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Project characteristics, project management software utilization and project performance: An impact analysis based on real project data

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Abstract:
Project management software packages are increasingly used by companies. These tools require a substantial financial investment, hence the importance of identifying the real contribution of project management software packages to the realization of projects. However, studies on the impacts of software packages on the performance of engineering project management are rare and mostly based on perceptions. 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 and project characteristics. 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. Project duration also seems to be the most critical project characteristic.

Keywords:
project management software; information technology; information systems; systems utilization; project performance.

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1. Introduction

The impacts of information technologies (IT) and information systems (IS) on organizations are numerous. IT/IS involve new organizational structures [1]-[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 their detection capability and capacity for response, which confers them a certain agility [7],[8] as they enable the flow and access to information required for good operations [8],[9]. Finally, IT/IS stimulates the learning capacity in organizations.

However, the implementation of IT/IS does not always result in positive outcomes. This problem, called *paradox of productivity* [10],[11] results from several factors such as the time lag between the investment and the observed outcome in productivity, poor management of IT/IS, poor qualified workforce, or the way investments in IT assets are accounted for in financial statements [12]-[17].

During the last 20 years, the paradox of productivity thus motivated the researchers to measure the impacts of IT/IS on organizations. However, few studies exist on the impacts of IT/IS on the performance of engineering projects. Project management makes use of business processes (supply chain management, human resources management, inventory control, planning, etc.) and IT/IS plays nowadays an important role in efficient project management (i.e. project management software packages).

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 project data. The originality of this paper relies on the use of primary sources of project data, obtained from an engineering construction firm, to investigate the impact of utilization of a project management software on project performance. Specifically, the objectives of this paper are:

- To examine the relationship between project characteristics and software utilization;
- To highlight the perceptions of system users that have an impact on the performance of projects; and
- To derive a software utilization profile for the best-performing projects from the firm.

The remainder of this article is organized as follows. Section 2 introduces the necessary background and definitions concerning project management software packages and presents a review of the studies performed, for the last decades, on the impacts of IT/IS on organizations and 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 project management software and its relationship with project performance and project characteristics. We conclude with limitations and call for future research.

2. Background and literature review

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". As such, project management software packages, commonly called Project Management Information System (PMIS), 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 effective project management practices. 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 activity 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. For example, the subsystem *Document management* receives information from the *Procurement management* and *Engineering process management* subsystems.

During the last decades, the impacts of IT/IS on organizations gave rise to a great deal of interest from the researchers. Besides allowing the implementation from an effective organizational management, IT/IS are innovation tools for organizational management [18],[19]. On the one hand, IT 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 software 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]-[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 software 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, Aral 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 and the expectations from the members of the project team and the customers. Raymond and Bergeron [28] showed that the quality 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 reveals important observations, but are not quantifying the impacts of project management software packages on the performance of engineering projects. The objective of this paper is to study, based on primary sources of project data, the level of use of project management software and its link with the project performance, as well the impact of project characteristics on this relationship.

3. Research methodology

In this section, we first present the operationalization of research variables and then describe the project data and our approach to analyze the data.

3.1 Research variables

Data on project characteristics, system utilization and project performance were obtained by a large international engineering 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].

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. To measure the intensity of use of a subsystem, the following ratios are used: the number of times a user is connected to a subsystem, divided by:

- The project duration (working days);
- The budget of the project for activities executed by the firm (hours);
- The duration of use of the subsystem, for the duration of the project (days);
- The size of the project (number of work packages); and
- The number of persons in the project team.

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. Table 3 summarizes the criteria for using the subsystems of the project management software.

The subsystems *Activity planning* and *Document management* are not treated in this study because they were used independently from the software. 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 (in working hours of the project team). Table 4 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 2. Research variables

Project characteristics	System utilization	Project performance
▪ Budget of the project for activities executed by the firm (hours) ▪ Budget of the project for activities executed by the key departments of the firm: project management, engineering, procurement and construction (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: ○ Number of hits on the software ○ Number of hits on the subsystems ▪ Duration of use of the subsystems (days)	▪ Project performance indicator, for activities executer by the firm (working hours)

