The Golden Day: Using Common Data Environments to Improve the Response Time in the Management of Change Orders

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Abstract
Change orders are considered as among the most important sources of cost overrun and decreased productivity in construction projects. If not well managed, changes can result in major contract disputes, with the potential to significantly contribute to project failure. The previous research works suggest that timing and response time are critical in the effective management of construction changes. However, the question of timing and response time remains problematic and very little research has been done on this, especially using the perspective of industry contractors. This article is based on a survey of 55 contractors to assess their perception of the issue. The results show that architects and engineers, in general, do not intervene quickly enough when an urgent change occurs on the site. As a result, the practitioners seem divided on their level of satisfaction regarding their collaboration with architects and engineers during a change on a site. The survey shows that an average of 48 to 72 hours elapses between the time they notify the architect or engineer of an urgent change, and the time it takes place. This period, which may seem short, nevertheless has a significant impact on the evolution of the project. 74% of respondents believe that the ideal response time for professionals to an urgent change should be 0.5 to 1 day, to avoid the change having significant consequences on the results of the project. Better still, 96% of respondents think that responding to an urgent change within 24 hours would have a positive impact on the progress of the project. Based on the survey responses, the article discusses the need for a "Golden day" for the response to urgent changes in construction, drawing a parallel with the principle of “Golden hour” in the trauma patients’ care. Similarly, a lack of rapid reaction to urgent changes could lead to considerable and irreversible trauma to the construction process. The article proposes a theoretical model of timing in the management of urgent changes in the construction industry and offers a discussion on the crucial role of Common Data Environments (CDE) in rethinking the information sharing among the different stakeholders involved in the project.

Keywords: Change orders, Collaboration, Golden day, Common Data Environment (CDE)

1 Introduction

Changes are the source of most of the cost overruns, claims and litigations during construction. Thus, change orders have been identified as ”one of the most common and significant causes of impact costs” [1]. As confirmed by Riley et al., “change orders are among the most significant sources of cost growth and disruptions to field productivity on building construction projects” [2]. Moreover, because of the peculiarities of the construction industry, changes are inevitable in construction projects and it is important to anticipate and to effectively manage changes in order

to avoid negative impact on the project. The recent trends encompass an increasing use of information technology, including Building Information Modeling (BIM) [3–6]. Despite some notable advances, the issue of changes in construction is far from settled.

Multiple research works have been dedicated to understanding and addressing the issues related to change and its management in construction projects [2, 5, 7, 8]. Timing, complexity of work and time response have been identified as the most important factors negatively influencing change order impact [1]. While complexity has been extensively addressed in the dedicated literature, timing and response time have received very little attention. Thus, very few works has been devoted to the subject, and virtually none using the perspective of industry practitioners.

The aim of this paper is to understand the perception of the contractors regarding the timing and the time response in the management of changes, and to discuss how information technology should be used in managing the timing and the response time, in order to reduce the organizational trauma that can be caused by critical changes. The rest of the paper is organized into 5 main sections. Section 2 proposes a literature review on change orders in construction, the 'organizational trauma' and the importance of timing and response time in change management, and the use of information technology to manage changes in construction. Section 3 introduces the research approach used in the study. Section 4 presents the main results, including how contractors perceive the response time of the architects and engineers, and their perception of the ideal timing and response time. Section 5 proposes a discussion of the 'Golden day' around how to better respond to the practitioners' willing by improving timing and processing time through a systematic use of Common Data Environments. Section 6 concludes the paper.

