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INFORMATION QUALITY IN LARGE ENGINEERING AND CONSTRUCTION PROJECTS: A DELPHI CASE STUDY

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Abstract

This Delphi study identifies problems that have significant impacts on profits gained from large engineering and construction projects in a European company. Information quality gained remarkable weight among the identified problems. The problems were ranked in accordance to their estimated impact on the project profit margins. Within a consolidated list of 125 problems identified altogether, the final ranking of the top 18 problems was strongly agreed upon by an expert panel. The panel involved experienced engineering and management professionals throughout the construction project supply chain. Among the top 18, eight problems, including the top six, concerned information quality. The results address a need for increased focus on information quality challenges in the target organization and provide a detailed account of such challenges in comparison to the previous literature on information quality in engineering and construction.

Keywords: Information quality, data quality, engineering and construction project, Delphi study.

1 Introduction

During the era of increasing business globalization, large-scale engineering and construction projects have also become global (Xue, Wang, Shen, & Yu, 2007). Whereas even local construction projects are often delayed and exceed their budgets (Al-Momani, 2000; Assaf & Al-Hejji, 2006; Chan & Kumaraswamy, 1997; Faridi & El-Sayegh, 2006; Long, Ogunlana, Quang, & Lam, 2004; Toor & Ogunlana, 2008), global and inter-organizational construction supply chains require even more coordination and effective utilization of information technologies (Xue, et al., 2007).

This article discusses about results from a Delphi study, in which 38 experts identified problems which cause significant impacts on profits gained from global engineering and construction projects in a European, multi-discipline, construction and engineering company. In slight contrast to previous literature on construction and engineering projects and related challenges, information quality gained remarkable weight among the identified problems in this case. The information quality issues in our target organization also represent a more detailed view on this issue than previously reported (cf. Dehlin & Olofsson, 2008; Toor & Ogunlana, 2008; Wantanakorn, Mawdesley, & Askew, 1999; Xue, et al., 2007). While the results illustrate how information quality is a problem in this case, we believe that the study represents also interesting insight into potential information quality issues in construction and engineering, which has, as a field, been less prominently present in the contemporary literature on data and information quality in general (cf. recent reviews by Batini, Cappiello, Francalanci, & Maurino, 2009; Madnick, Wang, Lee, & Zhu, 2009). This paper thus focuses on the research question:

What are the main information quality challenges in global engineering projects?

The rest of the paper is organized as follows: Section 2 gives a brief description of previous literature on information quality among the general-level problems in large construction projects. Section 3 introduces the target organization and describes the research process, and section 4 displays the results. In section 5 we discuss our findings and section 6 concludes with suggestions for further research.

2 Background: Information Quality and Large Construction Projects

The definitions of data quality and information quality have been characterized by a lack of consensus when it comes to distinguishing between the two. Data quality often (but not always) refers to technical issues while information quality usually refers to non-technical issues (Madnick, et al., 2009). In this paper we use the term information quality to cover both aspects.

The total quality management movement (e.g., Deming, (1982); Juran & Goferey(1999) has greatly influenced on the information quality research (Madnick et al., (2009). According to this approach,, information can be regarded as a “product” which is “manufactured” in organizations (Madnick, et al., 2009) and later on consumed by its users within and across organizations. *Information quality* has been defined broadly through its “fitness for use” (Wang & Strong, 1996), in relation to the recognized purposes of information use and user groups. Whereas the early research focused on query techniques on multiple data sources and data warehouses in the end of 1980s, the research field has later on spread to a number of new application areas, such as customer resource management, knowledge management, supply chain management and enterprise resources planning (Madnick, et al., 2009).

Batini et al. (2009) identify altogether 28 quality dimensions in their review of data quality methodologies. Four core dimensions, *accuracy, completeness, consistency* and *timeliness* have been emphasized frequently throughout the methodologies. Since the definitions of the dimensions vary in the literature it is important to declare what definitions we make use of. *Completeness* means that all values required for a certain record should be recorded (Batini, et al., 2009). *Consistency* refers to the values of data, which are expected to be identical in similar situations (Wand & Wang, 1996). In our context, it means that for the occurrences of the same data in different registers the values should be identical. *Timeliness* is often defined as whether the data is out of date but can also be defined as availability of output in time, i.e. the time the data are actually used (Wand & Wang, 1996). In this sense, it corresponds also to the dimension of speed below.