Table 3. Criteria for use of the project management software subsystems

Subsystems	Subsystems utilization criteria
Project definition	This subsystem is always used in project management as it is the basis for the creation of projects in the software databases
Environment management	Management plans and training activities are present in the subsystem
Health and safety management	Management plans and activities are present in the subsystem
Estimating process management	Data concerning estimations are present in the subsystem
Working hours management	Tasks are defined in the subsystem
Document control	Documents are listed in the subsystem
Engineering process management	Data regarding engineering material are present in the subsystem
Procurement management	Procurement items associated with the material can be found in the subsystem
Cost management	Data concerning order forms or contracts can be found in the subsystem
Construction activity management	Construction activities are defined in the subsystem

Table 4. CPI performance levels

Performance levels	Description
CPI > a	Excellent performance
$a \geq$ CPI > 1	Good performance
CPI = 1	In accordance with the budget
$b \leq$ CPI < 1	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. The data collection process was conducted between April and October 2012. Table 5 presents the data collected on the 21 projects and the statistics describing the sample data.

For all projects, the following subsystems were used: *Project definition*, *Working hours management*, *Document control*, *Procurement management*, *Cost management*, *Construction activity management* (contract definition). The following modules were used in some of the projects considered: *Estimating process management*, *Engineering process management*, and *Construction activity management* (contract follow-up). The subsystem *Document management* was not treated in this study because it was used independently from the project management system.

Table 5. Data collected and descriptive statistics

Project	Project duration (working days)	Budget[1] (hours)	Project size (work packages)	Number of persons	CPI (working hours)
1	547	445 732	227	297	0.83
2	1339	2 058 387	1092	414	0.91
3	947	97 233	144	79	1.02
4	1304	80 844	8	36	0.62
5	1531	342 277	1023	55	0.87
6	1022	27 949	99	71	0.78
7	1217	103 738	175	57	0.93
8	1329	127 446	420	62	0.99
9	2022	208 500	275	128	0.84
10	1819	292 425	407	57	1.03
11	1968	230 961	297	52	0.76
12	1217	99 471	254	143	0.94
13	674	467 879	21	35	0.88
14	1198	2 239 759	322	257	0.90
15	1803	91 019	105	40	0.85
16	3029	779 107	411	86	0.77
17	1041	206 295	189	80	0.76
18	2082	552 023	360	74	0.78
19	1534	37 453	61	45	1.04
20	2229	431 453	241	62	0.89
21	2217	760 818	682	101	0.97
Mean score	1527.1	460 989	324.43	106.24	0.88
Standard deviation	594.74	603 757.64	290.53	98.05	0.11

[1] Budgeted hours for activities executed by the firm.

3.3 Data analysis

Statistical tests were performed in SPSS using project data from an engineering construction firm recognized internationally. The analysis is based on the concept of 'fit as profile deviation' [30], which assumes that the degree of adherence (or fit) to an ideal profile is positively related to performance. We build upon a methodological approach developed by Lefebvre and Lefebvre [30] to identify a best-performing profile among a group or a sector. Based on their recommendation, we use the mean scores to establish a 'calibration sample', usually defined as the top 10 percent of a group [31]. Deviations from this ideal profile should impact performance. As highlighted by Lefebvre and Lefebvre [30], such an empirically derived profile is close to the concept of strategic benchmarking, rather straightforward and intuitively appealing.

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 considered the value of the CPI on all projects, and defined, based on the CPI threshold values determined by the firm, that the best-performing projects (CPI > a) represent the calibration sample (n1 = 6). Considering the sampling of the 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 (n2 = 10), and the size of the less-performing group is five projects (n3 = 5).

4. Results

Statistical tests were conducted in four 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. 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. In the third phase, relationships between project characteristics and software utilization are analyzed. This provides a better understanding of the critical factors affecting project management software utilization. Finally, the last phase serves to highlight the perceptions of system users that appear to have a significant impact on the performance of projects.

4.1 Phase I: Software usage time

Table 6 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 6. 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. However, 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.

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 observations made in the literature [28],[29],[32].

4.2 Phase II: Subsystems intensity of use

Table 7 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 bilateral tests for the differences in means (Mann-Whitney). The ratio considered corresponds to the number of times a user is connected to a subsystem, divided by the project duration.

Table 7. Subsystems intensity of use: mean scores[1]

	Mean scores			**Mann-Whitney**		
Subsystems	**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   *$p < 0.10$ **$p < 0.05$ ***$p < 0.01$
[1] Ratio used to measure the intensity of use: number of hits on the subsystem, divided by project duration

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). Also, for two thirds of the subsystems (6 out of 9), the intensity of use related to the less-performing group differs significantly from that of the study sample. Finally, we note that there is no real difference between the level of use of the *Estimating process management* subsystem by a group and that of another, this subsystem being sometimes maintained using other estimating software packages, independent of the project management software package developed by the firm.

