Integration of Constructability and Project Risk Management

L. Farina, E. Danesi, A. Travaglini, Mauro Mancini and P. Trucco

Abstract The research concerns the EPC world and Mega-Projects. The focus is on two disciplines: Risk Management and Constructability. An innovative integration model is proposed, aiming to bridge the existing gaps, to support a structured decision-making process and to facilitate the integration of the two disciplines characterised by different approaches and competences, but with a common target: the megaproject success. The validation of the model is carried out by mean of a cost/benefit analysis on four case studies of an EPC contractor (Saipem SpA).

Keywords EPC contractor · Construction · Integration · Constructability · Project risk management

1 Introduction

Nowadays EPC contractors have to deal with increasingly complex projects, characterized by fragmented and articulated processes. The development of appropriate tools and techniques is necessary to make the project management efficient and to avoid waste in terms of time and resources. Othman (2011) states that most of these problems can be overcome by implementing procedures that focus on techniques for the improvement of project quality and efficiency. In particular, the main arguments of this research are. Academics and practitioners have explored Project Risk Management (from now on PRM) and Constructability (two disciplines largely adopted by EPC contractors since the 90s) separately, but there is a big gap on their integration.

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2 Research Problem Definition

Construction projects are often part of a complex and dynamic environment, resulting in circumstances of high uncertainty that could threat the project success. PRM cannot disregard the construction activities since the major part of over-costs and delays comes from construction inefficiencies (Zhao and Duan 2008). Schieg (2006) asserts that the integration of a PRM system must permeate all areas, functions and processes of the project. Hiley and Paliokostas (2001) argue that there is the need to structure a better relationship between PRM and Constructability processes, because promoting the latter can in turn reduce specific risks. This work answers the following research questions: (R1) What is the State of Art of PRM and Constructability and what is their degree of integration? (R2) How can the disciplines be integrated to improve the efficiency and effectiveness of the project processes? (R3) If the feasibility is proven, what are the costs and benefits of the integration?

3 Research Methodology

The followed research process complies with the guidelines proposed by several literature sources such as Kumar (2011). Adopted process steps are shown in Fig. 1.

Each step answers its related research question. The aim of literature survey (M1) is to understand the disciplines' state of art and the research progress about their integration. Both conceptual and empirical analysis has been reviewed. Moreover, previous research has provided explorative guidelines for the creation of a theoretical model (M2) where Constructability and PRM processes are integrated. The main reference standard is the IDEF 0, fit for function modelling. By integrating the theoretical model concepts into Saipem's[1] procedures, a time-dependent model has been developed (M3). After defining cluster domain for case studies, the model validation has been developed in four projects[2] subjected to a cost/benefit analysis. Figure 2 shows the data collection and the analysis development.

Data about construction criticalities (due to the lack of integration) have been collected from internal documentation and interviews with personnel involved in the examined projects. The triangulation of evidences (Yin 2012) from multiple data sources and the investigator triangulation (Bryman 2004) results in the process.

Within-case analysis provides (i) costs calculation of model application depending on boundary conditions of the project through a proper spreadsheet

[1]Nowadays Saipem SpA is the Italian leader EPC contractor in Oil & Gas sector.

[2]Among the projects characterised by being closed, recent, data abundant, covering the cluster domain and with criticalities not strongly influenced by big company-independent issues, the cases have been chosen through judgment sampling, aided by company experts.

