

## **Conceptual Framework of Resource Allocation Procedures and Practices in Construction Projects**

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### **Abstract**

Optimal resource allocation for successful project completion is critical in the field of construction. All construction projects are composed of several concurrent activities, which may comprise of numerous resource constraints. Resource allocation like other management tools strongly influence and act as one of the effective management tool. It is not unusual that some construction projects cost many times their fair value. This practice has a tremendous impact on the economy. The recent economic situation has had further notable effects on construction projects. The detail literature review was conducted to comprehend the fundamentals, related to resource allocation procedures. The key factors for a conceptual framework were identified and further analysed. Resource allocation procedures provide versatile managing tool to allocate resources in construction project. The conceptual framework of resource allocation is recommended for construction projects. The benefits include improved construction management process and resource management system.

### **Keywords**

Resource Allocation, Resource Management, Resource Optimization, Construction Management, Project Management.

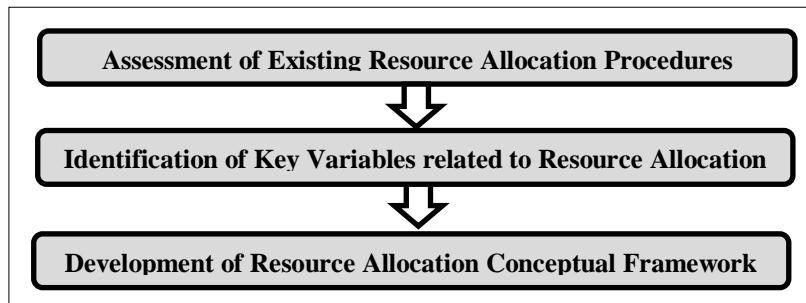
### **1. Introduction**

Resource Management is one of the nine knowledge areas whose practices are defined extensively in PMBOK® Guide (PMI, 2004). The progress and development of nations are usually achieved over a long period of time. Economical, technological, cultural and industrial development may take a century or more to reach a highly advanced level. The construction sector is very important for country's economic growth and infrastructure development. It is not uncommon that some construction projects cost many times their fair value. This practice has a tremendous impact on the economy. The recent economic situation has had further notable effects on contractors. A contractor firm must have the necessary expertise and appropriate tools for effective planning and scheduling of their construction projects.

Following are the identified objectives for this research work:

- To study the *resource allocation* fundamentals and techniques for construction projects.
- To propose a conceptual framework for resource allocation procedures for construction projects.

The research work based on the initial assessment of the resource allocation procedures published and researched. The key variables are identified and conceptual framework is established for resource allocation system (Figure 1).



**Figure 1: Research Framework**

In the current environment of the business, construction companies are more worried about their operations, looking for unexploited yield-boosting prospects and fresh sources of economical discrimination. With this analysis, the managers and executives are determining the processes for managing the resources in terms of manpower, tools, equipment and materials, the process often referred to as “*Construction Resource Management*” (ToolWatch, 2006).

