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Management of Changes in Projects - a Structured Literature Review

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MANAGEMENT OF CHANGES IN PROJECTS - A STRUCTURED LITERATURE REVIEW

Research full-length paper

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Abstract

Project management plays a crucial role in enhancing the success of projects in organizations. However, regardless of the quality of management, changes will always arise during the development of projects. These changes may be, for example, related to requirements, scope, cost, resources, and time, among many others. Thus, it becomes essential to analyze the impact of these changes before they are accepted and reflected in the project so that success is not affected. This paper presents a structured literature review of current methods and techniques for impact assessment and change control in projects. Results show that the methods and techniques analyzed do not integrate all the knowledge areas of project management (they mainly focus on the triple constraints). Another conclusion is that some of the suggested artifacts are difficult to understand and learn, and it is unclear how to assess the impact of changes in practice. Overall, there is a need for further research to propose methods and techniques that fully address the demands imposed by project changes, taking into account all the knowledge areas of project management.

Keywords: Change, Projects, Project management, Integrated change, Change management, Integrated change assessment, Integrated change control.

1 Introduction

Project management has a high value in organizations (Shirazi et al., 2017; Wu et al., 2023), being fundamental for the success of projects (Varajão, 2016; Varajão, 2021). Project success has traditionally been defined with the help of the "Iron triangle", exemplified as adherence to budgetary constraints, a timeline, and the goals specified for the project (Nyman and Öörni, 2023).

However, regardless of the planning quality, changes frequently arise during a project, making it necessary to revisit one or more aspects of the planning (PMI, 2017; PMI, 2021). Although these changes are inevitable, they are a significant source of risk in the project development process. Furthermore, changes are one of the most frequent causes of project failure since they can substantially impact project time, cost, and quality and give rise to many risks (Hu and Liu, 2008).

Project changes are frequent and can be either beneficial or detrimental, depending on how and the perspective the change is seen and its effects (Ibbs et al., 2001). Although changes are usually perceived as something negative, they can be an opportunity for project improvement (Lechler and Edington, 2013). However, they can be detrimental since changes to the plan can affect, for example, budget compliance and project duration (directly or indirectly), negatively impacting the expected results (Ibbs et al., 2001).

There are several definitions in the literature for the concept of "change", which is applied in various contexts, such as organizational, project, and technological changes. However, in this article, change is understood as any event that results in modifying the original project scope, execution time, costs, quality, or other aspects (Ibbs et al., 2007).

For instance, customers can require changes originating from new ideas/suggestions from the project team, or changes may result from a new manager in the project with different ideas for its execution (Dvir and Lechler, 2004). Thus, it is essential to have techniques that allow for the systematic evaluation of the impact of changes on the various dimensions of the project. A method or technique that helps to deal with the changes that arise in projects increases the probability of success (Ibbs et al., 2001).

This structured literature review aims to identify, organize, and describe the current methods and techniques to assess and control project changes and the possible impacts that arise from them. The underlying research question is: What methods and techniques are proposed in the literature to evaluate and control project changes? The purpose is to enable a better understanding of the various changes that occur in projects and the impact they cause, presenting the methods and techniques for their assessment and control.

The next section provides the conceptual background. Then, section 3 describes the research method. Section 4 presents the results, and section 5 discusses them. Finally, section 6 presents some final considerations and research avenues.

2 Background

This section discusses several aspects related to changes in projects: the concept of change, the causes and types of changes in projects, the possible impacts caused by implementing changes, and the main aspects related to change control.

2.1 Project Changes

2.1.1 Causes of Changes

Projects, although temporary, usually suffer changes during their life cycle (Butt et al., 2016; Teah et al., 2019). Therefore, to better understand the changes that arise throughout projects, it is essential to understand their causes.

Changes in projects can occur for a variety of reasons (Butt et al., 2016), caused by internal or external factors (Bhatti et al., 2010; Hu and Liu, 2008; Mejlænder-Larsen, 2016; Sjögren et al., 2018; Vuorinen and Martinsuo, 2018).

The client usually requests changes from external factors, while the project team originates changes from internal factors (Mejlænder-Larsen, 2016). Love et al. (2002) present a more comprehensive view, stating that external (organizational) environment factors include governmental uncertainty, economic uncertainty, legal uncertainty, technological uncertainties, institutional influences, and natural causes. In opposition, there are the factors of the internal environment (of the organization), which

lead to the appearance of changes in the project, such as project uncertainty, organizational uncertainty, financial uncertainty, human uncertainty, and conflicts of interest.

Research focusing on requirements changes proposes a different organization for the causes of changes, classifying them as essential or accidental. Essential causes are outside the control of the work team or organization. They are due, for example, to changes in market demand or the environment. On the other hand, accidental causes can be controlled and avoided. The vague existence of a product vision and strategy and a lack of thorough business assessment are examples of unintentional causes (Bano et al., 2012).

There may be several reasons to change the initial requirements of a (software development) project. The customer may suggest these changes 1) if changes occur in the customer organization's business processes, 2) if the analysts do not understand the customer's requirements, or 3) if initial requirements are incomplete. Depending on the nature of the project and the type of gaps in the initial requirements, there may be other reasons for the customer requesting changes. The project team may also request changes to the requirements if they are technically impossible to implement or if some requirements are outside the contractual scope (Bhatti et al., 2010).

