RESOURCE ALLOCATION POLICIES, PROCEDURES AND PRACTICES FOLLOWED BY CONTRACTOR FIRMS

By

Muhammad Jawad Ansari
(2009-NUST-MS PhD CE&M-26)

A Thesis submitted in partial fulfillment of
the requirements for the degree of

Master of Science
in
Construction Engineering and Management

DEPARTMENT OF CONSTRUCTION ENGINEERING AND MANAGEMENT
NATIONAL INSTITUTE OF TRANSPORTATION
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
NATIONAL UNIVERSITY OF SCIENCES AND TECHNOLOGY
SECTOR H-12, ISLAMABAD, PAKISTAN
(2011)

This is to certify that the

Thesis entitled

RESOURCE ALLOCATION POLICIES, PROCEDURES AND PRACTICES FOLLOWED BY CONTRACTOR FIRMS

Submitted by

Muhammad Jawad Ansari

(2009-NUST-MS PhD CE&M-26)

Has been accepted towards the partial fulfillment

of

the requirements

for

Master of Science in Civil Engineering

Dr. Muhammad Babar Khan

School of Civil & Environmental Engineering

National University of Science & Technology, Islamabad

DEDICATION

Dedicated to my beloved Father and Mother for their continuous support and prayers. And to my wife, son and daughter, who had put up with so much while I worked on this thesis. Grateful to my brothers also who helped so much in the effort as well.

ACKNOWLEDGEMENTS

This acknowledgement will hardly justify my sense of profound veneration for my revered supervisor Dr. Muhammad Babar Khan for his indelible help, unprecedented enthusiasm, constructive criticism and perceptive encouragement.

I am highly honored to Dr.Rafiq Muhammad Choudhryfor his expert guidance during my research. I sincerely thank him for his valuable suggestions, thoughtful criticism and sustained encouragement during pursuance of my master program.

No words can suffice my feelings of immense gratitude to Dr. Muhammad Irfan and Lecturer MoinUd Din for his whole hearted, ever available help, technical acumen, moral support and comradeship. Without their untiring help and prompt advice, I could not have completed my statistical analysis in time.

I am thankful to the Faculty of Department of Construction Engineering and Management for the guidance and support in every aspect for the completion of this thesis. I am thankful to National University of Sciences and Technology for the financial support of the complete research work. Acknowledge is also addressed to all the contractor firms of Pakistan who have whole heartedly participated in the survey with true letter and spirit.

I extend special thanks to my parents and wife for their help and strength owing to which I could work peacefully.

(Muhammad Jawad Ansari)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Resource allocation is one of the fundamental elements for successful project completion. An optimal resource allocation is critical in the field of construction and acts as an effective management tool in construction projects. Construction projects are composed of several concurrent activities, which may comprise of numerous resource constraints. Resources are often limited and activities need to be adjusted in a way that resources are available to the relevant activities at the right time and right place and project duration is respected as planned. This research study explored the process of resource allocation. Project management, project planning and scheduling, resource planning, resource allocation and resource automation system are identified as basis for a conceptual framework for resource allocation procedures. An interviews based survey is conducted to figure out the trends and practices followed by contractor firms in Pakistan. The collected data is analysed to get the perception of the contractor firms for resource allocation practices within the conceptual framework identified. The study indicates that 16.9% of contractor firms perceived project management of significant importance and 61.5% of contractor firms hardly plan their projects on schedule. Furthermore, 7.7% of contractor firms agree to plan their project resources and 10.8% of contractor firms practice resource allocation procedures. Only 1.5% of contractor firms agree to incorporate the software based resource allocation procedures and has incorporated the automated systems. Resource allocation procedures are barely practiced by contractor firms. Resource planning and scheduling need to be emphasized more as compared to other factors. The fact supports that resource allocation practices can play vital role in influencing the performance of the organization in construction projects. The resource allocation aspects are found to be directly proportional to perceived performance of the organizations. The conceptual framework is analysed and recommended of resource allocation practices for construction projects in Pakistan.

