On Considering a PLM Platform for Design Change Management in Construction

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Abstract. Design change (DC) which refers to any type of design or construction modification made once a contract is awarded is an important issue in today's construction. DCs usually would lead to an increase in the cost and time overrun of the project. It is thus important to manage them by using an effective management process. Various design change management processes (DCM) have been proposed by different research studies as well as different DCM processes are used in practice (real world). In addition, IT tools have an important role in the DCM process that could provide various functionalities to facilitate the DCM process. However, according to the scientific literature, there is still a need for improvement/offer of a collaborative platform in construction. This article aims to evaluate whether a platform, typically categorized as a PLM (Product Lifecycle Management) tool, is capable of meeting the collaboration requirements of DCM. 3DExperience is a cloud-based collaborative platform that is used in PLM-supported industry. This collaborative platform is a connected online environment where all the design, collaboration, and data management capabilities are stored in a single user interface. More precisely, this article investigates how PLM platform functionalities could address the needs of the DCM process in construction. By assessing the research findings of this article, it is demonstrated that PLM platforms have the potential to be utilized for DCM. Such an evaluation could lead to improved productivity in the DCM process within construction.

Keywords: Building Information Modeling, Product Lifecycle Management, 3DExperience, Design Change Management, Engineering Change Management.

1 Introduction

The goal of design change management (DCM) is to establish an organized and effective approach to recording and managing design change (DC) [1]. DCM plays an important role in controlling and overseeing modifications to a building design throughout its construction phases. It ensures that changes are executed in an orderly and methodical way and that the

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resulting changes are precise, consistent, and abide by applicable standards and regulations [1], [2].

It is important to mention that building information modeling (BIM) is a collaborative approach that encourages effective communication and information management between all parties involved in a construction project [3], [4]. It appears to have the potential to solve some persistent construction difficulties (interoperability, information flow optimization, etc.), which would lead to improved productivity [5].

Using a collaborative platform for DCM allows various stakeholders to communicate as well as work together effectively on design changes. This can help to ensure that all necessary parties are informed of DCs and that any issues or concerns are addressed in a timely manner [6]. Additionally, a collaborative platform can help to streamline the DCM process, making it more efficient and effective [1], [2]. The involved stakeholders (e.g., designers, engineers, etc.) could access and share the data and allow for real-time updates in a collaborative platform. In other terms, a collaborative platform could facilitate the communication and collaboration between the involved departments and teams for both internal and external exchanges [2], [7].

Although various tools and methods have been proposed by different research studies [1], [6], it seems there is still a need for improvement/offer of a collaborative platform to address the aforementioned needs [1]. BIM platforms are commonly used in construction projects to support various activities, including DCM. However, some scientific literature [1], [2] advocates that PLM platforms are more advanced and therefore it is important to consider whether they could also be used to support construction activities.

This article intends to address the following research question "*Can a PLM platform be utilized to support design change management in construction?*" Therefore, the objective of this paper is to evaluate the potential of a specific PLM platform to support the DCM process in construction projects. By examining the features and capabilities of such a platform, we aim to determine its suitability for managing design changes in construction projects. 3DExperience is typically used in the PLM-supported industry and we selected it as the specific PLM platform for this article. This PLM platform was chosen as the primary focus of this research due to its significance and prominence within the field. This platform is a software platform that developed by Dassault Systems[2], which is used for product design, simulation, analysis, and manufacturing. It comprises various applications for different phases of the product development process (e.g., CATIA for design, SIMULIA for simulation, and ENOVIA for data management).

It is important to mention that such a platform provides tools for design change management, which can be used to control and manage changes to the product design throughout its development and manufacturing. It helps to ensure that changes are made in a controlled and systematic manner, and that the resulting changes are accurate, consistent, and compliant with relevant standards and regulations [8].

The aim of this article is to assess the potential of a PLM platform for design change management within construction. It examines the various functionalities of the platform and how they can be utilized to enhance communication, collaboration, and data management in the design change process, ultimately improving the overall efficiency and effectiveness of the

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construction process. This article, therefore, provides some understanding of how a PLM platform can be utilized to support the design change management process in construction and its potential benefits.

