Managing Distributed Software Development with Performance Measures

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Abstract: The Distributed Software Development (DSD) has been increasingly adopted for providing advantages over traditional software development. But this approach presents some challenges such as communication difficulties, cultural differences among the involved and low proximity among developers. This paper presents a set of performance measures for management through five perspectives: financial, customer, internal processes and, learning and growth, based on Balanced Scorecard (BSC).The fifth perspective, geographical dispersion, has been proposed as an extension of the BSC System for DSD projects. The performance perspectives aim measure and to support the decision making process of stakeholders through metrics related to the attributes of quality, productivity, cost, time and geographic dispersion, fundamental in the software project management. So, the performance measures are a mechanism to evaluate the return on financial investment, the satisfaction of customers and employees, the performance of processes running on the DSD, the continuous improvement of the organization and the success of the geographical dispersion.

1 INTRODUCTION

The demand for software is constantly growing, and therebythe requirements and abilities of software development companies also evolved. The Distributed Software Development (DSD) has been adopted by software development companies with distributed teams across different locations (states or even different continents). This approach can provide benefits such as better utilization of available resources, customer proximity, possibility of 24 hours development (follow the sun), and higher productivity. On the other hand, it brings some challenges in the planning and carrying of DSD projects, such as those related to communication, coordination and cooperation.

Therefore DSD projects can be highly profitable, but for this they require an effective planning due to the difficulties arising by geographical dispersion, as well as an efficient management of available resources.

The Organizational Performance Management (OPM) proposes to measure the critical activities and processes performance of the business model. The results obtained from performance measurement system arise relevant information for the implementation of new improvement actions and decision making more robust (Bititci *et al.*, 1997). The difficulties inherent in DSD projects demand for an effective system of management processes and activities with a view to performance evaluation.

The Performance Measurement System is a set of measures that can be used when adopt the strategy of DSD, providing to the project manager the necessary support in decision making based on performance metrics. So, the performance measurement system integrated to DSD strategy supports decision making at critical design factors, eg, time, cost, project quality and geographically dispersed resources. These elements were proposed as basic attributes that should be monitored by a set of performance metrics.

The objective of this paper is to present a set of performance measures for DSD project management through five perspectives: Financial, Customer, Internal Processes, Learning and Growth, and Geographic Dispersion. The first four are from the Balanced Scorecard (BSC) and the fifth perspective was considered in order to meet the DSD context.

The text of this paper is organized as follows: Section II presents the background (Distributed Software Development, Organizational Performance

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Management and BSC). In Section III is the set of measures proposed. Section IV presents the discussions. Finally, in Section V are presented the conclusions, emphasizing the contributions and guidelines to future researches.

2 BACKGROUND

2.1 Distributed Software Development

The Distributed Software Development (DSD) is different from traditional software development by allocating geographically distributed developers, feature that enables the development known as follow the sun, which means producing for 24 continuous hours with teams physically distant. Some characteristics make the DSD more interesting than traditional ones, such as: search for experts who reside elsewhere; reduce costs with the use of cheaper hand labor, but still qualified; software production more agile, among others (Huzita *et al.,* 2012).

Although these DSD peculiarities provide favorable attributes to the organization, it requires planning and management focused on the difficulties of geographically distributed allocation. Some of them are: difficulties of communication, cultural differences among the involved, management and control of projects and, low physical proximity among developers. These difficulties reflect on several factors in the organization, including: strategic issues (feasibility study on the use of distributed development or not); cultural issues among development teams (values, principles); technical issues (infrastructure and knowledge to collaborative development) and, issues of knowledge management (ability to create, store, process and information sharing in distributed projects) (Jimenez *et al.,* 2009).

2.2 Organizational Performance Management

Organizational Performance Management (OPM) can be defined as the planning, monitoring and evaluation of activities, processes and actors performance that make up the organization. According to Marçal (2008), Performance Management aims to evaluate whether the organization is in accordance with what was outlined in the strategic vision and, thereby ensure the survival and sustainable growth through a constant organizational performance improvement.

