Towards Task Allocation in Global Software Development Projects

Sajjad Mahmood, Sajid Anwer, Waleed Umar, Mahmood Niazi, Mohammad Alshayeb
Department of Information and Computer Science
King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia
Emails: {smahmood, g201303950, g201207040, mkniazi, alshayeb}@kfupm.edu.sa

***Abstract*— Global Software Development (GSD) initiative aims to facilitate software development process by providing access to skilled workers at a relatively low cost and a 24/7 software development model. Previous work suggests that a significant number of companies that have tried GSD have failed to realize the anticipated benefits, which have resulted in poor outsourcing relationships, high costs and overall poor software products. Task allocation is one of the critical factor for a successful GSD project as project managers not only need to consider their workforce but also need to take into the account the characteristics of the geographically distributed sites involved in a project. In this paper, we present a task allocation process with an aim to utilize different geographically distributed sites for a GSD project. The task allocation process uses project scheduling techniques, e.g., Critical Path Method (CPM)/ Program Evaluation and Review Technique (PERT), and a multi-objective optimization technique to allocate GSD project tasks. We also present an application of the task allocation process to Obesity Health Clinic System (OHCS) case study.**

Keywords-global software development; task allocation; work distribution; software project schedules.

I. INTRODUCTION

Global Software Development (GSD) occurs where a company (client) contracts out all or part of its software development tasks to another company (vendor), who provides services for remuneration [1]. GSD has been growing steadily as a large number of organizations aim to take advantage of using highly skilled workforce at a relatively reduced cost. Furthermore, GSD has the potential to reduce project's time to market by using different time zones to organize a 24/7 development model.

A good number of organizations that have tried GSD failed to realize the expected outcomes, which resulted in misunderstanding of requirements, poor global relationships among clients and vendors, high costs and overall poor services [2][3]. These failures are usually traced back to two main causes: insufficient abilities (e.g., absence of domain knowledge, high turnover rate, etc.) at different sites, and problems at the interfaces between two distributed sites due to cultural barriers.

These issues are directly impacted by the decisions taken at the task allocation phase of a GSD project. Existing research suggests that tasks need to be allocated to different geographical sites based on a number of often conflicting objectives such as low cost [4][5], reduced development time, and increased productivity [6]; and minimum communication and coordination between different development sites [7]. For example, Tran and Latapie [8] have presented models for structuring teams and work in globally distributive projects by taking into account the dependencies between components at a higher abstraction level.

In this paper, we present a task allocation process that takes into account the interdependencies between project tasks and geographically distributed sites' capabilities. The task allocation process has two inputs, namely, GSD project tasks and number of geographically distributed sites, which have the required skills to complete the project tasks. The task allocation process uses either CPM [15] or PERT [15] to develop schedule of a GSD project. Next, the tasks are ranked based on the precedence requirements and these ranked tasks are used an input to a 'goal program', a multi-objective optimization technique, to select suitable geographical sites for a GSD project.

The rest of this paper is organized as follows: Section II reviews the related literature. In Section III, we present the task allocation model and Section IV presents a case study. We conclude the paper and discuss future work in Section V.

II. RELATED WORK

This section presents different approaches that researchers adopt for task allocation in global software development. Setamanit et al. [6] propose a simulation model based on two factors of software process model development time and productivity and it compare different task allocation strategies proposed in research against these two factors. They consider different important properties of software, i.e., coupling between activities, sites capabilities and project plan for comparing different approaches. In fact this model is proposed for comparing different site allocation techniques not allocation tasks to different sites in GSD.

Lamersdorf et al. [9] proposed qualitative approach intended for understanding and identifying different criteria that are practically used for task allocation in GSD. They conducted interviews from different industry peoples to collect data. They showed that type of required system and sourcing strategy mainly affects the task allocation criteria. Their study analysis shows that market proximity, turnover rate strategic planning and labor cost are main factors that need consideration during task allocation.

Lamersdorf et al. [10] presented a risk driven customizable model to suggest different task allocation approaches based on the target system and software development process model and critically evaluated this model based on risks related to tasks allocation in GSD. They also evaluated proposed approach by interviewing different peoples from Information Technology (IT) industry that are related to software development in GSD.

Narendra et al. [11] presented an integrated formal technique for analyzing all tasks and developed optimal tasks allocation model for GSD projects. The proposed model predicts estimated effort required for particular task based on the overall allocation of tasks over estimated effort and effort required to execute a particular task on particular site.