This article is structured in six sections. The second section provides a brief overview of existing literature on design change management. The third section details the research methodology used in this study. The fourth section presents the findings of the study, focusing on the results of using 3DExperience as a collaborative platform for a typical DCM process. The fifth section discusses these findings, providing insights and analysis on the implications of the results. The final section concludes the article.

2 Background Research

The definition of design change (DC) states that it refers to any modification made to the design or construction of a project after the contract has been awarded and signed. An interesting aspect of this definition is that it highlights the timing of the DC, which occurs after the contract has been signed. This similarity between the definition of DC and engineering change is noteworthy [1], as both involve changes made to the design or construction of a project after a certain stage in the process has been completed. The primary objective of DCM is to ensure that all design changes are recorded accurately and managed efficiently, so that they do not cause delays, budget overruns or other issues throughout the project lifecycle [1].

Design change management helps to identify, evaluate and implement design changes while ensuring that they are consistent with the product's original design intent, technical specifications and regulatory requirements. It helps to minimize the potential for errors and inconsistencies, as well as reduce the risk of delays in the design process [1], [2], [6], [9]–[12].

Design change management also helps to ensure that all necessary parties are informed of changes, and that any issues or concerns are addressed in a timely manner. This can help to minimize the potential for confusion and misunderstandings, and can ensure that the final product meets the needs of all stakeholders [1], [10].

Design change management also provides a historical record of all design changes, which can be useful for future reference and for compliance with regulations [1]. The effectiveness of using the DCM approach can vary significantly depending on the specific characteristics of the project. Factors such as the nature, type, complexity, and size of the project, as well as the types of contracts involved, can all play a role in determining how successful the use of DCM will be [11].

To automate such a process, one must first comprehend the information that needs to be changed. In addition, to enhance its efficiency, one should also have a clear understanding of how the information should be classified, organized, interconnected, and managed [13]. However, the overall improvement of the change process cannot be achieved unless all types of business information are integrated, structured, and made easily accessible to all involved parties [13].

Hence, a collaborative platform can significantly enhance the effectiveness of the DCM process by enabling a variety of functionalities such as facilitating information sharing, communication, and ensuring that relevant information is accessible at the appropriate time [7].

Despite the numerous techniques and tools that have been proposed for this purpose [1], research studies have shown that there is still a gap in this area, and there is a pressing need for a collaborative platform that can effectively address the requirements of the DCM process [1]. This platform should be designed to bridge the gap between the different parties involved in the process and provide a centralized location for all the necessary information and tools.

3 Methodology

This research article presents a methodology with four key stages. The first stage entails a thorough examination of the existing scientific literature to understand and analyze the DCM process in construction that utilizes BIM technology. The purpose of this literature review and analysis stage is twofold: to describe the main components of the DCM process and compare them with the ECM process in PLM-supported industry, and to determine the necessary functionalities needed to adequately support the DCM process. The main actions in this stage are literature review and analysis, and requirement gathering.

The second stage of the methodology focuses on extracting and analyzing the tools and functionalities provided by the selected PLM platform to support the ECM process. The end goal is to determine the requirements necessary to effectively execute the ECM process within the environment of the selected PLM platform. The main actions in this stage are platform analysis, functionality identification, and requirement determination.

The third stage of the methodology involves a comparison of the extracted DCM process in construction and the ECM process in PLM side. The aim of this stage is to identify and evaluate similarities and differences between the two processes. These comparisons contribute to mapping the offered functionalities to meet the requirements of the DCM process. The main actions in this stage are process comparison and functionality mapping.

The final stage of the methodology highlights how the functionalities provided by the selected PLM platform can address the requirements of the DCM process. This stage provides a visual representation of the functionalities offered by evaluated platform and illustrates how they can be utilized to satisfy the needs of the DCM process. The end goal of this stage is to present a clear understanding of the capabilities of the PLM platform in supporting the DCM process. The main actions in this stage are functionality demonstration and capability presentation.

It's worth mentioning that this article presents the outcomes of the aforementioned methodology, but it does not present all the stages of the methodology.

