Journal of Architectural Design and Construction Technology
Volume 3 | Issue 1

HELICS GROUP Scientific Networks

Research Article Open Access

De-Risking Construction Inefficiency Through Continuous Risk Management Over Workflows at Project Level

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Citation: Muntés-Mulero V, Dominiak J, González-Vidal E, Rudziński D, Ros-Batlle X. De-Risking Construction Inefficiency Through Continuous Risk Management Over Workflows at Project Level. J Arch Des Cons Tech. 2022;3(1):17-28.

Received Date: January 27, 2022; **Accepted Date:** February 28, 2022; **Published Date:** March 16, 2022

Abstract

Risk management excellence is regarded by most large corporations in the construction sector as one of the main strategic challenges today. However, many companies are still at the beginning of the journey in terms of efficient risk control, focusing in many cases on regulation compliance checks or some specific financial aspects. In spite of this, many risks remain unmanaged, as they are caused by overlooked chain reaction effects originated by multiple accumulated issues that affect the assets of a project (e.g., delays in the documentation, permissions, tasks, etc.) and end up generating project delays and budget overruns. This situation becomes more challenging because of poor digitization. Data fragmentation and lack of interoperability among digital tools used to manage these different assets makes the implementation of mechanisms to control these types of risks in real-time more difficult. In this paper, we discuss a use case in a real construction project, analyzing one of their workflows and performing risk management on top of it. We discuss the need for new methodologies and non-intrusive AI-driven technology to control risks over business processes in real-time, without requiring organizations to change their current digital tools and business processes.

Keywords: Continuous risk management; Artificial Intelligence; Data fragmentation

Abbreviations

AI	Artificial Intelligence
API	Application Programming Interfaces
BTA	Bow-tie Analysis
BPM	Business Process Model
BPMN	Business Process Model Notation
EDMS	Electronic Document Management System
ETL	Extract, Transform, Load
GC	General Contractor
LL	Lessons Learned
RM	Risk Management
VFR	Vinci, Ferrovial Construction and Razel-Bec

Introduction

According to Forbes, the worldwide market for construction services is expected to grow by 85% to $15.5 trillion by 2030 [1]. The construction sector generated around 1.42 trillion euros in 2018 only in Europe[1] and it is one of the largest economic sectors in the region. According to McKinsey[2], three trends drive the construction industry globally, and they are expected to continue doing so in upcoming years: (i) Investment acceleration: in 2013 the investment in energy, infrastructures, mining, and real estate was around $6 trillion. This is forecasted to grow up to $13 trillion by around 2030; (ii) Megaprojects: the investment mentioned in the

[1] FIEC, Annual Report, 2019: http://www.fiec.eu/en/library-619/annual-report-english.aspx
[2] The construction productivity imperative. July 2015. Sriram Changall, Azam Mohammad and Mark van Nieuwland. https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/the-construction-productivity-imperative

previous bullet point aligns with an increase in the realization of megaprojects budgeted at more than $1 billion; and (iii) Problems of finalizing projects on schedule: the construction industry are not able to finalize projects on time, according to budget and to the original project specifications: 98% of megaprojects suffer from budget overruns exceeding 30% of the budget and 77% are at least 40% later than expected.

The construction sector is actively facing a digitization challenge. According to a study of the level of digitization of different sectors in the US by McKinsey in 2016, the construction sector was in position 21 out of 22 analyzed sectors, with only agriculture and hunting being less digitized[3]. The same index also positions the construction sector at the end of the list in Europe[4]. In the past years, most of the attempts towards digitalization aimed at increasing the productivity and quality of office work, e.g., digitizing change handling workflows using project management systems (e.g., Procore), improving design coordination and visualization through BIM software, optimizing schedules through scheduling software or creating better estimates based on BIM models (e.g., model-based estimating software) [2]. Nevertheless, these tools have had limited impact, because they are still not measuring the operational performance of the project through the digitization of workflows but they are mostly related to project management functions, as studied in the DiCtion project[5].

The need for controlling risks in construction projects is well documented. For instance, Szymanski presents an exhaustive list of relevant risks in the sector [3], where the importance of starting the risk management process even before the signing of a new contract is remarked, together with the need to increase the predictive capacity on forecasting risks and to better exploit analytics. Besides, methods used are still based on traditional risk management methodologies, which can handle neither the complexity nor the current dynamism of construction projects. Different methodologies for risk management currently exist. Traditional approaches based on reliability theory and risk management have proven insufficient [4, 5, 6], and the lack of digitization in the sector does not facilitate the exploitation of new AI-based mechanisms. Aymerich and Turro analyzed risk control in construction projects related to transportation [7]. They specifically focus on excessive costs and delays, highlighting the lack of the industry's capacity to capitalize knowledge from previous projects to control risks in new projects and the need for controlling risks in large capital projects. The lack of high-quality information caused by insufficient data or capacity to explore existing data are presented as two key factors. Also, continuous control of risks, after initial assessment is also essential [8]. For instance, according to the Department of Transportation of California[6], risk management should include a risk monitoring strategy to control risk evolution.