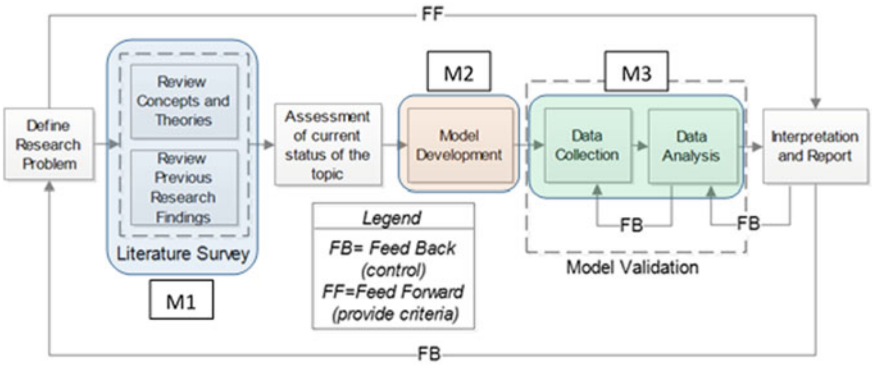

Fig. 1 Research methodology process

Fig. 2 Data collection and data analysis

(developed thanks to interviews and analysis of past project resources) (ii) cross-checking the issue data (qualitative and quantitative) against related Risk Registers, ROBS, Constructability Log and Checklist. Extra-costs of such issues represents the virtual benefits of model application. *Cross-case analysis* concerns instead (i) identification of macro similarities and differences between cases (ii) estimation of model convenience patterns on the established domain.

4 Findings

The outcomes of M1 (R1) are the states of art of the disciplines (singularly) and the explorative studies about their integration. Constructability definition dates back to 1986 by the Construction Industry Institute as the optimum use of construction knowledge and experience in planning, design/engineering, procurement, and field operations to achieve overall project objectives. Some principles[3] are reported for a proper Constructability Program development are the following: Integration, Site Layout, Construction Methodology, Planning, Flexibility, Availability of resources, Feedback, Contracting Strategy. To achieve the major benefits,[4] Constructability shall take place at earlier design stage (Zolfagharian et al. 2012) overcoming barriers such as complacency with the status quo, reluctance to invest resources in early project stages, limitations of lump sum competitive contracting. Many authors (e.g. Hillson and Simon in 2007) and institutes (APM 2012; ISO 2009) generally agree upon the meaning of the word "risk". Several authors (e.g. Gajewska and Ropel 2011) consider the management of project risks as a key discipline for EPC contractors and their competitive advantage. EPC general contractors need a high level of PRM because they have two huge components of risk in the bidding decision-making phase: one part is the risk deriving from the design scheme and the other part is the risk stemming from the bidding offer. Moreover, Mohebbi and Bislimi (2012) and Hiley and Paliokostas (2001) recognise the importance of getting the (PRM) processes started since the early steps of the tendering. Other authors define barriers to the proper PRM. Kutsch and Hall's (2010) research asserts that the strong willing to win the tender and the deliberate ignorance ("irrelevance") of personnel involved in the identification implying the negligence of some risks, turning RM into ineffective or counterproductive. Mohebbi and Bislini (2012) indicate that many companies properly invest in RM systems only after the contract award. Since the early 2000s, few literature contributes have been dealing with the integration between Constructability and PRM. Whenever discussed, it is often cited as part of the integration between Value Management (VM) and PRM. VM is a multidisciplinary effort towards achieving the best value at the lowest overall life cycle cost, in according with set criteria. Value Engineering (VE), moreover, is recognised as a "hard approach" of VM. Mootanah (1998) defines it as a systematic approach to deliver the required functions at the lowest cost without detriment to quality, performance and reliability. Constructability has the same objective as VE, but concerning the construction discipline. While VE aims to reduce the total life cycle cost of a facility, Constructability focuses upon optimization of the entire construction process. In particular, Hiley and Paliokostas (2001) assert that the integration of PRM and VM would enhance the outcomes of both procedures and improve decision-making: PRM adds a further dimension to the evaluation of VM proposals, VM can improve the effectiveness of risk responses through creativity.

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[3]To see a more complete list, please consult Nima, M., Abdul-Kadir, M. and Jaafar, M., 2001. Evaluation of the role of the contractor's personnel in enhancing project constructability.

[4]The benefits of Constructability are multiple, e.g. minimized contract change orders, reduced project cost and duration, enhanced project quality, increased owner satisfaction, and higher trust among project team, as well as a better design and a more effective construction planning (Pocock et al. 2006).

