Aspects of Quality Assurance in Global Software Development Organization

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Abstract – Global Software Development has become an increasing practice in modern software engineering. It is especially important for getting competitive advantage on the market. However, distributed development puts many new challenges such as contextual, cultural, organizational, geographical, temporal, and political. To keep quality level in such new conditions, collocated development practices have to be adapted and improved. In this paper we present some aspects of quality assurance in global software development.

I. INTRODUCTION

The commonly accepted practice in modern software development is globalization of software development work. By global software development (GSD) we mean software development with globally distributed teams, in more than one location and often on more than one continent. The main motivators for increased usage of GSD practice is many advantages it promise such as concern for cost, the need to tap global pools to acquire highly skilled resources, finding an appropriate mix of expertise for a project, satisfying investment requirements imposed by governments in foreign markets, and mergers and acquisitions as pointed by [8].

Nevertheless, these benefits of GSD bring to software projects completely new concern such as how to effectively and efficiently coordinate GSD projects. From the industry experience reports that are available in literature we conclude that managers and developers involved in GSD projects basically agree that cross-site, cross-cultural projects “do not just happen.” The GSD projects are confronted with many challenges throughout whole project lifecycle from the project set-up, to progress control, to day-to-day communication, and even to managing of cultural conflicts. With this concern all knowledge areas, needed to effectively and efficiently manage the software projects are affected.

In this paper we will focus more particularly into Software Quality Assurance (SQA) activities since all of above mentioned issues can become serious obstacles to quality of software products. The paper presents best practices related to SQA activities in GSD environment. The main goal of the case study presented in this paper was to reach the quality goals that were set in advance, based on historical database and organizational business goals. Data set used to evaluate the goal fulfillment comes from available project documentation and measurements performed within the project. Reported results are used to judge over success of goal fulfillment. The best practices presented can be useful to other organizations working in GSD.

In the following chapter we introduce basic concepts used in the paper. Then, in the third chapter we present a real case study of how SQA activities were performed within an industrial GSD context, particularly in Ericsson organization. In fourth chapter we examine GSD project results in relation to predefined goals that were the main issue of SQA activities. Finally, we conclude the paper in chapter five.

II. SOFTWARE QUALITY ASSURANCE

According to [1], the software project is successful if completed within allocated time period, within the budgeted cost, at the proper performance or specification level, with acceptance by the customer/user and with minimum or mutually agreed upon scope changes. This main software project objectives, time, cost, scope and required quality level are usually defined within the project contract. The GSD projects are frequently divided into more manageable components or subprojects that are then contracted by diverse functional units [2]. Subprojects are often contracted to external enterprise or to another functional unit in the performing organization. The GSD projects are then managed as multi-contractor projects.

The Project Quality Management (PQM) is one of the knowledge areas defined within Project Management Body Of Knowledge (PMBOK), [2]. It involves processes in assuring that the project will satisfy objectives for which is undertaken. According to IEEE Standard [3], the SQA process that is part of the PQM processes, is a set of activities designed to evaluate the processes by which the software products are developed in order to satisfy requirements.

One of the very first IEEE standards in the field of Software Engineering discipline was IEEE standard for Software Quality Assurance (SQA) [4], with the main purpose to provide uniform, minimum acceptable requirements for preparation and content of SQA plans [5]. According to [6], the SQA is software projects assurance that products and procedures conform to standards and plans. By using the SQA plan the software projects define their SQA activities.

Within the CMM the SQA is one of the key process areas defined at CMM level 2, [7]. According to CMM definition, the purpose of the SQA is to provide management with appropriate visibility into the process being used by the software project and of the products being built. The best practice is SQA group that is responsible to establish plans, standards, and procedures that will add value to the software project and satisfy the constraints of the project and the organization's policies. Finally, the SQA group, frequently during the project lifecycle, reviews the project activities, audits software work products and reports to management whether the software project is adhering to its established plans, standards and procedures [2].