The proposal of performance management process is to align the organizational goals with their strategies. The objective of this process is to provide a system of proactive control, in which the corporate and functional strategies are implemented in all business processes, activities, tasks and staff. So, this system provides feedback that allows proper decision making (Bititci *et al.*, 1997). Specifically, for an environment of performance management the main challenge is to ensure an integrated business model that allows obtaining information / performance metrics appropriate with the activities progress.

2.2.1 Balanced Scorecard

The Balanced Scorecard (BSC) proposed by Kaplan and Norton (1992), is a strategy management system very well known and commonly applied by organizations opting to use performance assessment in their planning processes and organizational management. The BSC is based on four perspectives: *financial* – focused on financial and economic variables of enterprise, *customer*– represents the satisfaction and meeting needs of external customer, *internal processes* – evaluates the performance of critical areas, *learning and growth* – focused on collaborators satisfaction and knowledge.

It is also common that users of performance measurement system propose other performance management perspectives, for example, issues associated with sustainability, innovation, collaboration / cooperation, product development, among others (Norreklit, 2000).

The main criticisms mentioned the BSC are: i) does not incorporate methods for identifying the critical processes of performance; ii) does not address the definition of the characteristics of the metrics (Schneiderman, 1999); iii), does not demonstrate how to build the relationship between the metrics and performance perspectives, characterized as independent model (Norreklit, 2000), and iv) does not promote the participation of the user information in the development process of performance measurement.

3 PERFORMANCE MEASURES FOR DSD PROJECTS

The difficulties and challenges found in DSD projects demand by an effective processes and activities management. The goal in the formulation

of the measures was to establish metrics that effectively support the measuring the performance of processes and features present in DSD projects. The measures proposed in this paper are stratified into five perspectives. Four of them were from BSC system and a distinguished as exclusive feature of DSD projects: Geographical Dispersion was also included (Ramasubbu *et al.,* 2011).

So, in order for an effective performance measurement in DSD projects were identified five perspectives:

- **Financial:** perspective proposed to monitoring the performance of financial aspects related to the project (profit), efficient and effective use of geographically distributed resources (project sites, trip number and work hours) and monitor the performance of human resources (training expenses).
- **Customer: p**erspective that aims to monitor the expectations (needs) and perception (satisfaction) of the stakeholders involved in DSD. Aims to ensure quality and product innovation.
- **Internal Processes**: the purpose of this perspective is to monitor and analyze the performance of processes / activities planned for the DSD. Information that makes the process more robust decision-making, foster cooperation and ensure a more transparent communication between the project team.
- **Learning and Growth**: perspective proposed to ensure human resources development and, consequently, the product quality, internal processes, financial return and efficiency of distributed resources.
- **Geographical Dispersion**: the purpose of this perspective is to monitor the human and technological resources to ensure project performance, business and consumer satisfaction. The information analysis will ensure the quality, time and cost competitive product and coordinate resources.

They were derived as result from research directed for software development processes and metrics for software. The set of metrics assigned to software process found in the current literature were changed and refined aiming to characterize the specific attribute of DSD. Thereafter, for performance evaluation was proposed 23 performance metrics distributed in: financial (5), customer (4), internal processes (7), learning and growth (4) and geographical dispersion (3) perspectives.