Similar results were obtained with the following ratios:

- Number of connections to a subsystem, divided by the budget of the project for activities executed by the firm (Table 8);
- Number of connections to a subsystem, divided by the duration of use of the subsystem (Table 9).

Table 8. Subsystems intensity of use: mean scores[1]

	Mean scores			**Mann-Whitney**		
Subsystems	**Less (1)**	**Study (2)**	**Best (3)**	**1-3**	**2-3**	**1-2**
Project definition	0.003	0.010	0.018	NS	NS	NS
Estimating process management	0.001	0.002	0.002	NS	NS	NS
Working hours management	0.004	0.013	0.019	0.082*	NS	0.099*
Document control	0.016	0.092	0.186	0.052*	NS	0.099*
Engineering process management	0.003	0.013	0.008	0.082*	NS	NS
Procurement management	0.009	0.031	0.027	NS	NS	NS
Cost management	0.013	0.102	0.230	0.052*	NS	0.028**
Construction activity management (contract follow-up)	0.002	0.039	0.121	NS	NS	NS
Construction activity management (contract definition)	0.002	0.051	0.123	0.082*	NS	0.003***

NS - Not significant   *p < 0.10   **p < 0.05   ***p < 0.01
[1] Ratio used to measure the intensity of use: number of connections to the subsystem, divided by the budget of the project

Table 9. Subsystems intensity of use: mean scores[1]

	Mean scores			**Mann-Whitney**		
Subsystems	**Less (1)**	**Study (2)**	**Best (3)**	**1-3**	**2-3**	**1-2**
Project definition	0.493	2.635	1.387	NS	NS	NS
Estimating process management	0.308	1.087	0.157	NS	NS	NS
Working hours management	0.471	5.730	1.921	NS	NS	0.019**
Document control	3.148	30.066	18.276	0.052*	NS	0.040**
Engineering process management	6.507	10.698	8.578	NS	NS	NS
Procurement management	5.271	27.164	3.577	NS	NS	NS
Cost management	3.830	35.209	18.170	0.052*	NS	0.040**
Construction activity management (contract follow-up)	0.642	3.279	10.940	NS	NS	NS
Construction activity management (contract definition)	0.741	16.357	11.750	0.052*	NS	0.005***

NS - Not significant   *p < 0.10   **p < 0.05   ***p < 0.01
[1] Ratio used to measure the intensity of use: number of hits on the subsystem, divided by subsystem duration of use

A three-group analysis (best-performing n1 = 6; study sample n2 = 10; less-performing n3 = 5) also yields significant differences between the means on a three-group basis (Kruskal-Wallis test, Table 10).

Table 10. Three-group analysis

	Kruskal-Wallis		
Subsystems	**Ratio 1[a]**	**Ratio 2[b]**	**Ratio 3[c]**
Project definition	NS	NS	NS
Estimating process management	NS	NS	NS
Working hours management	0.067*	NS	0.062*
Document control	0.057*	0.080*	0.069*
Engineering process management	NS	NS	NS
Procurement management	NS	NS	NS
Cost management	0.057*	0.040*	0.069*
Construction activity management (contract follow-up)	0.099*	0.099*	0.099*
Construction activity management (contract definition)	0.024**	0.022*	0.024**

NS - Not significant   *p < 0.10   **p < 0.05
[a] Number of connections to the subsystem, divided by project duration
[b] Number of connections to the subsystem, divided by the budget of the project
[c] Number of connections to the subsystem, divided by subsystem duration of use

However, the scores for all the subsystems, except for the *Construction activity management* (contract follow-up) subsystem, are higher in the study sample than in the ideal profile, although not significantly (see Table 7). This result strongly suggests that, above a certain performance level, system utilization does not allow for the distinction between the project groups and 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 bilateral tests however showed that the four project characteristic variables are not significantly different across the three subsamples (Table 11). Moreover, correlation analyses show that project characteristics do not seem to be related to project performance (the correlation coefficients are not significant, Table 12).