2 Related works

2.1 Change orders in construction

Change orders have been defined as "any event, which results in a modification of the original scope, execution time or cost of work" [9]. In fact, a change order is a "written authorization provided to a contractor that approves a change from the original plans, specifications, or other contract documents, as well as a change in the cost" [10] or in the completion deadlines. Two sources of change are generally identified: the owner-generated changes and the unforseen generated changes [2]. "An owner directed change order is defined as any change order resulting from a change in scope or other owner decision by the owner to modify the original contract" [2]. On the other hand, unforeseen generated change orders are defined as any change order resulting from field conditions, field conflicts between construction systems or a design error or omission [2]. While both types of change orders can induce several negative effects on the construction projects cost and schedule [2], it seems important to distinguish changes due to errors or misjudgment by the contractor from errors coming from other project stakeholders (designer, engineer, client, etc.). The latter will have impact on the time and the cost, but these are typically recoverable by the contractor in the form of claims. They are thus much less important since contractors generally use those to recover margins. So, while all changes are generally bad for a project, all the project stakeholders are not impacted the same way.

Change are very common in construction [11] and "inevitable on most construction projects due to the uniqueness of each project and the limited resources of time and money available for planning" [7]. Thus, change orders are considered among the most common key performance indicators. This can be explained by the fact that changes are the source of most of the cost overruns, claims and litigations during construction. Thus, change orders have been identified as "one of the most common and significant causes of impact costs" [1]. As confirmed by Riley et al., "change orders are among the most significant sources of cost growth and disruptions to field productivity on building construction projects" [2]. Hao et al. added that that "a critical change may cause consecutive delays in project schedule, re-estimation of work statement, and extra demands of equipment, materials, labor, and overtime" [11].

In the recent years, change orders have been increasingly used to measure the success of BIM projects [12] [13]. The framework proposed by Barlish and Sullivan [14] was based on a literature review and evaluated through three case studies. They identified eight main metrics among

which, requests for information (RFI), change orders and project duration appears to be the main 'return metrics'. The framework proposed is very interesting especially for stable environments such as companies. However, according to the authors, other variables should be used when applied for projects or less stable environments.

2.2 Organizational trauma and importance of timing and response time

There is no consensus on the definition of the term "trauma" which still gives rise to much controversy [15]. Thus, several definitions exist and apply to specific areas. According to Shapiro, trauma can be defined as "any event that has had a lasting negative effect upon self and psyche" [16]. The American Psychiatric Association specifies that trauma involves events with a significant physical, emotional or psychological threat to the safety of the victim [17]. While 'trauma' generally refers to individual person, the concept of 'organizational trauma' (OT) applies to organizations. Multiple definitions have been proposed to characterize organizational trauma [18–20]. Hopper defines OT as "a set of potential organizational responses to internal or external acts or events" [19] while Burke noted that it "can affect one or more organizations simultaneously" [20]. The literature review proposed by Peña et al. showed that "a parallel can be drawn between things that trigger an OT and 'potentially traumatizing events' that are mentioned in theories of individual trauma" [21]. These authors identified five categories of consequences on the organization, namely groupthink type behavior, trauma propagation, loss of points of reference and emotional security, expression of stress, and structural dysfunction.

Groupthink type behaviors, also referred to as "Janis effect" to describe how the group leader's decision-making is affected by the dynamics of the group, refers to "the way in which group realities are affected in their entirety" [21]. The trauma propagation refers to fact that "whereas the OT may only affect a part of the organization at first instance, it will eventually spread to the entire organization" [21]. The loss of reference point leads to a disruption of the organization, its constituent elements and its values [21], with consequences for the behavior of the organizations' group [19]. The expression of stress refers to the fact that the individuals within the organization can express the trouble caused by the trauma in different manners, including dissatisfaction and absenteeism [21] or rumors appearing within the organization and inducing paranoid behaviors [22]. Regarding the structural dysfunction, as response to an organizational trauma, the working environment can become unstructured and unpredictable, with an increasing role of informal structures [21, 23].