The proposed perspective for software project management process in DSD approach, are aligned

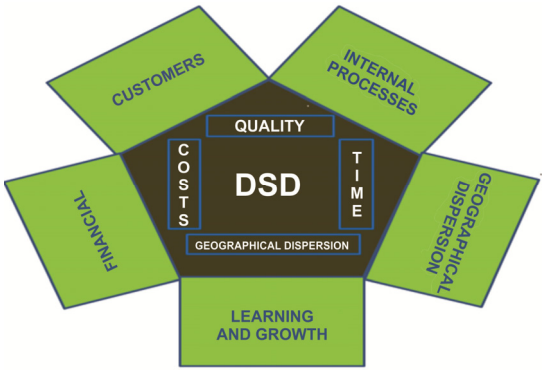

Figure 1: Success Attributes for perspectives of DSD projects (Based on Kaplan and Norton, 1992).

with quality, cost, time and geographical dispersion attributes. Figure 1, shows the relation of these four success attributes with five perspectives that compose DSD projects. These attributes are considered critical success factors in DSD projects, because good performance in them contributes to achieve the managerial and financial goals.

The characteristics of these attributes are described as following:

- **DSD Project Quality:** The DSD project quality is related to effectiveness in the process of software development, where customer requirements included to the final product or service. So, the quality management seeks to introduce improvements to the processes of software design. Usually, to obtain quality in development processes there must be good communication and cooperation among stakeholders, whether they are separated geographically or not (IEEE Computer Society, 2004). When DSD is considered, the quality depends greatly on the management of the relationship among distributed development sites.
- **DSD Project Costs:** Software Project costs are all expenses considered, including those related to requirements elicitation process until delivery of final product or conclusion of services. There are also some costs resulting from distribution, such as those related to: trip expenses and information technology (IEEE Computer Society, 2004; Kankanhalli and Tan, 2004).
- **Time on DSD Projects:** According to PMBOK (2004) software project time management involves managing all tasks and processes that make up the software project. Three processes are essential for managing project time: estimated duration of each process and activity, schedule development and schedule control. The

motivation that leads enterprises to adopt the DSD is justly the possibility of reducing this development time, using follow the sun.

- **DSD Geographical Dispersion**: Geographic dispersion among developers is one of main characteristics of distributed software development projects. So, to manage the geographical dispersion is necessary to know time zone and cultural diversity among those involved, beyond politics, religious, customs, laws, among others.

The metrics related to performance perspectives for DSD are presented on the following sections. For the definition of each one of them has been obeyed the following format: name, formula, unity and goals. Table 1 illustrates some metrics for the development and management of internal process perspective. Were proposed metrics for each of the other perspectives, which are described in detail in Santos e Galdamez (2013).

3.1 Measures for Financial Perspective

Measures from financial perspective make possible to determine the fulfillment of financial goals that the company expects to achieve from the investments and efforts available to perform software design. This perspective reflects the attainment or not of the other dimensions of the organization. So, since the internal processes are being carried out successfully, customers will be satisfied and the organization will be in a constant learning and growth. Furthermore, the difficulties imposed by geographical dispersion are being overcome and, consequently, the expected financial results are being attained (Kazi, Radulovic and Kazi, 2012; Parviainen, Kommeren and Rotherham, 2012; Ramasubbu et al., 2011; Edvinsson et al., 1998; Malone, 1997).

The following are the main characteristics of the metrics:

- **Profit per Development Site:** Shows the net profits per development site. The rate of profit generated is of great importance to justify the financial resources invested.
- **Ratio Between the Financial Return on Development Time for Each Development Site:** Obtain the contribution of each development team to with the profit achieved by the enterprise in the project. It allows managing the efficiency of development sites.
- **Number of Hours Per Task for The Site:** Calculated by the number of hours spent to perform certain amount of tasks designed for the team. It allows quantifying the efficiency of each distributed team.
- **Geographical Distance (Kilometers/miles) Spent on Trips of Employees:** Allows to manage the resources allocated with trip expenses**.** These expenses are common in enterprise in which the employees are distributed geographically. This metric returns a value with the kilometers/miles traveled by developers in each site.
- **Rate of Employee Turnover:** The importance of this metric lies on the fact that, firing and hiring generate financial costs due to subsequent needs as training for employees and unemployment insurance. The measurement is done separately for each project and site, admissions and firing are considered only that occurred within the period of project development. The metric returns a percentage regarding the turnover rate of each development site.

