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The need to improve communication about scope changes: Frustration as an indicator of operational inefficiencies

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Abstract

Early and timely sharing of information can provide a sustainable competitive advantage. However, even if lean information management aims to improve this information flow, it has mainly been investigated in 'operations-based companies'. This paper fills this gap, drawing upon the experience of the authors working within a large project-based company engaged in the 'engineer and manufacture to order' of a complex piece of equipment costing millions of dollars, for its strategic long term client, both working in the same industrial field, i.e. nuclear decommissioning. This research investigates the information flow regarding scope changes between the project-based company and the long-term client adapting and applying a five-step framework to highlight operational inefficiencies, reduce the corresponding transaction costs, and increase the overall company's competitiveness. This is exemplified through a particular case, but can be applied to other project-based companies dealing with strategic clients involved in long-term relationships.

Keywords:

Information Management, Interorganizational Relationships, Performance Improvement, Scope Changes, Nuclear Decommissioning.

1 Introduction

There are many different interpretation of knowledge management and the lack of a clear distinction between knowledge and information management has been recognized as a major issue within the literature (Alavi & Leidner 2001; Bouthillier & Shearer 2002; Shih et al. 2012). Knowledge management is defined by (Kaivo-oja 2012, p.207, quoting (Giland 2004)) as the '*deliberate design of processes, tools, structures, etc., meant to increase, renew, share, or improve the use of knowledge represented in any of the structural, human and social elements of intellectual capital'.* Information management does not refer only to the gathering of past knowledge and lessons learned to be applied to current practices, but mainly to managing the data that are created on a daily basis, how they are stored, retrieved & shared, both within the company and eventually with clients and suppliers. The early and timely sharing of information can provide sustainable competitive advantage, especially to companies involved in interorganizational relationships (Oliver 1990). Still, '*too much distribution of information can lead to information overload which could paralyze action*' (Bouthillier & Shearer 2002, p.16). Indeed, efficient information management can provide steady advantage to generate financial and economic benefits, only if the information flow is accurate, updated and complete.

Lean information management refers to the application of lean thinking to information management, where information management involves "*adding value to information by virtue of how it is organised, visualised and represented*" (Hicks 2007, p. 233). Lean information management can improve organization performances by reducing inefficiencies, streamlining the information flow and focusing on establishing roles, responsibilities and practices in order to increase the overall value of information and knowledge (Ibbitson & Smith 2011; Bevilacqua et al. 2015). Lean management has historically been investigated in the field of operations and within 'operations-based' industries (e.g. automotive (Taylor & Taylor 2008), supply chain management (Martínez-jurado & Moyano-fuentes 2014) and health care (Toussaint & Berry 2013)), and only limited research has explored this issue in project-based companies.

Project-based companies (also called 'project-based firms' (Kujala et al. 2010)) are defined as '*organizational forms that involve the creation of temporary systems for the performance of projects'*, which '*conduct the majority of their activities as projects and/or provide project over functional approaches*' (PMBOK 2013, p.552). However, the 'engineer to order' industry still suffers from the lack of a specific production planning and control process (Adrodegari et al. 2015) and only limited research on lean information management has been undertaken within the 'engineer to order' industry.

This paper fills this gap, drawing upon the experience of the authors working within a large Project-Based Company (called PBC) engaged in the 'engineer and manufacture to order' of a complex machine costing millions of dollars for its Long Term Client (called LTC). Both the PBC and LTC belong to the same complex and highly regulated field, nuclear decommissioning. This research analyses the information flow between PBC and LTC relating to scope changes and how the information flow both influences and is influenced by the changes. Scope changes are here understood as any change to the project scope that requires an adjustment to the project cost or schedule (PMBOK 2013, p. 562). This study considers scope changes that arise both from clients and contractors, who need to communicate to the other party their additional requests or the necessity to address previous omissions or errors. These can easily escalate in long and complex projects (where complexity is intended here both as technical and organisational (Locatelli et al. 2014)).

According to (Stuart et al. 2002), there are different types of contribution to knowledge, i.e.: (i) discovery, description, understanding; (ii) mapping, relationship building; (iii) theory validation, extension, refinement. This research falls in the first group, as it *discovers* the presence of frustration caused by operational inefficiencies, it provides guidance on how to *describe* these inefficiencies through visual representation and increase the overall *understanding* of the company's current-state.

This ultimate aim of this research is to show the importance of monitoring and addressing 'weak signals' (e.g. frustration) to deliver better performance. To do this, this paper adapts and applies a five-step framework to highlight operational inefficiencies, reduce the corresponding transaction costs, and increase the overall company's competitiveness.

2 Theoretical background

2.1 Transaction cost and information management

A transaction takes place when a service is exchanged across distinct interfaces (Williamson 1981), and transaction costs are related to the organization of economic activities of a company (such as searching and information costs, bargaining and decision costs, and policing and enforcement costs (Durugbo et al. 2014)). Notably, (Clemons et al. 1993; Stratman 2008) argue that the major components of transaction costs are associated with the collection and integration of information into the decision process and the cost of the risk that the other party will fail to meet the contractual obligations due to opportunism. Durugbo et al. (2014) also state that when aiming at delivery reliability, information flow plays a pivotal role, both externally and internally, and that '*the interplay of vertical integration, market relations and long term, voluntary relations […] is required to effectively manage delivery-related integrated information flow*'. This statement is particularly relevant for the current research, and is aligned with the standpoint of Zhao et al. (2006), who argue that information

integration is the foundation of the broader supply chain integration. In fact, optimized information flow can facilitate delivery, supporting both internal and external interactions. Hence, there is a need to investigate empirically the efficiency of the information flow, especially for project-based companies in industrial sectors that are dealing with increased pressure for enhancing projects delivery, such as nuclear decommissioning (Invernizzi et al. 2017a), or public infrastructure construction projects, where tax payers pay for the additional costs (Love et al. 2017).

2.2 Information management and lean information management

In its endeavour of streamlining and optimizing the information flow, lean information management has recently raised the interest of both practitioners and academics (Bevilacqua et al. 2015; Jaaron, Ayham & Backhouse 2011; Hicks 2007). However, limited research has analysed the potential of lean information management in project-based companies. Lean thinking has to be adopted as a holistic business strategy, rather than an activity isolated in operations to reach its full potential (Fullerton et al. 2014). However, because of the considerable increase of the information generated, recorded, stored, retrieved and shared, the focus of information management needs to be extended to project-based, 'engineer-and-manufacture-to-order' companies.

