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Project management software utilization and project performance

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Abstract

The impacts of IT/IS on organizations gave rise to a great deal of interest from the researchers during the last decades. However, studies on the impacts of IT/IS on the performance of engineering projects are less numerous. Moreover, the impacts from IT/IS on engineering projects are rarely based on real data of projects. The objective of this study is to investigate, from real project data, the level of utilization of a project management software package, developed by an engineering construction firm recognized internationally, and its link with project performance. Results stemming from non-parametric tests and correlation analyses show that the level of use of the software, and some of its subsystems, appears to be linked to project performance.

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Keywords: Project management software; Information technology; Information systems; Systems utilization; Project performance.

1. Introduction

The impacts of information technologies (IT) and information systems (IS) on organizations are numerous. IT/IS involve new organizational structures [1,2,3] and result in an increase of the productivity of the individuals [4], so facilitating the increase of organizational productivity. IT/IS also allow to reduce the size of organizations [5] and to facilitate the coordination within organizations. Better coordination allows realizing more complex projects bringing together many actors [6]. Furthermore, IT/IS helps organizations in improving

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their detection capability and capacity for response, which confers them a certain agility [7,8]. Finally, IT/IS stimulates the learning capacity in organizations. They enable the flow and access to information required for good operations of organizations [8,9].

However, the implementation of IT/IS does not always result in expected outcomes. This problem, called *paradox of productivity* [10,11], can be produced by an error of productivity measure, delays in the observation of an increase of productivity, poor management of IT/IS, poor qualified workforce, or the difficulty to estimate, by means of an accounting treatment, the result (profit/loss) of an investment in IT/IS, which are intangible assets [12,13,14,15,16,17].

During the last 20 years, the paradox of productivity thus motivated the researchers to be interested in measuring the impacts of IT/IS on organizations. However, few studies exist on the impacts of IT/IS on the performance of engineering projects. Nevertheless, project management makes use of business processes (supply chain management, human resources management, inventory control, planning, etc.), which are handled by means of IT/IS (i.e. project management software packages).

According to the standard ISO/IEC 2382-1:1993, a software package is a "complete and documented package of programs provided to several users, with the aim of the same application or function". Project management software packages generally facilitate the integration of project data, the interaction with enterprise systems and the interoperability with new IT. Besides optimizing the productivity of the teams, the system allows to make better decisions, to maintain a competitive advantage and to implement an effective project management. This type of software consists of subsystems developed to treat various aspects of project management: procurement, construction, cost control, planning, etc. Table 1 presents the subsystems usually found in a project management software package.

Table 1. Project management software subsystems

Subsystems	Function
Project definition	Define project parameters (employees, classification codes, etc.) and project characteristics (person in charge, dates, contract type, etc.)
Activity planning	Schedule project activities via a specific professional software
Environment management	Manage environmental plans, preventions, training and follow-up actions on inspections and accidents
Health and safety management	Manage health and safety plans, preventive measures, education, preventions, inspections and follow-up actions on accidents and incidents
Estimating process management	Establish detailed estimate of project (project work breakdown structure, work packages, etc.)
Working hours management	Achieve follow-up on working hours provided by the firm according to the contract type defining the project
Document control	Control documents (internal and external) generated during the execution of the project
Document management	Manage processes related to the documents and archive documents
Engineering process management	Carry out recording, follow-up on equipment and materials resulting from engineering, allow purchase requisitions and give an interface with engineering tools
Procurement management	Manage procurement processes related to the project (purchasing, training, contract administration, logistics, procurement follow-up and inspection, material management on site)
Cost management	Carry out follow-up on the project budget, invoicing and payments
Construction activities management	Manage construction contracts, do a follow-up on the construction progress and manage implementation activities

The several interactions between the software subsystems enable the flow of information. Each subsystem thus becomes an information source for other subsystems. Figure 1 illustrates the typical interactions between

the subsystems of a project management software. The arrows indicate the direction of the information flows between the subsystems. For example, the subsystem *Document management* receives information from the *Procurement management* and *Engineering process management* subsystems.