3.2 Measures for Customer Perspective

The main objective of measures for customer perspective is to control, by quantitative data the satisfaction level of clients. They will provide data showing client opinion about the organization (Kazi, Radulovic and Kazi, 2012; Parviainen, Kommeren and Rotherham, 2012; Ramasubbu et al., 2011; Edvinsson et al., 1998; Malone, 1997).

The performance measures characteristics are below described:

- **The Degree of Performance of Distributed Teams:** Calculates the performance of distributed teams from the ratio between the amount of requested projects and the amount of projects completed by team.
- **The Degree of Interaction among Distributed Teams:** Measures the communication ability among developers. Communication tools such as e-mail and others, to register the measurements could be used.
- **Customer (internal) Satisfaction with his/her Development Team**: Denotes for all distributed team, the member satisfaction with the team to which he/she belongs. The data obtained from the metric provides the project manager with important data for the allocation or changing member of each one of distributed teams, since it is defined based on a good relationship among collaborators.
- **Relationship Between Amount of Faults Found in Components Designed and**

Table 1: Measures Internal Processes Perspective in DSD (Parviainen, Kommeren and Rotherham, 2012; Ramasubbu *et al*., 2011; Edvinsson *et al*., 1998; Malone, 1997).

Measures	Formula	Unity	Goals
Number of worked hours in tasks by development site	$\frac{Tasksdesignedforthesite}{\sum hoursworkedinthesite}$	$T/\sum h$	Manage effort of distributed teams
Number of faults from performed test by development site	$\frac{Faults/_{Performed\ Tests\ (T)}}{Development\ Sites\ (S)}$	$\frac{F/T}{S}$	Manage the quality of processes carried out by distributed teams
Number of delivered components by development site by year	$\left(\frac{Components\ delivered\ by\ site}{All\ components\ delivered\ by\ the\ sites}\right) \times 100$	%	Manage output of distributed teams
Change performed within the given time	$\left(\frac{Changes\ performed\ within\ the\ given\ time\ by\ site}{Changes\ designed\ for\ the\ site}\right) \times 100$	%	Manage development time oriented to change
Number of faults found from corrective maintenance by development site	$\frac{Faults/_{Corrective\ Maintenance\ (CM)}}{Development\ Sites\ (S)}$	$\frac{F/CM}{S}$	Manage the process quality carried out by distributed teams
Attainment of the activities within given time	$(Features\ (F) to\ be\ implemented) - [(Features\ per\ day) \times (remaining\ time)]$	F	Monitor the tasks will be implemented within established time
Reason among planned effort and real effort on code generation step within given time by site	$\frac{Total\ time\ estimated\ (Te)\ for\ code\ generation\ for\ site}{Time\ consumed\ (Tc)\ for\ code\ generation\ by\ site}$	$Te/_{Tc}$	Ensure the adequate use of effort on tasks

Delivered by the Site: Calculates the amount of faults found in components designed and delivered by the site, in order to ensure final customer satisfaction by quality control of sites service.

3.3 Measures for Internal Process Perspective

The use of software process metrics is important to quantify the activities performance to determine the gap within them, and so define improvements for critical process quality.

Following some of its features are described.

- **Number of Hours Worked on Tasks per Development Site**: The metric allows managers to quantify the efficiency in performing tasks designed to the site, based on the amount of tasks designed for the team on total hours worked by the team throughout the project.
- **Number of Faults From Performed Tests by Development Site:** It is a metric that represents the number of faults found by tests performed per development site**.**
- **Number of Components Delivered by Development site at One Year:** Allows the manager to verify the contribution of each distributed team to the project. The metric also provides data to compare the yield of all development sites.
- **Changes Done Within the Time Limit Given:** It aims to manage for each team distributed the efficiency to perform the changes addressed for each one.
- **Number of Faults Found in Corrective Maintenance Per Development Site:** The metric measures the number of faults found during corrective maintenance. The value corresponds to failures generated per development site.
- **Attainment of Activities Within the Time Limit:** The metric allows to manage the attainment of tasks within the time limit

predetermined. Features reference to a deliverable of projects. Deliverable could be calculated as output using function point technique or sprints from Agile Methods (for example).