Hicks (2007, p.324) discussed the application of lean thinking on information management, reporting that '*fundamental to the successful application of lean is the identification of value, understanding of flow and characterization of waste*'. Waste, however, is more visible within manufacturing, but less tangible in the context of information, where the culture of 'performance measurement' is less developed. Nonetheless, Hicks (2007) argues that an analogy can be drawn, and waste in information management (failure demand, flow demand, flow excess and flawed flow) and in manufacturing (over processing, waiting, overproduction and defects) can be matched, as shown by Table 1. These waste categories can also be used to cluster the waste categories in lean information management i.e.: waiting, conveyance, inventory, correction, defects, incompatibility, unnecessary transfer of information, and inappropriate systems (Hölttä et al. 2010, p. 1460).

Waste in Manufacturing Systems	Corresponding Waste in Information Management	Comments
Overproduction	Flow excess	Flow excess is defined as the resources and activities that are necessary to overcome a lack of information.
Waiting	Flow demand	Flow demand concerns in the time and resources spent trying to identify the information elements that need to flow.
Extra processing	Failure demand	Failure demand relates to the time and the resources that are necessary to overcome excessive information.
Defects	Flawed flow	This includes the resources and activities that are necessary to correct or verify information, including unnecessary or inappropriate activities that result from its use.

Table 1. Waste in manufacturing and corresponding waste in information management, adapted from (Hicks 2007)

In the current research, the authors argue that one indicator of operational inefficiencies consists of the 'weak signals' (such as frustration – see section 2.3), shown by human resources during their everyday activities concerning the information flow regarding scope changes. In this case, the 'waste' mostly consists of the time and effort required to generate, acquiring, and identify the additional (missing) information, but also to the time and effort spent to determine whether the information received is relevant and urgent or not, and the eventual 'mistakes' in judging its importance and/or activities that result from its use. This is exacerbated by the fact that project-based organisations have to deal with a huge number of non-repetitive information, not always accurate enough, and that cannot be easily tracked and/or that is not able to flow (Bevilacqua et al. 2015).

2.3 Operational inefficiencies and stakeholders' frustration

The discussion about the role of 'weak signals' in the organizational and institutional systems and strategic decision-making has been prolific in recent years (Kaivo-oja 2012). Acknowledging the ambiguity of the term 'signal', Sidhom & Lambert (2011, p.42) affirm that signals can be classified as 'weak' if they are fragmented, embedded in '*a mass of useless information*' and characterized by '*low palpability*'. Sidhom & Lambert (2011, p.41) report the definition of 'weak signals' by Ansoff (1985), who defines them as *'warning (internal or external) events and developments that are still too incomplete to allow for an accurate estimate of their impact and/or to determine a full adapted response*'.

Following this definition of 'weak signals', the authors focus on frustration, anger, helplessness, powerlessness as described by (Baker et al. 2010; Gelbrich 2010; Ceaparu et al. 2004). Frustration might occur at an interruption of the goal-attainment process, where a barrier or conflict is put in the path of an individual (Ceaparu et al. 2004) or depends on blame attribution (Gelbrich 2010), which means that people hold uncontrollable circumstances responsible for an aversive event. Frustration

can be described as a sense of dissatisfaction or annoyance, and can be associated with confusion and boredom (Baker et al. 2010), and described as a milder version of anger (Gelbrich 2010). Helplessness is an emotion that results from the prospective evaluation of future perceived irrevocability to control an adverse situation; powerlessness refers to the feeling of being controlled by others (Gelbrich 2010).

These 'weak signals' of stakeholders' discomfort are challenging to identify and assess, and have been often overlooked and only limitedly investigated (Hölttä et al. 2010), mostly in the field of human-computer interactions (Baker et al. 2010; Ceaparu et al. 2004; Bessiere et al. 2003; Jefferson 2006) and behavioural research (Harrington 2005). Harrington (2005), for example, developed a frustration-discomfort scale made of 47 items on a 5-point-likert scale, to quantitatively investigate the correlation between the coping inventory item and the frustration-discomfort scale itself. Conversely, in its dynamic analysis, Grundy (2000) symbolically displayed the curves representing the 'energy of the team' and 'frustration over time', showing that over time, the 'energy level' of the team decreases as the 'frustration' increases. In the field of healthcare, Cogin et al. (2016) adopt a qualitative research design to investigate job attitudes (such as low morale and frustration) and operational efficiency.

It might be difficult to quantitatively measure weak signals of frustration, but weak signals of stakeholders' discomfort should not be ignored. Weak signals could and should be used to highlight the underlying cause of these complaints. This idea is based on the assumption that the 'frustration points' can be caused by operational inefficiencies, and that stakeholders' complaints can be used as indicators of these inefficiencies. During the fieldwork, weak signals of frustration, anger, helplessness and powerlessness, have been systematically recorded by the authors, and being the frequency and the repetitiveness of these comments and complaints striking, the authors derived a methodical investigation, presented in the framework presented in section 4. This five-step framework stems from the consideration that the relationship between operational inefficiencies and weak signals of stakeholders' deserves more attention both from academics and practitioners.

Figure 1 illustrates the focus of the current research through the big red arrow, i.e. relationship between operational inefficiencies that can be the cause of frustration and other 'weak signals' of negative emotions. Indeed, this relationship is remarkably under investigated, especially when compared with the one between operational inefficiencies and business delays and cost overruns (dotted arrows in the lower part of Figure 1), and the relationship between both retrospective and prospective emotions and both confrontational and support-seeking coping responses (thin green arrows in the upper part of Figure 1 analysed by (Gelbrich 2010)).