Chapter 1

INTRODUCTION

Construction activities invariably require the combination of inputs of materials, equipment, labour and human intellect. The presence of modern-day infrastructure and ancient wonders of the world related to physical facilities and structures both stem from construction. It is another reality that development of a country or a region is directly proportionate to the construction activities. 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. Pakistan had started to attempt towards the achievement of that level of development hardly in a decade or so. The Pakistani construction sector contributes 2.3 % of the GDP in 2009-2010. Share of Pakistan's construction sector in 1967-70 was 4.2% as against the current share of 2.3% which implies that there is a declining trend in the Pakistan's construction sector during the couple of years (IPS 2011). At present the situation is such that Pakistani constructors, although they are in large numbers, are unable to undertake most of the mega-projects in Pakistan – not because of the lack of potential but due to the absence of required support and effective measures. The impediments faced by the Pakistani constructors are summarized in the report of the experts' meeting on national experiences with regulation and liberalization held in Geneva from October 23-25, 2000 under the auspices of the United Nations Conference on Trade and Development (UNCTAD) entitled "Experience of Pakistan,"

The construction sector is very important for country's economic growth and infrastructure development. Construction industry is one of the important sectors in any nation's development plan. It not only effects the country's economic growth, but also the infrastructure development (APCA 2010). The volume of construction is an indicator of a nation's progress and economic prosperity. Construction is the second largest sector in Pakistan's economy after agriculture. In Pakistan, roughly 30-35% of employment is directly or indirectly

attached with the construction industry. Pakistan has experienced a construction boom of unprecedented volume during the current decade, attracting construction professionals from all over the world, witnessing immense infrastructure growth and development. An intellectual and behavioural change in the mind-set of all participants in the construction process is necessary if the construction sector has to improve its performance and competitiveness (Farooqui and Ahmed 2008).The construction sector has experienced drastic changes which have resulted in problems such as instability in the quality of buildings, lower profits and unavailability of projects in the market. This situation has led to a decline in the construction process increasing the problems including project delays, quality construction and mismanagement of resources. This means that what happened to the construction industry must have been a matter of national concern. The above mentioned factors were the reasons for this study, which have made this area of research an important field for future improvement in the construction sector in Pakistan.

1.1 SIGNIFICANCE OF THE STUDY

A contractor's success is dependent on his ability to accomplish projects in the most economical manner. They can achieve this objective by managing their available resources effectively and efficiently. One of the methods of being competitive and qualified is to plan, schedule and control construction operations, while maintaining the same or improved quality of work. Generally, achieving the main target of cost control through planning, scheduling and managing the resources will help the contractors in developing opportunities to get new jobs and to survive in the future. Owners and clients of construction projects may be directly affected by delays in the construction contract completion time. Delays may require expenditures beyond the project budget and resources. For effective project control, a contractor should be aware of project progress, actual job conditions and methods of relevant financing and ultimately the correct allocation of resources in a timely manner. All of these benefits help construction parties to improve the construction management process and reduce the chance of delay, litigation, claims, conflict and other future diverse actions.

1.2 PROBLEM STATEMENT

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. They are forced to be more efficient in running their construction businesses. Therefore, a contractor firm must have the necessary expertise and appropriate tools for effective planning and scheduling. Due to the transfer of technology between developed and developing countries occurred via other channels such as the literature provided by education centres, the exchange of technical staff, and from research agencies, led the contractor firms having many different techniques and approaches at hand(Schwendt 2005). This will give opportunities to progress in the trends of optimization of resource allocation as a means of survival in the construction sector of this country, in a more competitive scenario.

1.3 OBJECTIVES

Following are the identified objectives for this research work:

- To study the *resource allocation* fundamentals and techniques for construction projects and identify a conceptual framework of *resource allocation* procedures.
- To conduct an interview based survey, based on the conceptual framework identified, of contractor firms and ascertain the *resource allocation* policies, procedures and practices followed within the organization.
- To evaluate the identified procedures and practices of re*source allocation* by contractor firms using statistical analysis.
- To propose a conceptual framework of *resource allocation* procedures and suggest the improvements in the resource allocation practices for construction projects in Pakistan

1.4 SCOPE OF THE THESIS

The scope of the research is “CA Category” (No Limit) contractor firms of Punjab and Islamabad, registered with Pakistan Engineering Council (PEC). The interviews are conducted with the senior management level, including senior project managers, construction managers, directors, managers operations and chief executives or chairman.

