claims → Reduced Delays: If project quality improves, the number of claims decreases, which in turn reduces delays and costs. This is a negative feedback loop that leads to project improvement and stability.

Specific Examples of Feedback Loops in Hospital Projects

a. Positive Feedback Loop: Reduced Quality and Increased Claims

- Budget Cuts → Reduced Quality → Increased Claims → Higher Project Costs → Further Budget Cuts
  This positive feedback loop illustrates the reciprocal effects of budget cuts and quality, leading to increased claims and ultimately higher project costs. This self-reinforcing process can create significant problems for the project.

b. Negative Feedback Loop: Improved Quality and Reduced Delays

- Improved Execution Quality → Fewer Claims → Less Time Spent on Claims → Reduced Delays
  In this negative feedback loop, improved quality leads to fewer claims, better project timing, and greater stability.

c. Positive Feedback Loop: Frequent Design Changes

- Design Changes → Increased Project Scope → More Claims → More Delays → Higher Costs → Need for Further Design Changes
  This positive feedback loop shows how frequent design changes increase project scope, resulting in more claims, delays, and higher costs, which in turn necessitate further design changes.

Challenges in Managing Claims and Delays from a System Dynamics Perspective

In claim management, the primary challenges stem from these feedback loops. Any change or decision within the project can create a chain reaction of new issues. Therefore, in system dynamics modeling, the goal is to identify these feedback relationships and manage their effects to improve project performance. Causal and feedback loops help us better understand the complexity of the project and identify the interactions between different variables. In hospital projects, these relationships are particularly important in managing the budget, quality, scheduling, and claims.

This Causal Loop Diagram (CLD) of a hospital project illustrates how key variables like budget, quality, claims, delays, and project scope interact with one another:

- Budget affects quality: A reduced budget can lead to lower project quality.
- Quality affects claims: A decline in quality increases the number of claims.
- Claims lead to project delays: An increase in claims causes delays in project completion.
- Delays increase claims: This is a positive feedback loop that leads to more claims and further delays.
- Changes in project scope increase claims and delays.

This diagram effectively illustrates the feedback relationships between variables, helping to better understand their interconnections and impacts on project outcomes.

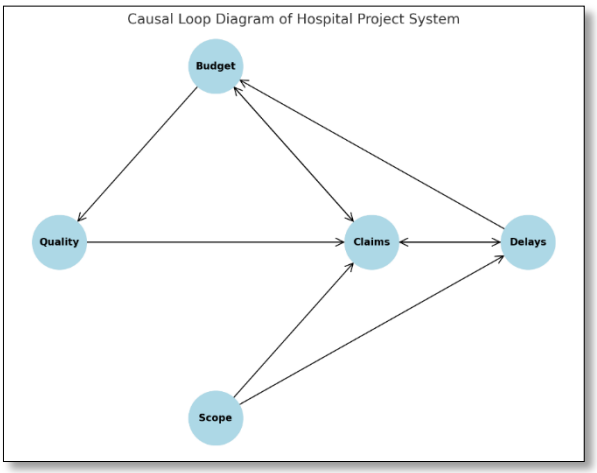

Figure 3: Causal Loop Diagram (Feedback Loops)

Positive Feedback Loop: Delays, Claims, and Budget

In this loop, increased delays lead to an increase in claims. These claims place pressure on the project budget, which ultimately results in a decline in quality. The decline in quality, in turn, leads to more claims, and the cycle continues. This positive feedback loop amplifies the problems and complexities of the project, leading to further escalation of issues.

Negative Feedback Loop: Quality Improvement and Claim Reduction

In this loop, improved quality leads to a reduction in claims. As claims decrease, delays also diminish, which helps improve budget control. Better budget control subsequently leads to enhanced quality, contributing to greater project stability. This negative feedback loop helps stabilize the system and fosters improvement.

These diagrams clearly illustrate how interactions between variables can generate different behaviors within the system.