Wickramaarachchi and Lai [5] proposed a method for work distribution to different locations with an aim to minimize overhead costs. The method categorizes the offshore tasks based on software process model. It also proposes a method to distribute work to suitable tasks using work specific matrix, work dependency matrix and site dependency matrix.

Mockus and Weiss [7] proposed an approach for task allocation in GSD that mainly addresses the communication problem between sites and ultimately reduced the overall overhead in distributed development and used optimization algorithms to implement this approach. Proposed approach is well understood and easily applicable in GSD but they only consider one factor that affects GSD. As there are other factors that can affect the distributed development like cost, site capabilities and tasks dependencies and due to this limitation this approach however, cannot be used for tasks allocation in GSD.

Vathsavayi et al. [4] discuss the solution of work allocation problem in GSD using genetic algorithms. They proposed a model that take different activities of software development process as an input and find the near optimal solution. Their model is capable enough to accommodate the change management and other concerns related to project management. They considered only duration and cost factors of site for tasks allocation in GSD.

Lamersdorf and Munch [12] proposed task allocation approach that considers different factors, i.e., time zone difference, sites capabilities, labor cost and cultural issues. They developed a tool named Task Allocation based on Multiple criteria (TAMRI) using Bayesian network [12]. This model is applicable across a number of products by just modifying the underlying Bayesian approach.

Shen et al. [13] proposed approaches to solve the multi criteria task allocation problem using fuzzy numbers and linguistic scales. Linguistic scales are first used to measure quantitative properties like individual capabilities and then fuzzy numbers are used to measure and quantified these scales. Four criteria, namely, workload, familiarity with task, capability and social relationships with other team members are used to assess the individual that is suitable for this particular task.

Tran and Latapie [8] proposed a task allocation model from architectural point of view and considered the dependencies between components as criteria for task allocation. They allocated architectural integration to one site and other activities to other sites based on dependencies exist between them while other sites coordinate with the main site. The main limitation of this approach is that they consider dependencies at component level (abstract level) and dependencies inside the component can cause delay.

III. TASK ALLOCATION PROCESS

In a traditional software development environment, a project manager typically distributes work tasks among its team members who are present at a single development site. However, in GSD projects, a project manager needs to assign tasks to teams who are usually present at different geographical locations. This introduces an extra complexity at the task allocation phase of a project as one GSD vendor can be cheaper than other while another vendor might have more skilled workers. We present the task allocation decision model, as shown in Figure 1, which acts as a tool that helps managers to assign tasks in a GSD project.

The task allocation process has two inputs, namely, GSD project tasks and number of geographically distributed sites, which have the required skills to complete the project tasks. A project task is defined as a small manageable unit with a time requirement. Resource requirements for a task define the manpower required for the activity. Project tasks usually are not standalone and have precedence relationships with other tasks in a project. Furthermore, the precedence relationship also defines that what tasks can run concurrently with other tasks.

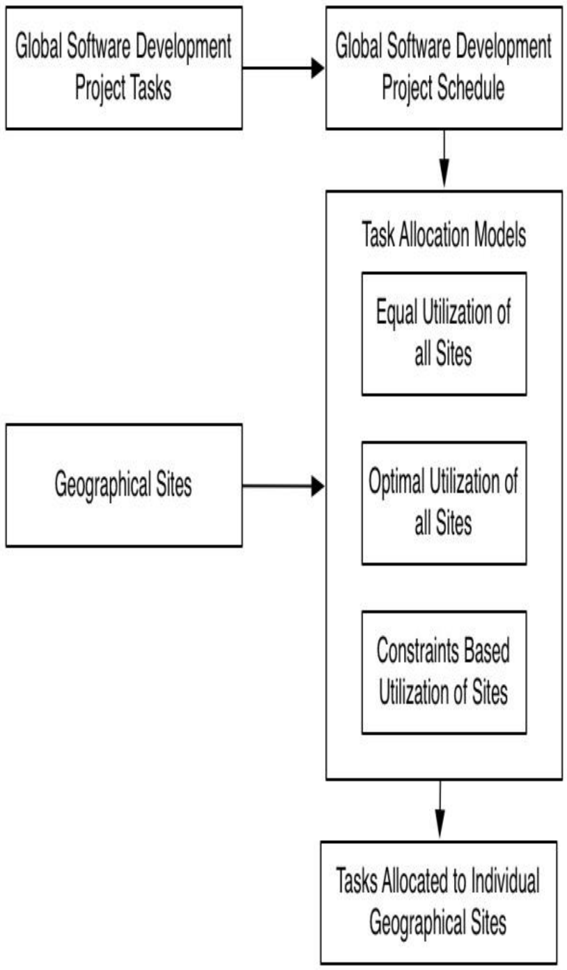

Figure 1. Task Allocation Process.