- **Relationship Between Planned Effort by Real Effort in Code Generation Step in a Given Time by Sites:** It is very important to measure the performance of the code generation process, since it is responsible for the translation of the detailed design representation to the programming language. Values generated less than "1" shows that, according to schedule was used an excessive time and effort in the code generation process**.**

3.4 Measures for Learning and Growth Perspective

This perspective aims at long-term to measure the growth of the organization, because alongside financial progress, enables the evolution on staff training as well as the structural and technological capacity of organization. The performance measures allow monitoring actions that aim to measure the progress through staff training, as well as new investments in structural capital of the company (Edvinsson et al., 1998; Malone, 1997).

Characteristics of the metrics are described as follow:

- **Persons Qualified to Play Project Manager Role for Each Development Site**: Measuring the team members skills, it is possible to identify potential candidates for management and the needed investment to train employees. It makes possible to distribute more appropriately whose with skills and experience to manage teams. So, best qualified teams should be established.
- **Number of Workout Aiming at Education and Training of Employees Per Development Site:** Investment in training is aimed at training and organizational growth. The metric provides a value corresponding to the number of training carried out in a year and destined for each distributed team.
- **Percentage of Workout Destined to Sites:** Generates the percentage of value regarding to training that is targeted to distributed teams. If this value is equal 100%, all training investment is destined for the site in a matter. The metric is important for sharing evenly among distributed teams the resources for training.
- **Research and Development (R&D) Investment Per Distributed Site:** The resources invested in R&D for each site is calculated. Investment in R&D enables, through of basic or applied research, innovation in products and services that enable continued organization growth in terms of scientific and technological development.

3.5 Measures for Geographical Dispersion Perspective

The performance measures for geographical dispersion perspective provide the visualization of the magnitude of the kinds of dispersion that characterize the distributed development environment (Ramasubbu et al., 2011).

The metrics characteristics are described as follow:

- **Geographical Distance among Team Members:** Provides for the project manager the geographical distance that separate team members. These data are important to manage communication, time zone and cultural differences among team members. The calculation can be done with any number of distributed teams and also members.
- **Number of Workplaces**: It provides the number of geographically distributed sites those are being used or will be used by project. If the value generated is high, it implies in difficulties for project management due to temporal and cultural differences among distributed teams.
- **Unequal Experience Distribution among Sites**: It makes possible to calculate the difference on the experience among distributed teams. If it is well managed, it contributes for establishment of more efficient teams.

4 DISCUSSIONS

This section presents a qualitative analysis of proposed metrics considering the five perspectives presented on section 3.

The “Profit per development site” metric is important to make possible analysis of the project viability and allows to determine the contribution of each site with the enterprise earning. The “ratio between the financial return on development time for each development site” metric provides information concerned to effort spent in each site when compared with the earning from project. They consist in important data for adequate distributed team management. It is important measure the efficiency while performing the tasks for these do

not extend for longer than necessary. The delay of the completion of the project could lead to fewer profits and possible failure of it. The “number of working hours per task for the site” metric informs the time amount expended in activities for each site. Due to geographically distributed allocation, in DSD projects there is common travel spending by employees. For that, “kilometers/miles spent with employees travel” metric help to determine the viability of DSD project. The "index of employee turnover" metric is critical to identify corrective actions on the sites since the site that presents high turnover will have a negative impact on the cost and time of project development.