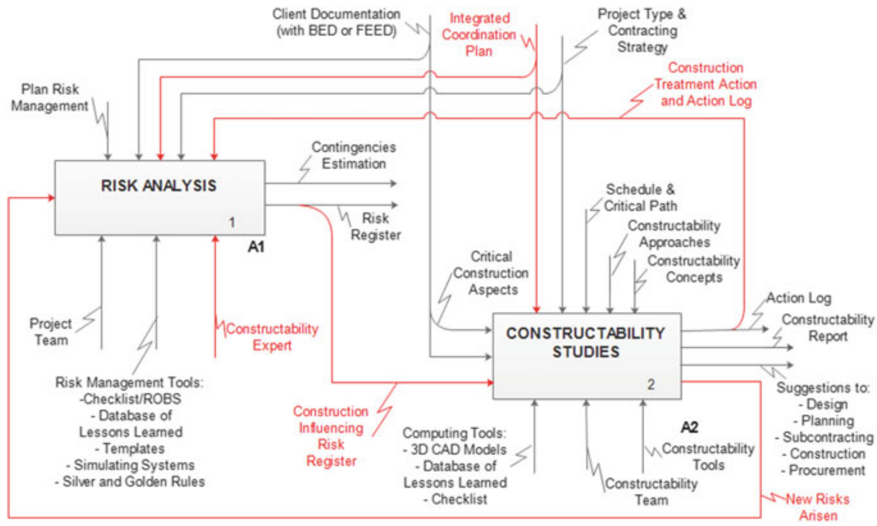

Fig. 3 Theoretical integrated model

Integrated Model Development. The PRM and Constructability embrace all the aspects[5] of the projects, but they look at the criticalities with different objectives. While the PRM aims to evaluate a critical aspect in terms of potential economic impact on the project, the Constructability is more technical. In this sense, they can complete each other. A conceptual model aiming to overcome the recognized barriers—e.g. the short time available to prepare the bid, reluctance to invest additional resources in early project stages, inadequate lessons learned collection, scarce effort on closeout reports draft—shows the logic behind the integration and how the two disciplines can exchange information (R2). Its objective is to design the most flexible solution to face a risky situation. It does not want not to revolutionize the two discipline, but to improve and bridge the gap between them. It considers information, personnel and tools exchange. The right information has to be provided at the right time (mature enough to allow a specific study) and to the right person. The relationship between functions has been modeled through the IDEF 0[6] standard (Virginia Department of Commerce 1993).

The proposed model is applicable to any EPC contractor and it can be implemented in the bid or executive phase, for any kind of project. The innovative characteristics of the model in Fig. 3 are: (i) *integrated coordination plan* shall rule the timing of information exchange (previously approved) and shall contain the information (lessons learned and closeout report) from similar past projects

[5]RM and Constructability involve external environment, laws, financial/economic aspects, engineering, procurement/subcontracting, the execution plan, construction/installation, safety.

[6]Each function box, processes the inputs (by left side) to create outputs (coming out from the right side). Controls enter in the upper side of the box, whereas mechanism from the lower side.

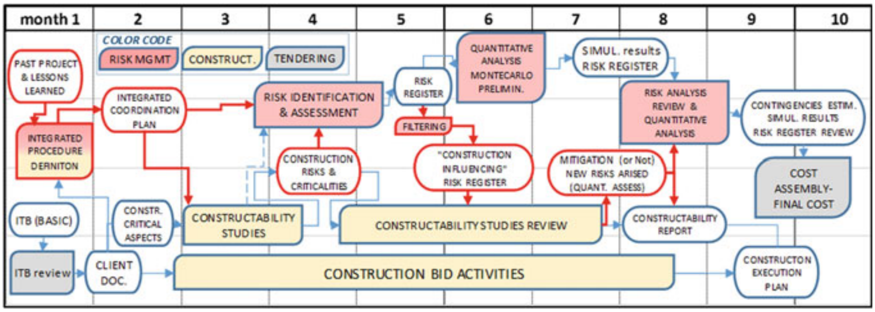

Fig. 4 TO-BE model in saipem

(ii) *Construction treatment action and Action Log* (Constructability's corresponding document to the risk register) through its technical competence and studies, it can treat the construction risks (iii) *Constructability expert* can highlight criticalities of construction activities. (iv) *New risks arisen* come from the construction criticalities suggested by Constructability studies. (v) *Construction influencing Risk Register*, so that only the list of potential risks impacting the construction phase would be treated (e.g. procurement risks of a critical item). Saipem SpA has allowed the application and the validation of the model on its internal procedures (R3). Constructability is not enough developed during the bid phase due to time constraints, whereas it is broadly used during the project execution. PRM is always performed even in the bidding phase but it is often mainly based on qualitative information. Consequently, the integration of the two disciplines is very little. Business Process Modelling technique has been used to represent the Company's activities. The AS-IS model, by inserting the IDEF 0 model (red slots and arrows), becomes the final TO-BE (integrated) situation (Fig. 4).

