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HUMAN RESOURCE ALLOCATION IN ENGINEERING DESIGN COMPANIES

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The human capital is a major asset for engineering companies. On-time completion of project tasks and cost effectiveness are contingent on proper allocation of human resources. In practice, most engineering mangers assign resources according to availability without considering the level of employee's expertise while making the assignment decision. This may result in lower quality of design production or a difficulty in meeting deadlines in case an employee requires training or coaching. To better attain project requirements, the assignment practice could be improved by including resource characteristics and critical project information. This paper is part of an ongoing study that aims to develop a reliable resource assignment mathematical model that takes into account engineers' years of experience, their level of familiarity with different software programs used by the company, and other task-related attributes. Examples of the latter include scheduled submission date, and range of estimated period required to complete a task. The output of the model consists of assignment variables through pairing a group of human resources to a group of tasks with the objective of minimizing project duration and cost while maximizing resource utilization. Extensions to the model can allow engineering managers to monitor and control the progress of the project or the lack thereof.

Keywords: Project duration, Project cost, Resource assignment, Employee attributes, Project complexity, Resource utilization.

1 INTRODUCTION

Despite the advancements made in technology, machinery, and software programming, large scale design companies are still characterized by their main asset: human resources. The latter play a critical role in determining the level of quality of the company's work, which in turn translates into project success or failure. Nonetheless, companies tend to focus more on the technical perspective of a project and less so on human resources. To be able to survive the competitive market, corporations need to continuously enhance their performance (Garavan *et al.* 1999, Hodgetts *et al.* 1999, Losey 1999) which can be achieved through proper human resource management (Ngwenya and Aigbavboa 2017).

Managing employees is thought to be a troublesome activity that differs from handling capital or technology (Pirzada *et al.* 2013). One form of managing human resources is the process of allocation whereby individuals are assigned to certain tasks within the chosen development projects. This process is peculiarly critical since several attributes relating to the individual need to be taken into account and current allocation practices usually neglect the aforementioned and distribute resources according to the managers' intuition and availability of the resource

(Yoshimura *et al.* 2006, André *et al.* 2011). An employee ends up working on tasks whose skillset requirements do not match the worker's profile, and this translates into inefficient performance throughout the execution of the project. In addition to that, the estimated duration for design tasks may be inaccurate due to the lack of quantifiable features and the uniqueness of projects that leads to imprecise estimation of the effort an individual would need to invest to complete a certain task. Evident consequences of these inaccuracies are schedule and cost overruns (Bashir and Thomson 2001).

The objective of this paper is to develop a robust human resource allocation tool for engineering design companies that bases its assignment decision on resource-related and project-related factors when nominating individuals to work on specific tasks. The tool also aims at (1) making sure the time required to complete the demand of tasks does not exceed the allocated time for each task and (2) minimizing the total cost of engineering work-hours devoted to finalizing the project. The paper is organized as follows. The next section covers the literature on human resource allocation in various disciplines and the tools used to carry out this process. This is followed by a description of the model for resource allocation in design companies followed by a case study that demonstrates how the model works. The final section offers conclusions, discusses limitations of the work, and provides suggestions for future studies.

2 LITERATURE REVIEW

Several studies were carried out to come up with reliable human resource allocation models in different work fields ranging from health-care organizations, software developing companies and contracting companies. These tools were also developed using different methods like goal programming, decision making support system, multi-objective multistage combinatorial optimization models, dependency structure matrix, Taguchi's parameter design, and constraint satisfaction problems, to name a few.

Some examples include studies done by Otero *et al.* (2009) who detected delay in delivery software development projects due to the need for training employees who do not have the required skill set for certain tasks. Such an issue may rise when qualified staff members are preoccupied with other projects/tasks. Thus, Otero *et al.* (2009) developed systematic personnel assignment methods that evaluate the skill sets of employees against required skills for certain tasks using the Best-Fitted Resource approach. Their study, however, only focuses on the skills acquired by each employee and does not include other factors that normally affect the performance of the designer.

Similarly, Silva and Costa (2013) and Tsai *et al.* (2003) analyzed possible human resource allocation alternatives depending on the capabilities of employees and skill requirements for tasks related to software development projects. However, the authors also added the complexity of each project as a factor to be considered to weigh the type and number of professionals needed. Their ultimate goal was to minimize, or at least decrease, the cost and amount of time necessary to complete a project since software design projects almost never meet their deadlines.

Albers *et al.* (2012) handled human resource allocation with the use of Dependency Structure Matrices (DSM), which are normally used for modeling the structure of complex systems for organizational and planning purposes. The used model presents a multi-domain framework of the activities required for product development and a number of human resources responsible for fulfilling these tasks. It elaborates on the effect of different resource allocation options on the flow of information between activities, and how it enhances the dynamic relationships between the objective of a project, the objects used for completing the work and the operation systems. Nevertheless, the model does not discuss the characteristics relating to resources, or whether each

resource is considered as being unique. The main focus is on how dependent the activities are on one another and if they require common resources to work on them.

Kwak and Lee (1997) used a variation from linear programming model, referred to as goal programming (GP) that also aims at minimizing total payroll costs while addressing the needs of patients at a healthcare organization. This technique gives goal constraints in addition to system constraints like minimum payroll goal, physician utilization goal, and physician assignment goal.