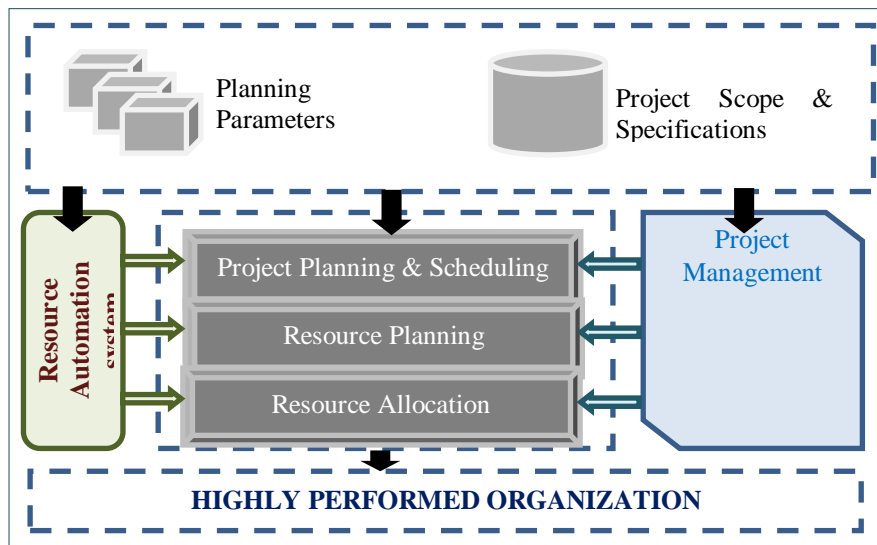
## **2. Literature Review**

The output of the detail literature review is the five key variables, driving the process of resource allocation. Most of the researchers focus their concept of resource allocation procedures to these variables. They include:

- Project Management
- Project Planning and Scheduling
- Resource Planning
- Resource Allocation
- Resource Automation System

Project management includes the management, executives and stakeholders responsibilities, staffing policies, PMO, decision making policies and effectiveness and organizational goals and strategic planning. Project planning and scheduling concerns the activities and skills required, realistic scheduling, internal targets and deadlines, performance, monitoring and scheduling techniques. Resource planning parameters include the resource handling standard procedures, resource breakdown structure, resource availability, adequacy and capacity planning, resource loading, resource histogram, resource calendars and ultimately complete resource management plan. Resource allocation practices involves allocation of resources as per schedule, resource levelling, resource time-cost trade-off, schedule crashing and reallocation of resources, resource constraint scheduling and resource scheduling across multiple projects. Resource automation system helps in the process in not only maintaining the electronic data record of the resource availability, capacity, utilization and performance but also helps in decision making, resource management and planning by using sophisticated software.

During the last two decades, the construction industry has progressed in this trend of improving resource allocation not merely out of interest, but as a means of survival in a more competitive world. However, it is apparent that in the Figure 2, resource planning and resource allocation will still present considerable challenges and sources of frustration to researchers in applied mathematics and operations research.



**Figure 2: Conceptual Framework of Resource Allocation**

## 2.1. Project Management

Project management is the application of various knowledge areas, skills, tools and techniques to different project activities to achieve the project requirements. The concept of the project management system refers explicitly and specifically to a tool that is used by the project management team. The project management team's professional responsibility do include its stakeholders (PMI, 2004). The function of a project manager is to fulfil the requirements of the construction contract with the owner. The project manager is responsible for the quality, costs, and schedule. It is usual for a project manager to be responsible for several projects, depending on the size and complexity of a project. Successful contractors update their costs to date to compare with their estimated costs (Levy, 2009). Project management aspect of resource allocation is linked with several indicators including the project stakeholders, organization staffing policies, project management organization (PMO) and project priorities and selection criteria. The influence of the stakeholders on the project is highest at the start and reduced as the project continues. The phenomenon is that the cost of changes and correcting errors generally increases as the project progresses (PMI, 2004).

Construction industry highly depends on the capabilities and competency of its employees. This dependency of the construction industry is little higher to any other sector. Construction companies need managers for their projects to make management decisions that support with the overall strategic philosophy of the organisation and which fulfil the operational staffing requirements of their individual teams. This staffing function is also known as '*Employee Resourcing*', which contribute the great aspects of the resource management function. Investments on human resource derive performance benefits (Loosemore et al., 2003).

A Project Management Office (PMO) centralizes and coordinates all the management of the projects under its responsibility. Key feature of a PMO include to share and coordinate resources across all the projects under the responsibility as well as centrally monitor all the project timelines and budgets. It also

contributes to the effectiveness of decision making. Project manager generally responsible for the assigned project resources to utmost meet the project objectives, whereas PMO optimizes the use of shared resources of the organization across all the projects under its responsibility (PMI, 2004).