4 A PLM Collaborative Platform

The objective of this section is to evaluate the different functionalities of a specific PLM platform that can be utilized in managing design changes. To accomplish this, the DCM and ECM are compared in the construction and PLM-supported industry to identify similarities and differences. In the second step, the functionalities of the selected PLM platform used in ECM are briefly presented, along with their potential use in the DCM process. The highlighted functionalities will be aligned with the specific requirements of DCM, providing a comprehensive understanding of how this platform can be effectively employed to manage design changes and meet the needs of construction.

4.1 Comparison of the DCM in construction and ECM in PLM-supported industry

In this step, it is necessary to compare the DCM process from construction and the ECM process from the PLM-supported industry. It is worth noting that in our previous research [1], we conducted a comparative analysis of DCM in construction and ECM in the PLM-supported industry. The comparison and data presented in this article aimed at identifying the main activities and requirements of these two processes. In addition, this study concentrates on the initial four phases of DCM and ECM since they comprise the majority of activities in these processes. Additionally, the table below compares the features of the DCM process utilized in construction with those of the ECM process in the PLM-supported industry [14]. The table presented below outlines the DCM process extracted from the research of [1] and the ECM process extracted from the research of [14].

Table 1. Comparison of the DCM in Construction and ECM in PLM-supported industry

Phase	*DCM process in Construction*	*ECM process in PLM-supported industry*
Phase 1	**Initiate** ✓ Initiate the request for information (RFI) ✓ A design change request (DCR) is collected or initialized. ✓ The DCR should address the reason for the change, the priority, the type of change, and which components are likely to be affected.	**Request** ✓ The engineering change request (ECR) is submitted.
Phase 2	**Evaluate** ✓ The DCR impact analysis and feasibility studies are conducted. ✓ A set of potential solutions for the design change is defined. ✓ One solution will be selected and analyzed by the professionals (change management team). ✓ Update mark-up drawings and documents.	**Instruction** ✓ The request is analyzed to determine whether it is worthwhile to make the change. ✓ The change management team analyzes and proposes solutions. ✓ One solution is chosen. ✓ Update mark-up drawings and documents.
Phase 3	**Approve** ✓ Based on the evaluation of the proposed change, the change management team (including professionals and client) decides whether to approve or reject the change.	**Execution** ✓ The change management team prepare the documents (drawings, specifications, etc.) for the chosen solution. ✓ Based on the evaluation of the proposed change, the change management team decides whether to approve or reject the change.
Phase 4	**Implement** ✓ Released the latest version of the documents (e.g., design change notice) for implementation. ✓ Notify the involved teams. ✓ Implement the proposed change. ✓ Monitor and track implementation.	**Notification/Application** ✓ The solution for the change is carried out at the company level over the specified time frame.

In the initial phase of both processes, a problem is identified. In the case of ECM, these problems can arise from design reviews, manufacturing, or even in the field that would lead to ECR. This definition is consistent with the concept of a DCR described in the scientific literature. Similarly to a DCR in literature, any member of the organization can raise an issue. Once identified, the problem can be submitted, tracked, prioritized, and resolved [8]. It's appropriate to note that a request for information (RFI) is a type of technical request used to clarify an issue. If the clarification provided to respond the RFI is sufficient to resolve the issue, the case will be closed. However, if further clarification is needed, it will result in a request for a DCR.

The instruction phase in the PLM side is similar in nature to the evaluate phase in the DCM process. Both phases involve assessing and analyzing proposed changes in order to determine their impact. Specifically, the primary task of this phase for both processes is to perform a thorough examination of the requested change, including an analysis of its potential effects on the over-all project or product. In essence, both the instruction phase in the PLM-supported industry and the evaluate phase in the DCM process are focused on ensuring that any proposed changes are carefully considered and evaluated before being implemented.

The third phase of both the DCM and ECM processes requires obtaining approval from the change management team. A key difference between the two processes is that during this phase of the DCM process, there are usually multiple meetings, negotiations, and discussions between teams and departments to determine the cost of the change. Once the change management team approves the chosen solution, the change order moves to the implementation phase. This phase is critical in ensuring that any changes are approved efficiently and in a timely manner.