In particular, the importance of proper management of non-physical assets such as programs, documentation, consents, and inspections, to mention some examples, was evident in recent large projects. Originally planned to open in October 2011 and budgeted at 2.83 billion euros, the Willy Brandt Airport, Berlin Brandenburg International Airport has encountered a series of delays and cost overruns[7]. The airport finally received its operational license in May 2020 and opened for commercial traffic on 31 October 2020. The actual estimations raise its expected final budget to around 10 billion euros. Project delays were caused by several factors including poor construction planning, execution, management, as well as corruption. In particular, planning, design, and execution issues were commonplace. Inspectors uncovered many examples of poor workmanship due to a lack of proper supervision and documentation.

While projects, and especially large ones, are unique, they share different features such as construction workflows and processes and tools used [9]. This indicates that problems are likely to re-occur in future projects if not properly mitigated [10]. This has motivated the development of different approaches to capture, store, retrieve, and disseminate risk-related knowledge in forthcoming ones, such as for instance that presented in [11].

In this paper, we analyze the risks related to workflows used in a real-world use case based in construction works related to the ITER project. The objective of the current work is to provide a practical example that contributes to the validation of the following research hypothesis: lack of control in workflows and of operational performance is a significant risk per se and has the potential to produce significant budget overruns and delays. We discuss that many risks are caused by misfunctions in those workflows and argue that risk management (RM) tools are not capturing these types of risks.

The rest of the paper is organized as it follows. First, we discuss the methods used in the work. Then, we present the results. Finally, we discuss those results and draw some final conclusions.

[3] McKinsey Global Institute digitization index, 2016.
[4] https://www.mckinsey.com/business-functions/mckinsey-digital/our-insights/digital-europe-realizing-the-continents-potential
[5] https://www.aalto.fi/en/diction
[6] Project Risk Management Handbook, Second Edition. California Department of Transportation, 2007.
[7] https://en.wikipedia.org/wiki/Berlin_Brandenburg_Airport
[8] https://www.iter.org/

Materials and Methods

ITER project context

Currently, ITER[8] is probably the most ambitious energy project in the world. ITER aims at harnessing nuclear fusion power, a potential source of safe, non-carbon emitting and virtually limitless energy. ITER builds the largest and most powerful fusion device in the world and the first to generate net energy. The project was originally planned to construct a functional reactor by 2016 and budgeted at 5 billion euros. Currently, the reactor is expected to be switched on in 2025 with an actual cost of around 20 billion euros. In the upcoming years, around 4,000 workers will be required for on-site building, assembly, and installation activities.

Methodology used for this research

We study a real-world use case based in construction works related to the ITER project. A consortium, composed of subsidiaries of Vinci, Ferrovial Construction and Razel-Bec (from now on, VFR), worked under a contract with Fusion for Energy (F4E), the European Union's organization for Europe's contribution to the International Thermonuclear Experimental Reactor (ITER), to build the Tokamak complex building and to design and build several auxiliary buildings at Cadarache, north of Aix-en-Provence in southern France. To control quality and risk, VFR conducts a strict control of the construction process through the strict management of the internal documentation of the project and the schedule to deliver this documentation.

To pursue this research, we conduct interviews and iterative processes to understand some critical workflows and the most relevant risks, related to those. In particular, we interview 10 individuals playing different roles in this complex construction project including project directors, technical engineering managers, quality managers, site engineers and documentation controllers. We also analyzed the digital tools used to manage all aspects related to documentation control.

Following the requirements from the ITER team, we focus on workflows related to generating, reviewing and approving documentation and the risks associated to these workflows. Workflows are defined using the Business Process Model Notation (BPMN v2.0) [12].

We conduct several in-person interviews with technical engineering managers, quality managers, documentation controllers and other personnel from the quality department to precisely define the workflow to be controlled. These interviews are complemented with additional conversations by e-mail to refine the workflow BPMN model.

To realize the risk analysis, we use Bow-Tie Analysis (BTA) [13], an increasingly popular method often employed in high-hazard industries such as mining [14, 15], or other critical environments such as those related to medical safety [16, 17, 18]. We select BTA because of its ability to show both existing and potential controls as well as highlighting where gaps in control may exist [17]. Besides, BTA provides a quickly understood overview of the risk controls linked to initiating events [19]. BTA combines features of fault-tree and event-tree analysis to identify initiating events within an incident, their contributing factors and consequences, and both preventative and mitigating control measures [20, 21]. At the core of each BTA, we spot an initiating event (usually called top event) which represents the loss of control of the hazard leading to increased risk.