III. SQA IN GLOBAL SOFTWARE DEVELOPMENT – A REAL CASE STUDY

In order to present the real case study, first we give environmental description and organizational process where the study is performed. Thereafter, we explain the SQA activities taken during the cause of GSD project which involved two development locations within Ericsson organization.

A. *Project Environment*

This paper describes and characterizes a successful collaboration between two development locations of Ericsson organization. The prime contractor of the observed GSD project in this paper is 'Ericsson Nikola Tesla' (ETK), that is Croatian development location in Ericsson responsible for part of AXE software system. The complete system software is developed in collaboration between Italy, Germany, and Sweden development locations. At completion of development activities the software is hand over to internal customer, and that is integration and verification centers placed in Germany, Canada and internally in ETK. Later on the product is integrated to many network suppliers worldwide. In order to manage with overload conditions, ETK uses other Ericsson development sites as subcontractors. In this case, the subcontractor was design centre in Shanghai. Throughout the remaining of this paper, we use the ZG acronym for Zagreb/Croatia development site and SH for Shanghai /China site.

The AXE software system is developed for telecommunication equipment to serve as switching platform for telecommunication services. Due to nature of telecommunication services such as need for real time execution, concurrent execution of more then million subscribers, the software quality attributes defined by International Standards Organization (ISO) [3], are even harder to achieve. The software product has evolved over the last 30 years by using in house developed model based on Waterfall model which evolved into mutation of incremental, iterative, and feature driven development. The development process is well defined, and has a number of SQA activities, roles and processes built in. The continuous evolution of the process is secured through continuous improvement programs that are often result of the SQA activities. The overview of the used processes is presented in following subsections.

B. *Organizational Process*

The project lifecycle presented in this paper follows project methodology especially designed to meet Ericsson organizational needs [9]. The project lifecycle consists of the four phases, as depicted in Fig.1:

- Project analysis phase (PA)
- Project planning phase (PP),
- Project execution phase (PE) which consist of establishment (PE-E), realization (PE-R), and hand-over (PE-HO), and
- Project conclusion phase (PC).

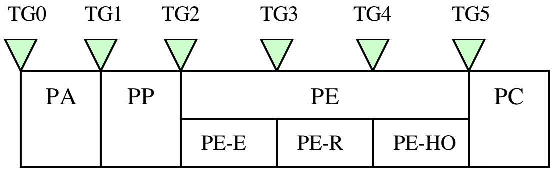

Figure 1. Software development project lifecycle

Each project phase is further described from two perspectives: project management perspective and technical perspective.

Project analysis (PA) is the preparatory phase in the project model during which a business opportunity for the expected outcome of the potential project is assessed. Stakeholders are identified and their requirements and expectations on the project outcome are collected and analyzed. Based on that, resources and the competence needed for the project are identified. The budget and project time-schedule is also prepared. The project analysis work is documented and handed over to the project sponsor as a basis for tollgate 1 decision to start the project planning phase (marked as TG1 in Fig.1).

Technical vise, the system study process is triggered with objective to interpret customer requirements, to analyze whether a product is to be developed and to outline system architecture. Results of these activities are collected in a Modeling Proposal (MP) document, along with cost, time and resource estimates for the project planning phase and preliminary cost estimates for the execution phase.

In ***project planning (PP)*** phase, the project scope is finaly defined and the project goal is clearly formulated. Based on scope, the project organization is established and potential risks and value opportunities are assessed. A quality system for the project is defined to ensure that the project outcome and performance is aligned with the quality demands expressed by the customer and the organization. The project planning work is documented in the project specification, which is handed over to the project sponsor at tollgate 2 (marked as TG2 in Fig.1)

The high level technical impact on design base System Modules (SM), as derived from requirements, is described in Implementation Proposal (IP) document.

The IP also includes an estimation of the amount of work needed to carry out the implementation [10].