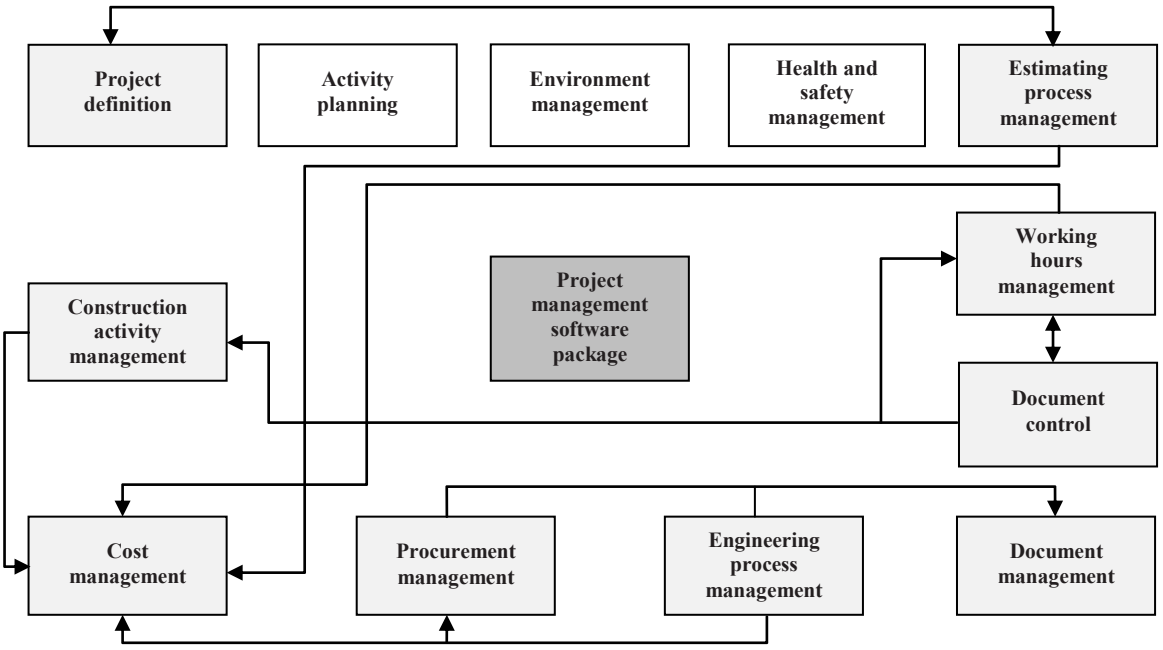


Fig. 1. Interactions between subsystems

While project management systems are now used extensively for conducting engineering projects, the analysis of their impact on the performance of projects has been largely ignored in the literature. Moreover, studies on the impacts of IT/IS on engineering projects are rarely based on real data of projects. Recognizing this limitation, the objective of this paper is to investigate, based on primary sources of project data, the level of use of a project management software, developed by an engineering construction firm recognized internationally, and its relationship with project performance. Specifically, the objectives of this paper are to derive a software utilization profile for the best-performing projects from the firm and to examine the relationship between system utilization and project performance.

The remainder of this article is organized as follows. Section 2 presents a brief review of the studies on the impacts of IT/IS on the performance of engineering projects. Section 3 describes the variables studied, the data collection process and the research methodology. Section 4 presents results and analyses on the level of use of a project management software and its relationship with project performance. We conclude with limitations and call for future research.

2. Background work

The impacts of IT/IS on organizations gave rise to a great deal of interest from the researchers during the last decades. Besides allowing the implementation from an effective organizational management, IT/IS are innovation tools for organizational management [18,19]. On the one hand, TI includes communication vehicles

and tools (Internet, intranet, e-mail, videoconference, etc.) ensuring the linking between IS and individuals within organizations [13,19]. On the other hand, IS includes softwares and databases used in organizational management processes (e.g., ERP system, project planning management system, etc.).

Many studies on the impacts of IT/IS on organizations concern the determination, analysis and quantizing of the impacts of IT/IS on productivity, improvement of processes and innovation [3,5,19,20,21,22]. Some studies only consider the impact of IT on organizations. For example, Boudreau et al. [8] showed that IT has an impact on the coordination, reactivity, effectiveness and learning capacities in organizations. Other studies consider the impact of IS on organizations. As an illustration, Vemuri and Palvia [23] and Velcu [24] showed that ERP systems allow organizations to achieve economies of scale, to reduce general and administrative costs, as well as the duration of organizational processes, and to insure a better inventory turnover.