We conducted several sessions with site engineers and quality department personnel including documentation controllers to analyze the main risks in the above-mentioned workflow as the main source for the BTA.

Results

In this section, we describe the main aspects of the digital ecosystem used in the construction project under analysis, focusing on those digital tools and methods relevant for the workflow studied. Then we define the workflow in detail, and we finally analyze the risks related to such workflow.

Analysis of digital ecosystem

First, we analyze the digital tools or mechanisms used to manage the submittal, review and approval of documentation. The VFR offices manages a large number of documents (around 1200 documents per month for 5 years). The status of documentation is dynamic, and many stakeholders are involved at design time, usually in highly repetitive operations.

To manage these processes, they mainly use the following digital tools and channels:

- **An Electronic Document Management System (EDMS):** VFR uses an EDMS which is a proprietary tool created by one of the partners in the joint venture. The software has been used for more than 10 years and it does not provide APIs to access the information. The EDMS is used by the VFR office to host all the documents and control their status. The EDMS communicates all the changes in a document through sending e-mails automatically to all the stakeholders indicated as related to the document in the EDMS.
- **A different EDMS for the client:** the client of the joint venture requires a different EDMS where all documents

[9] SGTi4 - collaboratives solutions and applications for project management

need to be uploaded for client's review. They use SGTi[9] solution, which means a completely different technology compared to the proprietary EDMS used internally.

- **A spreadsheet to keep the documentation schedule:** in order to control the whole documentation schedule, an additional Microsoft Excel spreadsheet is used with more than 20,000 lines. This spreadsheet contains all the documents including those delivered, those being prepared and those planned in the future. The schedule contains documents that have not been created and uploaded to the internal EDMS, so they only exist in the spreadsheet. Whenever there is a change in the status of a document, the spreadsheet is updated manually, usually by the documentation controller. Manual changes are prone to human errors, and it is not infrequent to find discrepancies between the EDMS content and the spreadsheet.

- **A project planning tool:** an independent software is used to manage the project schedule. VFR uses Oracle Primavera for this purpose. The actual link between the documents and tasks in the program is not captured explicitly in this tool and in any other tool described before. The complexity of the project and the large number of documents makes it impossible in practice to get the program to the level of detail where we have a specific task for each document that needs to be prepared and approved. In some cases, tasks are defined that act as deadlines or milestones towards which documents are linked. This specific aspect makes it difficult to manage risks related to documentation deadlines in general, and it usually requires several members of the team with different roles to gather and spend several hours to align program and documentation statuses and get a high-level overview of the risk status. This analysis will usually lack accuracy or even currency after a few weeks.

These tools lack features that allow for deep data analytics and lack interoperability among them. This forces VFR team to perform a lot of manual ETL processes, that may potentially generate data noise, lack of accuracy or lack of coherence. Besides, along the different interviews, we perceived workload is high and there is a general reluctance to replace tools with completely new tools that require significant training or modify workflows teams were already used to.

Analysis of a documentation management workflow

After analyzing the digital ecosystem in the project studied in this paper, we analyze the workflow related to documentation submittal, review and approval. The complexity of the construction projects related to ITER is immense, and the construction companies with design and build contracts need to manage project schedules, with thousands of tasks. Most of these tasks depend on documentation approvals, resulting in several thousands of documents per year. If any document is not ready, linked tasks are delayed potentially causing millions of euros in losses. Every time a single task in the project schedule changes in the project planning tool, the level of risk for each document changes. However, these changes are usually not notified to document owners or documentation controllers, although the GC needs to control this workflow to avoid delays and budget overruns.

This process is particularly challenging, as different stakeholders from different organizations are involved. For instance, most of documents are generated by subcontractors, although a relatively small portion of them is also generated internally by the general contractor's (GC) staff (this latter case is not studied in this paper). Besides, the GC's client is also involved in the review process and needs to issue the final approval for the document to be considered valid to be used in next steps. While the GC does not have full visibility on the work done by the rest of the stakeholders, it still has enough information to understand the health of the execution of a workflow.

(Figure 1) shows the workflow analyzed in the context of our use case, discussed with the project staff, and described using BPMN v2.0. This workflow represents the submittal, review, and approval of documentation in the project. It was obtained as a result of several interviews with the staff involved in the workflow, as mentioned in the previous section. Note that this is a simplified version of the BPMN process that has been designed for the sake of simplicity and understandability. For instance, in a strictly formal BPMN diagram, each actor in different organizations would need a starting point and an ending point for each of their subprocess. These have been omitted to improve readability of the diagram.