Table 11. Project characteristics

	Mean scores			**Mann-Whitney**		
Project characteristics	**Less (1)**	**Study (2)**	**Best (3)**	**1-3**	**2-3**	**1-2**
Project duration	1884.8	1358.2	1510.5	NS	NS	NS
Budget of the project for activities executed by the firm	369 846	641 669	235 808	NS	NS	NS
Project size	253	358	328	NS	NS	NS
Number of persons in the project team	65.60	141.60	81.17	NS	NS	NS

NS - Not significant

Table 12. Relationships between project characteristics and project performance

Project characteristics	**Correlation coefficients**[a]	**P**[b]
Project duration	- 0.036	NS
Budget of the project	- 0.057	NS
Project management budget	0.221	NS
Engineering budget	0.056	NS
Procurement budget	0.243	NS
Construction budget	- 0.114	NS
Project size	0.168	NS
Number of persons in the project team	0.057	NS

NS - Not significant
[a] Spearman correlation coefficients
[b] Levels of significance for unilateral tests

Table 13 sheds some additional light on the relationship between project performance and the intensity of use of the subsystems.

Table 13. Relationships between project performance and subsystems intensity of use[1]

Subsystems	**Correlation coefficients**	**P**
Project definition	0.295	$p < 0.1$
Estimating process management	- 0.037	NS
Working hours management	0.244	NS
Document control	0.331	$p < 0.1$
Engineering process management	0.191	NS
Procurement management	0.248	NS
Cost management	0.445	$p < 0.05$
Construction activity management (contract follow-up)	0.339	$p < 0.1$
Construction activity management (contract definition)	0.443	$p < 0.05$

NS - Not significant
[1] Ratio used to measure the intensity of use: number of hits on the subsystem, divided by project duration

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.

Therefore, project performance depends not only on the use of the *Project definition* and *Document control* subsystems, but also on *Cost management* and *Construction activity management* subsystems.

Similar results were obtained with the other four ratios used to measure the intensity of use of the subsystems (Table 14).

Table 14. Relationships between project performance and subsystems intensity of use

Subsystems	**Correlation coefficients**			
	Ratio 2[a]	**Ratio 3[b]**	**Ratio 4[c]**	**Ratio 5[d]**
Project definition	0.266^{NS}	0.161^{NS}	0.144^{NS}	0.291^{NS}
Estimating process management	- 0.060^{NS}	- 0.043^{NS}	- 0.049^{NS}	- 0.043^{NS}
Working hours management	0.227^{NS}	0.217^{NS}	0.158^{NS}	0.210^{NS}
Document control	0.314*	0.290^{NS}	0.113^{NS}	0.360*
Engineering process management	0.265^{NS}	0.101^{NS}	0.070^{NS}	0.192^{NS}
Procurement management	0.240^{NS}	0.227^{NS}	0.121^{NS}	0.218^{NS}
Cost management	0.494**	0.401**	0.366*	0.535***
Construction activity management (contract follow-up)	0.317*	0.342*	0.342*	0.328*
Construction activity management (contract definition)	0.466**	0.434**	0.425**	0.516**

[NS] NS - Not significant *p < 0.10 **p < 0.05 ***p < 0.01
[a] Ratio 2: number of connections to the subsystem, divided by the budget of the project
[b] Ratio 3: number of hits on the subsystem, divided by subsystem duration of use
[c] Ratio 4: number of hits on the subsystem, divided by project size
[d] Ratio 5: number of hits on the subsystem, divided by the number of persons in the project team

Finally, we also tested the impact of the nature of the subsystems used on the performance of projects. Correlation analyses show that an increasing statistical relationship exists between the use (yes/no) of the *Construction activity management* subsystem and the performance of the projects: when the subsystem *Construction activity management* is used, the CPI value seems to increase (Table 15). We note that only the *Estimating process management*, *Engineering process management* and *Construction activity management* subsystems were considered in the analysis, as these subsystems are the only ones presenting a variation in their use (yes/no). The other subsystems are not taken into account since they have always been used for the management of all projects (mean score = 1.0, standard deviation = 0).

Table 15. Relationships between project performance and use (yes/no) of three subsystems

Subsystems	**Correlation coefficients**
Estimating process management	- 0.079^{NS}
Engineering process management	0.000^{NS}
Construction activity management	0.300*

NS - Not significant *p < 0.10

Moreover, at the significance level of 0.01, results show that, for each subsystem, there is no real difference between the use (yes/no) of the subsystem by a group and that of another (Table 16).