A construction project is, by nature, a temporal organization in which multiple permanent organizations collaborate in order to achieve a common goal [24]. To fully understand organizational trauma that some poorly managed changes orders can cause to a construction project's organization, it seems important to resort to Leonard's description of change orders on the construction process. According to Leonard [1], individual change orders impact the progress of the project activities in terms of disruption and delay (Figure 1). While disruptions and delays appear to be the most frequent effects of individual change orders, other causes can impact the performance of entire activities [1]. Disruptions refers to the fact that workers are prematurely moved from one task to another, causing "delays to the completion of only a portion of the affected activities" [1]. In the cases examined by Leonard, disruptions and changes "result from changes requested by the owners and architects or engineers, which put the affected work on 'hold', and design errors and omissions, which prevented performance of the affected work" [1].

The accumulation of delays and disruptions gradually deteriorates the original schedules. Leonard [1] noted a diminution of gain in job rhythm and learning curve for delayed and disrupted activities, leading to a reduction of labor motivation and productivity. However, besides those immediate impacts, a ripple-effect is induced by the change order on the unchanged activities, indirectly affected by change orders. Leonard explained it by the interdependency of the construction operations [1]. If not well managed, this can cause a significant organizational trauma to the delivery of the project. Such a trauma can be expressed in terms of unbalanced crews, loss of confidence, toxic collaboration environment, with potential of severe consequences on the overall project productivity.

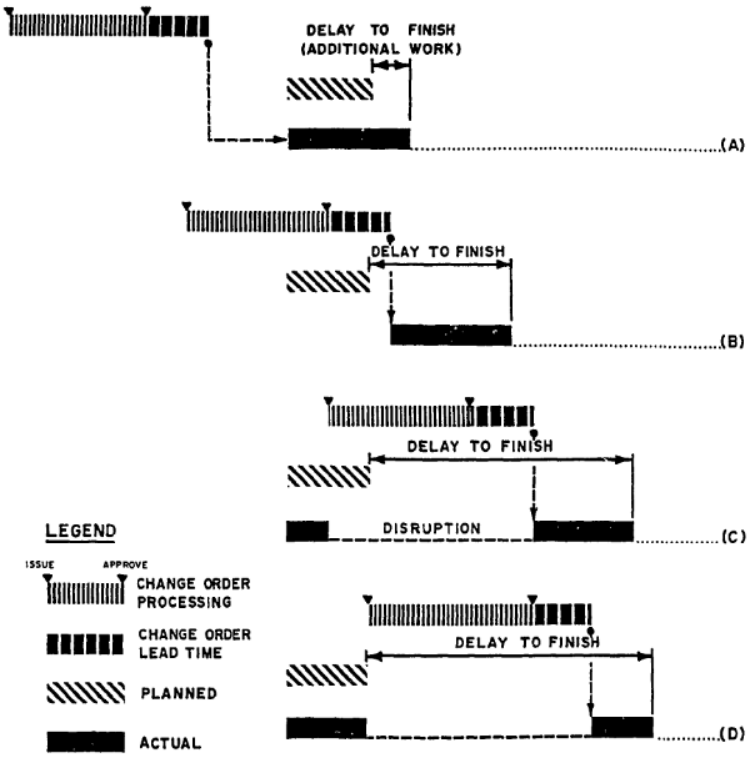


Figure 1. Timing of instruction to proceed in relation to start of affected activity [1]

Another aspect that increases the risk of trauma is that several organizations are involved in a change, including the architect, engineers, general contractor, sub-contractors, suppliers, etc. Managing a change order involves chain reactions between these different actors. The general contractor must assess the extent of the change and identify the specialties involved in order to mobilize the subcontractors concerned in each of the changes initiated. It is important to note that a change can involve several subcontractors and, consequently, several suppliers. Subsequently, subcontractors will have to analyze in detail the scope of this change to determine an execution price and for the supply of the necessary equipment, materials and labor. A fail or a delay in managing the change order therefore has unfortunate consequences for not only the actor directly involved, but also for all the actors indirectly affected. This creates a cascade of negative effects on the entire supply chain, with a risk of deterioration of the collaboration climate. The risk of deterioration is all the greater since, for various reasons related to the functioning of the construction industry, collaboration and trust are particularly difficult [25]. In the case of multiple change orders, the consequence and the risks of deterioration dramatically increase and could easily become very hard to control.