Other potential quality dimensions in previous research have been currency, volatility, uniqueness, appropriate amount of data, accessibility, credibility, interpretability, usability, derivation integrity, conciseness, maintainability, applicability, convenience, speed, comprehensiveness, clarity, traceability, security, correctness, objectivity, relevancy, reputation, ease of operation, and interactivity (Batini, et al., 2009).

In the field of large construction projects, several researchers have reported frequent delays as the main problem to be tackled (Long, et al., 2004; Sambasivan & Soon, 2007; Toor & Ogunlana, 2008). Delays are costly (Faridi & El-Sayegh, 2006), and cause negative impact on the profit margins (Ling, Pham, & Hoang, 2009). In a recent study, Toor & Ogunlana (2008) reviewed the literature on construction project delays and identified 75 problems encountered in a number of countries. The most common problems include: lack of resources, lack of adequate communication, poor contractual management, design delays, changed orders, deficiencies in public agency organizing, deficiencies in planning and scheduling, inadequate site planning and control, lack of experienced subcontractors, and poor resource estimations. During the first decade of the new millennium, some new types of problems have also emerged, including: lack of contractor experience, slow decision-making by owners, owner's lack of experience, escalation in material prices, lack of labour, complex and changing legal systems, and lack of design standardization. Toor & Ogunlana (2008) categorize the 75 problems further to eight categories, based on the entities related to projects, such as: problems related to clients, designers, project management and consultants, contractors, labour, finance, contract, communication, site and environment, and miscellaneous.

Within this exhaustive list of problems and categories, however, few information quality problems are mentioned. In fact, Toor & Ogunlana (2008, pp. 400-401) mentioned only three problems among their list of the 75, which we could recognize to represent information quality in light of the definition above:

- Confusing and ambiguous requirements (from the client), which we would categorize as a problem of information interpretability, concerning the requirements documentation.
- Errors and omissions in design documents (by the designers), which we categorize as a problem of information accuracy and completeness, concerning the design documents.
- Incomplete contract documents, which we thus categorize also as a problem of information completeness.

In addition, Toor & Ogunlana (2008) identify lack of IT use for information, coordination, and interface management and, in general, poor quality control over projects also among the 75 problems. These may involve more specific issues representing certain information quality dimensions, if studied further in context.

In the scarce literature discussing information quality in construction projects in more detail, a study in Thailand found that incomplete drawings were a major cause of delays in 75% of the projects (Ogunlana, Promkuntong, & Jearkjirm, 1996). Information completeness thus has played a very important role at least in one national context. Lim & Mohamed (2000), in an exploratory study, identified that "waiting for information", i.e., information timeliness and speed, was a major reason for delays in large construction projects in the UK.

Beyond the literature focusing on project delays, a few other articles also mention information quality as a potentially significant issue in the construction projects. For example, Wantanakorn et al. (1999), refer to a 10-item list of causes for human errors in project management, which they apply to construction projects. One of those items is information quality, which in this context refers to poor quality of managerial instructions and procedures from one person to another (ibid.). Hjelt & Björk (2007) mention information quality while evaluating adoption and use of an electronic document management system in a large construction project. To evaluate information quality, they mention the Delone & McLean (DeLone & McLean, 2003) model for information system success as their "framework of understanding". Delone & McLean's concept of information quality includes the quality dimensions of accuracy, timeliness, completeness, relevance, and consistency (ibid., p. 15). Furthermore, it proposes that information quality has a causal correlation to system use, user satisfaction, individual impacts and organizational impacts (ibid.). However, leaving out the direct impact of information quality on the organization, which is included in the Delone & McLean (2003) model, Hjelt & Björk (2007) discuss mainly about role of information quality in the user acceptance of the document management system. While low IT utilization in construction projects has been identified as a significant issue as such (Toor & Ogunlana, 2008), Hjelt & Björk (2007) thus highlight importance of perceived information quality as a *mediating* issue on project performance. Xue et al. (2007) also mention information quality, in general, as one of the issues which may impact on coordination and integration of construction supply chains.