Not surprisingly, phase four of both the DCM and ECM processes concludes by emphasizing the implementation of documented solutions across the company within a specific time frame. The updated versions of the documents will be shared with the relevant departments to facilitate the implementation.

It is worth noting that there are several notable similarities between the different phases of both the DCM and ECM processes. These similarities could suggest that the use of PLM solutions can be considered for implementing effective DCM practices within construction.

In the subsequent section, we will delve into the various functionalities offered by 3DExperience and describe how they can be applied to meet the specific requirements of the DCM process.

4.2 A PLM Platform for DCM

This section provides an understanding of the functionalities of a PLM platform that can be utilized to support the DCM process. It is divided into four parts, corresponding to the four phases of the D/ECM process in 3DExperience: issue management, change request, change order, and change action [8]. The characteristics of this process as well as the functionalities of the platform were gathered from two sources: the 3DExperience user manual [8] and the results of our previous research [1]. It is important to note that while the ECM process presented has four phases, in real-world scenarios, the ECM process may vary, with as few as one phase or as many as four phases depending on user needs. However, for the purposes of this research, the full ECM process, comprising all four phases, is considered. This section also examines how these functionalities can be tailored to the DCM process.

4.2.1 Phase 1: Issue Management—Initiate

An issue is a problem that can be raised by anyone in the field [8]. This phase encompasses a range of different functionalities, which are presented in Figure 1. This figure helps visualize the various components, which are classified using three distinct colors. Firstly, the central yellow node indicates the name of the phase, which in this case is "issue management." Surrounding this node are five green nodes, each representing a different functionality within this phase. Finally, the eleven blue nodes located around the green nodes represent sub-functionalities of the functionalities. These groups are also applicable to the subsequent phases.

Legend of the Figure (which is applicable for all phases):

- Yellow node: indicate the phase.
- Green node: indicate the functionalities.
- Blue node: indicate the sub-functionalities.

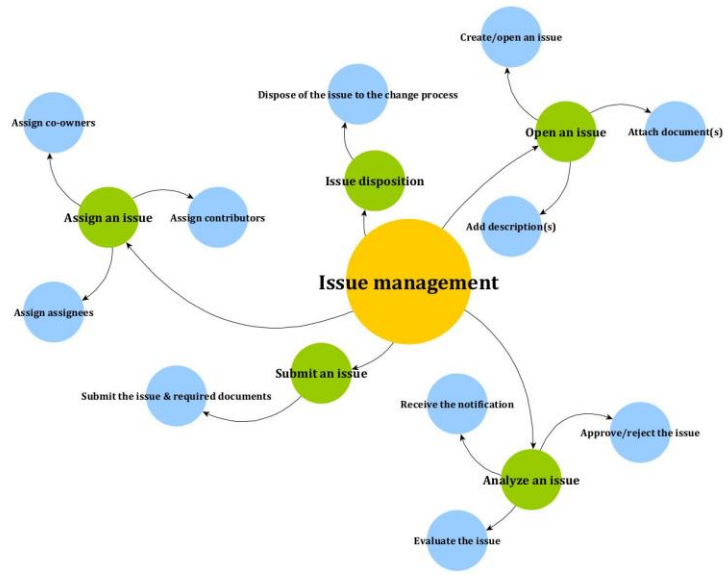

Figure 1. Functionalities and sub-functionalities of the issue management phase

During the Initiate phase of the DCM process, these five key functionalities can be utilized. These include opening an issue, submitting an issue, assigning an issue, analyzing the issue, and disposing of the issue. Each of these functionalities has its own set of sub-functionalities that can be customized to fit the specific needs of the project.

The issue encountered in this platform is reminiscent of the RFI/DCR encountered in construction. RFIs are initiated by any user by simply opening a new issue and attaching any relevant documents or explanations for the project team to access. Professionals can then be designated to respond to the RFI and determine whether a DCR is necessary. They perform a pre-feasibility study and provide feedback to the change management team. In this way, the RFI process ensures that all necessary information is gathered and assessed before making any design changes.