For achievement of the organizational objectives, the management requires the information about the resources available and their effectiveness. They may include equipment, material and money as well as people. Decision must be developed on basis to achieve organizational objectives, and that too with resource allocation decisions. Top management can best judge the relative importance of the organizational objectives while operational and technical managers can better evaluate the performance of various alternatives with respect to the priority objectives of the organization (Forman and Selly, 2001). Project priorities and selection process is a unique criteria for evaluation of various available alternatives. The policies concerning the organizational objective must be clearly defined for selection of best alternative. Basic description of project scope, duration, deliverables and forecast of the resources must be included for the investment analysis and feasibility. The relationship of the project to the organization's strategic plan identifies the management responsibilities within the organization (PMI, 2004).

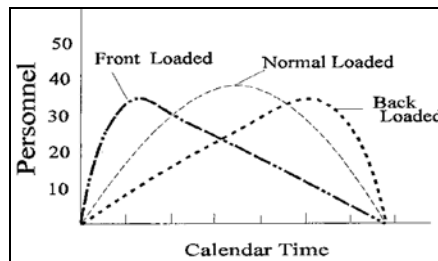
## **2.2. Project Planning and Scheduling**

After project management aspect for resource allocation, second most important significant factor is project planning and scheduling, on which complete resource management plan would be based. A construction project involves number of activities at its various stages, which need number of skills and competency levels. Schedules are key documents in managing the construction projects. A project schedule set up the start date, duration, completion date, and resources need for each activity in the project. Flaws and errors in the schedule may influence the project team to allocate resources to the wrong place at the wrong time or may prevent the parties from precisely evaluating about the project standing on the schedule (Menesi, 2010). The planning process includes various processes including project management planning, the scope, work breakdown structure, activities and their schedules (PMI, 2004). Planning is primarily about thinking ahead. If it is the project manager's responsibility to manage the project as per schedule developed, it is the planner's role to concern about the future. Projects never ever go according to plan. There may be the unforeseen ground conditions. Therefore projects hardly go the way they were scheduled. Project planning and scheduling is a modelling process. Project managers establish a model of the project and proceed through the activities to complete the project (Lock, 2004).

## **2.3. Resource Planning**

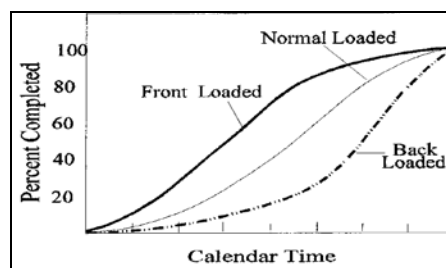
Once the planning and scheduling process is completed, resources are required to be planned on the schedule. In the 1990s, project planning methods gained increasing importance from their applicability to scheduling problems. Different generalizations of the basic resource allocation problems have received growing attention in recent years (He et al., 2005). The need for practical and optimization of resource utilization in the construction industry has increased in recent years as a result of the application of new and emerging construction contracting and project delivery methods (Yang et al., 2010). A Resource Breakdown Structure (RBS) is used to develop a hierarchical list of the resources. Activity lists, resource calendar, and resource estimating are the key RBS tools. RBS is an essential part of any effective project management in general and resource allocation in particular. Managing the project is the organizing project resources components to ensure that they are strategically productive throughout the project duration. Every type of resource is divided into a number of categories or resource-types. This process of categorization continues, until every resource-type is broken down into very manageable, simple individual entities. This develops a better control and management of different departments being easier to handle and supervise. With RBS in place, it is easier to define the total availability of various types of resources for different activities and departments and then manage their utilization (ADA, 2010).

Resource loading is generally the loading of manpower or employees to the project tasks. In resource loading, each employee is assigned a task of a project. Then the employee is assigned other tasks until reaches 100 % booked. Those mean that the resource is fully loaded and can be further employed. With resource loading, a project manager can estimate the total employee's hours for the year. Although the resource cannot be 100 % loaded. Unexpected happenings and non-ideal environment will never be in existence. Resource loading is basically to plan the resource (Bailey, 2010). Resource loading may be more clearly explained with the practical loading curves (Figure 3) and famous ‘S-Curve’. Theoretical Personnel Loading Curve is also referred as Normal Loaded Curve. The Front Loaded and Back Loaded Curves are the result of early and delay in the planned schedule of the projects.