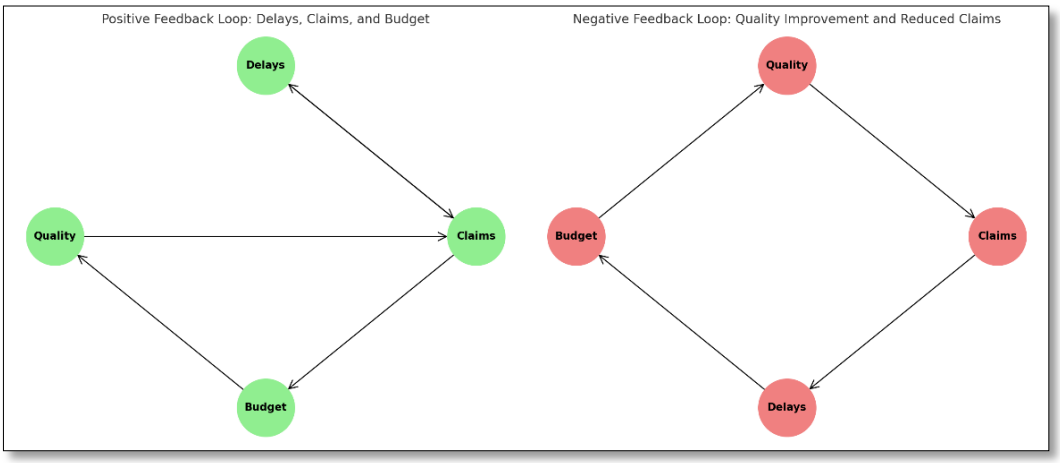

Figure 4: Diagrams of Positive and Negative Feedback Loops

5. Scenarios

Scenario 1: Delays in Budget Allocation

Simulation of the impact of delayed project financing on contractor claims and execution quality.

- Budget: In this scenario, the budget decreased at a higher rate (5% monthly delay), leading to a faster budget depletion over time.
- Project Scope: The project scope increased steadily.
- Quality: Over time, quality decreased, but not as severely as in other scenarios, as scope changes had a more direct impact on quality.
- Claims: Claims increased due to scope changes and budget delays.
- Project Delays: Delays grew continuously as more claims added to financial pressures.

Scenario 2: Improving Execution Quality

Simulation of the impact of improved material quality and project execution on reducing claims and delays.

- Budget: In this scenario, the budget decreased at a conventional rate, but changes in quality reduced the negative effects of the budget on other variables.
- Project Scope: The scope increased at a specified rate, but better-quality control mitigated the impact of scope on other factors.
- Quality: Quality continuously improved or remained stable, leading to fewer claims and associated issues.
- Claims: Claims were significantly fewer compared to the other scenarios.
- Project Delays: Higher quality and fewer claims resulted in minimal project delays.

Scenario 3: Frequent Changes in Project Scope

Simulation of the effects of frequent design changes and increased overall project costs.

- Budget: The budget decreased, but the project scope increased rapidly.
- Project Scope: Rapid increases in scope put more pressure on the budget and quality.
- Quality: Quality deteriorated quickly due to increased scope changes.
- Claims: Claims rose significantly due to frequent scope changes and quality issues.
- Project Delays: This scenario produced the most project delays, as scope changes and increased claims extended the project timeline.