It appears clear that changes orders should be avoided as much as possible by a better integration of the stakeholders from the very beginning of the project, the implication of the client and the contractor in the design phase. Unfortunately, changes are inevitable on construction projects for different reasons [7]. Thus it is important to manage changes in a way that they cause the lesser impact on the project since, if not well resolved through, changes "can become the major source of contract disputes, which is a severe risk contributing to project failure" [11]. And, as seen above, timing is particularly critical. Some seminal research works have established the impact of change orders on construction project productivity. One of the most known is the research conducted by Leonard [1]. Based on the study of 90 cases samples from 57 construction projects, Leonard proposed a model and graphs, referred to as the Leonard method, to predict the impact of change order on productivity. The work proposes a good illustration on how the change management steps (issue, quote, approve, lead time) can create some delay in the project

delivery. The work also identifies the factors that influence the impact of the change order (Figure 2). Among these factors, we see that the timing of the change appears as the most important factor (65%). Moreover, the processing time appears as another important factor (45%).

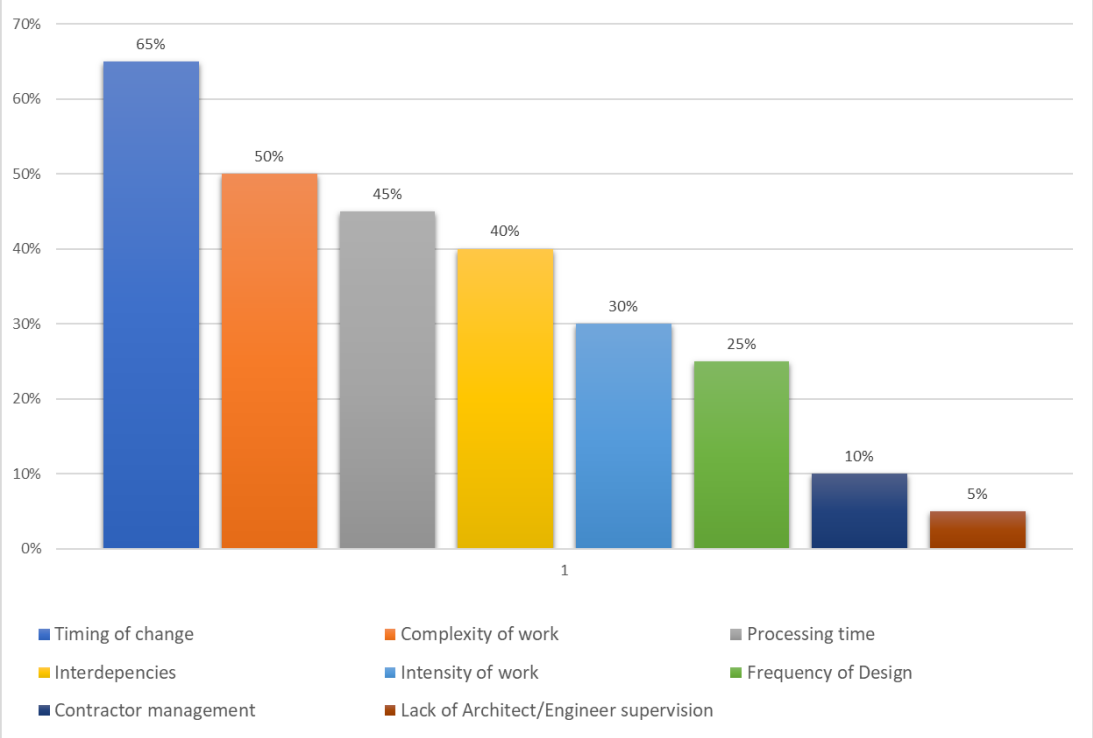


Figure 2. Factors negatively influencing change order impact (adapted form [1])

Information technology (IT) is increasingly used in the construction industry to improve the processing of design, construction and operation. It seems important in the next section, to explore how IT is used to improve the management of changes, in particular to address the issues related to timing and processing time of changes.