1.5 STRUCTURE OF THE THESIS

The thesis is divided into five chapters. *Chapter 1* presents an introduction to the resource allocation. The significance of the study in relation to the national need have been discussed. It also includes the objectives and scope of this research study. *Chapter 2* covers the thorough literature review of resource allocation procedures for construction projects. The basic fundamentals have been elaborated and gap is analysed with reference to the environment in the current scenario. *Chapter 3* describes the research methodology adopted for collection of the data and strategy for statistical analysis. *Chapter 4*discusses the statistical analysis and results of the interview based survey conducted. Various data analysis techniques have been utilized including test of normality, friedman test, spearman’s rho and descriptive statistics using SPSS 17.0 (Statistical Package for the Social Sciences, Version: 17.0). It is then followed by the discussion based on analysis and results. *Chapter 5*summarizes the main conclusion and recommendations formulated for the construction industry of Pakistan.

Chapter 2

LITERATURE REVIEW

2.1 INTRODUCTION

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). Resource allocation in project management date back to 1960(Rees 1963; Spencer 1969). The early work was concerned with three types of resource allocation problems(Schwendt 2005):

- The time-cost trade-offs problem
- The project duration problem
- The resource levelling problem

The *time-cost trade-offs problem* is a multi-mode resource allocation problem which arises when certain activity durations can be reduced at the expense of higher direct cost(Ammar 2011). The project budget is then regarded as the resource to be allocated.A survey of multi-mode resource allocation problems, including different types of trade-offs between the durations, resource requirements, and direct costs of activity execution modes, can be found in various research works(Ammar 2011; Geem 2010; Vanhoucke 2005). The *project duration* problem consists in scheduling the activities of a project, subject to the limited availability of renewable resources like manpower or machinery such that all activities are completed within a minimum amount of time(Eldosouky 2001; Ibbs and Nguyen 2007; Lo and Chen 2007; Schwendt 2005). The objective when dealing with a *resource levelling* problem is to "smooth" the utilization of renewable resources over time as much as possible, within prescribed maximum

project duration(Easa 1989; Hariga and El-Sayegh 2011; Neumann and Zimmermann 1999). The early procedures for resource levelling offered were based on sequentially moving in time slack activities(Spencer 1969). In the following years, a great deal of effort has been devoted to heuristic and exact algorithms for resource allocation and management (Chan et al. 1996; Doulabi et al. 2010;Liu et al. 2005). 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; Jiang and Shi 2005;Mingozzi et al. 1998). 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).

Resource management is one of the nine knowledge areas whose practices are defined extensively in PMBOK® Guide (PMI 2004).It is the system including planning, implementing and controlling the resources to fulfil the desired objectives. Basic objective of resource management concerns the supply and support the field operations in order to meet the planned time schedule and optimal cost expenditure (Sengupta and Guha 1995). Resource Levelling helps the managers to manage the resource over the project duration in a way that project resource demands do not exceed the available resources (Reiss 2007). Resource levelling aims at minimizing the resource usage fluctuations, which is accomplished by moving non-critical activities within their floats. The project duration is fixed and is not affected by the levelling. Most of resource levelling techniques assumes that activities cannot be split. Although this assumption is valid for most construction activities, but there are activities that can be split to achieve better resource levelling. There is an added cost associated with splitting such as start-up and restarting costs of the activities(Doulabi et al. 2010; Hariga and El-Sayegh 2011).

2.2 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. Project manager are often assisted by the project superintendent, who is responsible for the daily routine activities and operations on the site. It is usual for a project manager to be responsible for several projects, depending on the size and complexity of a project. One of the key functions of project management, along with quality control and adherence to schedule, is allocation of resources in a timely manner within budget and cost (Levy 2009). Project management is a significant variable, which highly influence the resource allocation practices and procedures.