2.1.2 Type of Changes

Eckert et al. (2004) distinguish between two types of changes, namely changes that are initiated in the product (initiated changes) and changes emerging throughout the product life cycle (emergent changes). Changes in the product have different characteristics, making it necessary to distinguish between these two types of changes (Sjögren et al., 2018).

Emergent changes occur spontaneously, not predicted or intentional (Mejlænder-Larsen, 2016). They arise from product properties (Jarratt et al., 2011) due to weaknesses in the product (Eckert et al., 2004). In contrast, initiated changes are planned and controlled (Sjögren et al., 2018), arising outside the product (Jarratt et al., 2011). These can occur at the customer's request, and new requirements arise when needs arise (Eckert et al., 2004).

Thus, while initiated changes are usually accepted at any stage of the design process, emergent changes are often perceived as negative for the project because they can slow down the entire process (Eckert et al., 2004). This happens because initiated changes have more associated knowledge than emergent changes (Sjögren et al., 2018).

Some examples of emergent changes, according to Jarratt et al. (2011), can be:

- Error correction - errors made at design and later identified during the product development cycle. These errors can be minor or affect the entire rationale of the product. Most problems arise in the product integration phase;
- Safety - for safety reasons, changes may be made to the product (if it does not meet the necessary safety requirements to prevent damage);
- Feature changes - these changes are necessary when the product does not meet the functional requirements initially defined;
- Product quality problems - poor product quality can lead to work restructuring and result from poor design, development, or implementation quality.

Initiated changes can arise for several reasons: cost reductions or meeting standards and norms established in the law. Other examples of initiated changes can be customer requests for new requirements, product innovation to meet market needs, internal organization policies, selecting new suppliers to reduce costs, and identifying new technologies where product improvement is possible for customer

benefit (Jarratt et al., 2011). In addition, initiated changes can be seen primarily as a form of innovation (Eckert et al., 2004).

A report on the analysis of 49 changes has shown 55% emergent and 45% initiated changes (Sjögren et al., 2018). The average time from change request to decision-making was 103 days for emergent changes and 56 days for initiated changes. Moreover, initiated changes had higher rejections than emergent changes, 32 and 15, respectively. These figures led to the conclusion that emerging changes are the most frequent and urgent to solve since they are not initially planned. However, for this very reason, it takes longer to understand whether or not they should be accepted, considering the impacts on the project.

2.1.3 Impact of Changes

Not all changes inherent to the project are negative (Ibbs et al., 2001). They can be made to reduce costs, time, and difficulties underlying the project. Changes can also arise due to mistakes made within the project that must be corrected (Mejlænder-Larsen, 2016). Changes are usually made to improve the product, i.e., to eliminate weaknesses and better meet the requirements stipulated by the customer (Eckert et al., 2004).

When emergent changes arise in the project, typically, development costs increase due to the time and resources required (Eckert et al., 2004). The cost and schedule of a project tend to be related (Majerowicz and Shinn, 2016). However, it does not mean that an increase in the project schedule results in increased costs. Most of the time, other factors give rise to delays, which in turn cause budget increases. However, whenever an increase in costs is identified, the schedule usually also increases, and vice versa. Similarly, when project risks become problematic, they typically result in schedule delays and cost overruns.

Product quality can also be affected when changes emerge in the project in response to problems that arise. These changes can also indirectly impact other products, processes, and project teams as human resources are reallocated to address immediate problems (Eckert et al., 2004).

A change rarely occurs alone, and several changes can interfere with other projects (Eckert et al., 2004). The research of Vuorinen and Martinsuo (2018) reveals that the various changes that arise during the project are interrelated. The changes initiated in the early stages of the project give rise to other changes in the future. Measuring and controlling changes' impact on projects is essential to avoid failure.

2.2 Change Control

If changes are not controlled, other changes in the project derived from that change may arise, negatively impacting the project (Shirazi et al., 2017).

Change control focuses on identifying, documenting, and approving or rejecting changes to project documents, deliverables, or baseline (PMI, 2017). Before deciding, all changes should be evaluated to quantify the impacts on project costs, schedule, and other areas (Alp and Stack, 2012). That said, a process should be in place to assist the project manager and other staff in monitoring changes (Gaber et al., 2016), thus helping to prevent and avoid project failure (if the change is negative).

According to Hu and Liu (2008), a well-defined process must be followed to request a new change. Sjögren et al. (2018) state that change processes can be formal or informal, depending on how the change is handled. Formal processes are the organization's norms and standards for managing the changes, such as creating meeting minutes. In contrast, informal processes are undocumented communications.

Developing an effective process to perform change management in projects is a complex task, as it requires an integrated solution to coordinate everything involved with the change in question (Hao et al., 2008). The change management module that some project management software applications claim to have is primarily a limited feature that only allows one to record requested changes and perform document approval. Most of these solutions do not implement change estimation, impact analysis, post-change analysis, statistics, or, most importantly, change monitoring.

The study by Vuorinen and Martinsuo (2018) shows evidence of the scalar potential of changes throughout the project. The authors also mention the importance of integrated change management. Thus, there is a need to perform an integrated control of changes that arise during the project so that the project is not negatively affected.

According to PMI (2017), integrated change control involves 1) checking all change requests, 2) approving those changes and managing changes to project deliverables, project management plans, and project documents, and 3) communicating decisions. The main benefit of this process is that it allows documented changes to the project to be considered in an integrated way while focusing on the overall project risk. Often, changes are made to the project without considering the overall project objectives or plans and measuring their impact.