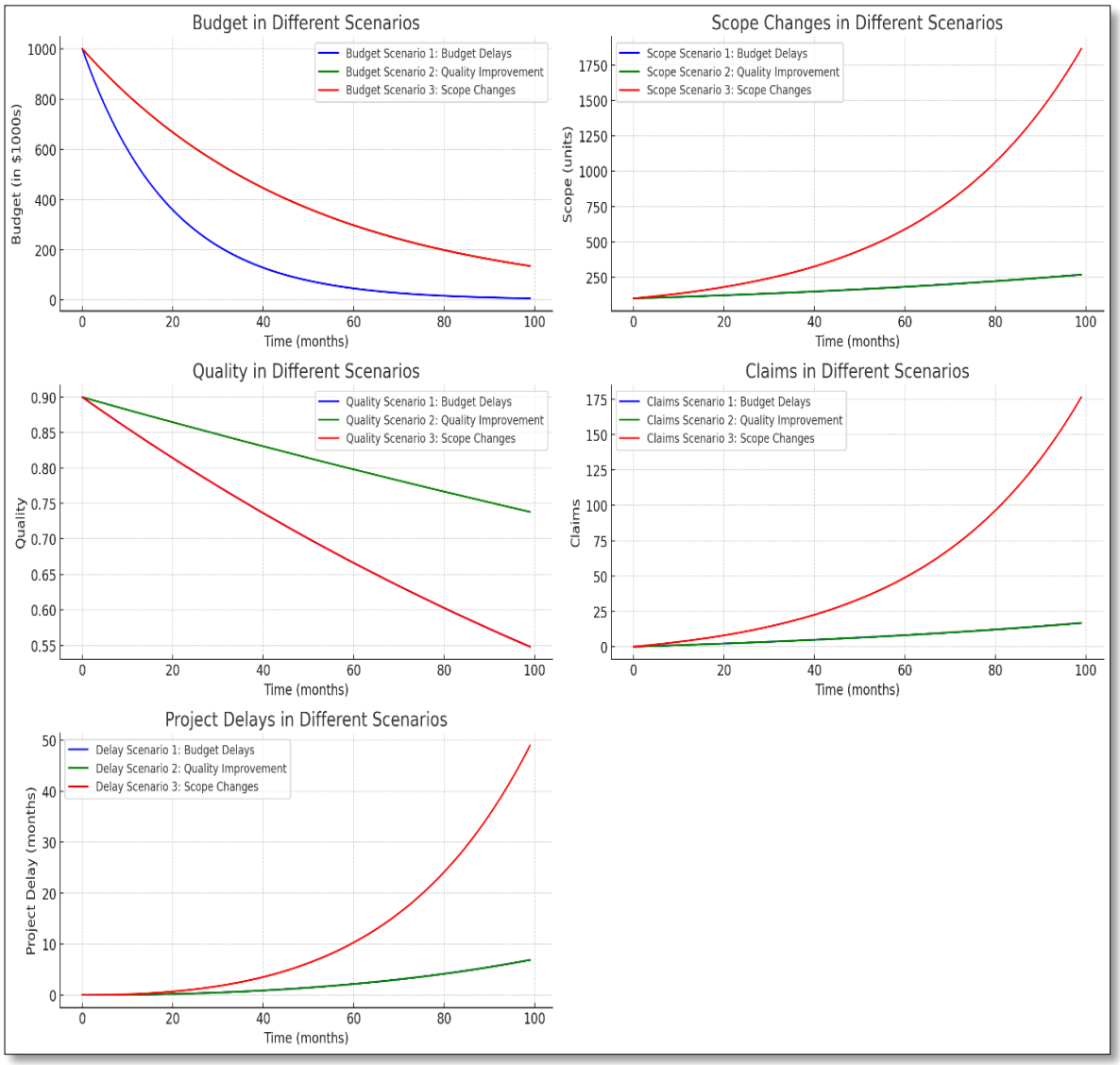

Figure 5: Simulation of Scenarios1-3

Scenario 4: Delays in Resource and Workforce Supply

A hospital project faces significant delays in securing skilled labour and key resources (such as construction materials). Due to labour shortages and supply chain issues, contractors cannot complete the work on time.

- Budget: Gradual budget reductions occurred due to delays in resource allocation.
- Project Scope: The project scope steadily increased due to new needs and changes.
- Quality: Over time, execution quality declined, reflecting the impacts of labor and resource delays.
- Claims and Project Delays: Claims steadily increased, and with each new claim, project delays escalated.

This scenario shows that delays in resource and workforce supply lead to budget reductions, increased claims, lower quality, and extended project timelines.