The workflow involves 3 different pools: one for the subcontractor generating the documentation, one for the GC and one for the GC's client. The GC pool is subdivided into 2 lanes, one for the internal owner of the document (typically a site or design engineer, or a quality officer) and another one for the documentation controller, involved in all documentation-related workflows. Following, we analyze the main steps in this workflow (or set of workflows):

- **Subcontractor generates a document:** the starting event in the studied diagram consist of an external subcontractor generating and submitting a document to the GC. Note that the steps to produce this document are not considered in this diagram, because they are not visible to the GC. Also, note that this workflow is flexible in the sense that it already acknowledges that some subcontractors may use the documentation management tool used by the subcontractor and upload documents directly to this tool, but it also recognizes that some subcontractors may decide not to use it and they may submit documents by e-mail, generating 2 parallel paths in the diagram which connect the subcontractor workflow with the GC's internal owner workflow.

- **Internal staff of the GC reviews the document:** there are several steps where the document internal owner (the person in the GC's organization responsible of validating the content submitted by the subcontractor) and the documentation controllers review different quality aspects of the document before sending it to the client. In particular, document owners may decide to refuse a document and send it back to the subcontractor for review in case it is not compliant with the standards. Documentation reviewers, in the studied use case, would not only upload the quality stamp to the GC's documentation management tool, but also update the documentation schedule in the spreadsheet and upload the document in the client's documentation management tool.

- **Client's staff reviews the document:** once the GC has approved the document internally, this is uploaded to the client's EDMS for the review and approval. Again, the GC normally does not have visibility on how this review and approval process happens on the client's side. Typically, the contract between the GC and the client will contain clauses, specifying the maximum permitted time the client has to review and submit the result to the GC. If the document is approved, usually the process is almost finished. Otherwise, in the worst-case scenario the document needs to be sent back to the subcontractor and we need to start the process all over again.

- **Closing steps:** in case a document is approved by the client or considered good enough to proceed to next steps (even if in some cases may still need refinements), documentation controllers need to upload the review from the client in the internal EDMS and update the documentation schedule spreadsheet. In this case study, there existed two options once the document was approved. If the document was created in the design phase, the workflow finishes after the documentation schedule is updated. However, if the document is to be used directly for construction tasks, they had established a particular procedure to create a new version of the document to indicate that the document is valid for construction.

Note that different steps of this workflow are related to different elements described above as part of the digital ecosystem:

- **Subcontractor** uses e-mails to submit documentation to the GC or they use the internal EDMS used by the GC.

- **Documentation owners** use the internal EDMS to manage documentation. They may also need to use e-mails forced by subcontractors that may reject using the EDMS. Also, they use e-mails to learn from changes in the documentation status, since the EDMS automatically sends e-mails to notify status modifications. Besides, they need to manually change the status of a document in the spreadsheet containing the documentation schedule. Manual updates are prone to errors that may jeopardize data coherence. Additionally, the data is never updated in real-time, but there is a delay which creates disruption and confusion among team members. Also, when the workload is high, the number of communications may saturate the capacity of different actors to consume the e-mails from their inboxes, causing further delays.

- **Documentation controllers,** once the document is validated by the owner, will review and update documentation status through the internal EDMS. However, they also need to upload documents to the client's independent EDMS, once these have been reviewed internally. Analogously to documentation owners, they also need to manually change the status of a document in the spreadsheet containing the documentation schedule, once significant progress occurs (i.e. a document is reviewed and accepted internally, or the review from the client is received).

- **Clients** use their EDMS, required by them through the contract signed with the GC.

While they do not play an active role in the workflow described in (Figure 1), there are two more roles that may impact, or benefit from, the activity described in workflow:

- **Project planner or program manager:** as we mentioned before, although this is usually not captured in a digital format, tasks in the program depend on documents. In other words, if a set of documents is not reviewed and approved in time, certain construction tasks cannot start. Apart from becoming an important source of risk, this also generates a lot of uncertainty in the process related to managing documentation. The construction project program is being continuously adjusted by the project planner, because of the continuous unexpected events occurring in the project. With every change, the deadline established for documents to be ready in time changes, making the control of those cumbersome.

- **Project director/Operations director:** manager roles may also need to participate in mitigating some risks related to the workflow described above. For instance, discussions and negotiations with subcontractors and the client may require their attention and involvement.

Analysis of risk in documentation management workflows

Following, we analyze the risks related to the workflow analyzed in (Figure 1). In order to perform this analysis, we conducted several sessions with quality managers, engineering managers, site engineers and documentation controllers to understand the main risks and create the associated BTA. (Figure 2) depicts the BTA related to the workflow analyzed in this use case.

As in any other BTA, we first analyze the main hazard in our current system. In the use case related to documentation submittal, revision and approval processes, the main hazard is that "A task (in the program) cannot start if related documents are not approved". From here, the top event we will need to avoid is "Document is not ready by the time related task needs to start".