An integrated change management system, to be effective, must support the following requirements (Hao et al., 2008):

- Consolidate all change information, including causes, origin, impacts, action steps, change processes, relationships with other aspects of the project, etc.;
- Evaluate all elements affected by the change in all phases of the project;
- Automating workflow processes for change review, approval, and implementation;
- Coordinate changes to other operating systems;
- Coordinate changes to a system shared by project management;
- Coordinate people's activities (including notifications and monitoring);
- Coordinate document distribution and management;
- Monitor daily operations and costs;
- Assign disagreement resolution procedures;
- Ensure traceability and perform a post-change analysis.

3 Method

The following research question was formulated: What methods and techniques are proposed in the literature to evaluate and control project changes? To answer the research question, we searched Scopus and Web of Science databases for the following expressions (and synonyms): "project", "program", "programme", "portfolio", "pmo", "change control", "integrated change", "change request", "scope change", "time change", "cost change".

We chose the Scopus and Web of Science databases since they can aggregate peer-reviewed publications. To narrow the search results, the logical operators "AND" and "OR" were added to the expressions used, and the theme-related subfields were also filtered. Table 1 shows examples of the expressions used.

We identified a total of 987 and 148 articles, respectively. All information regarding the articles was extracted into an Excel sheet. Repeated articles and non-English articles were excluded from this sheet, and the articles were filtered based on title, abstract, and keywords. From this first filtering, the result was 73 articles from Scopus and 13 articles from Web of Science. The weighting criteria used in the selection of these articles were mainly based on topics that focused on changes in projects (namely in the various knowledge areas), the respective causes and types of changes, current methods and techniques for evaluating the impacts of changes in projects, and the existing processes for change management. In cases where these three components of the article were not enough to understand their importance to the theme, the articles obtained were flagged for a further full reading. Next, a partial reading was made of the articles chosen in the first filtering to select the most relevant references to the proposed theme. The partial reading resulted in 23 articles, which were read in full. All articles considered pertinent to the theme under analysis were stored in a folder organized by levels of importance. The most relevant articles were studied in greater depth, having been read and analyzed several times to ensure that all pertinent aspects were considered. The main results of these articles are described in the next section. Note that, from the collected references, it was also possible to find other references of relevance and value to the present work by doing backward and forward searches.

Database	Expression
Scopus	TITLE-ABS-KEY ((project OR program OR programme OR portfolio OR pmo) AND ("change control" OR "integrated change" OR "change request" OR "scope change" OR "time change" OR "cost change")) AND (LIMIT-TO (SRCTYPE, "j") OR LIMIT TO (SRCTYPE, "p")) AND (LIMIT-TO (SUNJAREA, "ENGI") OR LIMIT TO (SUBJAREA, "COMP") OR LIMIT-TO (SUBJAREA, "BUSI") OR LIMIT TO (SUBJAREA, "SOCI") OR LIMIT-TO (SUBJAREA, "DECI"))
Web of Science	TS = ((project OR program OR programme OR portfolio OR pmo) AND ("change control" OR "integrated change" OR "change request" OR "scope change" OR "time change" OR "cost change")) Refined by: WEB OF SCIENCE CATEGORIES: (COMPUTER SCIENCE SOFTWARE ENGINEERING OR COMPUTER SCIENCE INFORMATION SYSTEMS OR COMPUTER SCIENCE THEORY METHODS OR MANAGEMENT OR OPERATIONS RESEARCH MANAGEMENT SCIENCE). Stipulated time: Every year. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI, CCR-EXPANDED, IC.

Table 1 Databases and search expressions

4 Results

In this section, the methods and techniques identified to evaluate the impacts of changes, as well as the management of changes in projects, are presented. Table 2 lists the methods and techniques found in this research.

4.1 Formal Requirements Change Management Process

Bhatti et al. (2010) suggest a method for the requirements change management process in a software development project, which consists of six phases: initiation, receipt, evaluation, approval or rejection, implementation, and configuration. An explanation of these stages of the change management process follows.

Initiating the change management process - at this stage, the main stakeholders are the customer or the project team, who request a change in the project requirements.

Receipt of change request - the change request is received and formally recorded on a change request form.

Evaluation of the change request - a group within the project team (named CCB - Change Control Board) should be responsible for processing the changes received. The CCB should evaluate the request through various checks, depending on the nature of the software project and the nature of the change request. The impact of the change should be analyzed against the existing requirements, and the change request should be evaluated against the project's technical constraints. A cost-benefit analysis should be performed against the change request, never putting aside the quality assurance of the project. At this stage, the output is an evaluation sheet that explains the details of the evaluation of the change request, describing whether or not the change is feasible.

Method/Technique	**Type**	**Focus (Project type)**	**Source**
Formal Requirements Change Management Process	Method	Software	Bhatti et al. (2010)
Change Control Process according to Xing	Method	Software	Xing (2010)
Change Management in Projects, according to Hu and Liu	Method	Software	Hu and Liu (2008)
Change Management Model in Practice (CMMiP)	Technique	Software	Hussain et al. (2016)
Classical Approach, EVA (Earned Value Analysis), and IPCM (Integrated Project and Change Management)	Technique	Software	Gaber et al. (2016)
Model proposed by Isaac and Navon	Technique	Construction	Isaac and Navon (2009)
Integrated Change Management System in Construction	Technique	Construction	Motawa et al. (2007)
Applying CCS (Change Control System)	Method	Construction	Mejlænder-Larsen (2016)
General Model of the Change Process, according to Hao et al.	Method	Construction	Hao et al. (2008)
Project Change Management System, according to Ibbs et al.	Technique	General	Ibbs et al. (2001)

Table 2 Analyzed methods and techniques

Approval or rejection of the change request - after the complete evaluation of the change request, this request must be approved or rejected by the CCB. The CCB formally issues the decision, so the final decision is to approve or reject the change request. In case of approval, the work team will be notified to implement the change. If, on the contrary, the request is rejected, the person who made the change request will be notified of the reasons why the request was rejected.