2.2.1 Project Stakeholders

Project stakeholders may include individuals as well as organizations that are involved in the project in one way or the other, or those having any interest concerning the project execution or completion. The key stakeholders of the organization are project managers, customers or users, project team members, project management team and sponsors. There are various names and types of stakeholders, including owner and investors, internal and external, seller and contractors, team members and their families, government agencies and media outlets. The key stakeholders must be identified by the management team, and must be taken care of the obligations and prospects, and manage their influence as per the requirements to ensure a successful project(PMI 2004).

Stakeholders have varying levels of responsibility and authority when participating on a project, which may include financial support, human resource supply, equipment holding and material supply. The stakeholders may have negative or positive influence on project resources. 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).

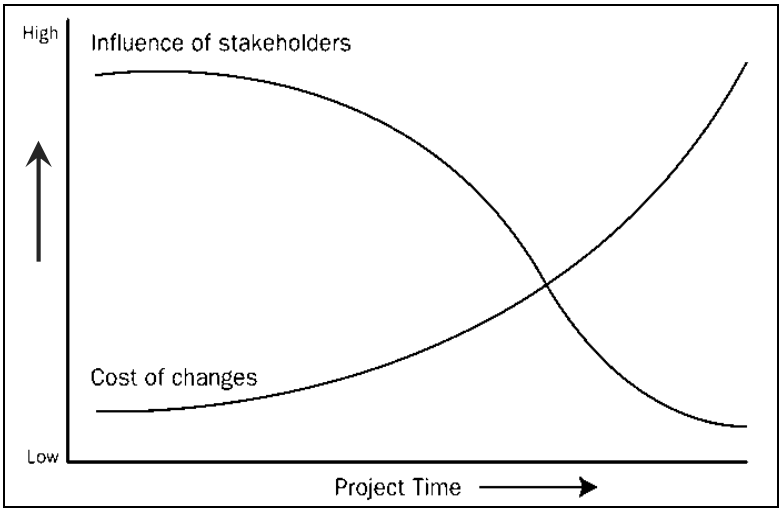

Figure 2.1. Stakeholders' Influence Over Time (PMI 2004)

2.2.2 Staffing Policies

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 organization and which fulfil the operational staffing requirements of their individual teams(Loosemore et al. 2003).

This staffing function is also known as ‘employee resourcing’, which contribute the great aspects of the resource management function. Employee resourcing activities intend to make sure that the true numbers of employees with the required skills and competencies are in the right place at the right time. Employee training and development should also closely interact with staffing and

performance activities. The organizations often benefit from encouraging newcomers with fresh ideas and approaches. Investments on human resource derive performance benefits.(Loosemore et al. 2003).

2.2.3 Project Management Office (PMO) And Decision Making Policies

A Project Management Office (PMO) centralizes and coordinates all the management of the projects under its responsibility, may also know as “PMO”, “Project Office” or “Program Office”. 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).

PMOis the most common organizational structure for implementation of projects, reason being that they have proven the value of having an organizational centre for project personnel, project practices, and project resources. Organizations that intend to success as the top performers can see rapid improvement by creating an effective and competentPMO, where project management methodology, the development and allocation of resources all work in concert(PMSolutions 2009).

2.2.4 Organizational Goals and Objectives

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. The relative importance of various objectives must be made to create a rational resource allocation. 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 objectives also include the measurable success criteria of the project. It may include costs, schedule and resource allocation. Every project has definite beginning and an end. The end is reached when the project objectives have been achieved (PMI 2004).

2.2.5 Project Priorities and Selection

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).