Case study domain. The consultancy of company experts has resulted in the selection of two parameters as mostly influencing the effort on Constructability and PRM (Fig. 6): (i) project dimension and technical complexity (Construction SMH[7]) (ii) complication of boundary conditions (Overall Project Complication). They are the two axis of the domain. X-axis reflects the overall project complications, which is a combination of several weighted factors.[8] As an example, one case study—a revamping project (Proj. 4)—is presented in the following paragraph. Its project team had to deal mainly with two critical aspects that reduced the constructability of the plant: limited space and interface with the existing working plant. All the costs and benefits monetary values are indicated as percentage of the total project value for business policy reasons of the company.

[7]Construction Standard Man Hours do not consider the delocalization and the productivity factors, but are an index consistent with the dimension and construction complexity of the project.

[8]Spatial availability, interference with running plants, Saipem SpA presence in the country, country industrial development, soil and geotechnical characteristics.

Table 1 Revamping project (Proj.4)—issues summary

Issue description	Integration improvement
Belt conveyor structure foundations. The client could not provide the "as built" of the area for the bearing structure of the conveyor. At first, the engineering considered the installation of classic foundations. After the excavation works, the space available was revealed to be not sufficient because of the interference with foundations of existing facilities	The risk is identifiable by a Constructability study, e.g. plot plan review or a checklist review. The uncertainty shall make the risk analysis start, allowing the project team to prepare a mitigation strategy. Examples of risk responses are: put an extra contingency; consider a clause in the contract to deflect the eventual extra cost to the client
Contaminated groundwater. The unexpected amount of contaminated groundwater led to waste of resources, extra costs and delays	Similarly to the previous case, the Constructability could have identified this issue since it is mentioned in the checklist

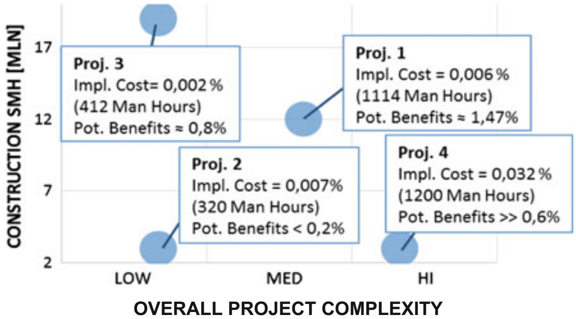

Fig. 5 Cost and potential benefits for each case study

Table 1 reports some of the construction issues,[9] underlining the constructability studies importance to identify the risks related to the project. The integration model implementation facilitates a more proactive approach. The PRM outcome is to change many *unknown unknowns* into *known unknowns* and manage them. The extra budget (issues effects) is due to: (1) delays of the subsequent activities in the same area and re-engineering man-hours for foundations. For example, just the extra material costs (piling) represents about the 0.06% of the entire project value. (2) unforeseen costs of second issue represent the 0.61% of project value (excavation of ponds for contaminated water, water transport costs, external water treatment, wrong treatment package) plus the delays of foundations installation. *Cross-Case Conclusions*. A significant trend is identified in the cluster domain (Fig. 5). For a project in the bottom-left area of the domain, the model benefits could be negligible since the construction inefficiencies are probably not very impactful. The required costs of implementation are very low (right lower than 0.007% of the project value), so they would be easily paid back. With the increase of project complications and

[9]An occurred risk becomes an issue.