Table 16. Use (yes/no) of three subsystems

Subsystems	Mean scores			Mann-Whitney		
	Less (1)	Study (2)	Best (3)	1-3	2-3	1-2
Estimating process management	0.600	0.600	0.500	NS	NS	NS
Engineering process management	0.800	1.000	0.833	NS	NS	NS
Construction activity management	0.200	0.200	0.667	NS	NS	NS

NS - Not significant

We also conducted Mann-Whitney tests for the difference in means on the following ratios:

- Ratio of number of users per subsystem;
- Ratio of number of persons who received training.

However, results show that there is no significant difference in means between the three groups.

4.3 Phase III: Project characteristics

Table 17, which summarizes the relationships between project characteristics and system usage time, on one hand, and the intensity of use for each subsystem, on the other hand, reveals some interesting results. First, project duration seems to be the most critical characteristic, as increase in project duration is related to lower system usage time. Similarly, negative correlation coefficients are observed between project duration and the intensity of use of the subsystems and most of them are statistically significant (6 out of 9). Moreover, the budget of the project for activities executed by the engineering department seems to have a significant positive impact on the usage time of the software and the intensity of use of its subsystems. In fact, the larger the budget of the engineering department, the more the project management software and nearly all subsystems (7 out of 9) appear to be used. The number of persons involved in the project management team also seems to have a significant positive impact on system utilization: the more the number of persons increases in the project team, the more the software, as well as four of its subsystems, appear to be utilized.

- Although the other project characteristics variables (budget of the project for activities executed by the firm, budget for activities executed by the project management, procurement and construction departments, project size) do not appear to be linked with system usage time (the correlation coefficients are not significant), results stemming from Table 17 nevertheless show that these characteristics can actually be related to the intensity of use of the subsystems. Indeed, for these characteristics, the following results are observed:
- The larger the budget of the project, for activities executed by the firm, the more the *Engineering process management* and *Procurement management* subsystems appear to be utilized (the correlation coefficients are positive and significant);
- The more the budget of the project is substantial, for activities executed by the project management, procurement and construction departments, the more the *Estimating process management* subsystem seems to be used;

- The more the budget of the project increases (for activities executed by the firm and by the project management, procurement and construction departments), the less the *Construction* (contract definition) subsystem appears to be used (the correlation coefficients are negative and significant);
- The larger the budget for activities executed by the construction department, the less the *Project definition* and *Working hours management* subsystems seem to be utilized;
- The more the number of project work packages increases, the more the *Estimating process management*, *Engineering process management* and *Procurement management* subsystems appear to be used.

Table 17. Relationships[1] between project characteristics and system utilization

	Project duration	Budget of the project [2]	Budget project management	Budget engineering	Budget procurement	Budget construction	Project size	Number of persons
System usage time	- 0.501**	NS	NS	0.460**	NS	NS	NS	0.379**
Subsystems intensity of use[3]								
Project definition	- 0.683**	NS	NS	0.325*	NS	- 0.391*	NS	NS
Estimating process management	NS	NS	0.642**	NS	0.590**	0.411*	0.362*	0.391**
Working hours management	- 0.685**	NS	NS	0.421**	NS	- 0.477**	NS	NS
Document control	- 0.486**	NS	NS	0.444**	NS	NS	NS	0.441**
Engineering process management	NS	0.456**	NS	0.658**	NS	NS	0.387**	NS
Procurement management	- 0.325*	0.431**	NS	0.597**	NS	NS	0.384**	NS
Cost management	- 0.479**	NS	NS	0.391**	NS	NS	NS	0.350*
Construction activity management (contract follow-up)	NS	- 0.420**	- 0.408*	NS	- 0.432*	- 0.432*	NS	NS
Construction activity management (contract definition)	- 0.503**	NS	NS	0.323*	NS	NS	NS	0.429**

NS - Not significant *p < 0.10 **p < 0.05
[1] Spearman correlation coefficients
[2] Budget of the project for activities executed by the firm
[3] Ratio used to measure the intensity of use: number of hits on the subsystem, divided by project duration

Similar results on the relationships between project characteristics and subsystems intensity of use were obtained from the following four ratios:

- Number of connections to the subsystem, divided by the budget of the project (Table 18);
- Number of connections, divided by the duration of use of the subsystem (Table 19);
- Number of connections, divided by the size of the project (Table 20);
- Number of connections, divided by the number of persons in the project team (Table 21).