Implementation of the approved change request depends on the nature and timing of the approval of the change request. If the change request is initiated and approved in the requirements analysis phase, in that case, implementation will only require changes to the project's requirements-related documents (e.g., use cases, requirements management plan, or SRS - Software Requirements Specification). If, on the contrary, the change request is initiated in later phases of the project, implementation will include changes in the execution phase, together with changes in all previous phases of the project. At this stage, the output is a document related to the details of the implementation of the change request.

Change request configuration - all project change requests are stored separately (by approval or rejection status) in the configuration repository (for future reference). The list of approved changes should be grouped with the implementation details, and the list of rejected changes should be kept along with the reasons for such rejection. The output of this step is a list of the parameters used to configure the change.

4.2 Change Control Process, according to Xing

Xing (2010) proposes a control process for change request management that is very similar to the model of Bhatti et al. (2010), adding the baseline concept. A baseline is defined as the desired value for a project dimension (e.g., scope, budget, schedule) or agreed plan, which will serve as a reference during project execution. Following the appropriate change management process, new baselines can be defined throughout the project life cycle (Maraslis and Kourounakis, 2018). The model includes four process steps: requesting the change, evaluating the change, accepting or rejecting the change, and finally, in case of acceptance, implementing the change.

4.3 Change Management in Projects, according to Hu and Liu

Hu and Liu (2008) analyze why changes arise in IT projects and the impact they generate, proposing a solution for change management and a procedure to implement the proposed solution. The solution allows project changes to be managed efficiently and effectively, promoting successful and higher-quality project completion. A typical change management process includes the following activities: request change, evaluate change, change (if the change is approved), check and test (if the change is put into practice), and close the change request. This process includes a set of procedures with the required steps to register a change request according to the expected impact of that change.

According to the authors, the underlying complexity of request management relates to the change type. However, regardless of the type of change, most change request management processes include the following steps: submission of the change request, reception of the request, evaluation of the change, decision-making, implementation of the decision, verification of the implementations, and finally, completion of the change request.

4.4 Change Management Model in Practice (CMMiP)

Hussain et al. (2016) developed a model of requirements change management that incorporates the types of formal and informal changes, thus representing more realistically the requirements changes that arise in a project.

In the proposed model (CMMiP), in the post-contractual phase, the activities concerning informal changes occur before the approval of the detailed project specification document. If the supplier accepts the change, the project activity cycle proceeds normally; otherwise, it goes through an informal negotiation cycle before the change is reformulated or rejected through a formal contract. Changes in requirements proceed from their collection through the implementation and testing phase, where decisions are made to address changes in contractual requirements (formally or informally). Therefore, at least some of the changes identified during the implementation and test phase go through informal change management activities.

From the supplier's point of view, changes in requirements identified as being outside the contractual scope have to be negotiated with the customer. To proceed with the contract, the options available to the supplier are to get the customer's approval, convince the customer to adjust the existing cost and schedule of the project, or bear the cost of these changes. In some cases, the supplier agrees to accept such requirements and change requests suggested by the customer, even though they are outside the

contract. By accepting such changes in requirements, the entire change process is handled informally, with no additional costs charged to the customer. Invoking the formal change management process is also unnecessary since the informal process for handling the change request is successfully carried out.

4.5 Classical Approach, EVA (Earned Value Analysis), and IPCM (Integrated Project and Change Management)

The study by Gaber et al. (2016) examines and compares three approaches to monitoring and controlling projects based on various schedule scenarios, showing the effect of applying each approach to project cost and time.

The first approach mentioned is the Classic Approach. In this approach, costs and durations are assigned to each project task, which will serve as reference points. These reference points determine whether the tasks are carried out according to the initially defined schedule and whether the project cost does not exceed the stipulated budget.

The second approach mentioned is EVA (Earned Value Analysis), which measures project progress objectively. It allows you to calculate the SPI (Schedule Performance Index) to assess the magnitude of variations from the original baseline of the project schedule, calculate deviations in project costs, and also calculate the CPI (Cost Performace Index), which measures the amount of work performed in relation to the amount spent to perform that work. This analysis provides an integrated view of the project by measuring the PV (Planned Value), the EV (Earned Value), and the AC (Actual Cost) (PMI, 2017; PMI, 2021).

Finally, the third and last proposed approach, IPCM (Integrated Project and Change Management), integrates change management and project management activities.

This work shows that IPCM is more efficient because it provides greater control in tracking change requests and improves the performance monitoring process (Gaber et al., 2016). According to the authors, the comparison of IPCM with other approaches is as follows:

From a task perspective, the IPCM approach interprets each task as a Change Request (CR) and integrates CR with the change management process. On the other hand, the Classical and EVA approaches are not well defined in the CR procedure.

From a quality perspective, the IPCM approach only integrates software design and change management activities to achieve quality. However, the EVA and classical approaches do not include quality guidelines within the project.