In ***project execution phase (PE),*** the project organization is fully established and the project execution is initiated (PE-E stage). During PE-R stage, the project outcome is finalized and integrated. Changes in the project are controlled according to routines for change request handling, as specified in the project specification. An active project management in this stage includes coaching, integrating and controlling the project teams, and steering the project toward its goal. All modifications to SM are specified in an implementation-independent manner, function is designed and new SM is verified with purpose to ensure that is complies with the requirements. For all outcomes of PE-R stage the SQA activities such as reviews apply. After the execution is completed, the PE-HO stage commences during which the project outcome is handed over for acceptance to the customer and the receivers.

Finally, at ***project conclusion (PC)*** phase experiences made in the project are documented in a final report and lessons learned are transferred to the organization. All outstanding issues are taken care of, and the project is formally closed.

C. SQA Activities within the Project

In GSD project, the SQA team of the prime contractor oversees the activities of the subcontractor by participating in reviews and conducting audits. Below we will describe the main SQA activities, along with the project dynamics, that were taken in the ZG-SH collaboration project in given environmental conditions.

During ***project analysis phase***, the resource estimates for the next two phases revealed the shortage of resources with specific competence at ZG design office. Therefore it was decided to involve external resources into the project. A collaboration is initiated with SH design office by contract agreement of senior executives from both locations. The first task was to define a budget and split of software domains between the two organizations. The software domains were split according to available system knowledge and criticality. By this split, the exact resource requirements for each design office had become known, so management was entitled to assess capability (i.e. staff availability) to perform the work in desired time frame.

There was a well-organized transition from ZG to SH of selected software subsystems, of infrastructure (software development environment, test automation environment), of know-how in the product domain and systems architecture, and of development processes. The list of development work responsibility is provided in the Table I. The first column in table represents the feature name which was supposed to be developed in the project. Next columns represent project phases and work division among ZG and SH development sites, with respect to main technical documents being produced (MP and IP) or system modules being impacted (SM A, SM B and SM C).

TABLE I
WORK DIVISION ZG-SH

	PA	PP	PE		
Feature	MP	IP	SM A	SM B	SM C
F1	ZG	ZG	ZG	ZG	-
F2	ZG	SH	SH	SH	-
F3	ZG	ZG	ZG	ZG SH	-
F4	ZG	ZG	ZG	ZG	-
F5	ZG	SH	ZG		SH

The real feature names, document and system module names are omitted since they are irrelevant for the purpose of this paper.

After the project had been formally initiated during PA phase, the task of ***project planning phase*** was to define project scope, to formulate project goal and setup the project organization. At this point the SQA activities in terms of defining a management process came in place. The organizational roles and responsibilities that participate in SQA activities were defined and clear communication paths had been set up in both directions, by fully including SH teams and colleagues into project management as well as engineering work of all R&D disciplines. Although the formal so-called “product ownership” is by the ZG project office, the relationship of ZG-SH locations was based on *peer-to-peer partnership* from the beginning, not on customer-supplier like treatment.

The project organization was established at ZG and SH (according to Fig.2) consisting of highly experienced senior managers, originally expert engineers with large and long global development experience. Project managers were responsible for managing the project according to well defined project management process. Quality coordinators had supported and coordinated project in all quality assurance activities. Technical and test coordinators took care of technical issues in design and test area respectively.

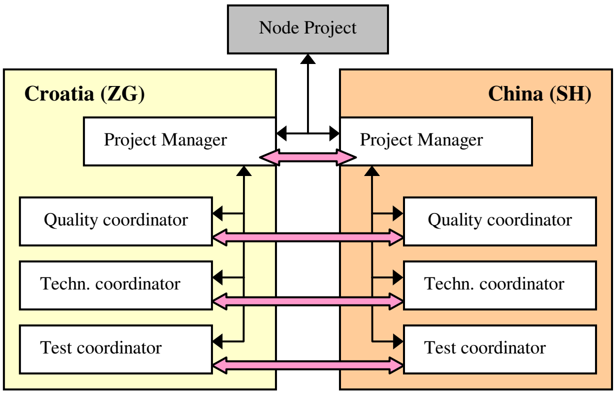

Figure 2. Project organization

During PP phase, project plans were prepared at a level detailed enough to establish realistic time and cost limits for the project and to ensure proper control over it. Being provided tollgate (TG) dates by ZG project manager, the SH project manager was entitled to prepare project plan and to identify needed resources in the project. This plan was reviewed and approved by ZG project management including SQA group responsible.