4.2.2 Phase 2: Change Request—Evaluate

It is at this phase where a thorough analysis of the requested change is conducted to evaluate its potential impact on the project. So it involves the use of various functionalities to perform the impact analysis effectively, which are depicted in the figure presented below. The figure comprises 11 green nodes representing different functionalities, and 34 blue nodes representing sub-functionalities. These elements work to support the impact analysis process and help to identify potential impacts that proposed changes may have on different aspects of a project.

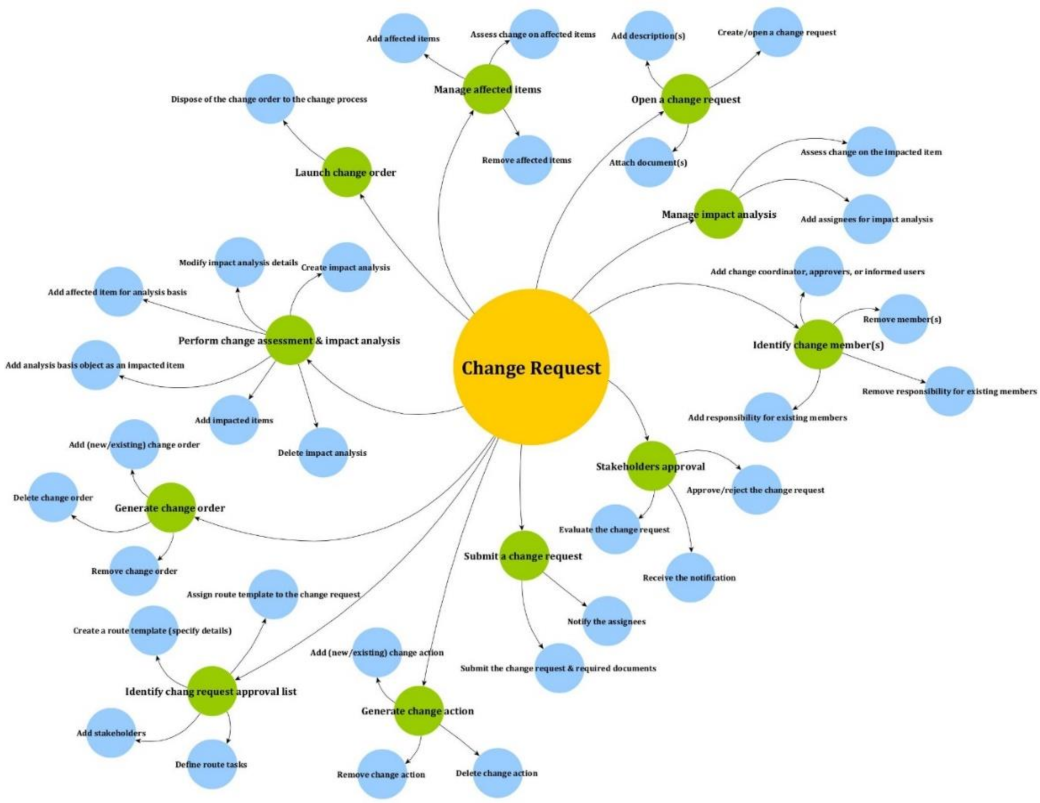

Figure 2. Functionalities and sub-functionalities of the change request phase

This phase of the DCM process is a crucial phase as it allows for a thorough analysis of the requested change and the proposed solutions. It is during this phase that the change management team can utilize the functionalities offered by this platform to gain a deeper understanding of the impact of the requested change. These functionalities include change assessment and impact analysis, which can help in identifying the potential risks and benefits associated with the change, as well as assist in determining the best course of action.

Furthermore, collaboration functionalities (e.g. notify the assignees) are also available for identifying and assigning responsibilities to specific team members. This allows for more effective communication and coordination within the team, ensuring that all members are aware of their roles and responsibilities. Other important activities that take place during this phase include managing affected items, generating a change action plan, managing the impact analysis, identifying and gaining approval from stakeholders, generating a change order, and implementing the approved change order. By managing affected items, the team can ensure that all items that will be impacted by the change are identified and addressed.