However, there is a lack of studies on the impacts of IT/IS on the performance of engineering projects. Argyres [6] showed that the implementation of a communication channel between the designers and the use of databases, CAD and common softwares facilitate the coordination between the various companies involved in the realization of a complex project. More recently, Jones and Young [25] observed an increase in the number of multi-divisional projects in companies having implemented an ERP system. Also, Bardhan et al. [15] highlighted the importance to connect IT/IS to the characteristics of a project (project duration, cost, quality, and timeliness of work) to improve project performance. This study revealed that BCT (Basic Communication Technologies) are especially used for high-performance projects, EST (Enterprise Software Technologies), e.g., ERP systems and project management software packages, are desirable for projects where the environment is well structured, and the GCT (Group Collaboration Technologies) must be given special weight for projects where the environment is less structured, uncertain and volatile. Furthermore, Brynjolfsson et al. [26] showed that the use of asynchronous tools (e-mail, databases) allows to simultaneously manage more projects and to reduce the duration of projects. The study of Bryde and Wright [27] revealed a significant correlation between the efficiency of the project management system (PMS) and the expectations from the members of the project team and the customers. Raymond and Bergeron [28] showed that the quality of the project management information system (PMIS) and the frequency of use of PMIS have a positive impact on the performance of a project. Dostie and Jayaraman [3] observed that the employees who use computers are more productive than the non-users. Finally, Ali et al. [29] showed that information quality and project complexity have a positive impact on the use of PMIS. Ali et al. [29] also observed that the use of PMIS has a positive impact on the performance perceived by project managers.

Taken together, these studies are not quantifying the impacts of project management software packages on the performance of engineering projects, and most studies are only rarely based on real project data. The objective of this paper is to study, based on primary sources of project data, the level of use of a project management software and its link with the performance of projects.

3. Research methodology

To precisely investigate system utilization and its relationship with project performance, statistical tests were performed using project data from an engineering construction firm recognized internationally. All statistical tests were performed using SPSS software. We first present the definitions and measurements of the research variables and then describe the project data and some methodological issues.

3.1. Research variables

Data on project characteristics, system utilization and project performance were obtained by the firm. Table 2 presents the variables considered in this study. The choice in research variables is consistent with measures used in the existing literature on the impacts of project management software packages [15,29,30].

Table 2. Variables studied

Project characteristics	System utilization	Project performance
• Budget of the project for activities executed by the firm (hours) • Duration of the project (working days) • Project size (work packages) • Number of persons in the project team	• Use (yes/no) of the subsystems • Frequency of use of the software : o Number of hits on the software o Number of hits on the subsystems • Duration of use of the subsystems (days)	• Project performance indicator, for activities executer by the firm

System utilization is measured with two metrics: software usage time and subsystem intensity of use. The usage time of the software corresponds to the total time of usage of the system (in days) over the duration of the project. The intensity of use of a subsystem corresponds to the number of times a user is connected to a subsystem, divided by the project duration. To define if a subsystem is used or not, we used the subsystems utilization criteria of the firm. For example, the Document Control subsystem is used if documents are listed in the subsystem. Project performance is calculated using the earned value management method. This indicator, called *Cost Performance Index* (CPI), corresponds to the ratio of the budget cost of work performed to the actual cost of work performed. Table 3 presents the threshold tests used by the firm in determining the performance of a project. The CPI threshold values *a* and *b* are fixed by the firm.

Table 3.CPI performance levels

Performance levels	Description
CPI = 1	In accordance with the budget
CPI ≥ *a*	Good performance
b ≤ CPI < *a*	Improvements required
CPI < *b*	Corrective measures needed

3.2. Project data

Aggregated data from 21 engineering projects executed (or being implemented) by the partner firm were collected. Table 4 presents the statistics describing the sample data.

Table 4. Descriptive statistics

Characteristics	Mean score	Standard deviation
Project duration	1 527.1 days	594.74
Budget of the project for activities executed by the firm	460 989 hours	603 757.64
Project size	324.43 work packages	290.53
Number of people in the project team	106.24 persons	98.05
CPI	0.88	0.11

For all projects, the following subsystems were used: *Project definition*, *Working hours management*, *Document control*, *Procurement management*, *Cost management*, *Construction activity management* (contract definition). Even if the subsystems *Estimating process management*, *Engineering process management*, and *Construction activity management* (contract follow-up) were not used for all projects, they are not excluded

from the analysis. The subsystem *Document management* is not treated in this study because it was used independently from the software.