From the perspective of project resources, the IPCM approach effectively uses project resources. In contrast, the EVA approach makes partial use of resources, and the classical approach makes no use of resources.

From a time perspective, the IPCM approach monitors all tasks or CRs throughout the project and provides clear values for any deviations in the project schedule. In contrast, the classic approach monitors the project using a project schedule baseline, which remains unchanged throughout the project and only serves as a comparison with other project schedules. Thus, one can check whether tasks are carried out according to the specified schedule or not. EVA monitors the project based on the rules: 0-100%, 20-80%, or 50-50%, determining whether the project is ahead or behind schedule.

From a cost perspective, the IPCM monitors all tasks or CRs throughout the project and provides concrete figures for any deviations in project cost. The classic approach monitors the project using a baseline that allows estimated costs to be related to actual costs. Finally, the EVA approach controls the project with some basic rules that determine whether the project needs to be recovered or not.

4.6 Model proposed by Isaac and Navon

Isaac and Navon (2009) present a model that facilitates the identification of the possible consequences of a change in a construction project at the time of the change request and before implementing that change. The proposed model uses the various sources of information available on the project to identify the impact of changes on the project's cost, schedule, and performance. According to the authors, a model that analyzes change impacts must explicitly link the project components to the sources identified as uncertainties and the probability distributions assessed on the cost and duration of the planned activities. Thus, correlations and dependencies between different project events can be considered; it also facilitates the monitoring of links between proposed changes, components, and probability distributions assessed for the attributes of planned activities. Such a model should integrate existing risk assessment and change management methods in projects.

The possible consequences of the different simulated change scenarios are identified through the relationships between the project elements (e.g., requirements, construction activities, and components). That is, since there are correlations and dependencies between project elements, it can be seen that the change made in one of the project elements will affect one or more of the project elements that are linked to that changed project element. The model assumes three fundamental aspects, namely:

- It links the customer's main objectives: cost, schedule, and performance;
- It is defined using a graph-based approach;
- It represents the project information in a stochastic way.

4.7 Integrated Change Management System in Construction

According to Motawa et al. (2007), during the development of change management systems, the various elements of the project must be considered, as well as possible causes that may lead to changes in the project. In their paper, they present an integrated change management system for construction. This system was developed to represent the most critical decisions for implementing changes, simulate the simultaneous iterative design and construction cycles resulting from unplanned changes, and identify the subsequent impacts. The system integrates a change prediction model based on fuzzy logic and the DPM (Dynamic Planning and Control Methodology) model, which was developed to evaluate the negative impacts of changes on construction performance. The developed system can manage various scenarios of project changes and assess the effects caused by the change based on the information available during the project's initial phase. Of the information required to simulate iterative cycles, the project's stability level is the same. The stability of a project can be predicted by studying the information available in the project in its initial phases.

The integrated system can help:

- Provide decisive actions in both planning and controlling the project;
- Identify the various dynamic impacts that occur in construction projects and iterative cycles;
- Plan grants for possible changes;
- Explore the relationship between cause and effect of the change;
- Analyze the impact of the changes in the various areas of the project.

However, while the proposed system has demonstrated potential regarding project change management, significant effort is still required to ensure its realistic implementation. Further simulations and testing should be conducted to establish robust mathematical relationships between other variables in

the change process. According to the authors, additional studies are needed to validate the effectiveness and efficiency of the developed system. This way, the system could improve its practical simulation capabilities and provide a more reliable and realistic implementation.

4.8 Applying CCS (Change Control System)

Mejlænder-Larsen (2016) presents a Change Control System (CCS) for managing changes based on the five stages of the change management process (change identification, submission, evaluation, approval, and implementation) and BIM (Building Information Modelling), which can be used to identify the impact and consequences of the change.

According to the author, the CCS develops, stores, controls, reports, and tracks design changes and deviations, supporting efficient change processing. When a design change request is made, it is submitted to the CCB to be processed, categorized, evaluated, and approved or rejected. The author presents a flow chart with the main CCS steps supported by the change management process activities described next.

Identification: A potential change is identified through a change request at the project's design phase. If this phase is not yet closed, the model suggests the possibility of not making a formal change request, especially if the change does not affect another aspect of the project. Otherwise, a change request is made during project design and assigned an identifier (a name and number), as well as data about the aspects of the project that are affected or other documents, such as change details and/or consequences of the change. The requested change will automatically be directed to the second step of the process (Submission).

Submission: At this stage, the change request is directed to the CCB, which will hold weekly or biweekly meetings to monitor the proposed changes and decide if they should be approved for the next step (Evaluation).

Evaluation: The CCB assesses the impact of the requested change using BIM. This evaluation is recorded in the CCS, along with a categorization assigned by the CCB. After the assessment, the fourth step of the process is followed (Approval).

Approval: After the CCB has the necessary information to decide, it can decide whether or not the change should be approved for implementation. The customer is also involved in the decision process, being informed about the possible impact on the project's cost and schedule.

Implementation: In cases where the change is approved, its implementation must be planned and coordinated, considering all affected aspects of the project.

Experiences from the execution of large oil and gas projects indicate that the dynamics of CCS, combined with the use of BIM, help to detail and control the changes in the project, reducing its overall impacts.

4.9 General Model of the Change Process, according to Hao et al.

The model proposed by Hao et al. (2008) was designed by synthesizing the change management process models found in the literature. The model proposed by the authors has five sequential steps: identify, assess and propose, approve, implement, and review changes.