The choice for use of distributed sites for software development occurs, mainly due to the need for an agile production and qualified teams. The "degree of performance of distributed teams" metric can measure the efficiency of teams. The "degree of interaction among distributed teams" metric becomes essential to estimate the difficulty of interaction among distributed teams, since development should be effectively cooperative even with the geographical distance and the dependence of the communication media. The good relationship between those involved is an indispensable element in DSD projects, especially among those belonging to the same distributed team. The "Customer (internal) satisfaction with his/her development team" metric measures this attribute. The "relationship between amounts of design faults of delivered components by site development" metric is very important to manage the quality of site production, since the index generated by it allows an analysis concerned to the qualification of the project teams.

The "number of hours worked on tasks per development site" metric allows to quantify the efficiency of distributed teams in carrying out their tasks. It enables a comparative analysis of the performance of each distributed team. The software project manager must have control on the number of faults found in testing or corrective maintenance. In DSD case, monitoring should occur according to site distribution. It can be measured using the "number of failures in tests carried out by development site" metric and "number of faults found in corrective maintenance by development site". In project developed with several teams, calculate the contribution of each one of them becomes essential for effective management. For this, the "number of components delivered by development site per year" metric allows this measurement.

The "changes done within the time limit" metric supports in managing a common bottleneck in productive systems: do changes. In DSD case, the metric allows managing the efficiency of each site. Projects that go beyond set up time for conclusion possibly have their earnings reduced. For that, the "attainment of activities within the time limit" metric measures the sufficiency of productive capacity to conclude the project within the preset time. This measurement could be carried separately for each distributed site or also taking into account the aggregate output of all sites involved.

The "persons qualified to Project Manager role" metric is essential due to the importance of project manager. When considering projects DSD, this position requires the ability to coordinate teams despite the geographical distance. The qualification of employees is important for the success of the organization which depends on of their employees performance.

The "number of workout session that aims to education and training of employees per development site" metric allows the calculation of the investment due to the number of distributed sites. In its turn, the "percentage allocated to workout session per sites" metric allows that the investment in training is evenly distributed among the teams. The "research and development (R&D) investment per distributed site" metric measures the amount of resources invested in research and development according to the amount of sites distributed, that is necessary when considering a long-term growth.

The geographical distance among teams members is the feature that makes the DSD so advantageous as complex to be managed. The "geographical distance between team members" metric allows the project manager based on this data to evaluate and so understand the diversity that involves employees in DSD projects. Teams at different sites require to be considered cultural differences as well as religious, politics, laws, among others. The "number of workplaces" metric returns the number of different sites that are located for a project.

A team with experience in software development will probably be more efficient than an inexperienced team. With the "unequal distribution of experience among sites" metric can be obtained the level of experience discrepancy between distributed teams and, with it, take action so that better balanced teams are established.

Therefore, as can be observed in the above discussions, these metrics will provide project manager the necessary support to mitigate the difficulties related to communication, coordination

and control aspects in DSD. The following subset of metrics: "degree of interaction among distributed teams", "persons qualified to project manager role" and "relationship between amounts of design faults of delivered components by development site" illustrate the use of measurements presented herein for each of the mentioned aspects. Furthermore, this set of measures will also provide a better organizational performance evaluation, ensuring thereby a strategic and operational planning based on data/facts. So, a favorable environment can be created making possible for the enterprise to offer products with better quality, less time and development cost and also with greater return on investment that yields higher profit and better client satisfaction.

5 CONCLUSIONS

The increasing demand for software products, leads to finding ways to provide improvements in both production and the product delivered. Given the characteristics of DSD, project managers continue with the challenge of identifying elements that return information about the performance of their team.

The paper presented a set of measures that can be used to evaluate the performance and, consequently, support in managing organizational performance. The presented metrics were obtained from the literature and provide a metric baseline for DSD, using as reference a consolidated model for managing performance, the BSC.

A future work proposed by researchers' team is to implement and analysis the performance evaluation system in a software development enterprise which adopts DSD approach, and so releases the results opportunely. Another research opportunity relates to the integration of proposed metrics with techniques for estimating the complexity and modularizes activities.

It is also considered by our research group develop a tool with these metrics. So project manager will have automated support for organizational performance management.

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