3 Target Organization and Research Process

3.1 Target organization

Our target organization is a European, multi-discipline engineering and construction company (EUMEC; this artificial acronym is used here to anonymize the target organization) with capabilities related to global management, design, procurement, completion and generally execution of complex installations for the oil and gas industry. EUMEC delivers engineering design for construction projects and possesses a significant share of global markets in its product and project domains. The most employees are involved in engineering and construction projects. The biggest projects may typically cost more than 100 million Euros and take up to three years of calendar time.

Engineering projects usually cover the design-related phases of a construction project. The final deliveries for an engineering project mainly consist of documentation, such as drawings and manuals. These are extracted from various data sources like engineering data bases. When the design is completed, outputs from the projects (e.g. drawings, documents and three-dimensional (3D) product models) are handed over to the assembly and completion phases. The latter phases are those, during which the most serious problems, especially delays, are typically manifested.

3.2 Engineering disciplines

Several experts representing different engineering disciplines are needed to design large, complex, robust and yet delicate constructions. Project teams are set up according to engineering and other professional disciplines varyingly required by the individual projects. Table 1 describes the engineering disciplines typically represented in the projects of our target organization. Every engineering discipline has a discipline manager. A discipline usually consists of several engineers, and their manager is responsible for the delivery as a whole. Every engineering discipline depends on input from the other disciplines throughout the project, due to a great number of interfaces and dependencies among the artefacts and systems to be designed and assembled. Together with tight project schedules this means that various activities must be performed in parallel despite that quality control of the results would be easier with sequential task organization. During such concurrent engineering (Sekine & Arai, 1994), quality assurance and possible adjustments are therefore conducted both during the project and then, again, in the assembly and completion phases.

Disciplines	Responsibility
Process	Design of industrial processes; all the facts, sequences and relations in the process and a logical placing of the different items.
Mechanical	Design (choice of equipment and its physical layout and weight).
Piping/Layout	Design of all piping.
Electro	Design and cabling of power distribution for electrical systems: equipment, lights, heat, etc.
Instrument	Design of control systems, i.e. the control of various valves, machines, the alarm systems, and instrumentation cables for distributing signals.
Telecom	Selection and location of radio and audio systems, alarms etc.
HVAC (Heating, Ventilating and Air Conditioning)	Capacity calculations and layout for ventilation etc.
Safety	Various safety assessments.
Structure (steel)	Design of steel structures, supports, outfitting like hand rails, stairs etc.
Architecture	Interior design.

Table 1. Engineering disciplines in EUMEC's construction projects.

3.3 Research Process

A case study approach was chosen because it provides a possibility to understand a phenomenon in its context, and allows a single entity examination (Benbasat, Goldstein, & Mead, 1987). To achieve a preliminary understanding of the problems encountered in the projects, a pilot study including four interviews of key personnel in EUMEC was conducted. As a conclusion from the pilot, EUMEC wanted to acquire more detailed information regarding problem areas with the most negative potential impact on the profit margins. Therefore, a Delphi study was chosen as the main method of collecting data, revealing the problems through an anonymous, balanced and unbiased process, achieving a consensus over the problems, and prioritizing the problems to tackle by a representative expert panel. The Delphi study process leaned on the phases and recommendations of Schmidt (1997) and Okoli & Pawlowski (2004).

45 experts were initially asked to participate in the Delphi study of whom 38 accepted the invitation and 25 followed the study until the end (Table 2). To be regarded as an expert, a candidate should have been a project manager, an engineering manager, or an engineering discipline leader of at least one major project. The list of participants so far was then shown to key personnel in the organization in order to make necessary supplements, and a few experienced engineers, expert site workers and commissioning workers were then added based on these peer opinions. To make sure they had the capacity and willingness as well as sufficient time to participate, an invitation to participate in the study was e-mailed to 45 people who matched one or more of these criteria.