Then sources of the top event are depicted on the left side of the bowtie and consequences are defined on the right side of the diagram. Note that we also define barriers to prevent the impact of the detected sources. In this scenario, we defined barriers to act before the top event happen as a natural way to avoid a document delaying the task with all the potential derived consequences. As an example, a document may not be ready in time because a "Subcontractor is blocking a process" and potential barriers to avoid this source of threat triggering the top event may be contacting the subcontractor to find potential mechanisms to unblock the situation or replacing the subcontractor (if that is possible).

Discussion

Following we discuss the main learnings we obtained out of the analysis of the workflow and the risks presented in the previous section.

BTA refers to a workflow that is repeated thousands of times over the life of the project, once per each document. Sources of risks happen during the actual execution of these workflows and can only be mitigated if they are captured early enough during this execution, as suggested in [2]. This makes it essential to have real-time control of the evolution of these processes and automated mechanisms to evaluate the evolving levels of risks. Otherwise, most of these risks can go undetected within the large amount of data generated in a project. For instance, following risk sources identified in the BTA (Figure 2), detecting if a subcontractor is blocking a process, if the document of a subcontractor is being rejected more than often, if internal resources are not available, if the workload is unusually high, or if the client does not review the document in time, require measuring the operational performance in real-time.

In general, risks are evaluated based on speculation rather than evidence [22]. This occurs already in highly digitized sectors like cybersecurity. The lack of digitization in more traditional sectors like the construction sector aggravates the problem. This lack of efficient mechanisms to manage risks causes companies to waste a significant amount of time before detecting and mitigating risks and results in unexpected additional costs. Most commonly, the risk control process is managed manually using spreadsheets and stored locally on a computer by an individual department [23], making data sharing very difficult and collaboration even harder. This approach quickly becomes inefficient when projects and teams grow larger. Cooperation and agility for risk control have already been proposed. For instance, Moran proposes the use of modified kanbans to control risks and make software development more agile [24]. Muntés et al. [25] propose a model to manage risks to support agile and collaborative environments and continuous development. Dominiak et al. [26] also propose a generic methodology for the continuous control of risks in the H2020 ENACT project[10]. To our knowledge, the impact of these proposals on the tools used in the construction sector is inexistent.

Continuous risk management over non-physical assets in construction projects such as the program, documentation, consents, contracts, etc. has not gained enough attention in the sector despite being a relevant source of delays and budget overruns. We envision more research and technology development will be necessary to enable this level of risk control in the sector. In particular:

- RM methodologies need to be updated to connect workflow execution with continuous RM practices.
- Evidence-based RM needs to be integrated to enable non-intrusive mechanisms that avoid adding extra work to construction project staff. These systems need to assume heterogeneity and fragmentation as two normal features of most construction projects' digital ecosystems.

Data fragmentation and lack of interoperability

As we have observed in the analyzed workflow, workflows depend on information that is managed across different non-interoperable digital tools. For instance, in the analyzed workflow, documents are stored and managed in a proprietary EDMS, some of them are sent by e-mail, program is managed by a project management tool, the client imposed the use of a completely different EDMS, and the documentation schedule was managed in a very large spreadsheet containing thousands of lines and updated manually. These tools do not allow transversal analytics and lack interoperability among them. This makes it very difficult for the staff in charge of managing the project from the back office to control workflows, as there is a lack of mechanisms to control operational performance. As a consequence, controlling anomalous situations, such as delays, during the execution of the workflow becomes impractical. These anomalous situations generate a snowball effect that has the potential to end up generating delays in the project, especially when

[10] https://enact-project.eu/

tasks in the critical path are affected by delays in the documentation and, therefore, budget overruns.

We envision more research and technology development to enable non-intrusive mechanisms to overcome these two issues. In particular, methods that do not force large organizations to change their current tools and workflows are mandatory. Through the interviews, we detected that construction project office teams are generally overloaded and cannot absorb changes in their digital ecosystems that require important retraining and additional work to incorporate new procedures.

Actionable Lessons Learned

Organizational learning has been identified as a core competency for project-based companies with industry specific challenges [27]. Although most knowledge is acquired during projects, companies can hardly manage and utilize accumulated knowledge in forthcoming projects [28, 29]. While learning from projects may be facilitated by using manageable formats to capture lessons and establishing a mechanism to disseminate lessons learned (LL) successfully [30], most of the current efforts are still focused on creating web-based tools that can be used to capture, disseminate, and reuse lessons learned [27] or based on implementing LL programs, usually in the form of knowledge bases. The ineffective management of LL leads to the reproduction of mistakes and unwanted situations and the occurrence of new delays and budget overruns that could have been avoided observing past experiences.