The task allocation process uses either CPM or PERT to develop schedule of a GSD project. CPM or PERT allows a project manager to define various components of a schedule such as floats, early start time, early finish time and project completion date. The task allocation process uses PERT when the end date for the activities cannot be defined but can be represented by expected probabilistic durations.

Next, the tasks are ranked based on the precedence requirements and these ranked tasks are used an input to a 'goal program' to select suitable geographical sites for a GSD project. 'Goal programming' helps achieving an optimal or near optimal solution for a set of goals.

In the following subsections, we present three models for task allocation, namely, 'equal utilization of all sites', 'optimal utilization of all sites', and 'constraints-based utilization of sites', respectively.

A. Equal utlization of all sites

In this model, we aim to equally distribute GSD project tasks to all geographically distributed sites. We propose to use a genetic algorithm to assign GSD project tasks, such that the standard deviation of total man-hours required at all GSD sites is minimized. The mathematical form of the proposed model as follows:

T.M.U at a site =

$$\sum_{k=0}^{n} (activity\ duration)\ x\ (Man - hours\ required\ per\ day) \quad (1)$$

where T.M.U= Total Man-hours Utilized, n is the number of the tasks to be performed at a site.

Mean =($\sum_{l=0}^{m}$ T.M.U at a site) / number of geographical sites

where m is the number of total geographical sites involved in the project.

$$\text{Variance} = \sum_{l=0}^{m}[(\text{T.M.U at a site}) - (\text{mean})]^2 \quad (2)$$

B. Optimal utilization of all sites

The aim of this model is to assign the tasks to the sites so that the each site is optimally utilized. The model tries to assign the various tasks to a site based on the capacity of a site and the man-hours requirement of individual tasks. The mathematical form of the proposed model as follows:

$$\text{Minimize the Goal} = (\sum_{l=0}^{m} \text{S.D.S.U}) \quad (3)$$

$$\text{S.D.S.U} = (\sum_{t=0}^{d} \text{S.D. Sites capabilities}) \quad (4)$$

where S.D.S.U= Standard Deviation of Site Utilization, S.D. = Standard Deviation, d is the duration and m are the total geographical sites.

C. Constraints-based utilization of sites

In this model, we enhance the 'equal utilization of all sites' and 'optimal utilization of all sites' by introducing a set of constraints. The 'utilization of sites based on constraints' allows project managers to assign tasks to a certain site. Mathematically, the objective function is defined as follows:

$$\text{Minimize} = \sqrt{\text{Variance}} + \sum_{l=0}^{m} \text{S.D.S.U} \quad (5)$$

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IV. CASE STUDY

This section discusses an application of the proposed schedule flexibility analysis to the Obesity Health Clinic System (OHCS). The OHCS allows health team members and patients to create obesity reducing health goals. The goals are added to the 'bank of ideas' and classified under the appropriate category (for example, physical, dietary, etc.). These goals can also be customized according to individual patient needs by the health team. The OHCS also has the 'goal suggestion' feature, which helps the health team to find appropriate goals for a patient according to his health condition.

Table I presents a list of OHCS tasks, planned durations in days and their respective dependencies. Figure 2 presents the CPM network of OHCS.