Through e-mail, the panel members were asked to state at least 6 problems, which had occurred in the assembly and completion phases of an engineering and construction project, and to give some brief problem descriptions. This resulted in a list of 217 problems. To obtain the overview needed to perform a consolidation and paring down of the original 217 problems list, we had to categorize them. Initially we used the categories as presented by Toor and Ogunlana (2008), and allocated the problems to those. However, this categorization was less meaningful for EUMEC's problems. There were no problems related to financial issues, such as "Shortage of funding" or "High interest rate". The problems that might come close to this group were more related to budgeting, such as "Lack of control in the registering of hour-lists". In addition, several problems concerning drawings and documents were identified, indicating that this should be a category of its own. None of the Toor & Ogunlana's (2008) miscellaneous problems was identified in this study. Nevertheless, 13 problems had to be allocated to this category while they did not fit any other category.

Discipline	No of respondents
Assembly and completion	2
Electro	1
Engineering manager	5
HVAC	1
Instrument/Telecom	1
Mechanical and Weight	4
Piping/Layout	2
Process	1
Project manager	4
Safety	2
Structure	2
Sum	25

Table 2. Number of final respondents representing the roles and engineering disciplines in EUMEC

Hence, we conducted a new categorization of the problems. This final categorization is displayed in Table 3 below. Thereafter, the most important problems were selected for further analysis. The consolidated list of problems (now categorized) from round one was emailed to the participants and they were asked to pick the 15 problems they regarded as the most important in relation to the project profits. They were also encouraged to comment, this time as to *why* they picked the problems they did. The categorization was not contradicted by any of the participants; some commented that the list was now more perspicuous, and the categories were comprehensible. This phase was completed by 29 participants.

After this phase the researcher can either eliminate all problems that were not selected by a simple majority of the participants, or, arbitrarily pare the list. Schmidt (1997) points out that the researcher should not be the one that decides the top issues. In our study a simple majority was not reached in this phase, which could be due to the rather large number of problems. Since a manageable number of items to rank are around 20 (ibid), and our results showed that the top 18 problems were voted for by at least 7 participants, a decision was made to select those problems. ("at least 6 participants" would have added 7 more problems and "at least 5 participants" would have added yet another 6 problems) To avoid the danger of the researcher *deciding* the top issues, this choice of the top problems was confirmed as representative by the participants.

For the ranking exercise, the problems in the consolidated list were presented in a random order in four different versions, and these versions were equally divided among the participants to avoid potential bias caused by the order of listing of the items (O'Neill, Scott, & Conboy, 2009; Schmidt, 1997). The rankings were analysed in the SPSS software (Statistical Package for the Social Sciences) in order to determine the level of consensus amongst the participants. Kendall's W, which measures the level of consensus among the rankings, was .151, representing "very weak agreement" (Schmidt, 1997). 25 participants participated in the second round of ranking, given the results from the first round, but 3 of the answers had to be rejected because of irregular ranking (e.g. leaving some problems unranked). After the second round, Kendall's W was now measured to .858 which is consistent with "strong agreement". According to Schmidt (1997), this was an appropriate exit point. Approximately 50% of the participants provided their qualitative comments and groundings on the second ranking round as well, confirming that the experts had put a good thought to the process as a whole, instead of merely selecting the overall ranking from the first round as such.

4 Results

Table 3 displays the final categorization together with the number of problems in each category respectively for the 125 consolidated problems list and the top 18 problems list.

Problem category	# Identified problems	# Top 18 problems
Problems related to documents and drawings (PDoc&Draw)	20	6
Problems related to copying of projects (PCopyProj)	5	1
Problems related to experience (PExper)	4	2
Problems related to budgeting (PBudge)	6	0
Problems related to procedures (PProced)	30	1
Problems related to changes (PChange)	7	2
Problems related to responsibilities/contracts/management (PR/C/M)	22	5
Problems related to design (PDesign)	6	0
Problems related to coding manuals and tag-numbering (PTagno)	5	0
Problems related to Data registers (engineering systems and 3D modelling application) (PDatReg)	8	0
Problems related to engineering (PEngin)	6	0
Problems related to equipment (PEquip)	6	1
Total	125	18

Table 3. Summary of problem categories for consolidated list and the top 18 problems.