2.3 PROJECT PLANNING AND SCHEDULING

A construction project involves number of activities at its various stages, which need number of skills and competency levels. A close coordination and relationship among the various activities would be necessary to make successful schedule for a project to be completed within time and budget (Sengupta and Guha 1995). 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 (PMI 2004):

- Project Management Plan
- Planning Scope
- Creation of Work Breakdown Structure (WBS)

- Activities Definition
- Activities Sequencing
- Activities Durations
- Schedule Development
- Graphical Representation of the Schedule

Planning is primarily about thinking ahead. If it is the project manager's responsibility is 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 are always deviations, hesitations, and interruptions. There are a number of things which become the hurdles to make the project go as per schedule. Things may arrive late, or not as per the specifications. There may be the unforeseen ground conditions. The more the future we look the less clear it gets. 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 or tasks to complete the project (Lock 2004).

In general, the scheduling of projects is concerned with the development of timetables, i.e., the establishment of dates during which the jobs or activities required to complete the project will be executed. The most widely used scheduling approaches are based on forming a network that graphically represents the relationships between the activities of the project. The amount of float or slack time associated with each activity i.e., the amount of time its duration may be prolonged or delayed without increasing the project duration, can be calculated. The activities having no slack are regarded as critical activities and have to be given particular attention by the project manager. Delaying the critical activity would delay the overall project duration. It is very essential that project is monitored regularly in all its aspects for its time duration and quality. Planned performance must always be compared with the actual progress regularly to monitor the deviations from the schedule and budget (Klein 1999). There are number of scheduling techniques available to plan the construction projects. The

Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT) are the two major techniques widely used:

2.3.1 Critical Path Method(CPM)

The most widely and successfully used technique for scheduling the projects. Use and application of this technique has been developed enormously. Its history date back to 50s. During the mid to late 60s, it was claimed as a complete project management tool. The use of CPM then becomes common in time-cost trade-offs, resource levelling and scheduling across multiple projects. It also helps in crashing the schedules, once the critical activities change the critical paths. CPM analysis has gained importance because of its accuracy in the delay analysis (Kelleher 2004).

2.3.2 Program Evaluation Review Technique (PERT)

PERT was created as a tool for evaluating the likelihood of achieving the project completion on time. It is basically intended to assist in planning when no historical cost or time data are available, with which an estimate can be made for overall duration and cost. PERT is used for planning and controlling new product development and research projects where the uncertainty associated with cost and schedule is evaluated. PERT is primarily a decision support system that do not optimize decisions but helped managers assess the effect of possible options (Baker and Trietsch 2009). It was originated to plan projects comprised of unknown events. PERT is also considered a probabilistic method because of its probability process into the computation procedures (Moder et al. 1983).

2.4 RESOURCE PLANNING

Resource planning can be completed without the required resources for the project scope i.e., materials, people, equipment and time. To keep the project as per schedule, material, labour and equipment required is necessary to be delivered at the right place and at right time. Most of the projects suffer just due to

inadequate planning of resources. To identify the quantities and type of resources is very crucial for resource planning. Resource information and database must be established to plan any project. In addition to the current market conditions, the pricing trends and availability of the material along with the vendor lists is also necessary to establish the resource database. That resource database would be precious in formulating the project resources plan. It is important that all the material, manpower and equipment required needed for the project is covered in the resource management plan(Mendoza 1995).

The demand of resource must be carefully planned and proves be defined for the demand and request process. Resources are required to be delivered at the defined place and time. Smoothing of resource is always attempted so as to improve the resource utilization by adjusting the timings of the activities within their floats. In addition, over-timing by labour and subcontracting is also utilized to smooth the resource in its utilization (Reiss 2007).

2.4.1 Resource Breakdown Structure

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. RBS is part of resource management. Every hierarchical level lists number of resources that are required for execution of various activities. Every type of resource is further divided into 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 or departments and then manage their utilization (ADA 2010).

2.4.2 Resource Loading

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 be100 %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 theoretical and practical loading curves.

2.4.2.1 Theoretical Loading Curve

The simple form of theoretical loading curve is the trapezoid as shown below in Figure 2.2. The curve is plot as personal versus schedule time of the project. The most ideally plan the project is like immediately staff the average number of manpower on day one, continue through the duration of the project until the last day of the project, which is practically not possible due to number of reasons. In actual, practical loading curve tend to make a bell shape instead of trapezoid. The area under the curve is the value equal to total number of man-hours required to complete the project (Mendoza 1995).