Table 18. Relationships between project characteristics and subsystems intensity of use[1]

Subsystems	Project duration	Budget of the project	Budget project management	Budget engineering	Budget procurement	Budget construction	Project size	Number of persons
Project definition	- 0.563**	- 0.627**	- 0.584**	- 0.325*	- 0.615**	- 0.704**	- 0.383**	NS
Estimating process management	NS	NS	0.545**	NS	0.473**	NS	NS	0.307*
Working hours management	- 0.666**	- 0.495**	- 0.469**	NS	- 0.479**	- 0.718**	- 0.294*	NS
Document control	- 0.446**	- 0.522**	- 0.531**	NS	- 0.477**	- 0.656**	NS	NS
Engineering process management	NS	NS	NS	0.365*	NS	- 0.579**	0.395**	NS
Procurement management	NS	NS	NS	0.395**	NS	- 0.511**	0.378**	NS
Cost management	- 0.445**	- 0.361*	NS	NS	NS	- 0.395*	NS	NS
Construction activity management (contract follow-up)	NS	- 0.499**	- 0.408*	- 0.337*	- 0.432*	- 0.432*	NS	NS
Construction activity management (contract definition)	- 0.437**	- 0.313*	NS	NS	NS	NS	NS	NS

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

[1] Ratio used to measure the intensity of use: number of connections to the subsystem, divided by the budget of the project for activities executed by the firm

Table 19. Relationships between project characteristics and subsystems intensity of use[1]

Subsystems	Project duration	Budget of the project	Budget project management	Budget engineering	Budget procurement	Budget construction	Project size	Number of persons
Project definition	- 0.709**	NS	NS	0.297*	NS	NS	NS	NS
Estimating process management	0.317*	0.314*	0.672**	NS	0.626**	0.477**	0.383**	0.377**
Working hours management	- 0.677**	NS	NS	0.396**	NS	- 0.441**	NS	NS
Document control	- 0.452**	NS	NS	0.412**	NS	NS	NS	0.431**
Engineering process management	NS	NS	NS	0.352*	NS	- 0.388*	NS	NS
Procurement management	NS	0.456**	NS	0.595**	NS	NS	0.416**	NS
Cost management	- 0.418**	NS	NS	0.371**	NS	NS	NS	0.321*
Construction activity management (contract follow-up)	NS	- 0.417**	- 0.408*	NS	- 0.432*	- 0.432*	NS	NS
Construction activity management (contract definition)	- 0.376**	NS	NS	0.353*	NS	NS	0.299*	0.485**

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

[1] Ratio used to measure the intensity of use: number of connections divided by the duration of use of the subsystem

Table 20. Relationships between project characteristics and subsystems intensity of use[1]

Subsystems	Project duration	Budget of the project	Budget project management	Budget engineering	Budget procurement	Budget construction	Project size	Number of persons
Project definition	- 0.681**	- 0.352*	NS	NS	NS	- 0.375*	- 0.566**	NS
Estimating process management	NS	NS	0.600**	NS	0.557**	0.422*	0.312*	0.381**
Working hours management	- 0.748**	NS	NS	NS	NS	- 0.495**	- 0.438**	NS
Document control	- 0.655**	NS	NS	NS	NS	- 0.454**	- 0.390**	NS
Engineering process management	- 0.321*	0.391**	NS	0.588**	NS	NS	NS	NS
Procurement management	- 0.340*	0.394**	NS	0.562**	NS	NS	NS	NS
Cost management	- 0.632**	NS	NS	NS	NS	NS	- 0.297*	NS
Construction activity management (contract follow-up)	NS	- 0.502**	- 0.408*	- 0.343*	- 0.432*	- 0.432*	NS	NS
Construction activity management (contract definition)	- 0.601**	NS	NS	NS	NS	NS	NS	NS

NS - Not significant *p < 0.10 **p < 0.05
[1] Ratio used to measure the intensity of use: number of connections divided by the project size

Table 21. Relationships between project characteristics and subsystems intensity of use[1]

Subsystems	Project duration	Budget of the project	Budget project management	Budget engineering	Budget procurement	Budget construction	Project size	Number of persons
Project definition	- 0.498**	NS	NS	NS	NS	- 0.563**	NS	NS
Estimating process management	0.324*	NS	0.624**	NS	0.572**	0.393*	0.371**	0.325*
Working hours management	- 0.608**	NS	NS	NS	NS	- 0.552**	NS	NS
Document control	- 0.451**	NS	NS	NS	NS	- 0.424*	NS	NS
Engineering process management	NS	0.414**	NS	0.604**	NS	- 0.416*	0.432**	NS
Procurement management	NS	0.442**	NS	0.569**	NS	NS	0.426**	NS
Cost management	NS	NS	NS	NS	NS	NS	NS	NS
Construction activity management (contract follow-up)	NS	- 0.405**	- 0.408*	NS	- 0.432*	- 0.432*	NS	NS
Construction activity management (contract definition)	- 0.295*	NS	NS	NS	NS	NS	NS	NS