Based on competence needs and resources assigned to the project at each location, the competence gaps had been identified per each assigned resource and their training plan for competence build up was defined. For the training purpose the resources were exchanged in between the development sites ZG-SH. The training plan is presented in the Table II.

TABLE II
TRAINING PLAN

						ZG, SH, both	Present., selfstudy, workshop			Des, Test, SysMgr
			Course						No. of part.	Part. role
No.	SM	Status	Name	Dur.	When	Where	Method	Instructor		
1	A, B	FI	BICC protocol	4h	w2	SH	Present	Jerry	20	Des
2	all	FI	APS tools	5h	w52	SH	Present	Bill	10	Des
3	all	PLAN	Delivery	4h	w5	SH	Present	Andrew	6	Des
4	A,B	PLAN	Screen mask	6h	w4	SH	Present	Wenliang	10	Des
5	A,B	FI	ISUP protocol	2 day	w1	SH	Present	Petar	20	Des/test
6	A,B	FI	IP1 present.	2 day	w3	ZG/SH	Workshop	Petar	10	Des/test
7	all	PLAN	IP2 present.	1 day	w4	ZG/SH	Workshop	Petar	15	Des/test
8	all	PLAN	IP3 present.	2 day	w4	ZG/SH	Workshop	Petar	10	Des/test
9	C	PLAN	Test env.	1 day	w8	SH	Present	Su Wang	10	Test
10	C	FI	Call path	4 h	w2	SH	Selfstudy	-	10	Test
11										

Technical vise, the SM documentation was written by ZG system management team (as specified in Table I), since it required system expertise from the concerned system modules. The SH technical coordinator was involved in all internal and product committee inspections of technical documents, in order to grasp technical details that were going to be further developed during execution phase. This way a smooth hand over to execution phase and support for SH design team during execution was secured.

The ***project execution phase*** was the most demanding from the SQA perspective, as it aimed at establishing strong quality procedures, metrics and processes that will be used during project execution. The quality laid within the responsibility of appointed project managers at ZG and SH, according to the Ericsson Operational Quality Manual [10]. However, the quality coordinators at both sites were responsible to guide project and support in quality related issues in order to achieve the highest possible product quality. This was accomplished by applying the following quality assurance strategies [11]:

1. Quality management network
2. Change control
3. Active risk management
4. Quality audits
5. Inspection strategy
6. Delivery strategy
7. Reporting and Measurements

In the remaining of this chapter each applied SQA strategy is described in more detail.

1) Quality management network: The ZG project and SH sub-project used a network for coordinating and communicating quality assurance activities. Regular phone meetings were taking place throughout project execution lifecycle. Physical or teleconference meetings were held prior to TG2, TG3 and TG5. The purpose was to co-ordinate project quality assurance activities, to benchmark in between design offices, and to evaluate and discuss results and strategies.

2) Change control: As one of the key importance processes, the change control was established through a Change Control Board (CCB) which was a cross-functional team consisted of delegates from ZG and SH. The CCB was supposed to decide on proposed changes for various affected parts of the product, based on well defined and approved change request acceptance criteria and described acceptance procedures. The project managers from both sides were supposed to make a decision on each change request, to identify activities needed for implementing approved changes, and to ensure that the activities are executed.

3) Active risk management: The goal of active risk management was to prevent problems from happening by identifying possible risks in early phases and by initiating corrective actions in a timely manner to minimize the risks. The risk matrix containing all risks with actions, responsible persons, ready dates and status was prepared by SH design office and made available to ZG project manager and quality coordinator on a weekly basis [12]. The SH subproject manager and quality coordinator were responsible for the risk management, and ZG project manager and quality coordinator were in charge of the follow-up activities.