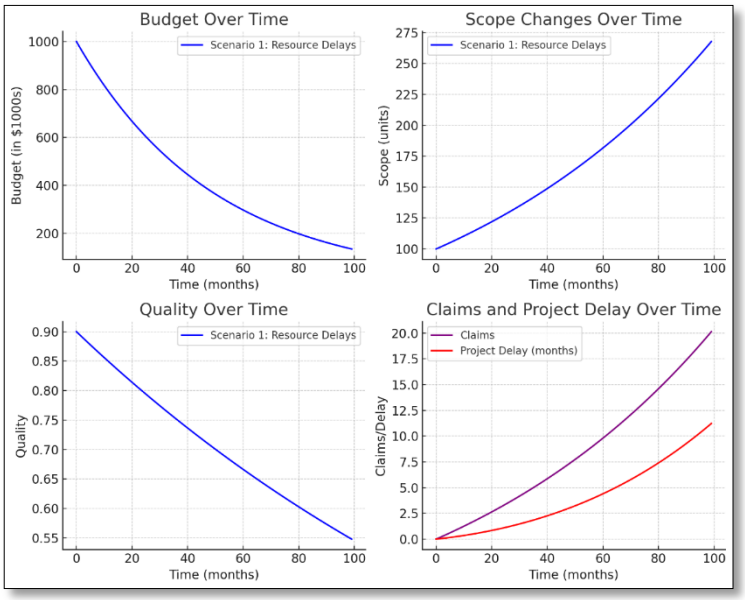

Figure 6: Simulation of Scenario 4

Scenario 5: Increase in Legal and Contractual Claims

Due to ambiguous contract terms and disputes over responsibilities and payments, the project faces a high volume of legal claims. These claims result in complex disputes between contractors and the client.

- Budget: The budget decreased over time, reflecting the impacts of budget delays and rising legal costs.
- Project Scope: The project scope increased steadily due to changes in contracts and new project requirements.
- Quality: Project quality declined due to legal issues and contractual disputes.
- Claims and Project Delays: Legal disputes significantly increased claims, and as claims grew, project delays worsened.

This simulation shows that legal and contractual disputes can reduce quality, increase claims, and cause significant project delays.

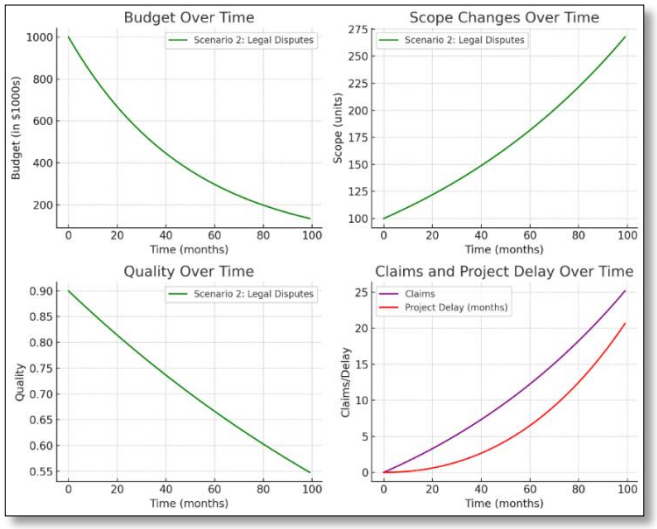

Figure 7: Simulation of Scenario 5

Scenario 6: Environmental and Social Impacts

A hospital project is located in an area with high environmental and social sensitivities. Local protests, environmental issues, and impacts on the surroundings lead to claims and project suspensions.

- Budget: Gradual budget reductions occurred due to delays caused by environmental and social issues.
- Project Scope: The project scope continuously expanded due to changes driven by social protests and environmental requirements.
- Quality: Project quality declined over time, reflecting the challenges of aligning with environmental and social regulations.
- Claims and Project Delays: A significant increase in claims due to social and environmental issues was observed, and as claims rose, project delays also increased.
  This simulation shows that social and environmental issues can lead to delays, increased claims, and reduced project quality.

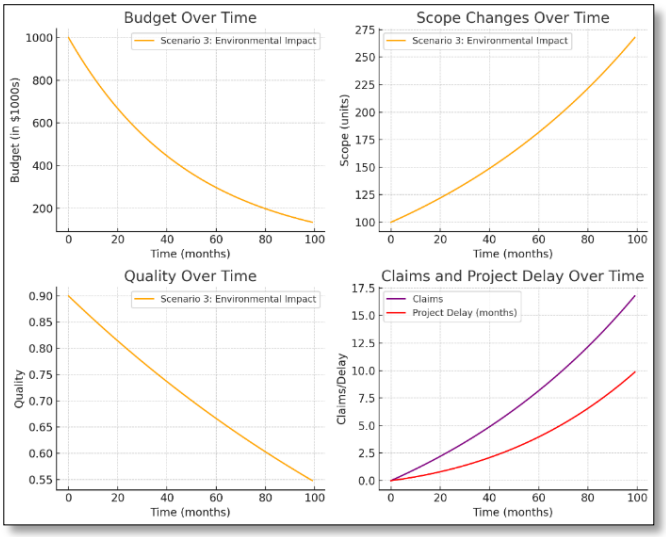

Figure 8: Simulation of Scenario 6

Scenario 7: Financial Challenges and Quality Reduction

A hospital project faces severe financial challenges, and sufficient funding is not provided on time. These financial problems result in poor execution quality and repeated project delays.