As a consequence of our analysis and the discussions we had with different roles associated to a megaproject, we believe that a relevant research direction is the use of AI approaches to make LL actionable automatically. Automatically learning models from the execution of projects that can be leveraged in subsequent projects in a way that is transparent to the final user would enable a new generation of LL mechanisms, producing much more actionable and embeddable information for these future projects. In particular, the control of workflows in a particular project enables the use of AI to learn the actual execution of these workflows and detect anomalous situations in workflow execution in the future, within the same project or even inter-project, when it is possible to define inter-project workflow use cases.

Impact of lack of real-time risk management

We have seen an example based on a workflow related to documentation management and the potential risks related to this workflow. Finally, we devote the final part of the discussion to the impact that controlling operational risks effectively can produce in terms of return of investment, to reflect on several informal conversations we had during the interviews processes. Several discussions with the staff at Ferrovial Construction and Vinci helped us understand that there exist 3 pillars that justify this return of investment:

- **Reduction of project delays:** anticipating unwanted incidents such as a document being late or a permission not being issued in time, to provide some examples, minimizes reaction time in decision making.
- **Better capacity to negotiate with providers and client:** understanding process performance and where bottlenecks happen allows decision makers to know who is the responsible for delays, improving their capacity to negotiate with customers and providers.
- **Total, team staff optimization:** information from business processes performance allows understanding potential bottlenecks created by the own resources of an organization, allowing for the optimization of teams' organization and procedures.

Specifically, we propose some high-level formula to approximate the potential financial impact of the lack of the risk management with respect to the thread sources and the consequences depicted in (Figure 2). Let B_{annual} be the average annual budget for a project.

- **Time savings in the project due to better documentation control:** the lack of risk management over workflows may generate delays in the project that could be avoided. Let us call t the amount of time in months that could be saved if we control workflow risks in real time. We can calculate the potential annual savings of reducing delays caused by delays in the documentation management workflow (ps_{delays}) as:

$$ps_{delays} = \frac{B_{annual} \cdot \mu}{12} \cdot t$$

where μ is the percentage of the budget invested in indirect costs. The rationale behind this simple equation is that by reducing delays in the project, you are saving all the indirect costs you would incur by having your project running for extra *t* months.

- **Savings produced by better negotiation capacity:** we focus on the negotiation with subcontractors. Let us call p the percentage of claims we could reduce thanks to the data we collect when controlling workflows (in the example, information that allows us to assess that a delay caused by a document was initiated by a delay caused by the subcontractor). We call α the percentage of subcontracting volume in a project and β the percentage of contracts that are usually claimed in that project. We can calculate the potential annual savings produced by a better negotiation capacity ($ps_{negotiation}$) as:

$$ps_{negotiation} = B_{annual} \cdot \alpha \cdot \beta \cdot p$$

Note that, controlling the workflow, you do not only monitor subcontractors' behaviour but also you may detect the number of times a client violates clauses in the contract limiting the maximum time allowed to review a document. This information could also be used to negotiate costs with the client. This is not considered in this example formula, and it could become a further source of savings.

Savings produced by total team staff time optimization: monitoring the execution of workflows may give you a lot of information that may allow you to optimize the time of your staff. Let us call o the percentage of time you are able to reduce thanks to the lessons learned from monitoring workflows. We can calculate the potential annual savings produced by total team staff time optimization ($ps_{time\ optimization}$) as:

$$ps_{time\ optimization} = B_{annual} \cdot \mu \cdot \sigma \cdot o$$

where σ is the percentage of the indirect costs used to cover office staff costs.

In (Table 1), as an example, we show the potential economic savings lost with the lack of real-time risk control in this use case, for different project sizes. In the example shown in the table, and base on the usual estimation done by the experts we interviewed at VFR:

- we assume $\mu = 0.14$ (14%) to calculate time savings in the project due to better documentation control.
- we assume $\beta = 0.08$ (8%) to calculate the impact to generated by a better capacity to negotiate with providers. The industry can be very variable regarding the subcontracting volume in a project. We assume that this volume oscillates between 35% and 60% of direct costs and we take $\alpha = 0.45$ (45%) to calculate the figures in the examples.
- we assume $\sigma = 0.75$ (75%) to calculate the impact in term of staff's time optimization.

As it can be observed in the table, saving can be significant, in the example, more than one million of euros per year.

Conclusion

Lately, control of workflows has gained some attention in the construction sector. However, despite its potential as a mechanism to digitally control activities and improve performance, it is still largely ignored in most projects. One of the reasons for this is the difficulties companies find to control those workflows and therefore to measure operational performance, which take place across inefficient digital ecosystems where data fragmentation and lack of interoperability among digital tools makes it almost impossible to control them.