4) Quality audits: Internal project quality audits were performed on different parts of the execution, covering any project relevant issue. Responsible for the SH internal audits was ZG quality coordinator. The results of the audits were complied in audit reports. Corrective actions related to audit findings were defined by the audited project management team and agreed with the ZG quality coordinator. The appliance of corrective actions was under responsibility of SH quality coordinator, and ZG quality coordinator was responsible for follow-up on the corrective actions.

5) Inspection strategy: In order to achieve increased product quality it was seen as most efficient to use resources on early manual inspections, rather than extensive testing. The SH subproject had prepared an inspection plan [13] covering all document inspections required in the project. Extensive code inspections, desk checks and basic test/simulation have been done in order to find faults as early as possible in the SW design process. The inspections and reviews were organized in 3-round manner: (1) internal review by SH design team, (2) review by SH technical coordinator and (3) review by ZG technical coordinator. The SH technical documents and software deliveries were broken down into detailed objects. For each object, a detailed plan and check point status was defined. A weekly follow up of project status was established between ZG and SH [16].

For the purpose of code verification, different testing configurations and environments were prepared and coordinated by ZG test coordinator. Test documents were subject to 2-round reviews: (1) review by SH test coordinator (and IP author if provided by SH), and (2) review by joined effort of ZG test coordinator and IP author. Testing was normally performed at SH site in simulated test environment, except for the key and complex features, for which testing was conducted at ZG test site by utilizing testing resources from SH. Test results were reported at each site independently, by following a trouble report handling procedure.

6) Delivery strategy: At execution hand-over, the project outcome was handed over for acceptance to the customer and the receivers. From that point on, the follow up period commenced, during which any defects found by receiving or internal customer should have been resolved. In that period, the SH design team took care of system module parts they had been responsible for during execution. At the end of follow up period, the stability assessment of modules delivered by SH was made. During assessment, the inflow of trouble defects was measured, along with the check on still open and not resolved defects. After positive outcome of assessment, a hand over of system modules to product responsible organization (ZG) took place.

7) Reporting and Measurements: The SH project quality status was reported to the ZG quality coordinator on monthly basis [14]. The report included quality risks and concerns, applicable quality statistics, possible risk products and other relevant issues.

At ***project conclusion phase***, experiences made in the project were documented and lessons learned were transferred to organizations. That way organizations were given full opportunity to learn from experience which may be used in the future collaboration projects.

IV. DISCUSSION AND EXPERIENCES

From the SQA point of view, effectiveness of quality activities, goals and strategies was measured by the results achieved in the project versus all predefined quality objectives. Hereby we mention the most important ones, although the list is not exhaustive.

A. Project Execution at Cost

The objective was that project cost precision should have been such that for all tollgates (TG2-> TG5) the project is within the budget limit agreed by product management for the year that the project is running. The Table III represents planned project cost for ZG and SH project respectively in comparison with actual project cost for each system module affected during project execution. The objective would be considered as met if the cost variation was not more than +/-5%. The cost variation for ZG project was within the limits (-1% in total), however, the SH subproject had planned bigger budget than needed. Over budgeting had been motivated by the fact that higher costs were expected in SH location due to extensive coordination activities between the two sites and lower competence profile at SH.

TABLE III
PROJECT COSTS IN SEK (x1000)

	ZG			*SH*		
System module	Plan. cost	Act. cost	Diff (%)	Plan. cost	Act. cost	Diff (%)
A	3.791	3.760	-0,82	862	705	-18,27
B	1.792	1.865	4,06	726	722	-0,60
C	8.521	8.340	-2,13	2.694	2.490	-7,59
Total	**14.104**	**13.964**	**-0,99**	**4.283**	**3.917**	**-8,55**

B. Inspection Status

The following objectives were met by both, ZG project and SH subproject, when it comes to IP inspection process during project planning phase [14]:

- All IPs have had internal inspections with all impacted parties present.
- Minimum 50% of the IPs were approved in the first Product Committee (PC) inspection
- No IPs were PC re-inspected more than once in the highest PC inspection body.