4.2.3 Phase 3: Change Order—Approve

The third phase of the DCM process may benefit from functionalities depicted in the accompanying figure, which comprises 12 green nodes representing different functionalities and 38 blue nodes representing sub-functionalities.

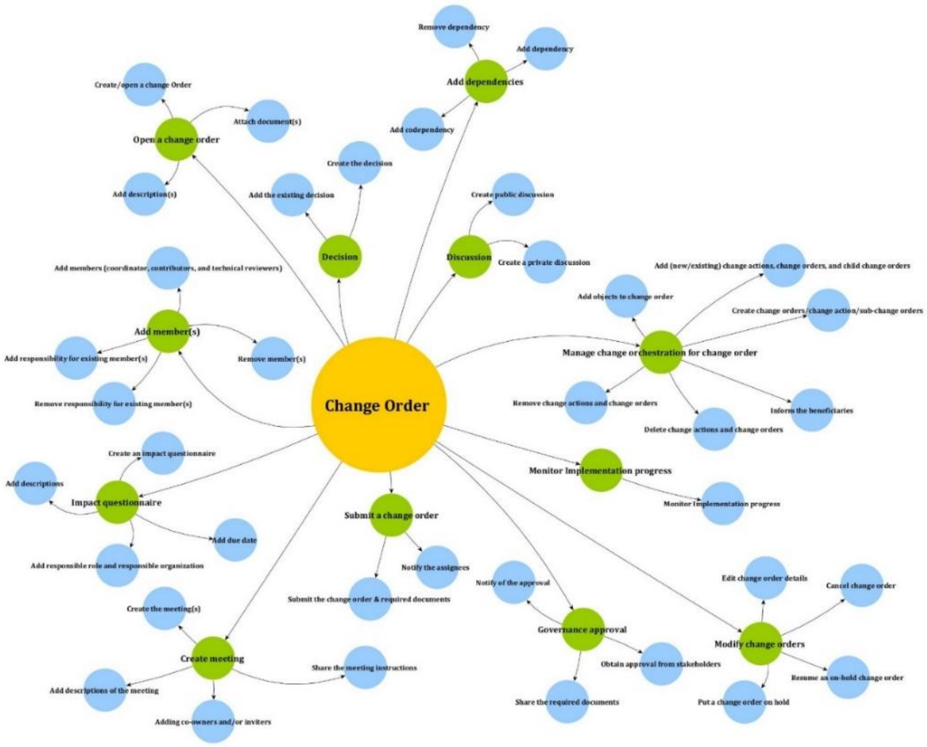

Figure 3. Functionalities and sub-functionalities of the change order phase

During this phase, the change management team must make important decisions regarding the proposed change, and negotiate with stakeholders to gain their approval. Additionally, collaboration functionalities are available for effective communication and negotiation with stakeholders, ensuring that all parties are aware of the requested changes and have an opportunity to provide feedback and approval.

Some of the functionalities that can be applied during the process include creating meetings, discussion sessions, and decisions, as well as gaining governance approval. Creating meetings and discussion sessions allows for effective communication and coordination within the team. These functionalities allow the team to schedule and hold meetings and discussion sessions, and to invite relevant stakeholders to participate.

Creating decisions functionality allows the team to document important decisions made during the process, and governance approval functionality allows the team to gain approval from relevant stakeholders and governing bodies. This is important to ensure that the requested changes are in compliance with established guidelines and regulations. Overall, the offered functionalities are allowing for effective communication and coordination, as well as making the process more efficient and effective.

4.2.4 Phase 4: Change Action—Implement

The activities of this phase include opening a change action, submitting a change action, proposing a change, adding attachments and dependencies, making a decision, and gaining governance approval. The offered functionalities are specifically designed to assist with these activities and are illustrated in the accompanying figure, which includes 7 green nodes representing different functionalities and 21 blue nodes representing sub-functionalities.