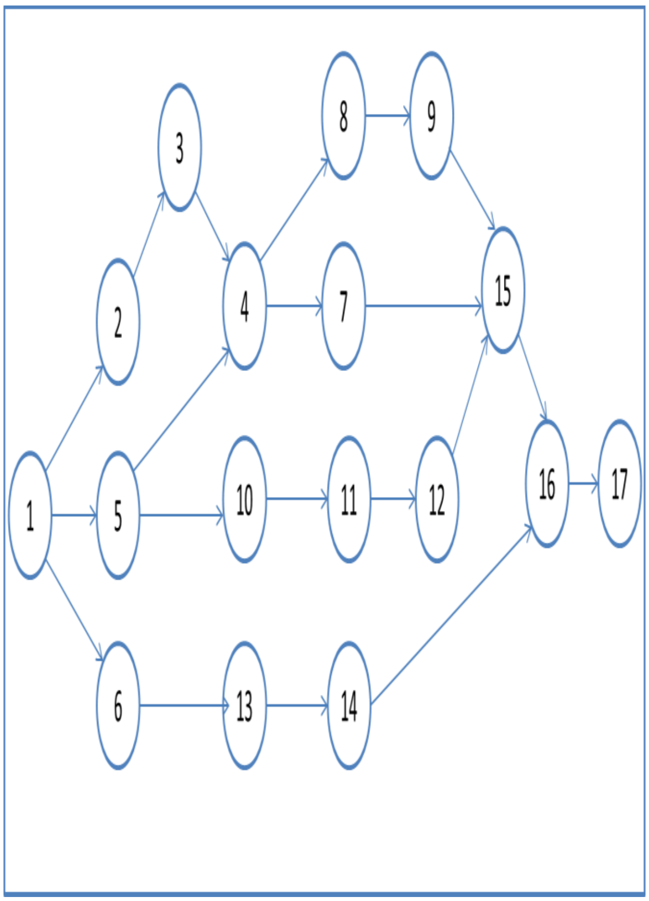

Figure 2. OHCS Activity Network.

Furthermore, Table II shows available resources (in term of man hours per day) at four geographical development sites for the OHCS project.

TABLE I. OHCS TASKS

Task ID	**Activities**	**Duration**	**predecessors**			**Man-Hour Per Day**
1	Source Node	0				0
2	Patient profile	7	1			5
3	Health Team Profile	11	2			4
4	Complete profile features	5	3	5		6
5	Database Implementation	14	1			5
6	Profile Management Screen layout	5	1			4
7	OHCS Reports	9	4			3
8	Goal Management	18	4			5
9	Goal Suggestion feature	21	8			6
10	SQL Queries	20	5			4
11	Implement Store procedures	9	10			5
12	Complete database implementation	5	11			5
13	Goal Management screen layout	5	6			4
14	Complete OHCS Screen layouts	14	13			6
15	Complete OHCS Feature and Database integration	12	7	9	12	3
16	Complete system integration	18	14	15		6
17	OHCS Deployment	6	16			6

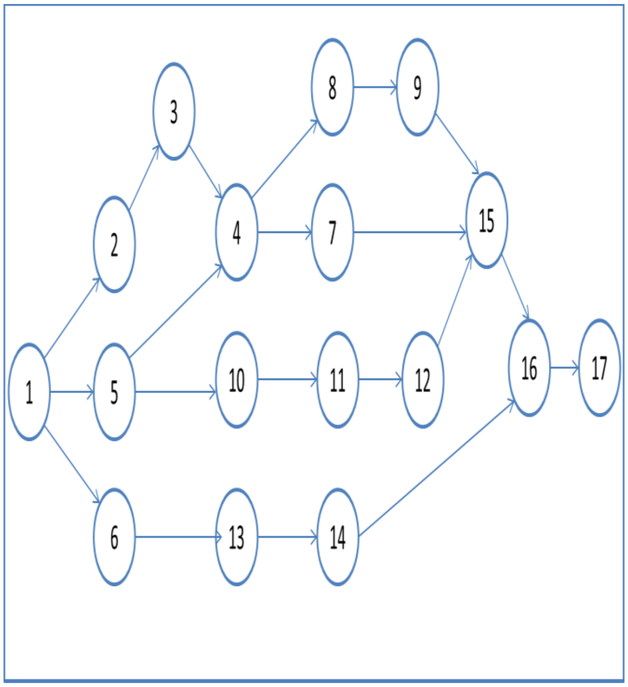

Figure 3. OHCS Activity Network.

TABLE II. OHCS GSD DEVELOPMENT SITES

GSD Sites	A	B	C	D
Resources Available (man-hour/day)	6	4	5	3

The OHCS project activates and project geographically distributed sites, presented in Tables I and II. OHCS project activities and the distributed sites are used as inputs such that all the GSD sites are optimally utilized. We used Evolver [14], a multi-objective optimization tool, to implement the three models for task allocation presented in Section III.