2.3 The use of information technology to manage changes in construction

The management of changes "is a pure application-oriented issue and requires engineering innovation to solve the problem" [11]. Thus, using information technology to improve the management of changes is not new in the construction industry. In 1992, Diekmann and Kim [26] developed SuperChange, an expert system to support inexperienced site engineers' decision making related to construction changes and disputes. Later, based on a prediction model using fuzzy logic and dynamic planning and control methodology, Motawa et al. [8] proposed an integrated system for evaluation of how changes can negatively impact the construction performance. The objective of the proposed system is to manage projects' change scenarios and to evaluate the effects of changes according to available information early in the project.

In 2017, Moayeri presented an automated model, based on BIM models, "to determine the ripple effect of owner-requested design changes on a project's schedule" [27]. The proposed model evaluates the changes' ripple effect, using a component-by-component comparison model. The as-planned schedules are linked with the new estimations in order to update the duration of the impacted components and the project planning [27]. Recently in 2019, Dawood et al. [28] proposed a web-based platform prototype, using Industry Foundation Classes (IFC) and Natural Language Processing (NLP), which objective is to automate the validation of change requests. The system "allows users to compare subsequent versions of IFC design models in terms of additions, modifications and deletions" [28]. Thus, the prototype is able to propose to designers a comparison of different versions of the same model, in order to allow an informed decision. More recently in 2020, Ali et al. [4] developed a BIM-based claims management system, consisting in a plugin for Autodesk Revit.

However, despite these notable advances, there is virtually no study on practitioners' perceptions of the processing time and how CDE can be helpful in addressing this issue.

3 Research approach

The investigation took place on February 21, 2019, on the occasion of the 22nd convention of the *Corporation des Entrepreneurs Généraux du Québec* (CEGQ), the main group of general building contractors in Quebec. The event had about 300 participants registered. The mission of this association is to serve the collective interests of general contractors. Founded in 1996, this association has given itself the mandate to remain at the forefront in the research and implementation of efficient means and tools, which allow its members to improve their performance in a highly competitive environment.

The survey was distributed in the morning, at breakfast before the start of the corporation's annual general meeting (the main event), in order to get as many respondents as possible. The questionnaires, printed on a page of paper, and pens were placed on the chairs at each table to ensure that everyone read the document. Participants were invited to complete the questionnaire. A total of 55 responses were retrieved and analyzed.

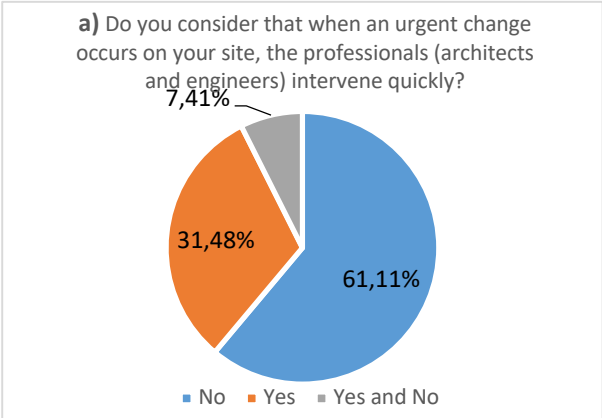
The responses collected were compiled into a Google form, chosen for its collaborative ease of use, in order to analyze the results. From this file it was possible to export the data to Excel in order to generate trends, graphs and conclusions.