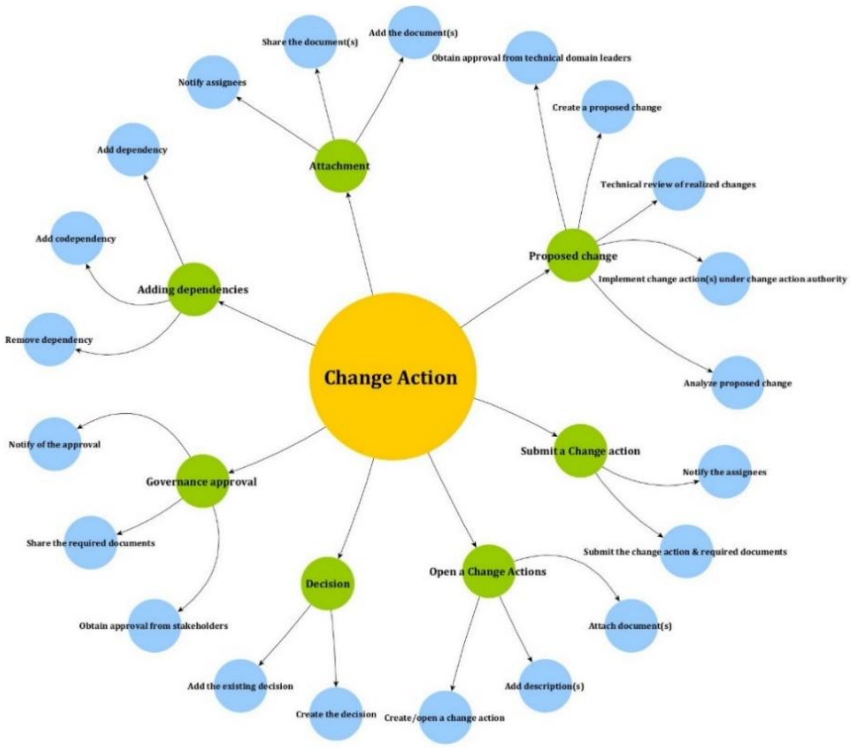

Figure 4. Functionalities and sub-functionalities of the change action phase

The Implementation phase of the DCM process requires a number of activities to be completed in order to implement the requested change. These activities include releasing the latest version of the documents, notifying the involved teams, and monitoring and tracking the implementation [1].

Releasing the latest version of the documents is an essential step in ensuring that all parties have access to the most up-to-date information. Notifying the involved teams is another important activity in the Implementation phase. The platform allows the team to quickly and easily notify the relevant stakeholders of the requested change, making sure that everyone involved is informed about the requested changes and given the chance to offer their opinions and give their consent.

Monitoring and tracking the implementation is a critical activity in ensuring that the requested changes are implemented as intended. The platform allows the team to track the progress of the implementation, identify any issues that arise, and take appropriate action to resolve them. This ensures that the requested changes are implemented efficiently and effectively.

5 Discussion

While construction has adopted BIM as a collaborative approach for enhancing communication and information management, the literature suggests that there is still a need for a better collaborative platform [15]. One potential solution is to utilize the current PLM platform within construction. The implementation of a PLM platform can significantly impact the management of design changes in construction. This is due to the platform's ability to provide a collaborative and integrated environment that enables various stakeholders, such as architects, engineers, and contractors, to effectively communicate and work together on design changes. The figure below illustrates the integration of the DCM process discussed in Section 4.1 with the PLM functionalities presented in Section 4.2. The purpose of this figure is to depict the potential adaptation of PLM functionalities to the DCM process, thereby mapping their compatibility.