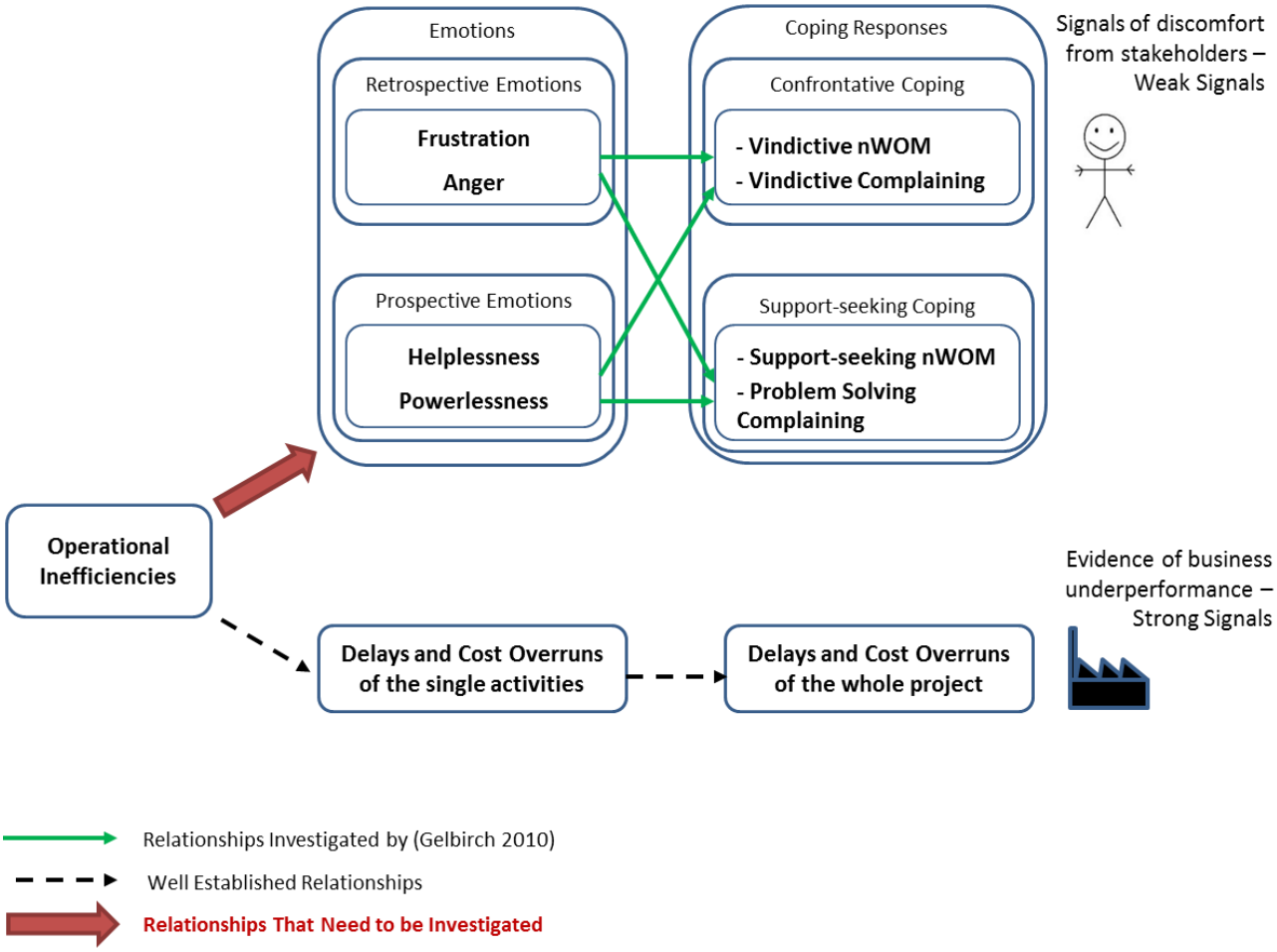

Figure 1. The direct consequences of operational inefficiencies

3 Derivation of the research questions

Project-based companies involved in long-term relationships with their client(s) can be related to the corporate-financial interlock described by (Oliver 1990), characterized by (1) the necessity of meeting necessary legal and regulatory constraints, (2) severe market constraints, (3) symbiotic, (4) potential for high quality advice, (5) high unpredictability in availability or acquisition of capital and (6) external pressure to demonstrate financial viability. In this context, where several change orders are placed by LTC to PBC over decades, transaction costs connected to the communication between the two parties have become substantive. Moreover, several people in both organizations are involved in this long-term relationship (e.g. the programme and project managers, engineers, manufacturing employees, etc.), so the efficiency of the information flow (i.e. benefit of generating and sharing information vs its cost) has become crucial. In this kind of relationship, the two key flows are the material (i.e. the product delivered) and information (Prajogo & Olhager 2012).

Drawing upon the theory and the experience of the authors working in PBC and stemming from the research background described in section 2, the authors have made a systematic bibliographic analysis related to the current study. Table 2 shows the number of publications from 2000 to September 2017, embracing the topics of transaction cost, lean management, lean information management, information management, scope change[1]. Interestingly, Table 2 shows that there have been some attempts to consolidate the concepts of transaction costs AND information management (95 publications), but only very limited research has focused on information management AND scope changes[2] (only 3 publications). This suggests that the two concepts have not been frequently juxtaposed, and that there is a gap in knowledge about the efficiency of the information flow regarding scope changes and its role in business. Only recently, Beauregard (2015) focused on cost overruns in the aerospace industry, presenting a lean risk management approach to reduce surprise and scope changes, emphasizing that non-recurring engineering cost overruns negatively impact on the organizations' credibility as well as profitability. Cheng & Carrillo (2012) stressed the importance of extensive information sharing and constant communication to minimize changes during the product development. Interesting is also the study about information flow and changes by Childerhouse et al. (2006), who discusses the 'pains' experienced by automotive suppliers in achieving a change and the barriers to information flow, which the authors cluster into technological, cultural, financial and organizational. However, according to Love et al. (2010), unforeseen scope changes are one of the underlying condition for disputes for contractors, and the PMBOK emphasize the need of an integrated change control in the project communication management (PMBOK 2013, p.304, 530-531). So, there is a need to address this topics.

Lean information management itself also remains remarkably under investigated (12 publications), but the year of publication highlight that there is a growing interest in the topic (the above-mentioned 12 research have all been published after 2007, and 7 of them have been published after 2013).

Number of results in Scopus from 2000 to September 2017	Transaction cost	Lean management	Lean information management	Information management	Scope change
Transaction cost	10,919	0	0	95	0
Lean management	-	801	0	35	0
Lean information management	-	-	12	12	0
Information management	-	-	-	93,713	3
Scope change	-	-	-	-	127

Table 2. Focus of the literature review

[1] Exact queries: 'transaction cost'; 'lean management'; 'lean information management'; 'information management'; 'scope change'.

[2] Exact queries: 'transaction cost' AND 'information management'; 'information management' AND 'scope change'.

In order to fill the gap in knowledge on lean information management and impressed by the 'weak signals' of frustration showed by stakeholders in PBC and LTC regarding the information flow on scope changes already in the very early stage of the collaboration with PBC, the authors derived the following research questions:

RQ 1: To what extent should and could weak signals of stakeholders' discomfort be used to highlight operational inefficiencies on the information flow associated to high transaction costs?

RQ 2: How can communication and information management be improved to address the stakeholders' discomfort, optimise the information flow and ultimately increase the overall project performance?

Indeed, in the context of the current research, the concept of efficiency is worth unpacking, as interorganizational relationships address different objectives and are incentivized by different generalizable determinants, namely: (1) necessity, (2) asymmetry, (3) reciprocity, (4) efficiency, (5) stability and (6) legitimacy (Oliver 1990) and the movement from the market-mediated transactions to formal interorganizational arrangement might occur as an attempt to reduce transaction costs and increase the company's efficiency.