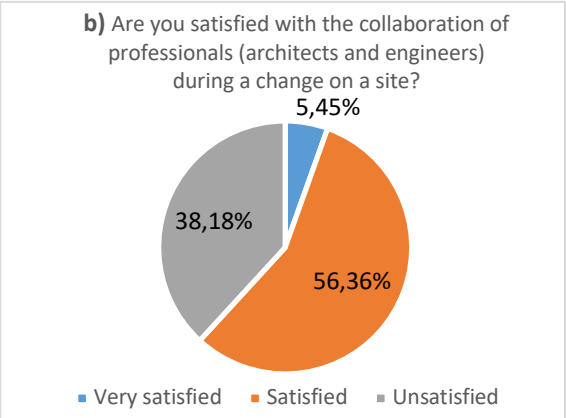
4 Main results

In this section, we present the main results of the study, including how contractors perceive the architects and engineers' response time and the practitioners' perception of the ideal timing in the management of changes.

4.1 How contractors perceive the response time of the architects and engineers

Figure 3 summarizes the practitioners' perception of the timing in the management of changes. The results show that from a contractor's perspective, architects and engineers, in general, do not intervene quickly enough when an urgent change occurs on the site. Indeed, only 31% of them responded clearly 'yes' while 61% responded 'no' and 7% felt that the answer was not clear (Figure 3a). Among the latter, one practitioner justified his answer by the fact that that it all depends on their mandate and the importance of the project in their order book.





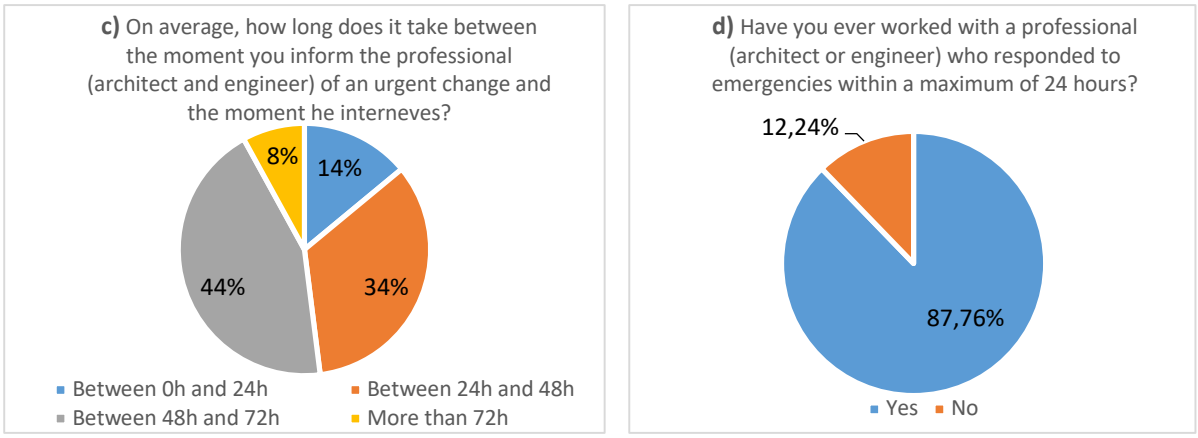


Figure 3. Contractors' perception of the response time of the architects and engineers

As a result, the practitioners seem divided on their level of satisfaction regarding their collaboration with architects and engineers during a change on a site. While 38% of them consider themselves clearly unsatisfied, 56% say they are satisfied and only 5% are very satisfied (Figure 3b).