**Figure 3: Practical Personnel Loading Curves (Mendoza, 1995)**

The importance of above mentioned situation is obvious once we evaluate the famous “S” Curve (Figure 4), being plotted percentage of man-hours completed against the scheduled duration of the project.



**Figure 4: "S" Curve (Mendoza, 1995)**

The “S” curve of the normally loaded project has a gradual start and finish, indicating smooth start and finish situation. Now the Front Loaded curve shows the fast project start up and even gradual finish than the normal curve at the end of the project. The personnel resource were made available more at start of the project creating a steep start up at faster pace at the initial stage of the project and completed in time with even lesser man-hours required at the finishing stages of the project. Whereas its vice versa in the Back Loaded curve, where the personnel loaded less at the start and highly at the end, depicting slow pace of the project in the start and steep curve with high pace at the end of the project. Here the important thing to remember is that Front Loaded Projects may slip to the normal loaded and still have the margin to complete the project in time, whereas Back Loaded Projects have little chance to increase their pace at the end as already heavily loaded at the finishing stage of the project (Mendoza, 1995).

Resource histogram consists of bar chart depicting the amount of time for a resource, scheduled to work for certain time period. Availability of resources may be shown as a line for assessment purposes. Vertical assessment bars may depict real amount of resource used as the project advances (PMI, 2004). The resource histogram is a tool that is often used by the project management team as a visual representation of resources and may also contain the comparative feature of resource availability, used for comparison purposes for evaluation of alternatives. They are often used in resource levelling as well as

comparison of time/cost graphs (Lock, 2004). Keeping track of the project activities as per schedules is one of the most necessarily important tasks that are the accountability of the project manager. The resource calendar is specific calendar that lists all of the working days as well as the nonworking days that the project manager require to determine the specific dates on which a typical resource is being engaged or disengaged (PMI, 2004). In numerous computer programs various resources can have a calendar linked with it. Such calendars indicate the days and hours, the resource can be engaged. On non-working days, the tasks are usually not processed unless specified (Reiss, 2007).

#### **2.4. Resource Allocation**

The most complex issue of project planning is resource allocation over time of the project for execution of various activities. On the basis of the duration and the work content, take each task and load them with the required resources over the time, so as to execute the task within the schedule time. Each task is considered in complete isolation. Determining the resource loading profile like this would lead to certain resource conflicts. The simplest solution to this is allocating the additional resources, resulting in additional cost expenditure. However, use of resource levelling and smoothing is advisable here, leading to schedule crashing and re-allocation of resources (Klein, 1999). Resource levelling or resource smoothing is the method of adjusting the timing of the activities within a plan to avoid over-demands for resources. An over-demand occurs when demand for a resource exceeds its availability at any time (PMI, 2004). After levelling, resource demand never exceeds resource availability. There are numerous approaches to the task of resource levelling. To keep the resource utilization minimum is also referred as resource levelling. Project managers and planners have to work hard in dealing with projects. The effective use of resources is very crucial. Expensive and heavy projects machinery is often available in limited quantity and time. Resource levelling reduces the large fluctuations in the resource requirements, reducing the cost (Neumann and Zimmermann, 2000).