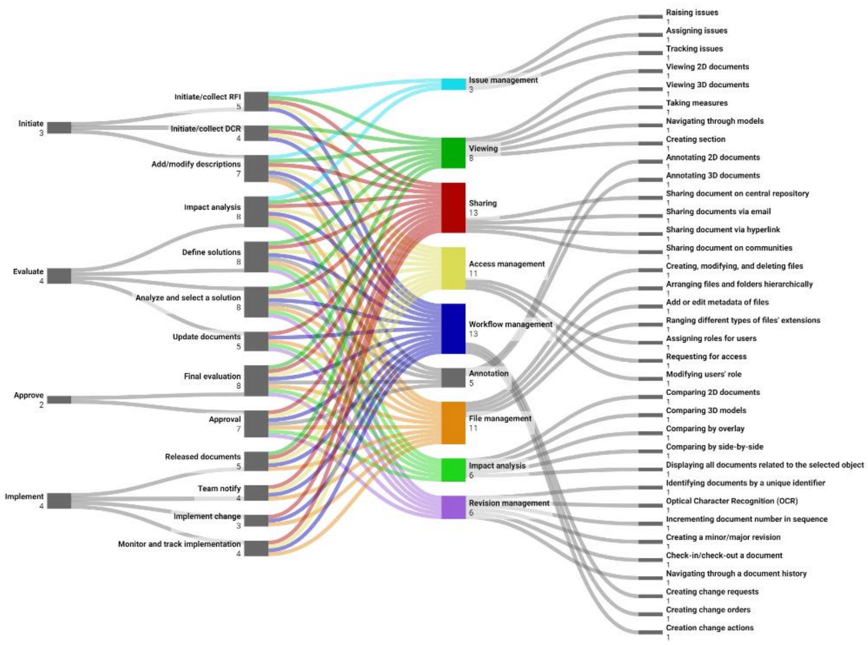

Figure 5. Exploring the Relationship between PLM Functionalities and the DCM Process

It is worth noting that the compilation of functionalities and sub-functionalities draws inspiration from the research of [16], and is subsequently generalized. This list effectively categorizes the functionalities and sub-functionalities according to the requirements of the DCM process.

The figure above displays the DCM process stages in the first column, while the second column presents the main activities associated with the DCM process. The third column showcases the categorized functionalities of the PLM platform, with their respective sub-functionalities listed in the fourth column. It is important to note that the numerical values assigned to each activity/functionality indicate the number of relationships it has with others.

The figure 5 highlights two notable observations. Firstly, activities such as 'impact analysis,' 'solution definition,' 'solution analysis and selection,' and 'final evaluation' have the potential to utilize the most functionalities of the PLM platform. Secondly, 'sharing,' 'access management,' 'file management,' and 'workflow management' emerge as the primary functionalities that can be leveraged in the context of the DCM process. It is important to note that this mapping represents a sample DCM process, and the relationship between DCM activities and functionalities may vary depending on specific company requirements.

The functionalities above could be used in the DCM process to increase productivity in the DCM process. One of the key benefits of using PLM platforms in construction is its ability to provide real-time access to building design data. This allows all stakeholders to access and share the same data, which can help to reduce the risk of errors and inconsistencies, and minimize the potential for delays in the design process. Additionally, the platform's data management capabilities can help to ensure that all necessary parties are informed of changes, and that any issues or concerns are addressed in a timely manner.

The evaluated PLM platform provides tools for design change management, which can be used to control and manage changes to the building design. This can help to ensure that changes are made in a controlled and systematic manner, and that the resulting changes are accurate, consistent, and compliant with relevant standards and regulations.

On the other hand, it is important to highlight that incorporating such a PLM platform into construction may present certain limitations that can be broadly categorized into three areas: complexity, integration difficulties, and cost. The platform may have a complex interface requiring a learning curve for users to be able to use its features and functions. Integrating such a platform with other existing design systems and tools may be challenging and require time and effort. Lastly, implementing a PLM platform can be a costly solution for companies, which might require budget allocation for implementation and maintenance.

6 Conclusion

The Design Change Management process plays a crucial role in construction. Its primary goal is to monitor and control design changes throughout the project's lifecycle. Utilizing a collaborative platform for DCM is vital as it provides a communication and collaboration hub for all project stakeholders to effectively manage design changes. This leads to a well-informed team, faster resolution of concerns and issues, and ultimately, a smoother project delivery.
The purpose of this article is to evaluate the potential of a PLM platform for DCM within construction. The findings of this article can be divided into two categories. Firstly, we compared the DCM process from construction with the ECM process from PLM-supported industry to identify similarities and differences. Since there are more similarities than differences, the article then outlines how a PLM platform can support the DCM process in construction. The analysis indicates that the PLM platform (e.g. 3DExperience) can be a potential platform as a collaborative solution for construction as examined from the DCM process standpoint.

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