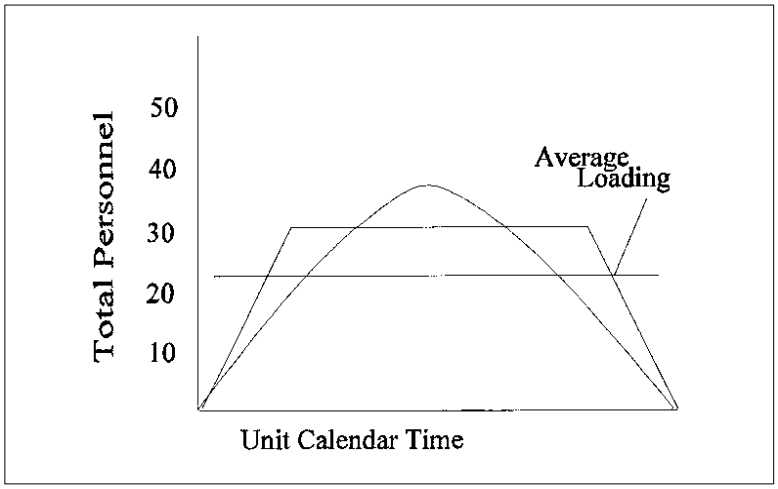

Figure 2.2. Theoretical Personnel Loading Curve (Mendoza 1995)

2.4.2.2 Practical Loading Curve

Theoretical practical loading curve is also referred as *normal loaded curve*. The other two curves shown below in Figure 2.3 are the *front loaded* and *back loaded* curves respectively. Now these front loaded and back loaded curves are the result of early and delay in the planned schedule of the projects.

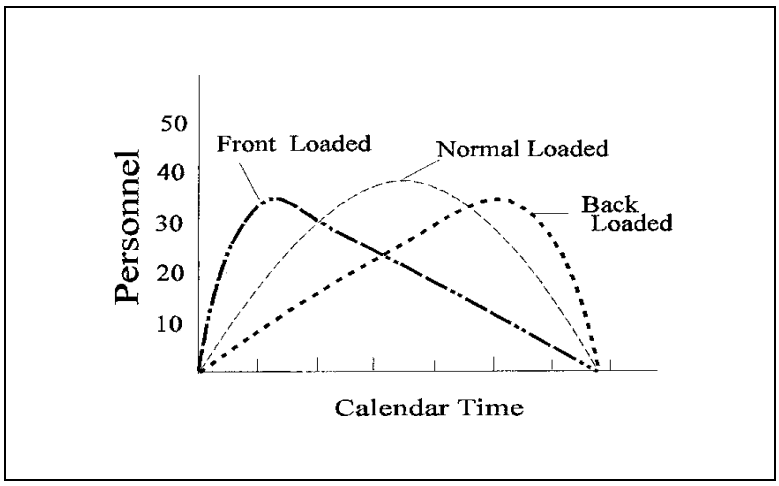

Figure 2.3. Practical Personnel Loading Curves (Mendoza 1995)

The importance of above mentioned situation is obvious once we evaluate the famous "S" curve, being plotted as percentage of man-hours completed against the scheduled duration of the project, are shown below in Figure 2.4.

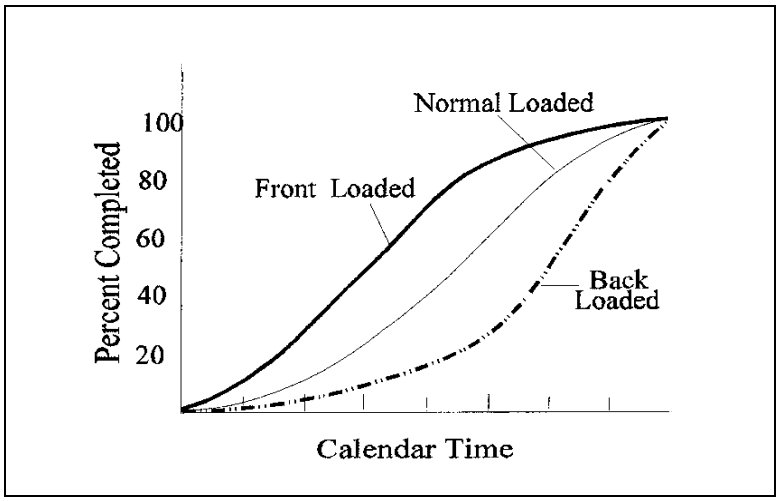

Figure 2.4. "S" Curve (Mendoza 1995)

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 resources 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. It is 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).