To answer to these research questions and tackle the challenges in communication, Section 4 develops and applies a systematic five-step framework, adapting business event analysis, event modelling and gap identification (Cadle et al. 2010). Section 5 provides a discussion of the results obtained from the application of the five-step framework on PBC and LTC. Section 6 summarizes the conclusions and suggests the way forward to optimize the information flow process.

This research is empirically-based and exemplified through the case of PBC and LTC, but the framework presented here can be applied on any project-based companies involved in long-term relationships with their strategic clients, such as the aerospace industry. The vast majority of the results will allow inferences to other industrial sectors as well, because, challenges related to scope changes might affect all projects. Also, similarly to requirement management (Jallow et al. 2008), change management is an activity that needs to be performed throughout a project and not only during its early stage.

4 The five-step framework

The five-step framework developed by the authors is based on case research (Zhang et al. 2017; Yin 2009; Stuart et al. 2002; Eisenhardt 1989) and implements lean information management following the approach proposed by (Bevilacqua et al. 2015) and (Wickramatillake et al. 2007). Similarly to

(Ketokivi & Choi 2014), the authors use a case study because of its duality of being both situationally grounded but also generalizable. However, lean information management has been remarkably under-investigated in project-based companies, so this paper presents the five-step framework developed and applied on the case of PBC and LTC to highlight inefficiencies and suggest improvement objectives.

The five steps are:

1. Understanding of the context;
2. Data collection and validation;
3. Creation of the current-state;
4. Analysis of the current-state (sometimes called 'as-is' analysis) and detection of inefficiencies;
5. Development of improvement objectives through the formulation of suggestions for the improvement of the information management system.

This framework will support the process of reducing inefficiencies, by firstly providing a way to transparently visualize them (highlighted by asterisks in the map in section 4.3). Secondly, by analysing the current-state and through the iterative discussion on potential improvement objectives to apply.

4.1 Understanding the context

The first step consists in understanding the context and the social environment of LTC and PBC, through the interpretation of their activities and the interactions of the key stakeholders of both organizations at the beginning of the scope change process, i.e. when the information about the change needs to be communicated. This first step entails a rigorous data collection from multiple sources, as in (Shih et al. 2012), and the immersion in the social setting for an extended period of time, as in (Wickramatillake et al. 2007). Secondary data (e.g. business documents) and primary data (preliminary, informal, un-structured, scoping interviews and participation to meetings) have been collected and analysed to guarantee a detailed initial understanding of the situation. Onsite observation and extensive field notes also provided a rich background for the interpretation of subsequently-collected data and information.

As introduced in section 1, the large-scale case study that is investigated in this research consists of the design, manufacturing, testing and delivery of a complex and bespoke machine for the nuclear decommissioning industry, composed by more than 30,000 components. These components are organised in composite modules, costing several million of £, and the project lead, i.e. the time between the placement of the order from LTC and its delivery, stretches over more than two decades.

4.2 Data collection and validation

The data collection for the creation of the current-state integrates the information previously collected through around ten semi-structured interviews. To perform the semi-structured interviews, personnel working both in PBC and in LTC were identified. These individuals were selected from different functions, since they play different roles in the communication process and have a different impression on its efficiency. The main roles engaged from both organizations were the programme manager, the project managers, the head of commercial and the responsible engineers. The project control manager, the commercial controller and the quantity surveyors were also involved, mainly for a validation purpose. However, interorganizational relationships also occur between the subunits of the two organizations or between individuals at lower hierarchical level (Oliver 1990) and these individuals (e.g. engineers) could discuss and agree scope changes, sometimes without sharing this information to the delegate authority at the commercial level. This is graphically presented in Figure 2: indeed, in theory, the changes discussed among engineers should be reported to the commercial controller that would raise the topic through official channels and in written form, to the commercial controller of the other party. However, in practice, this resulted not to be always the case, which generate misunderstandings and frustration.

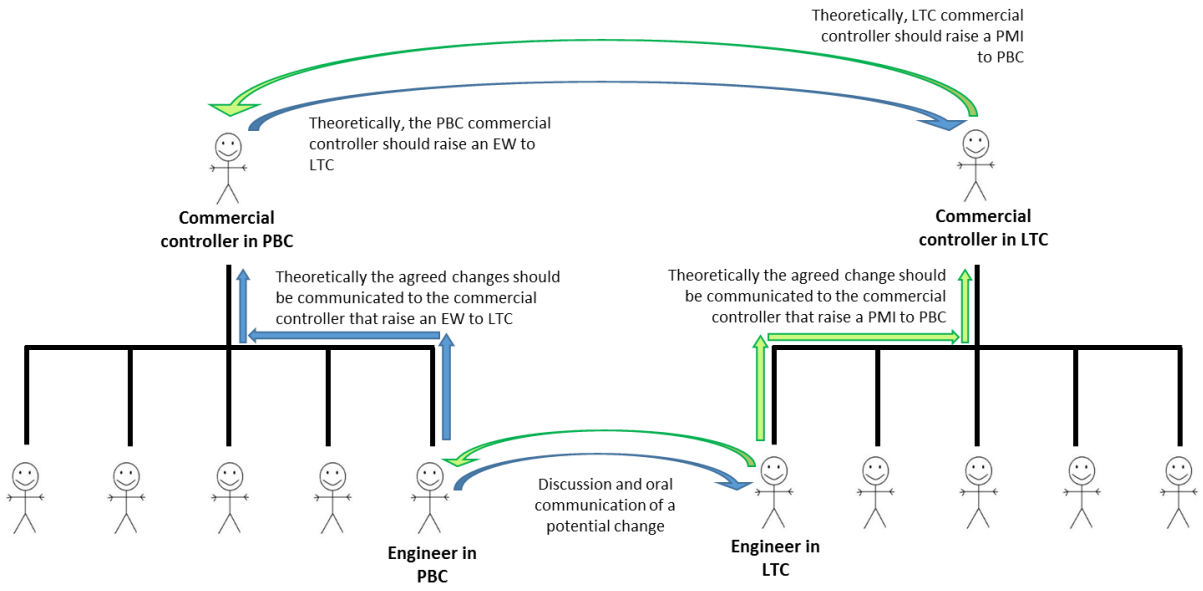

Figure 2. Scope changes agreed among engineers are not always clearly communicated at the commercial level

Semi-structured interviews were planned, following the structure described in (Cadle et al. 2010), i.e. introduction and scene-setting, main questioning, thanks and explanation of 'where next'. Due to the nature of the investigation, most of the questions were open questions. Closed question were asked mainly with probing purposes, i.e. only to clarify specific points that the interviewees were raising. The interviewees were informed about the objective of the investigation and granted anonymization.