The ranking result is displayed in table 4, together with descriptions of the identified problems. R is the relative rank and M represents the mean of the rankings. The problems marked with '*)' are those related to information quality, in light of the information quality dimensions by Batini et al. (2009).

5 Discussion

In comparison to the previously identified major challenges causing delays in construction and engineering projects (Toor & Ogunlana 2008), our target organization clearly experiences significant challenges with information quality. From table 4, we could identify 8 problems which relate directly to information quality (Table 5) – including the six top problems. In general, this finding highlights importance of information quality in our target organization more and in a greater detail than the general-level literature. In the following, we will discuss about the eight information quality problems in light of the previous research and outline the future managerial efforts to tackle those problems.

The problem of delays in distribution of drawings and documents (#1, table 5) is well in line with the exploratory results by Lim & Mohamed (2000), who also recognized that "waiting for information" was a major reason for delays in the British projects. The timeliness/speed issue relates also to supplier-delivered design documentation (#2) and equipment drawings (#3), which were identified as problem categories of their own. If the information is not available in time, engineering databases will either contain omissions or incorrect data (#4 also relates to this issue). The deliveries are extracted as drawings (mainly), from these databases, and if they are not complete and accurate, delays will occur on the assembly site due to extra use of work hours to correct errors or to recover missing information. Hence, our target organization would greatly benefit from improved tools and practices which would help to control and enhance the speed of delivery and timeliness of drawings and other design documents; monitoring them both inside the company and in the subcontractor relations.

R	Problem category	Problem	Comments	M
1	PDoc&Draw	Delays in distribution of drawings and documents *)	The engineers are waiting for documentation they need for proceeding with their work.	1,68
2	PDoc&Draw	Design is based on unfinished or incorrect supplier documentation *)	If the needed documentation does not arrive with the engineers on time, the proceeding design work might be based on incomplete documentation. In addition, if the documentation is on time, the information presented in the supplier documentation could be incorrect.	2,64
3	PChange	Equipment drawings change after engineering design is completed *)	When engineering design is completed, it adds a lot of work if the equipment drawings are changed because that could lead to change and alteration of the overall design.	3,32
4	PDoc&Draw	Errors and omissions in supplier drawings *)	Even if the designers discovers the errors and omissions in time to adjust the design before it reach completion, it still demands a lot of extra work. Comment from an engineer: One of the biggest problems we have is the *amount* of errors in third party drawings.	5,36
5	PDoc&Draw	There are great shortcomings in the interface documentation on drawings, (not correct information as size, weight, tag number) *)	When there are shortcomings in the interface documentation more time is used during the assembly phase. The interfaces might not even fit and adjustments have to be done.	5,59
6	PDoc&Draw	GA (General Arrangements/Assembly) drawings are not consistent with the equipment *)	The General Arrangement drawing displays, among other things, where different equipment should be located. If there are disparities between the equipment on the drawing and the equipment at hand, it takes more time to complete the assembling.	6,05
7	PEquip	Errors in delivered equipment are revealed in the end phases of the projects	Errors in delivered equipment revealed in the end phases of the projects leads to re-adjusting or even rebuilding of the equipment, which add work hours to the project.	7
8	PR/C/M	Insufficient delivery specifications, especially on internal and external interface (who does what)	This problem concerns the interfaces between the internal design and the external equipment (e.g. if the equipment needs a bracket of some kind, does it come with the bracket or does the organization design the bracket? E.g. is the bracket/equipment the interface, or is the steel structure/bracket the interface?)	7,68
9	PDoc&Draw	Lacking interface within our organization between engineering, equipment, control systems, flow diagrams (the drawings are not congruent) *)	The drawings are not consistent between the different engineering disciplines which create confusion and errors.	9,5
10	PProced	Mismatch between engineering plan and equipment plan	The organisation has one execution plan for engineering design and another for product development. In large projects where both plans have to be used simultaneously there seems to be a mismatch which could lead to delays.	9,68
11	PCopyProj	Copy projects always lead to recurring errors that we use hours to correct from project to project *)	When copying data registers from one project to the next, errors are copied as well if they are not fixed.	10,41
12	PR/C/M	Underestimation of work scope resulting in deliveries being ignored or a lack of someone in charge	Some engineers states that work scope is underestimated in terms of work hours, and that this could lead to deliveries being ignored or nobody is appointed to be in charge of that delivery.	11,09
13	PR/C/M	The demanding price for detail engineering scope is too low in lump sum projects	Setting a fixed price for a detail engineering scope is difficult and the engineers commented that the prices are too low when compared to the work hours used.	12,14
14	PR/C/M	We are too “kind” to the customers and often they get much more than they actually pay for	“Personnel need greater knowledge concerning the content of the contract, so we do not give them more than they actually bought. We need to be more cynical and more like a pedlar!”	14,09
15	PChange	The scope changes and new elements are being sneaked in	“Details concerning the scope are seldom given and the contractor is “forced” to take ownership because the contract describes “system responsibility””.	15,09
16	PExper	Our organization has no procedure that is followed when it comes to transfer of experience between projects	“We have tried to make a system for transfer of experience, but we have not succeeded.”	15,18
17	PExper	Important personnel leave the projects before installation and completion	“It is common that project personnel are transferred to a new project before completion. It is very important that these people give information to other people in the project to avoid using time on unnecessary search for information that already exist.”	16,77
18	PR/C/M	Being seated in three different locations in one town results in more errors in the projects	The engineers argued that they would like to be seated together in one location whenever that was possible, but due to shortage of office spaces that was difficult to accomplish.	17,73