Identify changes: this step requires an effective change management system to build relationships between requirements, faults, symptoms, and other aspects of the changes. According to the authors, this step is often skipped, and initially, the change is assessed and requested. This occurs because change management systems are not designed to understand the change's relevance automatically.

Assess and propose changes: based on criteria and options, the possible impacts that a change may have on other processes, in terms of time and cost, are calculated. Analysis and, if possible, optimization of change options are required to decide whether to proceed with any change options or conduct further investigations. This step requires significant efforts in modeling behaviors involved in the decision-making processes. The result of the assessment is a change proposal, which summarizes the change and its impacts (e.g., a new, updated action plan, cost, schedule, and other aspects of the project).

Approve changes: each identified change must go through a formal approval process. There is a set of predefined approval processes for different types of changes and construction contracts. First, all parties involved must agree to the proposed change described in the change request. This is done through a change review process. Next, client approval is required to finalize the proposed change request. This could include decisions regarding accepting, improving, or rejecting changes.

Implement changes: The change management process model requires all involved parties to keep records of all relevant information about change cases to build a baseline for future cases. A functioning system is needed to ensure that all aspects of the project are updated, that all stakeholders are notified of the change, and that all activities are performed correctly.

Review changes: Change and system performance analysis are performed based on the data collected during the change implementation phase.

4.10 Project Change Management System, according to Ibbs et al.

Ibbs et al. (2001) present a comprehensive project change management system based on five principles: promote a balanced change culture, recognize the change, evaluate the change, implement the change, and continuously improve with lessons learned. Each of these principles works together with another principle. In fact, each principle must interact with another to optimize the system. It follows an explanation of each principle.

Promote a balanced change culture - communication and documentation of the project team's critical success factors are essential, as these should be part of the project scope.

Recognize change - project team members are encouraged to initiate discussions and identify possible changes. Identifying changes before they occur can help the team better manage changes and anticipate the project life cycle.

Evaluate the change - this principle aims to determine whether the project team should accept and implement the proposed change. If the change is of high priority, the team should determine the funding source for provisional approval since any delay in implementing it will increase its cost. However, if the change is of minor importance, the proposed change should be considered with more time to determine whether or not it is necessary. This step is vital because it helps maximize the project's profits and reduce the negative effects of the change.

Implement the change - the principle of change implementation is very important in project management since this is the main reason for having this system. The approval of changes is an authorization by management and should be a high priority. This authorization should be given after all parties directly or indirectly affected have been made aware of the pending change. In most cases, changes lead to other problems and additional changes.

Continuous improvement with lessons learned - this principle is intended to understand the causes of changes and mistakes made so that they can be avoided in the future. Such analyses should be discussed openly among the project team members so that everyone can understand the causes of changes and mistakes made. This learning is necessary so that lessons learned in the past will help in the future, making it easier to think about, address, and manage problems proactively.

5 Discussion

Ten proposals for methods and techniques for assessing change impacts in projects and change management were reviewed. Of these, only a tiny fraction addresses the concept of integrated change assessment, considering the various areas of project knowledge, namely the study of Gaber et al. (2016).

Bhatti et al. (2010) suggest a formal methodology for requirements change management in a software development project, which consists of six phases: initiation, reception, evaluation, approval or rejection, implementation, and configuration. Xing (2010) also refers to a control process for managing change requests, very similar to the model of Bhatti et al. (2010), only adding the baseline concept.

Hussain et al. (2016) refer to the importance of formally or informally managing requirements change management, depending on the complexity of the change request. Most of the time, changes can be agreed upon between the customer and the supplier informally, and a formal process is not required. In the specific case of the first two processes presented, the informal process associated with the requirements change request is not present. This can be considered a weakness from the point of view of Hussain et al. (2016).

In general, the formal process used to manage changes proposed by several authors presents four common steps: requesting the change, evaluating it, making a decision (approval or rejection), and, in case of approval, implementing the change in the project. Some authors also add the step of monitoring the change (after its implementation). Finally, others emphasize storing all the information from this process for future reference and learning.

In the work of Sjögren et al. (2018), the practices used by ad-hoc teams to manage emerging changes in research and development projects are explored. They note that change requests are typically made formally in meetings; however, this formality is often a barrier, given the large amount of paperwork to fill out. As a rule, requests for changes are made in informal conversations. According to Sjögren et al. (2018), although the formal registration of changes is essential, informal discussions about evaluating the impact of the change on the project are also fundamental, as they help acquire knowledge that can later be applied to other decisions.

The analyzed works found that most of the presented models mainly evaluate the impacts on costs and project duration from changes within the project. For example, in Shirazi et al. (2017), the Fuzzy AHP method is applied to select the best strategy to manage changes in the project scope. The term fuzzy is used to capture the imprecision and subjectivity in choosing alternatives in multi-criteria decision-making in a project. The Analytic Hierarchy Process (AHP) technique is used in more complex (multi-criteria) decision-making. Alp and Stack (2012) sought to identify and analyze the practices used in project scope management and change control. They concluded that a rigorous process focused on using a WBS (Work Breakdown Structure) allows the work to be subdivided into manageable portions. This division of labor makes it easier to manage the scope subject to change and provide clear responsibility assignments. The WBS can be applied to manage the project scope and changes by controlling the parameters established in each division of work, such as activity duration, work hours, activity assignment, etc. Changes made to any of these parameters must be evaluated against the project's original scope, verifying the possible impacts of this change. Communication between project team members plays a key role in how changes in the project scope are identified, documented, and managed. Currently, communications take place via email, text messages, and telephone. However, regardless of the advantages and disadvantages, losing control over the project scope due to misinterpretation, decontextualization, or miscommunication has consequences. For example, emails can easily be sent to stakeholders who never intended to receive the message or can be misunderstood by those who did. There should also be control over project documentation to organize, review, and distribute all documentation. This is important concerning changes made within the project, allowing comparison between current versions and older versions of documents.