The interviews were not recorded to let the interviewees express their honest perspective on the quality of the information flow between LTC and PBC, and their emotions related to it.

The questions used in the semi-structured interviews were:

- How do LTC and PBC communicate scope changes?
- Are there written and agreed procedures in place?
- How do you think that the procedures for communicating scope change work?
- Who is responsible for the different steps of the communication regarding scope changes?

The semi-structured interviewees allowed the creation of the current-state, described in section 4.3. The creation of the map of the current-state resulted was an iterative process, as its delineation was be progressively refined by the different stakeholders involved. Indeed, all the interviewees were asked at least twice to check the completeness of the visual map, which was also a way to cross-validate its correctness.

4.3 Creation of the current-state

The first objective of a lean thinking is '*to eliminate non-value-added activities, also known as waste or Muda*' (Bevilacqua et al. 2015). Nevertheless, due to its scarce tangibility, it is challenging to measure the performance of the information flow and how this both is affected and affects changes. However, as one project manager in PBC mentioned during an interview: '*process inefficiencies cause frustration among people from both organizations and…this affects the client-contractor relationship!*' The graphical expression of the current-state addresses the issue of the limited visibility of the overall communication process and helps to collect and highlight the points of frustration that are caused by operational inefficiencies of both organisations.

The creation of the current-state is an interactive and iterative process that was validated through cross-checks, such as follow-up meetings with interviewees. This was necessary especially because not all the interviewees have a complete overview of the information flow process, and, as one engineer pointed out '*we just deal with the engineering bit…that our job! We do not deal with the commercial stuff…*'.

The current-state of the case of LTC and PBC is presented in Figure 3 and Figure 4 in the form of a map, as advocated by (Bevilacqua et al. 2015; Nurcan et al. 2006; Lewis 2001) and draws from the process approach (ISO 2015). The creation of the current-state is extremely powerful for visually represent less tangible 'frustration point'. The authors were therefore very careful in the systematic recording

of all the weak signals of stakeholders' discomfort (e.g. explicit complaints, repetitive negative comments on how the information flow could be optimized, etc.). Then the overall information flow to communicate changes was mapped and these weak signals of stakeholders' discomfort encapsulated in the graphical representations of the information flow. We also asked the different interviewees to cross-check the current-state map for validation purposes. Similarly to (Das et al. 2007), asterisks highlight operational inefficiencies that cause frustration (white asterisks in Figure 3 and Figure 4) and actual negative risks, such are the actual possibility that the information about scope changes is not communicated to the other party (red asterisks). White asterisks underlines weak signals of stakeholders' discomfort (i.e. frustration points), caused by:

- The complexity of the information flow process about scope changes;
- The use of unofficial routes to communicate the potential change;
- The lack of understanding of the impact of avoiding to use official routes due to the limited visibility of the overall process;
- The limited clarity regarding the delegated authorities;
- The limited clarity regarding the communication of priorities regarding changes;
- The long time elapsed in answering a communication from the other party.

Figure 3 represents the current-state of the information flow when LTC needs to communicate a potential change to PBC, while Figure 4 represents the information flow when PBC needs to communicate a potential change to LTC. As it can be noticed from these two figures, frustration occurs when the communication is not efficient, and it is necessary to re-iterate the process before the complete information about scope changes is actually conveyed to the other party. This inefficiencies not only cause a sense of dissatisfaction or annoyance, but also remarkably increases the overall lead time.

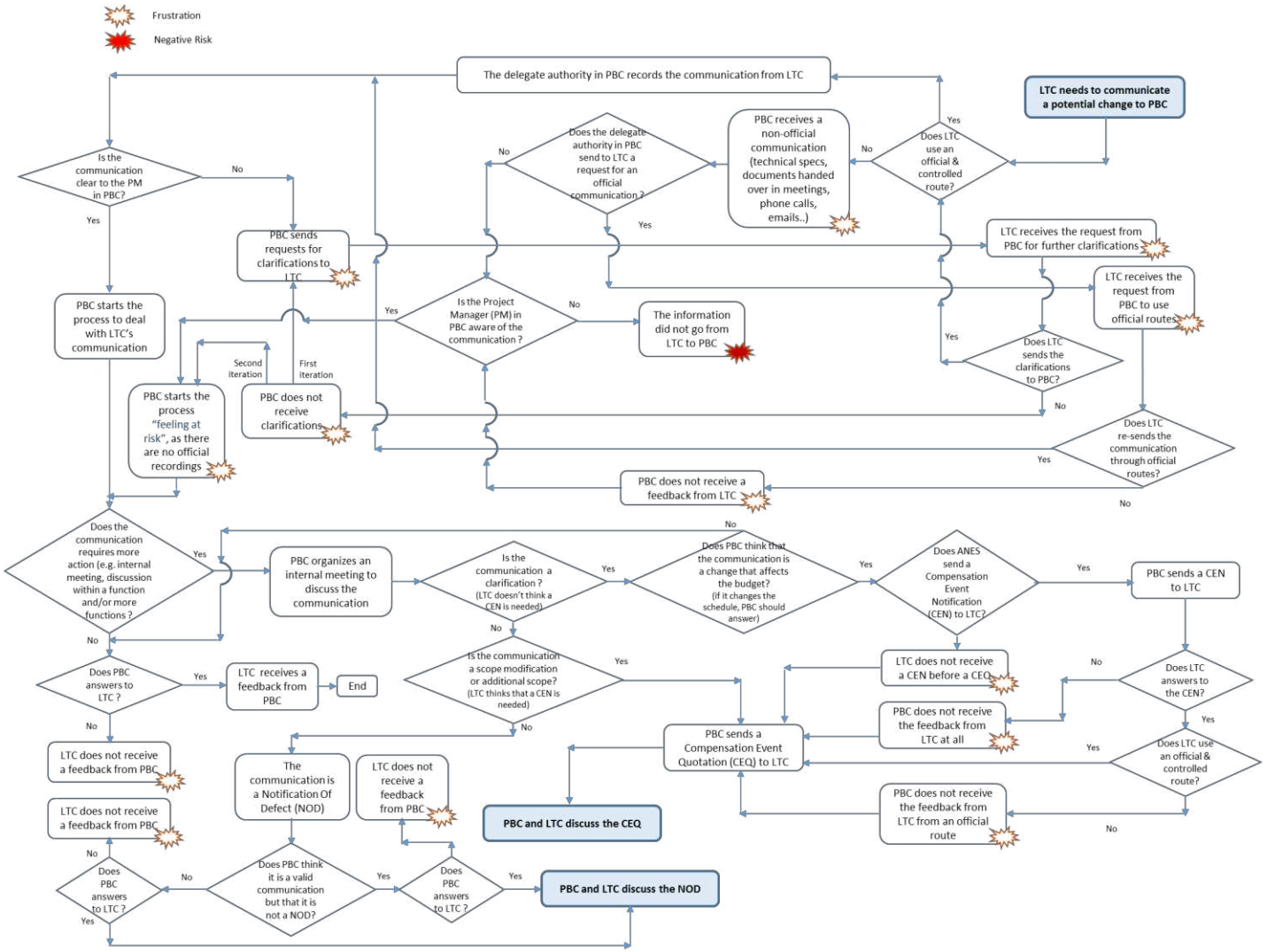

Figure 3. Information flow between LTC and PBC, when LTC has to communicate a potential change to PBC