NS - Not significant *p < 0.10 **p < 0.05
[1] Ratio used to measure the intensity of use: number of connections divided by the number of persons in the project team

Table 22 provides similar results on the relationships between project characteristics and the use (yes/no) of three subsystems.

Table 22. Relationships between project characteristics and use (yes/no) of three subsystems

Subsystems	Project duration	Budget of the project	Budget project management	Budget engineering	Budget procurement	Budget construction	Project size	Number of persons
Estimating process management	0.580**	0.334*	0.617**	NS	0.622**	0.590**	0.397**	0.350*
Engineering process management	NS	0.455**	NS	0.402**	NS	NS	0.482**	0.429**
Construction activity management	NS	- 0.417**	- 0.365*	NS	- 0.386*	- 0.386*	NS	NS

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

4.4 Phase IV: Users' perception of the project management software

The perceptions of the users of the project management software were collected from eleven project managers by means of a questionnaire. The results shown in Table 23 indicate that, for the best-performing projects, the users appear to have a better perception of the system in terms of the quality of information provided by the system and its ease of use.

Table 23. Users' perception of the project management software

Perceptual factors	Mean scores[1]		
	Less ($n_1 = 1$)	**Study ($n_2 = 7$)**	**Best ($n_3 = 3$)**
Perceived impact of system utilization on project performance	5,2	5,6	5,6
Functionality of the system	4,8	4,8	4,7
Information quality	3,9	5,1	**5,6**
Ease of use of the system	3,7	4,1	**4,8**

[1] Mean values of the responses on a seven-point Likert scale (1 = strongly disagree, 7 = strongly agree)

Furthermore, as regards the quality of information provided by the system and its ease of use, the analysis of the questionnaire replies revealed that, for the less-performing projects, project managers seem to perceive that the system does not necessarily provide simple information free of errors, that the system is not very user-friendly and that the use of the system is quite time consuming. Table 24 provides additional results on the relationships between perceptual factors and project performance.

Table 24. Relationships between perceptual factors and project performance

Perceptual factors	Correlation coefficients[1]	P[2]
Perceived impact of system utilization on project performance	0.179	NS
Functionality of the system	0.092	NS
Information quality	0.516*	0.05
Ease of use of the system	0.562**	0.04

NS - Not significant *p < 0.10 **p < 0.05
[1] Spearman correlation coefficients
[2] Levels of significance for unilateral tests

Two correlation coefficients are significant: the better the perception of the users of the project management software is, in terms of information quality and ease of use of the system, the more the value of the cost performance index of the project seems to increase.

However, correlation analyses between perceptual factors and system utilization show that the perception of the users of the project management software does not appear to be linked to the level of use of the system or the intensity of use of the subsystems.

5. Discussion and concluding remarks

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 and project characteristics. Statistical tests were performed on the basis of quantified data resulting from 21 large engineering projects executed by the firm.

Overall, the results suggest 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. 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 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.

In addition, project duration seems to be the most critical characteristic, as increase in project duration seems to be related to lower system utilization.

Finally, the perception of the users of the project management software does not seem to be related to the level of use of the system or the intensity of use of the subsystems. However, for the best-performing projects, which present significantly high system utilization levels (see Sections 4.1 and 4.2), users seem to have a better perception of the system in terms of information quality and ease of use of the system. This finding is consistent with the observations made in the literature: the more the information provided by the system is perceived as being of high quality, the more users intend to use the system [27],[29],[32]. Also, the ease of use of the system appears to be related to the intention to use the software [29].

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 high level (not necessarily the highest level as displayed in Table 7) 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 and project characteristics, 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 on all projects. Also, only one project performance indicator is considered in this study: the Cost Performance Index (CPI) for the working hours of the firm. However, project performance is often defined in terms of schedule, scope and cost. Thus, we may have obtained different results with other project performance indicators. Some subsystems could offer a higher control of the baseline which could be consistent with a better performance of project duration. Other project performance indicators should therefore be considered in future studies.

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