Time-cost trade-off has been the issue of research since development of critical path methods (CPM) by end of 50s. Time-cost in a project activity is actually the trade-off between the duration of the activity and its cost expenditure or expediting an activity is possible at the cost of allocating more resources or more expenditure (Vanhoucke, 2005). If a certain activity is a critical activity, trade-off between cost and time can be done to vary the activity. It is possible to consider the various combinations of alternative ways also. If cost is of prime importance, activities could be planned at its lowest possible cost. If time is of prime importance, activities could be planned to speed up to be completed in the best (crash) time (Ammar, 2011). Once a strict deadline is defined on the project completion time, problem arises. In that case, the only possible solution would be the rearranging the tasks and activities within their slack times. If this is not sufficient, then availability of respective resource would be increased temporarily. Time constrained scheduling is concerned with the rearrangement of non-critical activities within their slack times, such that that additional cost incurred is minimized and project duration is not delayed (Klein, 1999). The objective of the resource-constrained scheduling is to develop a schedule in a way that the project is completed within time, considering the restricted availability of resources (Klein, 1999). Resources are often limited. This tends to require the shifting of activities forward in time until resources are available, leading to a consequent extension of the total project duration. When a project is performed under contract, contractual provisions will generally be constraints (PMI, 2004).

#### **2.5. Resource Automation System**

Computers came into use by project managers in late 1960s. Since when there were no planning and control with use of computer (Lock, 2004). At the time computers were not only very expensive but also complicated and large ones. Experts were required to operate it. There were no graphic capabilities in the printers. Now, not only that every person has access to the computer, but also these machines became cheaper and smaller, besides their high capabilities and speed. They are friendly user

and there is huge IT Industry, who is making thousands of software on daily basis. Almost every field of the world has its software to handle the related programs, the activities, the databases, the routines, the monitoring systems, the account systems and even the training programs.

Numerous software have been developed for the construction industry to handle their various departments including, estimation and bidding, planning and scheduling, procurement, inventory and asset management etc. In planning and scheduling the resources, now a days Primavera, Online Project Management, On-track Project Management, Project Portfolio Management, Sure Track, Manage-Pro, Microsoft Project are in use. The computer software can, not only schedule resources but also calculate project costs. The results can be prepared as graphical representation as resource histograms, time/cost graphs or as spread-sheets. Spread-sheets can include cash outflow forecasts also. The resource scheduling capability can even be used to forecast a net cash flow schedule (Lock, 2004).

### **3. Conceptual Framework**

Resource allocation must start with a good solid plan. It cannot be accomplish without defining four essential elements which are materials, people, equipment, and time. Therefore, planning is very essential since many projects can suffer unavoidable delays from inadequate resource planning. In the planning phase, we must identify the required resources needed to complete the project. After we have identified the resources needed to complete the project, we must be able to allocate them in order to undertake the construction operation. When applying resource levelling, we assumed that we have an unlimited supply of resources required for the tasks, but we must remember that the real world situation may be different. The goal of resource levelling is to assign resources to project activities in a manner that will improve productivity and efficiency. As mentioned before, resources are often limited and this tends to shift the activities forward in time until resources become available. There are several software computer applications such as Microsoft project planner, Primavera, Sure-track and other programs that are commonly used for resource allocation and levelling purposes. Primavera project planner among them is the software application that most project managers use nowadays in Pakistan. The output of the detail literature review is the five key variables, driving the process of resource allocation. Most of the researchers focus their concept of resource allocation procedures to these variables. They are suggested as *Conceptual Framework* for resource allocation procedures and practices. These include:

- Project Management
- Project Planning and Scheduling
- Resource Planning
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The conceptual framework with its five key variables is proposed to be considered as standard practices.

### **4. Conclusion and Further Works**

The construction industry today is facing more and more challenges than ever before. This includes increased complexity of projects, more costly project and stricter rules and regulations under which to operate. Without the proper resource allocation, one will pay the price for late job completions and cost overruns. The construction industry has progressed in this trend of improving resource allocation not merely out of interest, but as a means of survival in a more competitive world.

An interview based survey of contractors of Pakistan for construction project has been conducted and in process for its test of the validity of the conceptual framework for the identified key factors. Research and analysis are also conducted to study the effectiveness of the key factors and its comparison with the organizational performance. The completed work will soon be ready for the further publication with its detailed analysis, conclusions and recommendations.

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