3.3. Methodological issues

The methodology is based on the concept of 'fit as profile deviation' [30], which assumes that the degree of adherence to an ideal profile is positively related to performance. In order to develop an ideal profile of the best performing firms in the aerospace industry, Lefebvre and Lefebvre [30] used the mean scores of a 'calibration sample', usually defined as the top 10 percent of high-performing companies [31]. Small deviations from this ideal profile should result in better performance. Such an empirically derived profile is close to the concept of strategic benchmarking, rather straightforward and intuitively appealing [30].

In this study, in order to identify an ideal profile, the mean scores on system utilization are considered from a calibration sample, defined as the best-performing projects of the sample of 21 projects, in terms of performance. Three subsamples are derived from the sample of projects. We defined, based on the CPI threshold values determined by the firm, that the best-performing projects (CPI $\geq a$) represent the calibration sample ($n_1 = 6$). Considering the sample of 21 projects, this is slightly more than the 25 top percent. The study sample consists of all the remaining projects with the exception of the less-performing projects (CPI $< b$), which corresponds to the bottom 25 percent. Removal of the less-performing projects is necessary to obtain an unbiased sample domain [30]. The study sample is therefore composed of 10 projects ($n_2 = 10$), and the size of the less-performing group is five projects ($n_3 = 5$).

4. Results

Statistical tests were conducted in two phases. First, the comparison of the mean scores on the software usage time of projects from the calibration sample allows for the identification of an ideal usage profile, which should be significantly different from the profile of remaining projects in the sample. In the second phase, we identify the core subsystems of the best projects. We also examine the relationships between the intensity of use of the subsystems and project performance. Significant positive correlation coefficients are expected since high usage levels would normally result in good performance.

4.1. Software usage time

Table 5 presents the mean score from the level of use of the software package for each group (less, group of study and best), as well as levels of significance of bilateral tests for the differences in means. The Mann-Whitney test (non-parametric test of differences in means) is used here since the distribution of the population is unknown and the sizes of the three subsamples are small.

Table 5. Mean usage time per group

Mean scores			Mann-Whitney		
Less (1)	Study (2)	Best (3)	1-3	2-3	1-2
7.699	121.359	51.900	0.03**	NS	0.055*

NS Not significant *p < 0.10 **p < 0.05

The results show that, at the significance level based on 0.05, the projects in the best-performing group display a significantly higher mean score from the level of use than the one of the less-performing group. Similarly, one can observe (at the significance level of 0.10) that there is a real difference between the level of use of the study group and that of the less-performing group. We also examined the relationship between the

level of use of the software and the CPI of the projects. As hypothesized, a significant positive correlation coefficient was obtained (Spearman correlation coefficient $r = 0.396$, $p < 0.05$): the more the usage time of the software increases, the better the CPI of the project is. This result is consistent under the observation made in literature [28,29,32]. Finally, Table 5 reveals that the mean score of the level of use of the study group is higher than that of the best group, although not significantly. We give a detailed explanation of this result in the next section.

4.2. Subsystems intensity of use

Table 6 presents, for each subsystem, the mean score on the intensity of use within each group (best, study and less-performing) as well as levels of significance of tests for the differences in means (Mann-Whitney).

Table 6. Subsystems intensity of use: mean scores

	Mean scores			Mann-Whitney		
Subsystem	Less (1)	Study (2)	Best (3)	1-3	2-3	1-2
Project definition	0.297	2.497	1.337	0.082*	NS	0.075*
Estimating process management	0.106	1.032	0.139	NS	NS	NS
Working hours management	0.339	5.356	1.778	NS	NS	0.028**
Document control	2.015	28.014	16.365	0.030**	NS	0.040**
Engineering process management	0.521	10.144	0.860	NS	NS	NS
Procurement management	1.456	25.084	3.032	NS	NS	0.075*
Cost management	2.428	33.850	17.230	0.030**	NS	0.040**
Construction activity management (contract follow-up)	0.480	3.012	10.094	NS	NS	NS
Construction activity management (contract definition)	0.522	15.139	10.517	0.030**	NS	0.008***

NS Not significant * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

The results show that projects in the calibration sample display significantly higher mean scores than projects in the less-performing group for almost half of the subsystems (4 out of 9). A three-group analysis (best-performing $n_1 = 6$; study sample $n_2 = 10$; less-performing $n_3 = 5$) also yields significant differences between the means on a three-group basis (Kruskal-Wallis test). However, the scores for all the subsystems, except for the Construction activity management (contract follow-up) subsystem, are higher in the study sample ($b \leq CPI < a$) than in the ideal profile ($CPI \geq a$), although not significantly (see Table 6). This result strongly suggests that, above a certain performance level, system utilization does not allow for the development of an ideal profile. We also verified whether the greater mean scores for projects in the study sample could be explained by the fact that the intensity of use of some subsystems is linked to a project's characteristic. Mann-Whitney tests however showed that the four project characteristic variables are not significantly different across the three subsamples.