- Budget: Gradual budget reductions were observed due to financial difficulties and delayed resource allocation.
- Project Scope: The project scope steadily expanded due to new needs and changes.
- Quality: Project quality significantly declined due to the use of cheaper materials and reduced execution quality caused by financial constraints. Claims and Project Delays: Increased claims due to poor quality and the need for compensation led to more project delays.

This simulation shows that financial constraints and quality reduction directly contribute to increased claims and project delays.

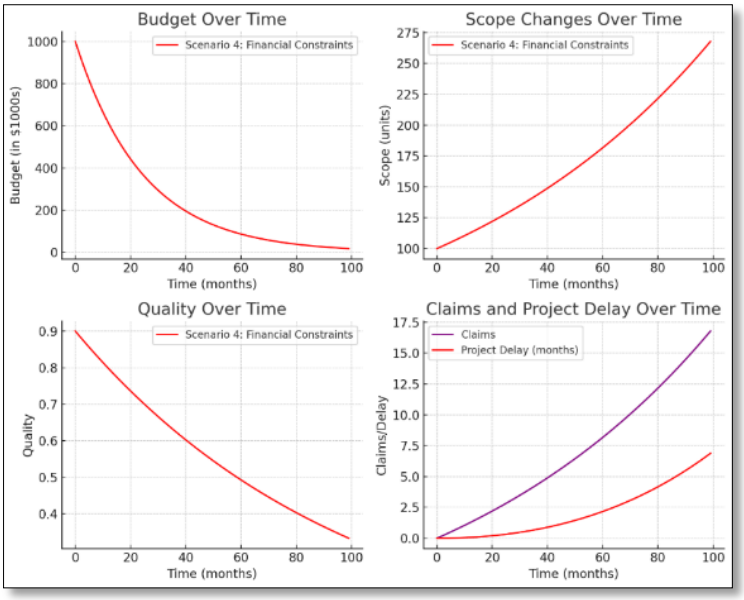

Figure 9: Simulation of Scenario 7

Scenario 8: Frequent Design Changes and Client Requirements

The client demands frequent design changes due to updated health standards or new requirements. These changes lead to increased project time and costs.

- Budget: Gradual budget reductions occurred due to delays caused by frequent design changes.
- Project Scope: The project scope significantly expanded due to ongoing design changes and new needs.
- Quality: Project quality deteriorated due to continuous changes, as these modifications often led to greater complexity and less focus on quality details.
- Claims and Project Delays: Increased claims due to frequent design changes and the need to adapt to new conditions resulted in more project delays.
  This simulation shows that frequent design changes can lead to increased claims, reduced quality, and project delays.

