

Earned value method as a tool of controlling complex engineering projects

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Abstract. This paper discusses the difficulty of controlling complex engineering projects with the help of the traditional control tools such as earned value method. The main problem with the controlling engineering projects is that the environment and scope of these projects are various from project to project and the project performance measurement system should adapt and flexibly reflect the variability of the engineering project scope and context. The article is based on the case study of the Russian engineering company that is needed a more flexible project performance measurement system. After the consideration of the limitations of the existing performance measurement methods and tools the authors elaborate the suggestion to improve the adaptability of the traditional earned value method which leads to better control of the engineering projects.

1. Introduction

Increasing competition, complexity and technological advances in the engineering industry have enhanced the importance of performance management for engineering companies. In order to cope with the competition and technological challenges engineering companies try to improve project management systems with the help of better performance measurement systems (PMS). Project management researchers have identified a vast spectrum of different measures that describe the status, outcomes and various success indicators of a project [1,2,3] (Bannerman, Freeman and Beale, Ling). The most commonly used project performance measures include schedule, cost, quality, technical performance and client satisfaction. Though according to Shenhar [4] and Luras [5] project PMS should be based on the multidimensional approach, many engineering companies use only a couple of performance measures, such as cost and schedule. The simplification of the engineering project PMSs leads to the poorer control of projects and worse results for engineering companies.

Another issue with the engineering project PMS is the necessity to adapt performance measures to the nature of the projects. Usually an engineering company deals with the different projects that have different scope and are performed in various environments. One

project has to cope with the high uncertainty whereas another one can enjoy the lower level of risks. Engineering projects also differ in terms of scale. It is clear that for different engineering projects the company should use different performance measures. High variety of engineering projects requires more flexible system of project performance metrics.

Many practitioners and researchers recognize the importance of project performance measurement and the need for multidimensional and comprehensive approach. As a result many engineering companies try to redesign their PMS[6] in compliance with the recommendations of researchers. However, recent research shows that the problems mentioned above are very far from being fully resolved [7].

2. Methodology

This article is based on the case study of the Russian civil engineering company “ART-Building”. According to Yin [8] the case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context. The problems of engineering project PMS mentioned in Introduction to this paper emphasize the importance of the real-life context. It is impossible to investigate the limitations of project PMS without consideration of the scope, scale and environment of the companies’ projects. Hence, the use of a case study approach seems to be appropriate for the identified issues.

The case study of the Russian engineering company included 13 interviews with the managers and technical engineers of the firm and the analysis of the company’s documents. Besides, three clients of the company were interviewed.

3. Company overview

3.1. Description of the business

The company “ART-Building” performs high-quality civil engineering and construction projects for different clients. The company’s projects are usually based on design and built contracts and include single family houses designed and built for affluent customers, condominiums (multi-unit dwellings) designed and built for developers, manufactured and modular housing projects for middle-class customers, communities and developers, commercial projects such as shopping centers for developers and so on. Within a typical project the company renders a wide range of services such as land surveying, computer graphics and design, landscape architecture, construction and project management.

3.2. Definition of the problem and the task

Due to the current economic slowdown and increased competition in the region the company finds itself in the rather harsh conditions. Recently the company’s management implemented several improvement projects which, however, did not bring the expected results. At the moment the firm wants to install new project management information system based on Primavera P6 ® software. The management realized that in order to increase the effectiveness of the software implementation project and subsequent improvement initiatives the company has to revise its PMS. The new PMS should be aligned with the operations strategy of the organization and reflect the nature of the firm’s core processes.

3.3. The company’s processes

As it is clear from the description of the business, the company's processes can be qualified as low volume and high variety processes. Construction business in Moscow region has pronounced seasonal variations in demand (due to low temperatures it is difficult and expensive to carry out construction work in winter). Besides, high variation in demand for real estate is determined by the cyclic patterns in the overall economic conditions. The visibility of the company's processes can be high for single family housing projects when customers often play a role of co-designer and supervisor. The visibility of processes in the projects for professional developers can be described as medium and in the modular housing projects – as low.

Obviously, the firm's operations consist of project processes. However, it is only a part of the business. "ART-Building" is a multi-project company and therefore performs several projects at the same time using a common pull of resources shared by these projects. Hence, among the company's processes there are jobbing processes. Moreover, the modular and manufacturing housing projects are based mostly on batch processes.

3.4. The company's operations strategy

The company does not have a properly articulated strategy. However, the strategic goals and priorities can be inferred from the decisions of the managers and the requirements of the company's clients. The great flexibility and high quality are considered as main, 'order-winning' objectives. At the same time, such competitive factors as speed, dependability and cost are just 'qualifiers'. Therefore, the implied operations strategy can be briefly formulated in the following words:

"Operations must be flexible enough to adapt to various requirements of different customers and guarantee customers the high quality of the products and services, at a suitable price, with acceptable dependability and speed"

4. Diagnosis of the current PMS

4.1. Performance measurement and the company's operations strategy

The existing PMS seems not to be based on the company's operations strategy. The key performance indexes do not reflect the operations management objectives. For example, there are no any metrics connected with the flexibility. Though flexibility is believed to be very significant for the company's success, it is not controlled by the current performance measures.