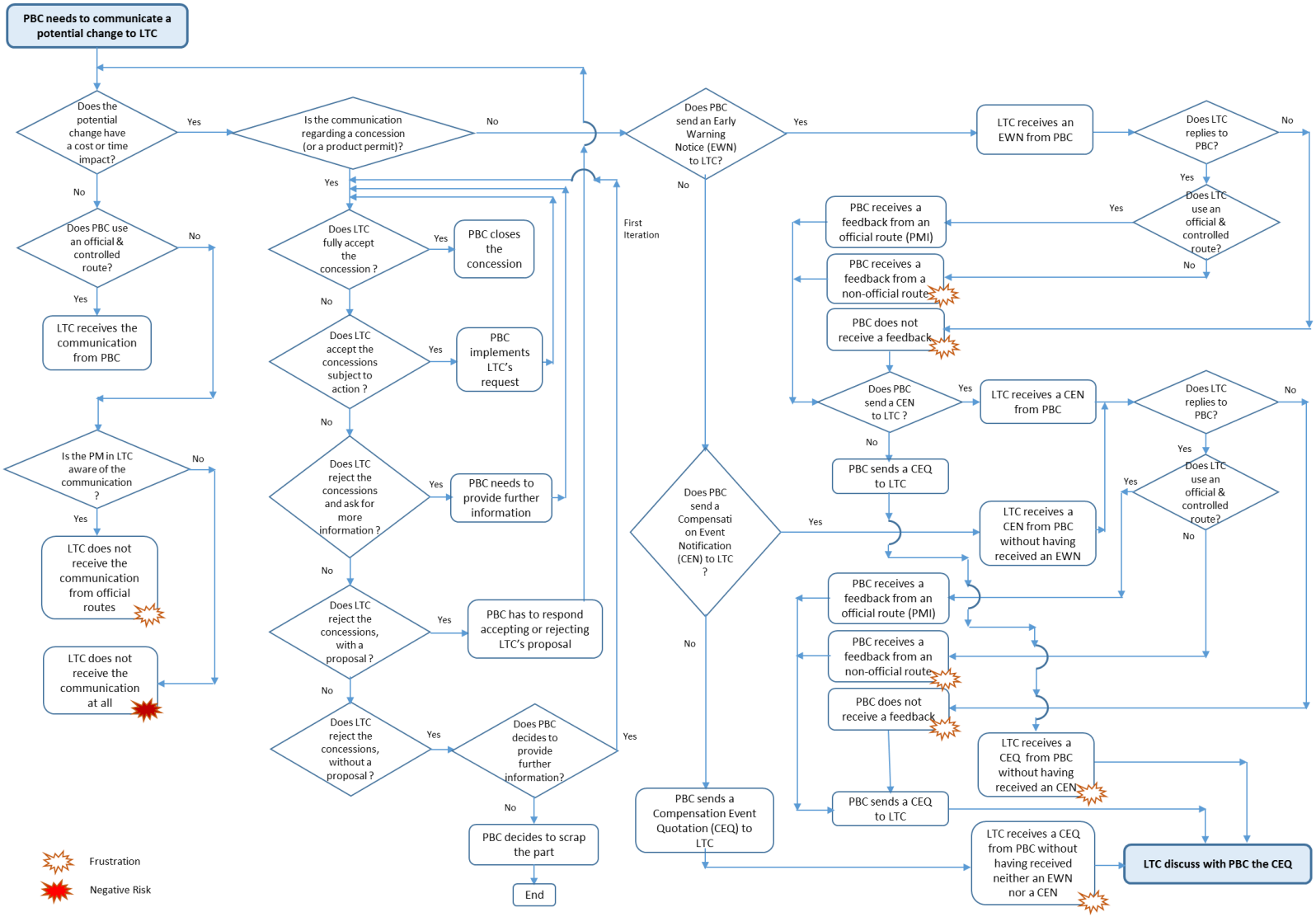

Figure 4. Information flow between LTC and PBC, when PBC has to communicate a potential change to LTC

4.4 Analysis of the current-state

As introduced in section 2.2, according to (Hicks 2007), there are several causes of wastes regarding information management, i.e. information that cannot flow because it has not been generated, information cannot flow because it cannot be identified, excessive information is generated and most appropriate information are hard to be identified, and inaccurate information flow resulting in inappropriate downstream activities, corrective action or verification. These causes give raise to four types of waste, called failure demand, flow demand, flow excess and flawed flow (Bevilacqua et al. 2015). Of the four waste categories, the analysis of the current-state of PBC and LTC detects wastes and inefficiencies connected mainly to:

- flow excess, as too much information was shared between individuals at different levels of the hierarchy and not always discussed between the hierarchical levels. This, as suggested by (Brookes et al. 2007) can lead to decision making becoming more time-consuming, as hoards of information are of little value (Alavi & Leidner 2001). Hölttä et al. (2010, p.1462) stress "*people in organizations are often faced with information overflow. Still, they do not seem to have access to all the information they need*" as well;
- flow demand, as information is normally generated but the information exchange is hindered by the limited agreement and clarity of the formal procedures that both parties should follow in terms of identification, recording and transmission of the information by all the different stakeholders involved;
- flawed flow, as the accuracy of the information exchanged is lower than expected (e.g. information exchanged during meetings, but not officially sent through the official routes and/or information sent through official routes, but not subject to formal check and validation before).

The rigorous identification of these inefficiencies allows the development of improvement objectives.

4.5 Development of improvement objectives

The improvement objectives stem from the implementation of steps 4.3 and 4.4. The majority of the improvement objectives that are proposed below, were suggested by one (or more) interviewee, and were subsequently presented to the other stakeholders, who were free to give their opinion on the effectiveness of the proposed solution and/or provide their own advice. The remaining improvement objectives derive from the literature on previously-analysed case studies and were discussed with the interviewees in follow-up interviews. The types of intervention proposed include both formal and informal changes in the organization. Some can be applied in the short term with limited effort,

sometimes called “quick win”, while others require longer time and more effort to be implemented, as presented in Table 3.