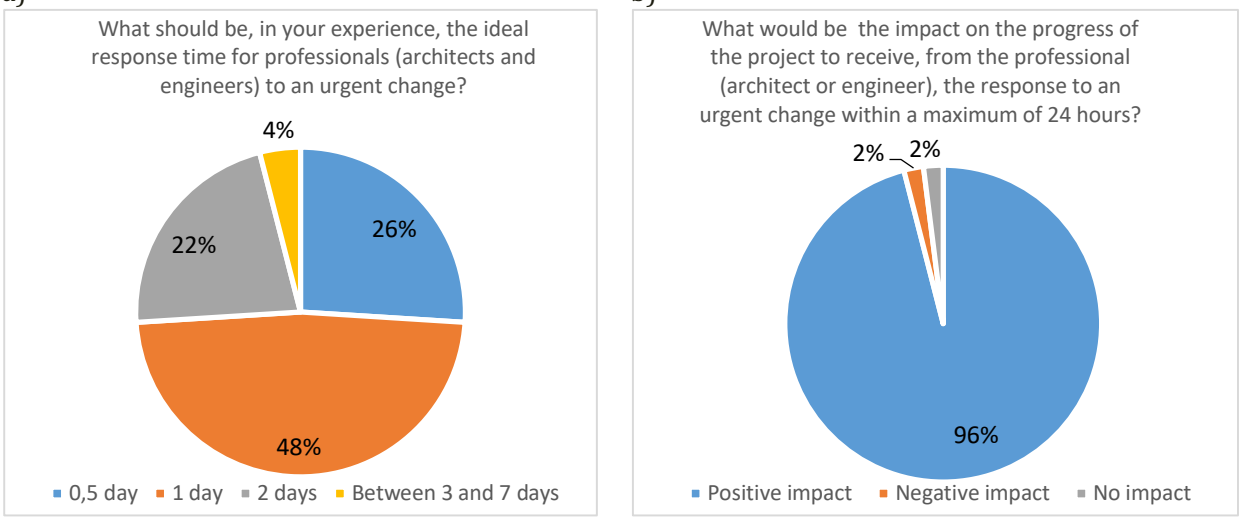
The survey also shows that an average of 48 to 72 hours elapses between the time they notify the architect or engineer of an urgent change and the time they intervene (Figure 3c). Only 14% of the respondents reported a time between 0 and 24 hours. However, when asked if they have ever worked with a professional who responded to emergencies within a maximum of 24 hours, a large majority (87%) of the respondents agreed (Figure 3d).

4.2 The practitioners' perception of the ideal timing and response time

As shown in Figure 4a, a total of 74% of the respondents believe that the ideal response time for professionals to an urgent change should be 0.5 day (26%) to 1 day (48%), to avoid the change having significant consequences on the project. Such a response delay (a maximum of 24 hours) would have a positive impact on the progress of the project for urgent changes for almost all respondents (Figure 4b). More generally, most of the respondents say that it would be desirable, when they have a question (not necessarily a change) on the site for architects and engineers, they answer within 24 hours (Figure 4c).

a)

b)



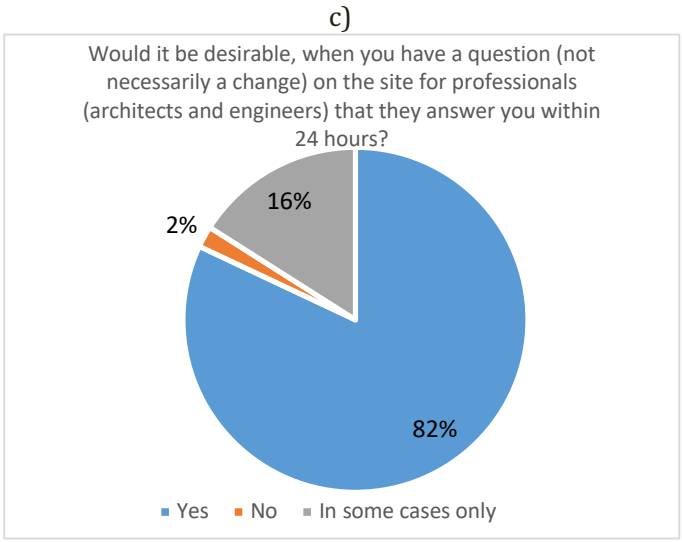


Figure 4. The practitioners' perception of the timing in the management of changes

5 The Golden day: Improving timing and processing time through using CDE

The level of control over the organizational trauma varies inversely with the response time: the more time we take to respond to the request for change, the less control we have over the risks of trauma on the project. Figure 5, inspired from Laufer and Tucker [29], illustrates the situation: the faster you respond, the less negative impact there is on the project; and the faster you respond, the more control you have over the trauma. Note that a parallel can be drawn with the MacLeamy curve on the "ability to impact cost and functional capabilities […] with design, and decision-making earlier in the design process [30].