Methodology and technology to facilitate workflow control, avoid data fragmentation and lack of interoperability and enable effective use of lessons learned using non-intrusive mechanisms will allow projects' staff to gain awareness and enhance decision making when managing their projects, enabling them to improve their negotiation capacity with subcontractors and clients, through a data-driven approach, and allowing them to optimize processes and focus on priorities based on a risk-driven analysis. We encourage the community to strengthen research in these promising directions.

Conflict of Interest

N/A

Acknowledgement

This work is supported by a grant from the Centre for the Development of Industrial Technology (CDTI) through the NEOTEC 2021 program (grant ID SNEO-20211182). CDTI is a Public Business Entity, answering to the Ministry of Science and Innovation of Spain. This program is funded by the European Union – Next Generation EU. We would also like to thank Oriol Ribas from his insightful comments based on his long professional experience.

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Figures

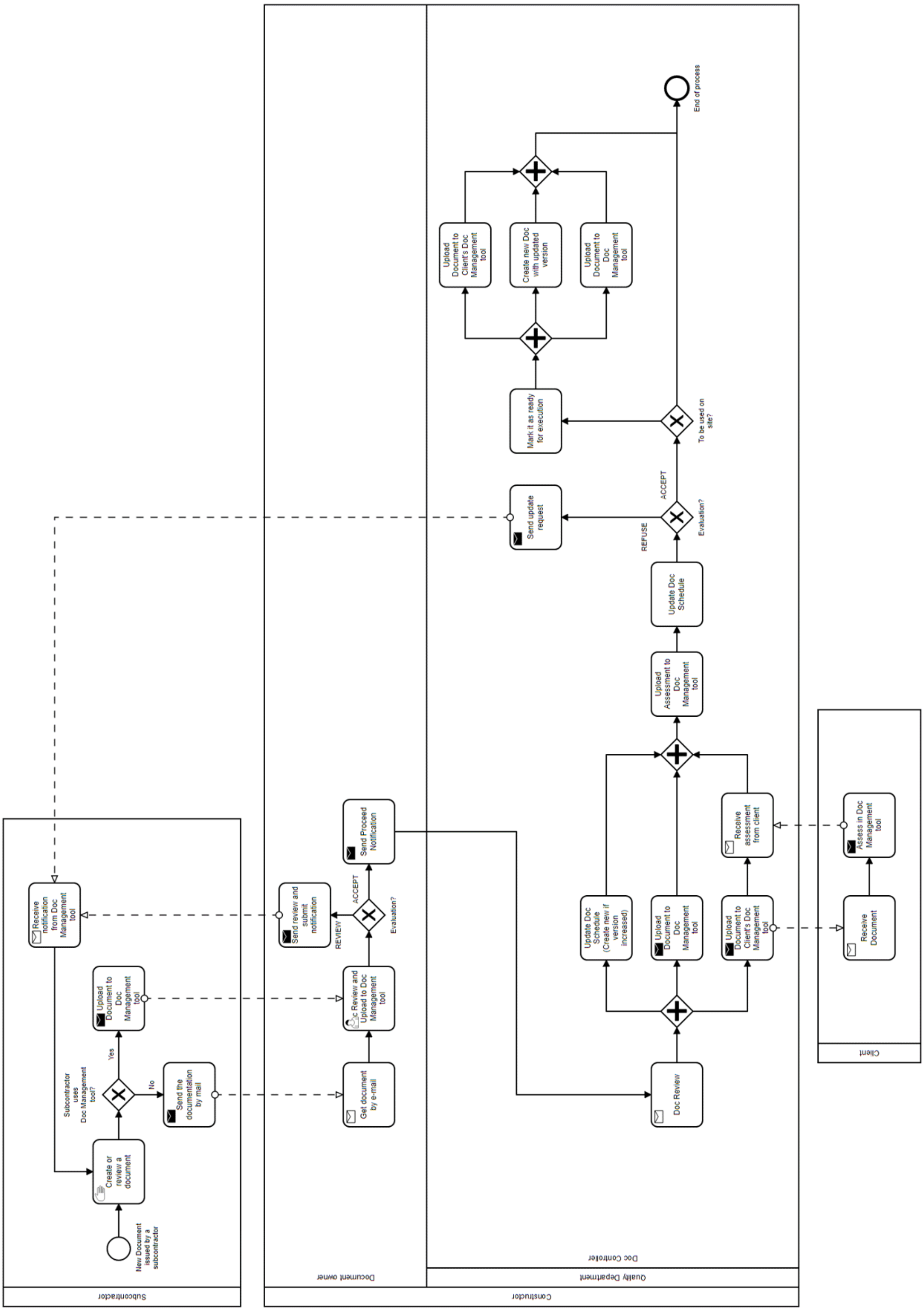

Figure Legend 1: Documentation generation, review and approval workflow obtained after the interview of different stakeholders related to this activity.