	Improvement Objectives Applicable in the Short Term	Improvement Objectives Applicable in the Long Term
Formal Changes	-The establishment and communication of clear delegate authorities in every step of the information flow process, approved by both parties involved -The establishment of a formal check before the information is send to the other party -The establishment of a system to define, highlight and monitor the actual priorities. For example, an inter-organisational IT infrastructure may support the constant flow of knowledge between two organisations (Roldán Bravo et al. 2017). Also, inserting a screening team could be considered, especially when the number of the change request becomes significant (Steffens et al. 2007).	-The establishment of an advanced dynamic system, supported by IT, to highlight the time elapsed since the last communication and an early-feedback system to communicate and record the reason for the delay (e.g. a “traffic light system”, or a whiteboard system as suggested by (Hölttä et al. 2010), or the application of Building Information Modelling (BIM) -The revision of the current process to manage and communicate Engineering Changes (ECs) and the establishment of a standardized one. Indeed, “*A standardized EC process must define tasks, responsibilities, rules of performance, and schedules. A standardized EC process should include answers at least to questions relating to information exchange, such as when and to whom the informing of ECs is done; who is responsible for transferring data from one IT system to another; who is responsible for informing suppliers about ECs; what templates must be used with ECs and how (e.g., EC request and EC order); and what is filled in on change information forms*” (Hölttä et al. 2010, p.1643) -The establishment of an “Enterprise Requirements Information Management (eRIM)”, as suggested by (Jallow et al. 2008)
Informal Changes	-The setting up of meetings to increase the visibility of the overall process, to highlight the commercial impact of decisions taken at a lower level of the hierarchy, e.g. engineers agreeing scope changes without reporting it to the commercial level	-The clarification of the nature of the information flow (i.e. pooled, sequential, reciprocal or iterative (Whinch 2010, p.209) -The establishment of a periodic regular meetings to discuss new issues arising in time

Table 3. Formal and Informal changes proposed to improve the communication flow, to be implemented in different time period

Meetings and discussion to increase the visibility of the overall process (informal, short-term change) might include discussion to periodically revise and clarify the procedures and official routes to be used both within and between PBC and LTC, e.g.:

- Early Warnings (EWs) should be promoted, even if they do not address recurrence (Meng 2014), they are effective for problem solving;
- a communication in a meeting should be followed by an official Project Management Instruction (PMI);

- a Compensation Event Notification (CEN) should be anticipated by a Compensation Event Quotation (CEQ);
- the answer to the other party as soon as possible, ideally within 10 working days, as in the NEC3 best practice (NEC 2017). Indeed, even if the NEC3 contract is not formally adopted, it is important to attempt to encourage people to communicate and cooperate in order to resolve disagreement as early as possible (Meng 2014), to manage disputes (Thompson et al. 2000) and to manage early, timely and proactively the arising challenges.

The application of Building Information Modelling (BIM) (a formal, long term change) can also be considered, as it increases the visibility of the change process, clarify the individual delegated to officially require the change and optimize the communication of changes between the parties, through dynamic graphical support. However, advantages of BIM have to be balanced with the risks and the drawbacks of implementing BIM (Kivits & Furneaux 2013; Bryde et al. 2013; Barlish & Sullivan 2012). Information and communication technology can support the development and operations management of lean supply networks by providing the enabling infrastructure required (Adamides et al. 2017). However, it is important to stress the fact that "*technology alone seldom represents a competitive advantage*" and that "*adding technology to a fundamentally flawed information management organization will do little to help and may even retard performance"* (Hölttä et al. 2010, p. 1463).

Both formal and informal changes address the waste highlighted in section 4.4. Indeed, applying these changes:

- information would be generated and shared in a systematic way;
- information about changes would be clustered according to their priority;
- the accuracy of the information would be enhanced.

5 Discussion

Several relevant themes intersect in this research, i.e. (i) the efficiency of project-based companies involved in (ii) long-term relationships with their strategic client, and (iii) the management of the information flow (iv) regarding the scope changes to be communicated to the other party. Individually, these topics have been vastly investigated by the literature, but only few studies of project-based companies have addressed the impact of the supply chain relationships on the project performance in construction (Meng 2012). However, the "*likelihood of poor performance such as time delays, cost overruns and quality defects usually increases step by step following the deterioration of supply chain relationships*" (Meng 2012, p.193), so these relationships require due consideration. In particular, the focus of this paper is the information flow regarding scope changes, as stakeholders' frustration and

discontent were expressed repeatedly by both PBC and LTC. What results from this analysis, however, is not applicable only to PBC and LTC, but it also generalizable to other industrial sectors. In fact, PBC and LTC work in the nuclear decommissioning industry, but other industries designing and manufacturing complex products could implement the five-steps described. This is the case, for instance, of the aerospace and naval industry, and of companies developing customized piece of robotics. The five-step framework could act as a guideline on how to investigate and visually represent the company's current-state and could be implemented in similar contexts, i.e. when a project-based company that delivers highly customized projects is involved in a long-term relationship with its long-term strategic client(s). A similar approach was undertaken by Bevilacqua et al. (2015), but limitedly to the automotive industry, where processes are overall more repetitive and standardized. Conversely, in a project-based company, non-repetitive operations are a daily occurrence, and also the information flow is less predictable, which generates reworks, delays and extra costs. Therefore, the information flow would still need to be optimized, especially if the number of changes required by the clients and/or highlighted by the contractor to address omissions or errors become numerous.

Changes in projects are common and might escalate with the increase of complexity of the final product itself. Therefore, a comprehensive project change management system (that also acknowledges the need of a transparent and optimized information flow) is necessary. When the information about the scope change is shared with the other party, the process to manage it, can start. Ibbs et al. (2001), for instance, present a change management system founded on the following five principle: (1) promote a balanced change culture; (2) recognize change; (3) evaluate change; (4) implement change; and (5) continuously improve from lessons learned. Continuous improvement is particularly significant, also bearing in mind that knowledge must be continuously re-created and that the transfer from individual to collective learning is not always straightforward (Love et al. 2015). In the context of this research, this translates into the understanding that the successful implementation of improvement objectives has to lay upon a company-wide understanding of the current-state (which present inefficiencies) and the collective willingness to apply and monitor these improvement objectives.