Control measures integrated with all project management knowledge areas are fundamental to obtaining more satisfactory results, contributing to the success of projects. Gaber et al. (2016) research focuses on this aspect, integrating change management activities with several areas of project management.

According to Kauffmann et al. (2002), EVPM (Earned Value Project Management) can support the effective control of complex projects by providing critical information such as 1) identifying the initial project plan for resource and cost allocation, 2) assigning specific responsibilities for completing activities, 3) tracking changes in the project scope and the impact of these changes on the project schedule and budget, and 4) developing a project performance history in terms of progress and measuring schedule compliance. In addition, changes and impacts related to project costs and schedules should be adequately identified, discussed, and agreed upon by all parties interested in implementing the change. As such, the EVA approach facilitates decision-making within a reasonable period, supporting agreement on the change before it is initiated.

Based on the results, the methods and techniques to control changes and assess the possible impacts present opportunities for improvement because managing changes does not consider all knowledge areas of project management. Only a few models were found that partially apply the integrated control concept, which seems insufficient. During the project, frequent changes arise related to the various areas of project management knowledge (PMI, 2017; PMI, 2021). The changes affect several aspects of the projects, thus requiring an integrated approach that considers all the project management facets.

6 Conclusion

Through the literature review, it is clear that it is commonly accepted that project changes are inevitable. The types and causes of changes were studied to enable a better understanding of their possible impacts on the project. These impacts can be positive or negative, depending on the change that is made. Although changes are often seen as something negative, they can also be an opportunity for improvement (Lechler and Edington, 2013).

Several authors argue that changes in projects do not have isolated impacts. That is, a change never occurs alone, and it can negatively or positively impact other project management knowledge areas (for example, cost, schedule, scope, quality, resources, communication, procurement, risk, and success, among others). The results obtained in Vuorinen and Martinsuo's (2018) research showed evidence of correlation and scalar potential of changes throughout the project. The authors also mention the need for integrated change management.

The structured literature review in this article provides an overview of change management methods and techniques. The analysis concluded that some of the models and processes currently available do not act in an integrated manner or do not fully address the needs imposed by project changes. For example, Hussain et al. (2016) state that although the efficient management of requirements change is a critical aspect of software engineering, the conceptions of these changes in the literature and the approach to their management practices seem rudimentary. The methods and techniques do not integrate all the knowledge areas of project management, considering most cases only cost, schedule, or project scope. Another aspect is that some of the suggested methods and techniques are difficult to understand and learn, and how to assess the impact of changes in practice is unclear. To conclude, it is clear that there is a need for new research on approaches, methods, and techniques capable of integrated change management, which is the proposal for future work.

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References

Alp, N. and B. Stack (2012). "Scope management and change control process study for project-based companies in the construction and engineering industries". *PICMET '12: Technology Management for Emerging Technologies*, Vancouver, BC, Canada, 2427-2436.

Bano, M., S. Imtiaz, N. Ikram, M. Niazi and M. Usman (2012). "Causes of requirement change - A systematic literature review". *16th International Conference on Evaluation & Assessment in Software Engineering (EASE 2012)*, Ciudad Real, 22-31. doi: 10.1049/ic.2012.0003

Bhatti, M. W., F. Hayat, N. Ehsan, A. Ishaque, S. Ahmed and E. Mirza (2010). "A methodology to manage the changing requirements of a software project". *2010 International Conference on Computer Information Systems and Industrial Management Applications (CISIM)*, Krakow, Poland, 319-322. doi: 10.1109/CISIM.2010.5643642

Butt, A., M. Naaranoja and J. Savolainen (2016). "Project change stakeholder communication". *International Journal of Project Management*, 34(8), 1579-1595. doi: 10.1016/j.ijproman.2016.08.010

Dvir, D., and T. Lechler (2004). "Plans are nothing, changing plans is everything: The impact of changes on project success". *Research Policy*, 33(1), 1-15. doi: 10.1016/j.respol.2003.04.001

Eckert, C., P. J. Clarkson and W. Zanker (2004). "Change and customisation in complex engineering domains". *Research in Engineering Design*, 15, 1-21. doi: 10.1007/s00163-003-0031-7

Gaber, A. M., S. Mazen and E. E. Hassanein (2016). "Comparative Study for Software Project Management Approaches and Change Management in the Project Monitoring and Controlling". *International Journal of Advanced Computer Science and Applications (IJACSA)*, 7(2). doi: 10.14569/IJACSA.2016.070236

Hao, Q., W. Shen, J. Neelamkavil and J. Thomas (2008). "Change management in construction projects". *CIB W78 25th International Conference on Information Technology: Improving the Management of Construction Projects Through IT Adoption*, Santiago, Chile.