C. Early Fault Detection

The most efficient way to decrease the costs and support project in terms of quality assurance is to detect faults as early as possible during execution phase. The objective in our project was that number of faults detected in early phases (basic test (BT) faults + code desk check (DC) faults) should have been more than 80% of the total number of faults (BT faults + DC faults + Function Test (FT) faults) found. The results obtained [14] are presented in Table IV.

TABLE IV
EARLY FAULT DETECTION

	ZG			*SH*			*ZG+SH*
SM	BT+ DC	TR	EFD (%)	BT+ DC	TR	EFD (%)	EFD (%)
A	90	5	94,7	20	2	90,9	94,0
B	82	15	84,5	33	10	76,7	82,1
C	-	-	-	-	0	0	0
Total	**172**	**20**	**89,6**	**53**	**12**	**81,5**	**87,5**

The objective was not met by SH design office for system module B, where early fault detection was 76,7%. However, the total (ZG+SH) early fault detection result for system module B was above desired 80% (82,1%). Also, the overall goal was met by reaching 87,5 % of faults found in early phases.

D. FT TRs per Test Cases Run

In order to measure effectiveness of function test it was required that the ratio of FT faults per test cases (TC) run, should not deviate by more than ± 20% from the previous project (where ratio was 8,9%). It means that ratio in this project should have fallen in the range between 7,1% and 10,7%. The final results [15] are presented in Table V. For ZG project the total number of TRs per TCs run was 6,5% and for SH subproject that ratio was even lower (3,4%). Apparently, the objective had not been met by either project organization. Indeed, due to low modification grade of the system modules, the probability of faults was rather low, thus making objective hard to meet. Moreover, the objective is somewhat in conflict with FT Fault density, as one excludes the other. In that sense, the FT TR's per test cases run was tracked just for the baseline.

TABLE V
FT TRs PER TEST CASES RUN

	ZG			*SH*			*ZG+SH*
SM	TC	TR	TR/ TC	TC	TR	TR/ TC	TR/ TC
A	155	5	3,2	60	2	3,3	3,3
B	154	15	9,7	162	10	6,2	7,9
C	-	-	-	136	0	0	0
Total	**309**	**20**	**6,5**	**358**	**12**	**3,4**	**4,8**

E. FT Fault Density

Fault density was measured as number of faults found during FT per modified kilobyte of non commented code [15]. The objective was to improve the fault density by -40% compared to the previous project (i.e. it should have not exceeded 2.4 faults/modified code). The results obtained in the project are presented in Table VI. Apparently, the system module B has encountered the largest fault density during execution. At the same time, the fault density across all system modules was as twice as higher in ZG project (3.026) compared to SH subproject (1,582). Reasons might be twofold. On one side, the complexity of design impacts at ZG was much higher than at SH, thus increasing probability of design introduced faults. On the other hand, the quality of testing was higher in ZG, resulting in more trouble reports found, as we have already presented for the previous objective. Indeed, the fault density objective (<2.4) was met in total ZG+SH (2,254).

TABLE VI
FUNCTION TEST FAULT DENSITY

	ZG			*SH*			*ZG+SH*
SM	Mod. Code	TR	FD	Mod. Code	TR	FD	FD
A	1.942	5	2,575	3.796	2	0,527	1,220
B	4.423	15	3,391	3.702	10	2,701	3,077
C	0.245	0	0	0.089	0	0	0
Total	**6.610**	**20**	**3,026**	**7.587**	**12**	**1,582**	**2,254**

V. CONCLUSION

With increasingly growing application of GSD in software development community, a number of new challenges arise, among which is assurance of the required software product quality level.

This paper intended to present and evaluate Ericsson best practices in this area. The case study performed in Ericsson organization proved that SQA planning for a cross-site project is extremely critical. We believe that setting ground SQA objectives and measurements, along with adherence to quality assurance processes and strategies is very important. Clear communication and reporting process, accompanied with close coordination of SQA activities, acting on quality issues and risks, and frequent monitoring of results are essential to meet quality goals. The evaluation of achieved results proved that Ericsson's collaboration project was successful.

The proposed practices could be reused by other organizations working in GSD environment in order to increase probability of quality goal achievement.

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