On the contrary, the budget performance metrics are widely used and rigorously applied for all projects despite the fact that in individualized single family house projects customers are often relaxed about budget increase if it is associated with the additional quality, functionality or customization. Even less customers are annoyed about delays of several weeks or even months if they get the opportunity to apply their talents in the project and see the results of their participation in the final version of the design or house. However, the project managers are strictly punished for the delays of the projects. The result is that the project managers and workers are not eager to meet customers' requirements connected with quality and flexibility if they imply violation of the budget or schedule constraints.

4.2. Performance indexes do not help to improve operations

The current PMS has not only discrepancies with the implied operations strategy but also some inner inconsistencies which prevent the organization from improving its operations. In particular, the existing PMS include several 'deadly sins of performance management'[9]. The most obvious 'sin' in the company is provincialism. There are two

main departments in the company – design and construction. Though both departments work on design-built projects together and use the system of concurrent engineering, each department has its own schedule performance indexes. At the first glance, it seems natural, but, as in many other instances of provincialism, the situation leads to suboptimization and conflict. The duration of the whole project can be decreased by the better interaction between design and construction departments. However, the more time the design department spends on interactions with other departments, the worse become the schedule performance indexes of the design department. The more designers concentrate on the duration of design works, the less willingly they cooperate with construction, procurement and other departments.

Among duration metrics there is another ‘deadly sin’, namely inanity. Most of the time metrics are based on the comparison of the planned and actual durations. In many individualized projects it is very difficult to use statistics from previous projects for the planning purposes because many decisions and designs are unique. That is why specialists from the construction department are engaged in the process of estimating works durations. However, being interested in the time performance, construction specialist increase the time estimates so that they can be easier observed. Obviously, this practice increase the duration of the projects.

In many cases the contradictions of the PMS with the operations objectives and the inner discrepancies in the PMS make the project managers less serious about metrics. Such an attitude becomes the main reason for the ‘deadly sin’ of frivolity. Even in the projects when performance measures work well, the project managers do not take them to the heart and use deficiencies of the PMS as excuses of the poor performance.

4.3. PMS and the nature of business

The general model of the existing performance measurement system is not consistent with the nature of the company’s processes. One of the main shortages of the company’s PMS is that the same metrics with the same priorities and same benchmarks are used for very different projects. The company operations are mostly based on low volume and high variety processes, whereas the existing measurement system is more oriented to repetitive and continuous processes. Performance indexes do not reflect the various objectives and scopes, quality requirements, time and budget constraints of different projects. For instance, whereas for the individualized projects the quality and flexibility objectives are very important, for manufacturing and modular housing projects the objectives of cost may become more significant. Therefore, the specialist from the design department, for example, should change the priorities in their work when they switch from one type of the project to another. But they do not, because their performance metrics do not reflect the differences between project types.

Current indicators do not reflect the various interests of different project stakeholders. Though for some projects, such as individualized house projects, it is appropriate to consider only the customer’s perspective to measure the project success, for other projects, for instance, multi-level dwellings for developers, it is a must to take into account interests of developers, future residents, nearby communities, municipalities, various citizen groups, such as ecologists, the company’s management, investors, the project team, and so on. Therefore, at the moment the project managers are not keen to recognize the needs of different projects stakeholders.

Finally, only the performance of the project managers is assessed by the metrics of the whole projects. The performance metrics of other staff are department-oriented and measure only parts of the whole end-to-end processes.

5. Improvement of the company's performance measurement system

5.1. Strategic model of performance measurement system

The new performance measurement system will be based on the conceptual framework that links together the inner development of processes and their contribution to the strategy implementation. In order to align performance indicators with the goals of improvement initiatives, operations objectives and strategic priorities, two models were combined. The first model is Organizational Project Management Maturity Model (OPM3) (Project Management Institute, 15) which describe all processes of project, program and portfolio management and the attributes of these processes. OPM3 was developed by the Project Management Institute (PMI) as a modification of the Capability Maturity Model (CMM) [10], designed by Software Engineering Institute (SEI). OPM3 implies that the development of a process should go through several level of maturity and it is impossible to skip one or more level. In OPM3 there are four process maturity levels (from the lowest to the highest) – Standardize, Measure, Control, Continuously Improve. The main difference between the process maturity levels is the ability of processes to achieve established benchmarks. To link the company's process development with the strategic development, the model developed in [11] can be used. In each stage of the operations development the company has to establish the new set of processes, performance measures and benchmarks. Therefore, the development of operations capabilities inevitably will go through all four levels of process maturity. As a result, each stage of operations development will consist of four maturity levels.

The dual model of operations development is very helpful because OPM3 provides additional details necessary for improvement planning and implementation. Moreover, OPM3 includes thorough description of many project management processes, their attributes on each maturity level, and even detailed performance and maturity measures. In general, the elaborated strategic framework helps to align process metrics with the improvement initiatives and the company's strategy. The reestablished links between performance indicators and strategic targets will hopefully help to overcome the 'deadly sin' of frivolity.