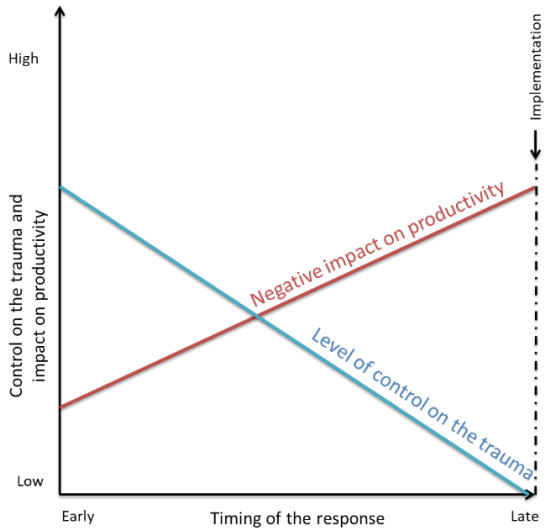


Figure 5. Effect of the timing on the productivity and the level of control on the trauma

Based on the results of the results above, it appears that the architects and engineers' response time should be within 24 hours: the Golden day. This concept draws a parallel with the principle of "Golden hour" referred to in the trauma patients' care as the fact that "that morbidity and mortality are affected if care is not instituted within the first hour after injury" [31]. Similarly, on can reasonably assume that the normal delivery course of the project can be affected if workers at the construction site do not get a feedback quickly from the architect or the engineer, ideally within the first 24 hours.

To achieve this, it is essential to integrate the sharing of information between contractors, architects and engineers, as well as with other project stakeholders, so as to ensure instant access to the right information at the good time. In a context of increasing diffusion of Information Technology in construction [32] and an evolution of practices [33], he best way to do this is undoubtedly to couple the change management process to a Common Data Environment (CDE). A CDE can be defined as "a central space for collecting, managing, evaluating and sharing information" [34]. Coupling change management to a CDE would not only reduce the time to access information, but also to avoid losses and other redundancies of information, while guaranteeing traceability and better security.

CDEs should, in addition to information storage (asset information and project information) and coordination spaces, develop production spaces adapted to the different stages of change management. This is about enabling users to initiate change requests and manage them collaboratively, each on their own, within the framework of the CDE. In fact, CDEs can be helpful to manage all the lifecycle of changes, including the requests for information (RFI). In this context, the use of the CDE will be based on appropriate workflow and structured information expressed semantically whereby the meta-data for each RFI would have to include: RFI category, priority, status, cost and schedule implications. Using such a CDE will not only save time and productivity in the processing of requests by better integration of information, but will also ensure good traceability of exchanges. Thus, there would be less scope for manipulation of the RFI system by certain stakeholders for the purpose of financial gain.

6 Conclusion and future works

Based on a survey of 55 general contractors, the paper discussed the "Golden day" concept, referring to the fact that, for major urgent changes, architects and engineers' response time should be within 24 hours, in order to reduce the risk of organizational trauma on the project. The paper also discussed the use of Common Data Environments as the best solution for sharing and managing information. These discussions contribute to a larger issue on the role of information technology in improving productivity and reducing cost overrun in construction projects.

However, the article focused only on the perspective of the contractor, without considering the opinion of the other stakeholders in the supply chain. This can be explained by the fact that only the field generated changes are considered in the study. Future works will extend the scope of the investigation in order to address these limitations. Moreover, the understanding of the possible association between CDEs and existing change management systems will be deepened, in order to formulate more specific recommendations.

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