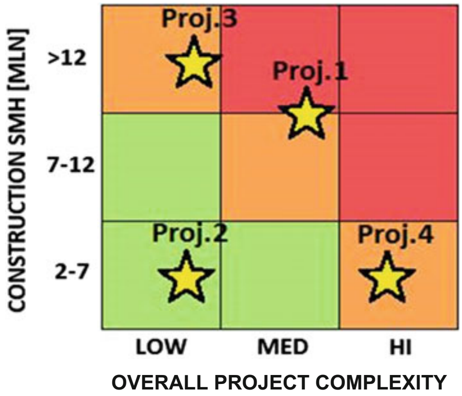

Fig. 6 Cluster domain

(above all) dimension, *convenience* becomes gradually more evident because the same issue has bigger economic and time impact.

Within-Case Conclusions. The estimated delta (between the AS-IS situation and the TO-BE) cost[10] for model implementation is about 0.032% of the project value and it is calculated by mean of the spreadsheet previously mentioned. The "virtual" saving of the issue cost can be considered as the benefit of the model application (excluding the qualitative ones) and it always exceeds the costs. The most impacting factor on the *implementation costs* (Fig. 5) is the "Overall Project Complexity". Obstacles such as spatial constraints, interferences with other plants, a poor industrialization level, soil conditions and a scarce knowledge of the country require a strong effort especially on constructability evaluations.

5 Conclusions and Further Research

Three main results can be highlighted. PRM and Constructability are well described by the academic world taken individually, but little has been discussed about their integration (R1). The proposed model provides the integration between the two disciplines procedures (R2). The model is applicable to a contractor's internal procedure. Its convenience has been demonstrated for different kinds of projects especially for those with high technical complexity and/or complicated boundary conditions (R3). The provided validation concerns only the onshore world. Further research could replicate this analysis within other branches, such as offshore and drilling projects. While building the cluster domain, differences between upstream and downstream typology have not been considered significant. Further research

[10]The number should not be considered by itself: current internal statistics have revealed that the Contractor has a ratio of 1 contract award out of 10 bids. The implementation cost shall include the additional resources spent for the unsuccessful bids as well.

may study the actual significance of this factor, maybe using a wider sample of projects and other experts' opinions.

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References

APM (2012) Body of knowledge. APM Publishing, VI

Bryman A (2004) Triangulation. Encyclopedia of science research methods. Sage, Thousand Oaks, pp 1142–1143

Gajewska E, Ropel M (2011) Risk management practises in a construction project—a case study. Master of Science Thesis in the Master's Programme Design and Construction Project Management, pp 1–60

Hiley A, Paliokostas PP (2001) Value management and risk management: an examination of the potential for their integration and acceptance as a combined management tool in the UK construction industry. Manchester, RICS Foundation

Hillson D, Simon P (2007) Practical project risk management: the atom methodology. Management Concepts Inc, s.l

Kumar R (2011) Research methodology—a step-by-step guide for beginners. Sage Publications

Kutsch E, Hall M (2010) Deliberate ignorance in project risk management. Int J Project Manage 28:245–255

Mohebbi AH, Bislimi N (2012) Project risk management: methodology development for engineering, Procurement and Construction Projects

Mootanah DP (1998) Developing an integrated Risk and Value Management framework for construction project management. In: Proceedings of the 14th annual ARCOM conference. Reading: Association of Researchers in Construction Management. pp 448–453

Othman AAE (2011) Improving Building Performance through Integrating Constructability in the Design Phase. Int J Organ Technol Manage Constr 3(2):333–347

Pocock J, Kuennen S, Gambatese J, Ruaschkolb J (2006) Constructability state of practice report. J Constr Eng Manage 132(4):373–383

Schieg M (2006) Risk management in construction project management. J Bus Econ Manage 7:77–83

Virginia Department of Commerce (1993) Integration definition for function modeling (IDEF 0), Springfield, VA: Virginia Department of Commerce

Yin RK (2012) Applications of case study research. Sage, Washington DC

Zhao Z-Y, Duan LL (2008) An integrated risk management model for construction projects. Cape Town, pp 1389–1394

Zolfagharian S, Nourbakhsh M, Mydin SH, Zin RM, Irizarry J (2012) A Conceptual Method of Constructability Improvement. Int J Eng Technol 4(4):456–459