*Table 4. Ranked results; *) = Information Quality problem*

R	Problems	Quality dimension(s)
1.	Delays in distribution of drawings and documents *)	Timeliness/Speed
2.	Design is based on unfinished or incorrect supplier documentation *)	Timeliness, Completeness, Accuracy
3.	Equipment drawings change after engineering design is completed *)	Timeliness, Accuracy
4.	Errors and omissions in supplier drawings *)	Accuracy, Completeness
5.	There are great shortcomings in the interface documentation on drawings, (not correct information as size, weight, tag number) *)	Accuracy
6.	GA (General Arrangements/Assembly) drawings are not consistent with the equipment *)	Accuracy
9.	Lacking interface within our organization between engineering, equipment, control systems, flow diagrams (the drawings are not congruent) *)	Consistency
11.	Copy projects always lead to recurring errors that we use hours to correct from project to project *)	Accuracy

Table 5. Information quality problems and the associated quality dimension(s)

Management of changes in equipment drawings (#3) in relation to on-going project documentations causes another challenge of information timeliness, realizing as an accuracy problem in the end. The problem results in inconsistency between the engineering design and the content of the drawing. The problem itself refers to an internal equipment drawing change, which is caused by changes in actual equipment, developed and produced by a separate department in EUMEC using the same data registers.

The issues of accuracy and completeness were highlighted especially in relation to supplier documents alongside the timeliness (#2, #4). However, accuracy issues were also related to general assembly drawings (#6), interface documentation (#5), and utilization of information from previous project designs (i.e., copy projects, #11), which are not supplier-originated problems. This observation is well in line with Toor & Ogunlana's (2008) category of "errors and omissions in design documents". In EUMEC, such errors and omissions take place in relation to varying categories of documentation throughout the projects. The high rankings of these problems are also well in line with the previously observed significance of drawing incompleteness in 75% of Thai construction projects (Ogunlana, et al., 1996). In EUMEC, the accuracy and completeness problems should be observed effectively both during the projects, to hinder subsequent designs and equipment assemblies based on inaccurate information, and after the projects, to ensure that the future projects would not copy the accuracy errors from the previous ones.

Inconsistency of drawings between different engineering disciplines (#9) was a problem with no direct correspondence to the literature on construction project problems viewed above. This issue highlights a need for focusing on co-operation between the engineering disciplines to ensure that their design documents and drawings would follow common conventions from the viewpoint of the whole design, in addition to being internally consistent and accurate.