2.4.3 Resource Histogram

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 and cost graphs (Lock 2004). Resource histograms are useful instruments to estimate precisely what resources are obtainable, what resources are being exhausted at the current time (or any required time for the information), and how extensive those resources are expected to be engaged(Reiss 2007).

The number of workers needed by each task is written in each bar of the chart as shown in Figure 2.5 below. Using this manning data, we can construct a time-based graph showing the total number of workers needed on each day of the project. This is called resource histogram(PMI 2004).

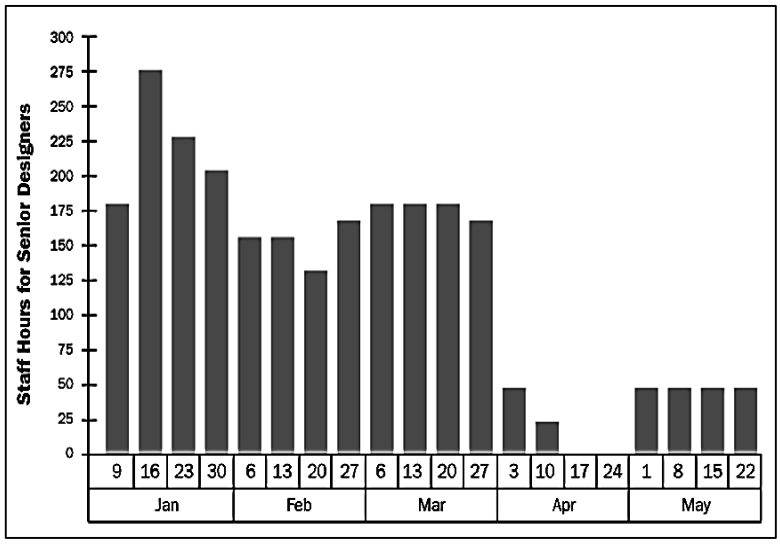

Figure 2.5. Illustrative Resource Histogram(PMI 2004)

A separate histogram is needed for each resource, equipment utilization and labour assignments. The histogram is based on every task starting at its earliest start time and the resource being used for the complete duration of the task (Mendoza 1995). The "*resource histogram*" is the most significant means used during resource levelling. Every bar on the histogram calculates the number of resources, required for that day. To generate the resource histogram, commence with a fenced bar chart (Tutor 2007).

2.4.4 Resource Calendars

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).

2.5 RESOURCE ALLOCATION

The most complex issue of project planning is resource allocation over time of the project for execution of various activities. At the project execution phase, the project schedule is implemented by monitoring and continuous supervision of the project management team. In case of deviation from schedule, the resource allocation has to be performed again (Schwendt 2005).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).

2.5.1 Resource Levelling or Resource Smoothing

It is the method of adjusting the timing of the activities within a plan to avoid over-demands of 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 for resource levelling besides to keep the resource utilization minimum. 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).

2.5.2 Time-Cost Trade-Off and Schedule Crashing

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. We can also consider an optimization problem with time-cost and trade-off problem as well, to simultaneously minimize the project cost and project time (Geem 2010).

Traditional time-cost trade-off analysis presumes constant value of activities' cost along project time span. However, value of money decreases with time, and therefore discounted cash flows should be considered when solving time-cost trade-off optimization problem. 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). It may include overtime, running of second shift or alternate equipment to accelerate the work. However, these alternatives may costs. Considering the "buying time" with time-cost trade-off analysis in order to avoid some penalties or liquidation damages might be useful for late projects. The anticipated additional profit for early completion bonuses may be of prime importance at times. The purpose of the time-cost trade-off analysis is to decide, which activity to "crash", to maximize the overall job profit. Decreasing the duration of the project may increase the cost, whereas increasing the duration enhances the overhead cost associated. The time-cost trade-off helps to find the sweet-spot between increasing costs of specific activities and decreasing overall project costs(Tutor 2007).