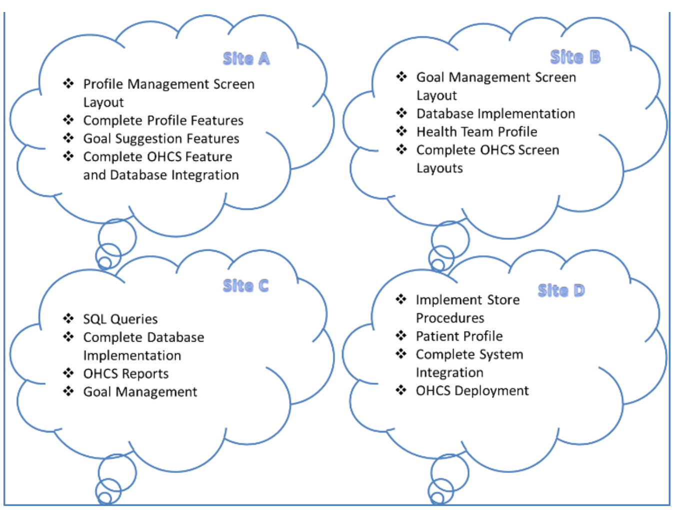

Figure 4. Equal Utilization of Four GSD Sites.

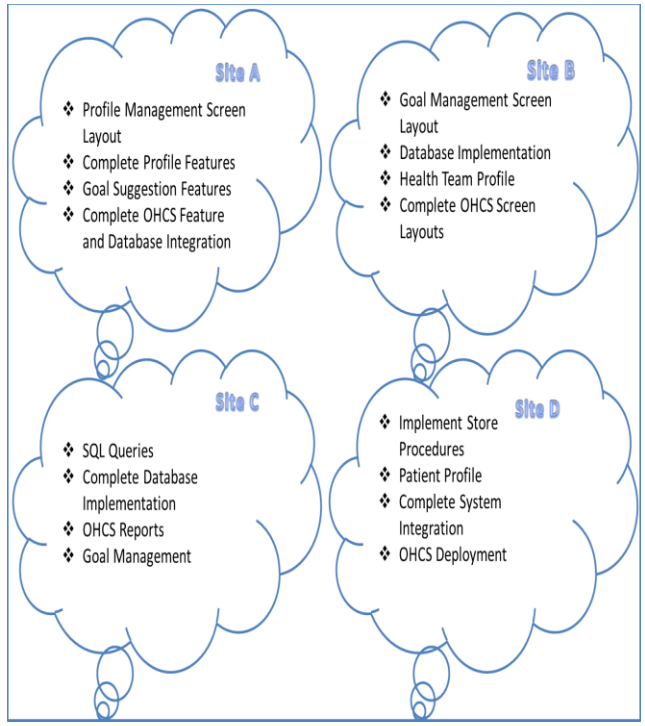

Figure 5. Optimal Utliziation of four GSD Sites.

Figure 3 shows the task allocation of OHCS project to four geographical sites using 'equal utilization of all sites' model. Figure 4 shows the task allocation of OHCS project based the 'optimal utilization of all sites' model. Similarly, Figure 5 shows the task allocation under the 'constraints based utilization of sites' model such that project managers wants to use site A's expertise in interface design and site D's expertise in database implementation.

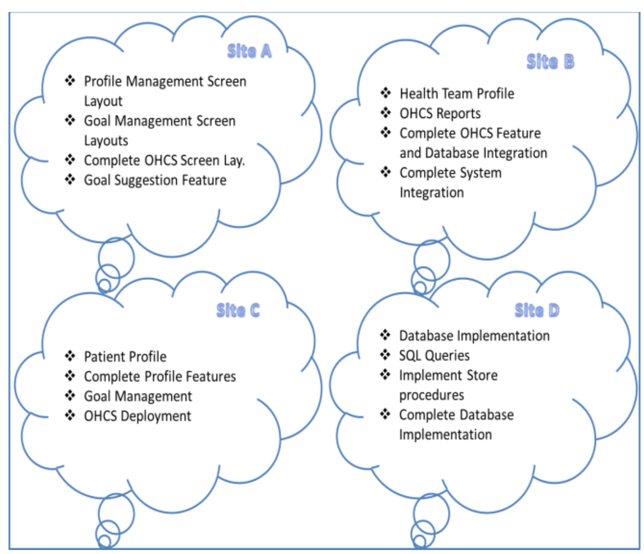

Figure 6. Utilization of four GSD Sites under Constraints.

V. Conclusions and Future work

Global software development approach is adopted by organizations with an aim to reduce development cost, improve overall software quality and increase productivity by having work carried out along the day using follow-the-sun concept. Task allocation is a key phase of GSD projects that directly impacts the benefits of adopting GSD. In this paper, we have presented a task allocation process to equally utilize different geographically distributed sites for a GSD project. The task allocation process uses a multi-objective optimization technique to allocate tasks of a GSD project.

In the future, we aim at extending the task allocation process to handle complex objective functions and improve work distribution among different sites of a GSD project. We also aim to evaluate the presented model using larger case studies.

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