The information quality problems (Table 5) altogether involved the four core quality dimensions (Batini, et al., 2009): accuracy, completeness, consistency, and timeliness. The dimensions could also be connected to particular types of design documentation in this case; e.g. flow diagrams and General Arrangement drawings. The timeliness dimension was especially connected to the speed of information delivery as an important factor to ensure timeliness, which could perhaps be expected in the context of concurrent engineering. The results give a starting point for further information management -related actions in our target organization for ensuring better information quality in their engineering projects.

The Delphi method does not reveal the potential cause-effect relationships between the identified issues, which remains as a shortcoming of this study. Hence, our next step is to delve deeper into *why* the organization has these information quality related problems, and what can be done, more specifically, to reduce the causes to them. The results also give a basis for choosing more detailed information quality assessment and coordination techniques (cf. e.g. those identified by Batini, et al., 2009) fitting to the information types and quality dimensions involved in this case. Especially, the target organization has already started an implementation of an information quality system, built upon the existing product and project data registers, which monitors the key indicators of these quality dimensions more actively already in the early phases of the projects.

The issues of ambiguous requirements and incompleteness of contract documentation, which were among previously observed information quality problems in construction projects (Toor & Ogunlana, 2008), were less prominent in our case. Emergence and foci of particular information quality problems in construction projects may vary from time to time and context to context. However, whereas studies focusing on information quality in large construction projects remain scarce, further research efforts are needed to identify the most common or stickiest problems at the industry level.

Information quality of managerial decision-making in projects (Wantanakorn, et al., 1999) gained no visibility in our results. This could imply that such information is already satisfactory in EUMEC, or that such information is not yet recognized to play a role related to delays or profit margins. In contrast to previous research discussing perceived information quality as an intermediating factor having impact on IT adoption (Hjelt & Björk, 2007) or supply chain integration (Xue, et al., 2007) in construction projects, our expert panel results imply direct impacts of information quality on the project profits in EUMEC. Here, management of information quality has become prioritized as a revenue-bringing issue in its own right, instead of only representing a partial cause for other mediating issues. This finding is well in line with the Delone & McLean (2003) model, in which such a direct causal relationship between information quality and organizational impacts has been previously tested explicitly in the retail industry (DeLone & McLean, 2003, p. 14; Teo & Wong, 1998).

The most of the remaining top issues (#7, #8, #12-18) could be mainly found among the previously identified problems of construction and engineering projects. Whereas the focus of this paper remains on the top-ranked information quality problems, we do not discuss about the remaining ones in more detail here. Problem #10, "Mismatch between engineering plan and equipment plan", although reminding a problem of information consistency at first glance, refers here to organizing of internal project execution plans between the engineering department and the equipment department. In large projects, where both plans are used simultaneously, there seems to be a mismatch which could lead to delays. The plans and planning practices are now being worked on to be revised and aligned.

6 Summary and conclusion

Our Delphi study in EUMEC resulted in an initial list of 125 problems decreasing the profit margins of large engineering and construction projects. A strong consensus on the relative importance of the top 18 problems was reached. Among the top 18, eight problems, including the top six, relate to information quality. This result contributes by providing more detail into the previous literature, which has hitherto mentioned the information quality problems in construction and engineering projects largely at a general level, without relating them explicitly to information quality research or quality dimensions. A concretization and prioritization of information quality problems in context provide a basis for targeting concrete management and systems development initiatives for their mitigation. Previous studies on information quality in this field are scarce, only indicating that it might have importance among many factors. Hence, future research efforts will be needed to estimate whether our results would imply a more general-level contemporary problem in the whole field of large-scale engineering and construction projects or whether the great prominence of information quality issues was only contextually specific to our target organization.

We plan to continue this research in cooperation with EUMEC by following their subsequent actions to manage information quality better through a dedicated information quality system initiative for engineering projects. The system will include concrete and maximally automated controls of the most important quality dimensions and measures, focusing on the issues found in the Delphi study. Additional field research efforts on contemporary information quality in large engineering and construction projects will be needed to bring up more generalizable knowledge on the important quality dimensions, tools, and practices for this industry in more detail.

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