Hu, E. and Y. Liu (2008). "IT Project Change Management". *2008 International Symposium on Computer Science and Computational Technology*, Shanghai, China, 417-420. doi: 10.1109/ISCSCT.2008.224

Hussain, W., D. Zowghi, T. Clear, S. MacDonell and K. Blincoe (2016). "Managing Requirements Change the Informal Way: When Saying 'No' is Not an Option". *2016 IEEE 24th International Requirements Engineering Conference (RE)*, Beijing, China, 126-135. doi: 10.1109/RE.2016.64

Ibbs, C., L. Nguyen and S. Lee (2007). "Quantified Impacts of Project Change". *Journal of Professional Issues in Engineering Education and Practice*, 133(1), 1052-3928. doi: 10.1061/(ASCE)1052-3928(2007)133:1(45)

Ibbs, C., C. Wong and Y. Kwak (2001). "Project change management system". *Journal of Management in Engineering*, 17(3), 159-165. doi: 10.1061/(ASCE)0742-597X(2001)17:3(159)

Isaac, S., and R. Navon (2009). "Modeling building projects as a basis for change control". *Automation in Construction*, 18(5), 656-664. doi: 10.1016/j.autcon.2009.01.001

Jarratt, T. A. W., C. M. Eckert, N. H. M. Caldwell and P. J. Clarkson (2011). "Engineering change: an overview and perspective on the literature". *Research in Engineering Design*, 22, 103-124. doi: 10.1007/s00163-010-0097-y

Kauffmann, P., C. Keating and C. Considine (2002). "Using Earned Value Methods to Substantiate Change-of-Scope Claims". *Engineering Management Journal*, 14(1), 13-20. doi: 10.1080/10429247.2002.11415144

Lechler, T. and B. Edington (2013). "The silver lining of project uncertainties: discovering opportunities to enhance project value". Paper presented at PMI® Global Congress 2013 - North America, New Orleans, LA. Newtown Square, PA: Project Management Institute.

Love, P. E. D., G. D. Hold, L.Y. Shen, H. Li and Z. Irani (2002). "Using systems dynamics to better understand change and rework in construction project management systems". *International Journal of Project Management*, 20(6), 425-436. doi: 10.1016/S0263-7863(01)00039-4

Majerowicz, W. and S. A. Shinn (2016). "Schedule matters: Understanding the relationship between schedule delays and costs on overruns". *2016 IEEE Aerospace Conference*, Big Sky, MT, USA, 1-8. doi: 10.1109/AERO.2016.7500722

Maraslis, A. and N. Kourounakis (2018). *PM² project management methodology Guide 3.0 (v3.0 ed.)*. Brussels, Luxembourg: Publications Office of the European Union.

Mejlænder-Larsen, Ø. (2016). "Using a change control system and building information modelling to manage change in design". *Architectural Engineering and Design Management*, 13(1), 39-51. doi: 10.1080/17452007.2016.1220360

Motawa, I. A., C. J. Anumba, S. Lee and F. Peña-Mora (2007). "An integrated system for change management in construction". *Automation in Construction*, 16(3), 368-377. doi: 10.1016/j.autcon.2006.07.005

Nyman, H. J. and A. Öörni (2023). "Successful projects or success in project management - are projects dependent on a methodology?". *International Journal of Information Systems and Project Management*, 11(4), 5–25. doi: 10.12821/ijispm110401

PMI (2017). *A guide to the project management body of knowledge*. 6th Edition. Pennsylvania, USA: Project Management Institute, Inc.

PMI (2021). *A guide to the project management body of knowledge.* 7th Edition. Pennsylvania, USA: Project Management Institute, Inc.

Shirazi, F., H. Kazemipoor and R. Tavakkoli-Moghaddam (2017). "Fuzzy decision analysis for project scope change management". *Decision Science Letters*, 6(4), 395-406. doi: 10.5267/j.dsl.2017.1.003

Sjögren, P., B. Fagerström, M. Kurdve and M. Callavik (2018). "Managing emergent changes: ad hoc teams' praxis and practices". *International Journal of Managing Projects in Business*, 11(4), 1086-1104. doi: 10.1108/IJMPB-12-2017-0163

Teah, T.-S., W.-Y. Wong and H.-C. Beh (2019). The Practical Implication of Software Quality Assurance of Change Control Management: Why Overall IT Project Activities Matters?". *2019 IEEE 7th Conference on Systems, Process and Control (ICSPC)*, Melaka, Malaysia, 131-13. doi: 10.1109/ICSPC47137.2019.9067982

Varajão, J. (2016). "Success Management as a PM Knowledge Area-Work-in-Progress". *Procedia Computer Science*, 100, 1095-1102. doi: 10.1016/j.procs.2016.09.256

Varajão, J., A. Trigo, J. L. Pereira and I. Moura (2021). "Information systems project management success". *International Journal of Information Systems and Project Management*, 9(4), 62-74. doi: 10.12821/ijispm090404

Vuorinen, L. and M. M. Martinsuo (2018). "Lifecycle view of managing different changes in projects". *International Journal of Managing Projects in Business*, 12(1), 120-143. doi: 10.1108/IJMPB-11-2017-0135

Wu, X., J. C.-A. Tsai and Y. Lei (2023). "Information Technology Project Management Research: A Review of Works by Influential Pioneers". *Project Management Journal*, *54*(4), 366-391. doi: 10.1177/87569728231171056

Xing, T. (2010), "Software configuration management of change control study based on baseline". *2010 International Conference on Intelligent Control and Information Processing*, Dalian, China, 93-96, doi: 10.1109/ICICIP.2010.5565288