Table 7 sheds some additional light on the relationship between project performance and the intensity of use of the subsystems.

Table 7. Relationships between project performance and subsystems intensity of use

Subsystems	Spearman correlation coefficients
Project definition	0.295*
Estimating process management	-0.037
Working hours management	0.244
Document control	0.331*
Engineering process management	0.191
Procurement management	0.248
Cost management	0.445**
Construction activity management (contract follow-up)	0.339*
Construction activity management (contract definition)	0.443**

NS Not significant * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$

As hypothesized (except for the Estimating process management subsystem), the correlation coefficients are positive and five are significant: the more the intensity of use of these subsystems increases, the better the CPI of the project is. Also, the correlation coefficients for the Cost management and the Construction activity management subsystems show stronger links to project performance than is observed for the Project definition and the Document control subsystems. The latter can be considered as a priori subsystems for project management. Once these are acquired, the Cost management and the Construction activity management subsystems may lead to superior project performance. Finally, we also tested the impact of the nature of the subsystems used on the performance of projects. At the significance level of 0.05, results show that, for each subsystem, there is no real difference between the use (yes/no) of the subsystem by a group (less-performing, study or best-performing) and that of another.

5. Conclusion

This paper focuses on level of use of a project management software package, developed by an engineering construction firm, and its relationship with project performance. Statistical tests were performed on the basis of quantified data resulting from 21 large engineering projects executed by the firm. The results show that the less-performing projects present significantly lower system utilization levels than the other projects. This finding corroborates the findings of Raymond and Bergeron [28]. However, system utilization for the best-performing projects is not significantly different from projects in the study sample. This result can be explained by the fact that, above a certain performance level, system utilization does not allow for the development of a distinct profile from the best-performing projects. Also, the performance of the projects appears to be linked to the usage time of the software: the more the software usage time increases, the better the CPI of the project is. Similarly, project performance also seems to be related to the intensity of use of four software subsystems: Project definition, Document control, Cost management and Construction activity management. The more intensively one or the other of these subsystems is used, the better the CPI of the project is. These subsystems are used to support project management processes requiring an important effort from the project management team, due to the amount of data required by these processes. As shown in Figure 1, these subsystems interact intensively with each other and are designed to be used together. This result seems to demonstrate the need to use a minimal subset of subsystems which can be referred as the core elements of an integrated project management software. This result is consistent with findings related to the use of other integrated software, such as ERP system, where some key modules (e.g., finance and logistic modules) are tightly integrated, which

provide in return the most important benefits for the organization. Key modules are often implemented first, while the other peripheral modules can be discarded or implemented in subsequent phases.

For project management practitioners, these findings provide four broad insights for in the initial phases of engineering projects. First, the selection of subsystems to be used for supporting one project should be guided by business process integration objectives and not decided based on function requirements. Second, the selection of subsystems to be used must favour the support of data intensive processes. Third, when monitoring projects, project managers should ensure that core subsystems are used at a sufficiently high level (not necessarily the highest level) to maintain good performance. Fourth, the use of parallel software or databases for conducting similar activities should be avoided. Training and monitoring activities should therefore be planned with care in the initial phases of projects in order to maximize the use of the core subsystems. Our observations show that lack of training is a common reason for bringing users to work with parallel systems.

Although this study provides insight into the use of project management software and its relationship with project performance, it has limitations and results may be interpreted with caution. First, the sample size is small (n = 21). A project is "a temporary endeavor undertaken to create a unique product, service, or result" [33]. As each project is unique with its own characteristics, a larger sample would be required to generalize our findings. Second, only one aspect of project performance is considered in this study. Project performance is often defined in terms of schedule, scope and cost. Thus, we may have obtained different results with other project performance criteria. Some subsystems could offer a higher control of the baseline which could be consistent with a better performance of project duration. Other project performance criteria should therefore be considered in future studies. Other data could also be collected via questionnaires to complement the project management system data.

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