5.2. Success factors and selection of measures

The strategic model of PMS provides the broad conceptual framework which should be adapted to the needs of the specific company. According to the approach described in [12] the first step in elaborating specific project measurement is defining the company's success factors. The problem of measuring project success is not easy one [13]. For design and build project the problem becomes even more difficult [14] and for multi-project companies defining the success factors is very complicated problem [15]. Leaving aside the long and controversial discussion about this problem, the approach of Shenhar and Dvir [16] is chosen as the most comprehensive and relevant to the problems with the company's PMS. In Table 1 the overall multi-project company's success measures are presented. The metrics are based mainly on Shenhar and Dvir's approach, but include some additions and adjustments from [14], previously identified strategic objectives and elaborated conceptual framework for PMS.

Almost all of the presented in Table 1 success measures are more or less important for the company, but not all of them are relevant to the current operations strategy of the

company. Therefore, the success measures which are the most importance for the company's strategy should be chosen and used for elaborating key performance indexes.

All success factors can be grouped into three categories – key success factors (connected with order-winning objective), basic factors (connected with qualifiers) and supportive factors (connected with the overall organizational development).

In the group of key factors (only the success measure directly connected with the main strategic goals. For example, skill development and new competencies are definitely helpful to increase flexibility and improve quality. In the group of basic factors the measures connected with time, cost and dependability are included. Some of the basic measures are influenced by the key factors. For instance, the customer loyalty is an indicator of the relationship between the company and its clients which is dependent on the key factors such as quality and flexibility. The supportive factors are the factors connected with the long-term development of the company, the regulatory issues and with the interests of stakeholders which are not usually very important for each project. The next step is to operationalize the structure of success factors or transform them into the groups of measurable and controllable indicators. It is worth mentioning that all success factors can be divided in two groups – with objective measures and with subjective measures. Considering these characteristics and using examples of performance metrics provided in [17] the set of measures for the company “ART-Building” was elaborated (see Table 1).

Table 1. Performance measurement system for “ART-Building”

Success factor	Performance measure
Quality	Number of specifications unmet Number of defects Level of complaints
Flexibility	Subjective assessment of requirements and expectations unmet Range of design decision available Number of new requirements met Time to change project documentation
Skill development	Collective evaluation of new skills developed
Profits	Return on capital exploited (for company) Net present value (for project)
New core competencies	Collective evaluation of new core competencies acquired
Schedule	Project duration (Completion date – Commencement date) Speed (Gross floor area / Project duration) Schedule performance index (Planned time/ Actual time)
Budget	Cost performance index (Budget cost/ Actual cost) Cost variance (Budget cost – Actual cost) Unit cost (Final contract sum/ Gross floor area)
Dependability	Revised contract period (Original contract period + Extension of time) Time variation ((Project duration – Revised contract period)/Revised contract period) Net value of variations (Final contract sum – Original contract sum – Final rise/fall + Contingency allowance) Percentage net variation over final cost (Net value of variations / Final contract sum x 100%)
Customer loyalty	Results of the regular surveys
Team satisfaction	Collective evaluation
Sales	Increase in sales (for company) Final contract sum (for project)
Market share	Increase in market share of company
New technology	Number of new technologies introduced
New product	Number of new products launched

Success factor	Performance measure
Safety	Accident rate (Total number of reportable accidents/ Total number of workers employed on project)
Environment	Compliance with ISO 14000
Brand recognition	Results of the regular surveys
Team member growth	Number of team members promoted
Team member retention	Number of people left the company/ project team
Regulatory approval	Number of approvals received from regulatory bodies
Next maturity level	Maturity level achieved
Next stage of development	Stage of development approached

As it is said in [17] the number of key performance indexes should be small, but they have to be ‘really key’. In “ART-Building” KPIs (Key Performance Indices) are the performance measures connected with quality, flexibility, skill development, profit and new competencies.

5.3. PMS as an improvement tool

The elaborated PMS will be used not only to control the performance of the company and to motivate employees and managers, but also to manage the improvement initiatives. The PMS can include the DMAIC (Define, Measure, Analyze, Improve, Control) cycle as a conceptual framework for improvements [18]. Each cycle is supposed to drive the process from one maturity level to another. As an integral part of the improvement planning process the importance-performance matrix should be to define the priority zones [17].

The performance measures should be revised when the company moves from one development stage to another or when the business environment of the company is changing significantly. For each new development stage all metrics should have revised target values. The target values of the metrics should be defined as a result of the benchmarking activities [19,20].

6. Conclusion

The development of PMS for a multi-project engineering company is a very complex and difficult process. The case study of the Russian engineering company “ART-Building” and its PMS gave the information about the current problems of the existing PMS. On the basis of this information the conceptual model of PMS, success measures and performance indicators were elaborated. Finally, the new performance measurement system was described as a powerful tool of improvement management. The new PMS will be implemented in the new project management information system and hopefully will bring many benefits for the company in the future. The suggested approach can be used in many other engineering companies to improve their performance measurement systems and project control systems in general.

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