Regarding the implementation of the five-step framework, the first fundamental step to undertake is the understanding of the context and the delimitation of the research boundaries (i.e. the frustration caused by the sub-optimized information flow regarding scope changes). However, this might be hindered by several factors, starting from the openness of the company to welcome an 'external expert' bringing his/her 'outside view' (here, one of the authors), and the willingness of the interviewees to openly share both their experience and emotions. Also, the 'external expert' has to

be granted a certain freedom in the selection of the interviewees, which should be conducted in an informal and relaxed environment favouring openness and intellectual honesty. In particular, it is better if the interviewees are not 'suggested' by the higher hierarchical ranks of the companies involved, but carefully selected according to their job description, expertise, frankness and willingness to participate in the research. Ultimately, the project-based companies (here, PBC and LTC) should be interested in identifying time-consuming non-value-added activities and keen to discuss improvement objectives.

Another challenge in the implementation of this five-step framework is related to the difficulty in identifying frustration and other 'weak signals' of stakeholders' discomfort caused by non-value-added activities in the information flow. Love et al. (2012) investigate claims and disputes, and identifies the main causes triggering these disputes: (i) for clients, the failure to detail and correct errors or to oblige for contractual requirements and (ii) for contractors, unforeseen scope changes. Ju et al. (2017) explore strategies to eliminate interface conflicts that affect the project effectiveness in complex supply chains, with multi-disciplinary participants and a limited interest in the holistic project performance. Unlike claims and conflicts, frustration and other 'weak signals', such as anger and powerlessness, have been less investigated. This is probably due to the fact that 'weak signals' and its causes (i.e. process inefficiencies, which translates in practice into avoidable costs) are harder to both identify and quantify.

Scope changes and the communication regarding scope changes, is a topic of great interest. Mello et al. (2015), for example, recently explored the factors that affect coordination in engineer-to-order supply chain, highlighting change orders and the communication effort spent to address these changes as one of the factor impacting on the lead time. Tam et al. (2011) analyse what affect the project performance of a multi-layer supply chain focusing not only on the 'standard' iron-triangle of time-cost-quality but also exploring the performance of communication and coordination, such as delays in communicating decision, increasing communication errors when increasing layers of subcontractors, poor or lack of communication, etc. This paper also fits in the stream of research, highlighting the inefficiencies of the information flow regarding scope changes between PBC and LTC.

6 Conclusions and future research

The process of communicating scope changes between contractors and long-term strategic clients can be lengthy and complex, which can hinder the timely reaction from both parties while addressing scope changes themselves. Indeed, scope changes and the communication about these changes can be a thorny topic. One exemplary case is presented by Steffens et al. (2007, p. 709), where '*project*

team members had purposefully started to avoid making change requests because of the bureaucracy of the change management system' (Steffens et al. 2007, p.709).

This paper investigates two research questions:
RQ 1: To what extent should and could weak signals of stakeholders' discomfort be used to highlight operational inefficiencies on the information flow associated to high transaction costs?

RQ 2: How can communication and information management be improved to address the stakeholders' discomfort, optimise the information flow and ultimately increase the overall project performance?

To answer these questions a five-step framework has been developed and applied on the real case of PBC and LTC. These five steps consist of (1) understanding of the context, (2) data collection and validation, (3) creation of the current-state, (4) analysis of the current-state, and (5) development of improvement objectives.

The development of the first three steps and their application on the specific case of PBC and LTC enabled the authors to address RQ 1. Indeed, the visual representation of the current-state of the information flow highlighted several frustration points, scattered all over the map of the current-state. Remarkably, these 'frustration points' were highlighted not only by one interviewee, but have been independently stressed during several different interviews, by stakeholders occupying different working positions. This primarily highlights how strong the dissatisfaction caused by the operational inefficiencies in the communication of scope changes was, but also indirectly corroborates the findings regarding the operational inefficiencies. Indeed, the hypothesis that frustration is triggered by operational inefficiencies is well-founded, once the boundaries of the study (i.e. the information flow about scope changes) is explained and the frustration arisen due to personal reasons (e.g. disputes with colleagues) elided. In this situation, the 'remaining frustration points' are those related with the operational inefficiencies and can therefore be used as indicators of non-value-added operations. The elimination of these non-value-added operations could optimize the communication between PBC and LTC and consequently reduce the corresponding transaction costs.

Conversely, the last two steps (i.e. the analysis of the current-state and the suggested improvement objectives) address RQ 2, as the analysis of frustration points can be used to bring out suboptimal process and foster the organization to investigate the causes underlying the stakeholders' frustration. The optimization of the communication flow and the reduction of the stakeholders' discomfort come therefore 'hand in hand', as tackling the causes is a way of eliminating negative consequences. Indeed, the gap analysis provides the basis for defining the actions to be taken in order to improve the current

situation and 'move' towards a more efficient one. For the case of PBC and LTC, these are imputable mostly to three of the four waste in information management described by (Hicks 2007) and reported in Table 1 , i.e. flow excess, flow demand and flawed flow. Failure demand was less emphasised by the interviewees. Section 4.5 proposes improvement objectives that could be applied to optimize the information flow between PBC and LTC, clustering them into formal and informal ones and highlighting the different timeframe that their application would require. Indeed, '*the role of information technology is not only to organise data into useful information, but also to enable the transformation of personal information into newly-created organisational knowledge'* (Adamides et al. 2017, p.37) so the cost and benefits of implementing longer-term, formal changes would need to be carefully evaluated.

The main limitations of this research are related to (i) the implementation of the five-step framework and (ii) the implementation of the improvement objectives proposed, which can trigger follow-up research questions.

Regarding (i), it has to be underlined that the 'outside view' provided by the external person inserted in the company is essential, as it could guarantee impartiality during both the data collection, and the creation and analysis of the current-state. Consequently, if possible, the authors recommend to rely on the 'outside view' during the implementation of the five-step framework. This could be a limitation as it could take long, for the company, to find an adequate candidate, and, for the candidate, to understand the company-specific situation (i.e. 3-4 months). Also, the presence of a 'new figure' in the company might cause some resistance among the employees, as he/she might be seen as 'an invader', and other employees might not be willing to share their experience with him/her. Nevertheless, the 'outside view' is the only practical way to deliver an unbiased analysis.

Concerning (ii), the selection between the improvements objectives proposed and their implementation has not been analysed in this paper, and could be subject of future work. Also, it could be interesting to anticipate the eventual resistance to the implementation of the improvement objectives and to investigate the best way to monitor the overall project performance. Lastly, future work could analyse to what extent "co-creation" (e.g. as discussed by (Romero & Molina 2011)) could be used to effectively limit scope changes.

Scope changes are a big challenge for project-based companies, and an efficient information flow is the first step to better manage them.

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