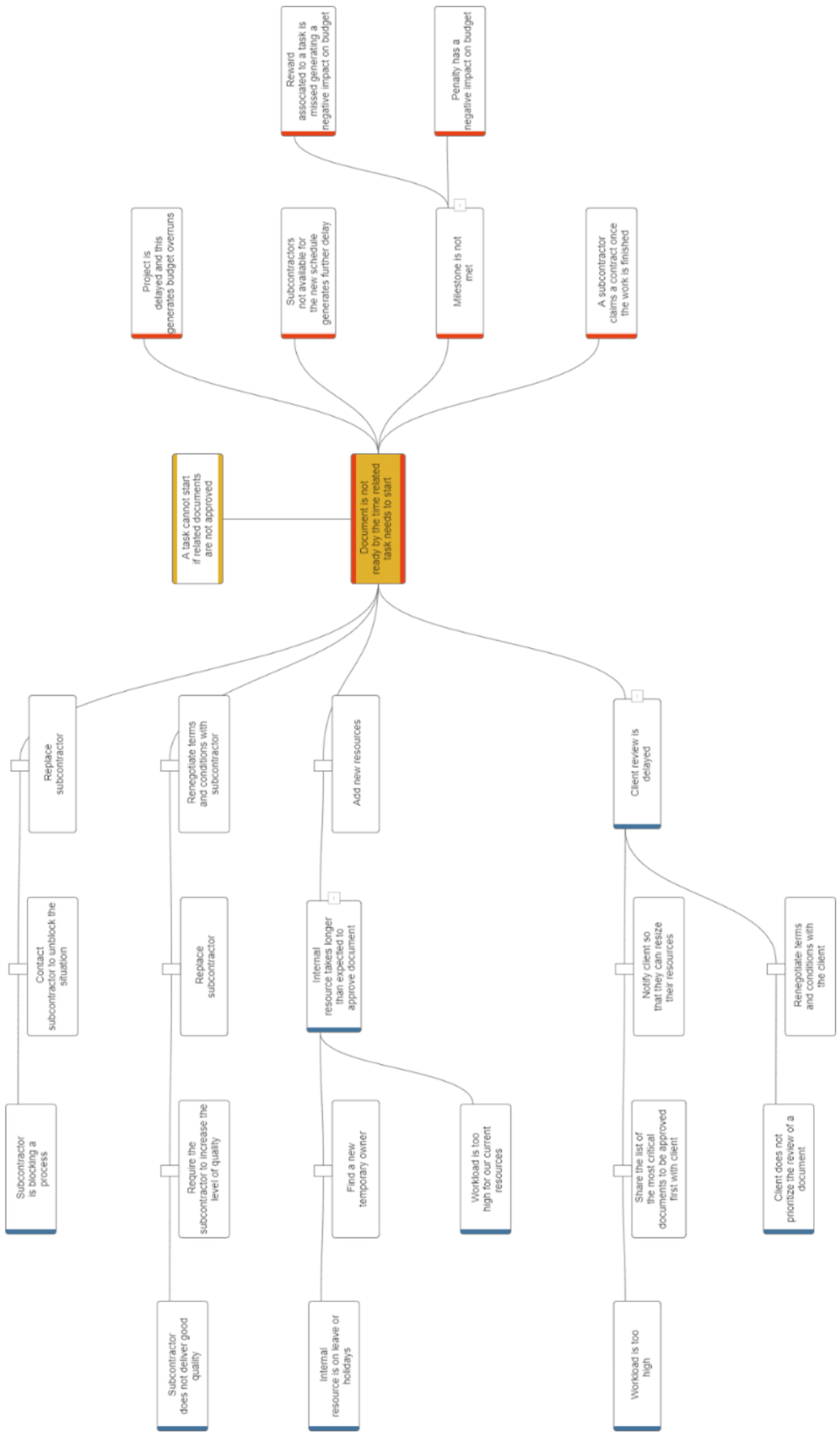

Figure Legend 2: BTA related to the documentation submittal, review, and approval workflow.

Tables

Table 1: Financial assessment example of direct annual savings thanks to controlling risks described in this paper

		Annual savings. Examples for constructions with budgets for X millions of € per year		
Savings Concept	**Estimated savings**	X=50	X=75	X=100
Time savings in the project due to better documentation control	1 month of delay per year	583,333 €	875,000 €	1,166,666 €
Better capacity to negotiate with providers	25% fewer claims	430,000 €	645,000 €	860,000 €
Total team staff time optimization	5% of total team time	262,500 €	393,750 €	525,000 €
	TOTAL ANNUAL SAVINGS	**1,275,833 €**	**1,913,750 €**	**2,551,666 €**