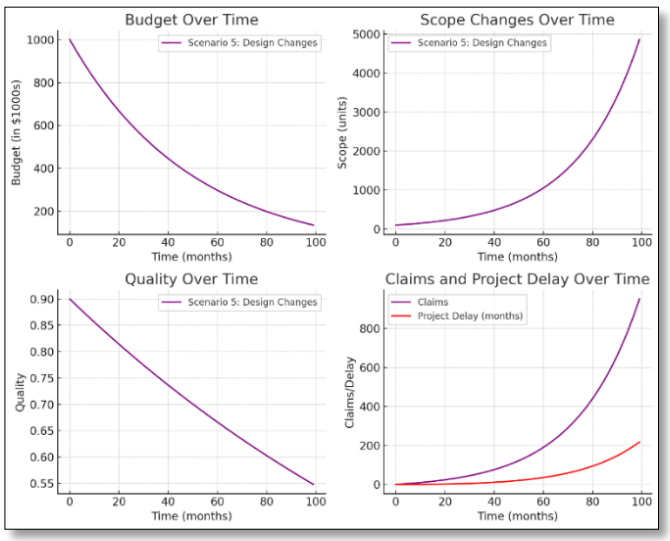

Figure 10: Simulation of Scenarios 8

6. Discussion

The analysis of various scenarios in hospital projects using the system dynamics approach revealed that these projects, due to their inherent complexity and interdependencies between various factors, face numerous challenges. In all scenarios, it became clear that the interactions among budget, quality, delays, claims, project scope, and workforce are such that any change in one of these factors sets off a chain reaction that affects the others. System dynamics enabled the simulation and prediction of these complex system behaviors, allowing for clearer visualization of the impacts of management decisions. One of the most significant findings was the undeniable and direct influence of the budget on overall project performance. In scenarios where budget cuts occurred due to financial problems or contractual disputes, it was observed that these reductions led to lower execution quality and reliance on cheaper resources. This drop in quality, in turn, directly increased the number of claims and project delays. Furthermore, claims emerged as one of the direct outcomes of the complex system interactions, playing a crucial role in increasing project costs and extending schedules. In other words, claims are not only the result of issues such as delays or poor quality but can also act as a negative feedback factor, exacerbating project conditions and leading to further delays and increased costs. Changes in project scope also appeared in most scenarios as a fundamental factor in increasing claims and delays. Frequent changes in design or project requirements, often driven by new client needs or updates to health standards, expanded the project workload and consequently led to a rise in the number of claims. These changes prompted contractors to file more compensation requests for additional costs or lost time, ultimately resulting in higher expenses and extended project timelines. Moreover, human resources and material availability played a critical role in the success or failure of hospital projects. A shortage of skilled labor or delays in securing key resources led to reduced productivity and extended project execution times. This was particularly evident in the scenario involving workforce and resource delays, where a lack of access to skilled labor and essential equipment resulted in increased delays and claims. Legal and contractual disputes were also identified as a key factor contributing to increased claims and delays in several scenarios. When contracts were poorly drafted or there were differing interpretations of contract clauses, disputes between the client and contractors led to legal claims. These claims not only drove up legal costs but could also halt project progress and cause further delays. In scenarios involving environmental and social issues, external pressures such as local protests or environmental challenges resulted in project suspensions and increased claims. This was especially significant in regions with high social and environmental sensitivities. In these cases, poor management of such issues could have severe negative impacts on project timelines and costs. Ultimately, system dynamics proved to be an effective analytical tool, demonstrating how small changes in one part of the system could have larger impacts on other areas. Therefore, management decisions in hospital projects must be made with a comprehensive understanding of these interdependencies and feedback loops to achieve optimal and predictable outcomes. Using system dynamics simulations allows project managers to foresee the effects of various decisions before facing real-world problems, helping to prevent larger issues from arising.

7. Conclusion and Recommendations

unique challenges such as workforce delays, legal disputes, environmental issues, financial constraints, and frequent design changes. The analysis of these scenarios demonstrated that hospital projects are highly sensitive to changes and fluctuations due to their inherent complexities and the interdependencies among various factors. Utilizing the system dynamics approach allowed for a more precise simulation of these complex interactions and facilitated the prediction of system behavior over time.

The findings revealed that each key variable—such as budget, quality, claims, and delays—affects others in a feedback loop manner. Positive feedback loops, like increased delays leading to more claims and subsequently causing further delays, represent significant challenges in managing hospital projects. Conversely, negative feedback loops, such as improving quality resulting in fewer claims and better scheduling, were identified as potential solutions for project enhancement.

The overall conclusion from this analysis indicates that employing system dynamics can play a crucial role in improving the management of hospital projects. This method enables:

Predicting Potential Problems: System dynamics allows for the simulation of various scenarios before encountering real issues, enabling the assessment of different decisions' impacts on the project. This proactive approach can prevent major crises from occurring.

Better Resource and Budget Management: Through system dynamics analysis, the effects of delays or budget changes on other parts of the project can be predicted, leading to more effective resource allocation. This facilitates the optimization of resource utilization and budget control.

Reducing Claims and Delays: Simulating negative feedback loops showed that enhancing execution quality and minimizing changes in project scope can decrease the number of claims, thereby reducing delays. This not only lowers additional project costs but also accelerates project completion.

Improving Decision-Making: System dynamics provides managers with a better understanding of the interactions and causal relationships among variables, enabling more informed decisions and preventing negative and unintended consequences.

Overall, the system dynamics approach offers a comprehensive view of complex systems, enhancing decision-making processes and project management. In hospital projects—which face numerous challenges due to high standards and reliance on financial and human resources—this method can fundamentally increase efficiency, reduce costs, and improve scheduling. By implementing this approach, projects can achieve better outcomes and avoid problems that often lead to failure or delays in construction and civil engineering projects.

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