The above-mentioned set of studies shows that human resource allocation may be achieved through various methods and requires careful assessment to ensure the success of the service provided by the resource. However, it is noticeable that limited research has been done to create a human resource assignment model specific to engineering design and consultancy companies. These companies generate and review work under various disciplines such as structures, architecture, environmental, transportation, mechanical, electrical, planning and urban development, and façade engineering divisions. As human resources are the underlying assets of these companies, their proper allocation should remarkably enhance the degree to which a project can be considered successful. Previously developed models have not accounted for all resource and project related factors simultaneously. In order to generate more accurate assignment decisions, this study proposes incorporating these factors into the resource allocation model that will be further discussed in the following section.

3 METHODOLOGY

The aim of the human resource allocation model is to assign a pool of resources to a pool of tasks while taking into account the attributes that are related to both. This assignment aims at minimizing the total cost of work-hours spent completing the design tasks and ensuring that the task duration does not exceed its scheduled time.

The individual resources, who will be part of the allocation process are those designers who have up to four years of work experience and who manually perform the design work. They are characterized by the following variables:

- The level of experience the designer has in his/her respective area of specialization. This may take the form of "skilled" or "unskilled";
- The level of familiarity of the designer with the different software programs used by the company to complete the tasks at hand. This may take the form of "novice" or "expert";
- A binary variable indicating the availability of each resource defined by whether or not this employee is already working on a task; and
- The wage corresponding to each employee that depends on the first two variables mentioned above. For illustration, Table 1 corresponds to a range of wages for civil engineers as estimated by the U.S. Bureau of Labor Statistics (BLS) in 2010.

Table 1. Estimated wage of civil engineers as published by the U.S. BLS.

Employee Characteristics	Employee Wage ($/hr)
Skilled & Expert	45
Skilled & Novice/Unskilled & Expert	30
Unskilled & Novice	20

The tasks, on the other hand, are characterized by the following two variables:

- The time period within which the tasks must be completed, which may take the form of a deadline

- The expected time period required by a specific resource to complete a particular task. Each task's duration follows a PERT distribution characterized by an average and a standard deviation. The graph is divided into three zones that mimic the grouping in Table 1. The first group has a time range close to the least amount of time needed to complete the task; the second requires a value close to the average time; and the third needs the greatest amount of time that is estimated based around the highest value in the graph.

Based on the listed variables, the primary assignment solution appoints human resources to specific tasks in a way that guarantees the minimum cost needed to complete all activities in a timely manner. Commercial optimization software programs (e.g., Python or MATLAB) may be used to code this model and reach an optimum solution.

The following assumptions were made when developing the model:

- Every working day is comprised of ten hours;
- Employees are not interrupted while working;
- Each employee is to work on only one task at any given time;
- The level of compatibility between individuals working on the same team does not affect the productivity of each designer; and
- The tasks at hand require only one software program to be completed
- The current version of the model is conceived for a single design discipline

4 CASE STUDY

To illustrate the proposed model, a case study was considered. The case relates to the assignment process of five tasks to ten resources, who works in the same company (a prominent design firm in the Middle East), out of which six are available to perform the activities. Table 2 and Table 3 illustrate attributes relating to the human resources in this firm and those relating to the tasks to be completed, respectively. Table 4 is a result of the two input tables. It shows the expected time required for the resources to complete the tasks at hand. The only resources that are qualified to be part of the model formulation are those who are available. Thus, Table 4 only contains the first, second, fourth, seventh, eighth and tenth resources. From this available pool of resources, the allocation model analyzes which employees are best suitable for completing tasks within the preset timeframe for each activity. For example, it is evident that Task 4 (T4) is very critical since it is due in 30 working hours and only human resource 1 (HR1) can perform it on time.

Table 2. Human resource related attributes.

Human Resource	Resource Availability	Level of Experience	Level of Software Program Familiarity	Wage per Resource ($/hr)
1	1	Skilled	Expert	45
2	1	Unskilled	Novice	20
3	0	Unskilled	Novice	20
4	1	Unskilled	Expert	30
5	0	Skilled	Expert	45
6	0	Skilled	Expert	45
7	1	Unskilled	Expert	30
8	1	Skilled	Novice	30
9	0	Skilled	Novice	30
10	1	Unskilled	Novice	20

Table 3. Task related attributes.

Task	Average Duration (hrs)	Standard deviation (hrs)	Deadline (hrs)
1	30	10	40
2	20	15	40
3	40	13	50
4	35	5	30
5	50	10	50

Table 4. Expected time (hrs) required by available human resource (HR) to complete task (T).

HR/Task	T1	T2	T3	T4	T5
HR1	22	8	30	**30**	41
HR2	**37**	30	52	38	57
HR4	28	18	35	35	50
HR7	32	**13**	40	36	47
HR8	26	15	36	37	**47**
HR10	39	29	**50**	40	57

The optimal solution provided by the model is one where HR1 works on T4, HR2 works on T1, HR4 does not work on any task, HR7 works on T2, HR8 works on T5, and HR10 works on T3 (results are highlighted in Table 4). This assignment combination ensures that all tasks are done on-time and allocation is formed in a way that minimizes the cost of engineering hours spent working on these tasks. The optimum cost to complete all of the activities is $4,890.

5 CONCLUSIONS AND FUTURE WORK

Human resource assignment is a serious process that may have detrimental effects on projects if not implemented properly. Reliable resource allocation in engineering design companies increases the likelihood of meeting project deadlines while maintaining the lowest possible cost of engineering work-hours. This paper builds the case for formulated mathematical model that allows information, related to the company's assets and projects, to be stored making it possible to further enhance this system.

The model may be expanded to look into more than one discipline and therefore account for the interaction between different departments. Other potential extensions to the model may include allowing managers to monitor and control the progress of the project by asking employees to update the status of the initially assigned tasks. The model would then rerun the optimization program to make sure constraints are still satisfied or else, designers would be reallocated to maintain the model's goals.

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