2.5.3 Resource Constrained Scheduling

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).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).

2.5.4 Multi-Project Scheduling and Resource Allocation

Scheduling and allocation of resources to multiple projects is further complex than for the simple small projects. The general approach is to consider various projects as if they are the components of a single project. Another way of attacking the problem is to consider all projects as completely independent. These two approaches direct to different scheduling and allocation outcomes. For either approach, the theoretical basis for scheduling and allocating resources is essentially the same. When there are numerous projects, having respective sets of activities, target dates, and resource constraints, scheduling of multiple projects under resource constraints become even more difficult to work out(Le 2008). The multi-project problem involves determining how to allocate resources and set a completion time for a new project that is added to an existing set of on-going projects. This requires the development of an efficient, dynamic multi-project scheduling system(Mendoza 1995).

2.6 USE OF COMPUTER APPLICATIONS

Computers came into use by project managers in late 60s. Since when there were no planning and control using computer(Lock 2004). At that 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 softwares 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.

2.6.1 Resource Planning

Numerous softwares 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. Most of the softwares are friendly user and capable of making the resources allocation and management plans electronically, thus saving lot of time. The computer softwares can, not only schedule resources but also, calculate project costs. The results can be prepared as graphical representation as resource histograms, time and 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).

A great characteristic of computer-generated schedules is that they can easily be changed to take account of progress or changes to the project. Changing any chart produced by manual methods can be extremely tedious, but the computer makes such changes almost too easy. If the computer is given no information on project working hours, it will probably use a default calendar contained within the software, which is based on working from Monday to Friday each week. The computer will probably assume a working weekday of eight hours. However, some programs can mix days, hours and even minutes in the same schedule. It is far better to use just one kind of time, such as hours, days or weeks(Lock 2004).

2.6.2 Resource Allocation and Levelling

Resource plans can refined by re-allocating resources or defining specific lags and durations to reflect the actual start and end dates for resource use. If resource use is nonlinear, we can use a resource curve to accurately define resource distribution across the activity. If resources are still overloaded, we can level them(Mendoza 1995).Resource levelling feature is used to redistribute critical resources across the schedule. Resource levelling compares the allocation of resources to availability and delays certain activities to remain within these limits. Resource levelling does not change activity durations or resource requirements; it can, however, delay schedule dates. During levelling, software reschedules activities whose combined resource needs exceed the availability limits defined. Before an activity can be rescheduled, all its predecessors must be completed, and all the necessary resources for the activity must be available for the entire duration of the activity. Software delays the activity until both requirements are satisfied. One can level the entire project. Additional reports can be produced, such as a tabular schedule, to examine the effects of levelling on the entire schedule. An additional option enables us to smooth resources based on time or resource constraints. Resource smoothing uses positive float to minimize sharp changes in resource use. During non-time constrained, smoothing software makes several attempts to schedule an activity within the maximum availability limit of the resource, thereby reducing the possibility of delays. When time is more important than resource availability, time-constrained resource smoothing automatically doubles the maximum resource limit in an attempt to schedule the activity without delays. Once resources are levelled, the levelled dates replace the current schedule dates for the project. If we calculate the schedule, software replaces the levelled dates with the schedule dates without the effects of levelling. Resource levelling helps us evaluate options and does not produce optimal solutions. Rather than accepting the results of any levelling run at face value, we should consider alternatives. Although there are many software applications as well as computer programs that can help us with resource levelling, Primavera project planner is the one software application that most of the project managers use today. This

application has managed to re-allocate resources or juggle the schedule to resolve conflict between activities that use the same resources. It also helps us to level our resource plan and examine the resource use to determine whether the plan contains hard to manage peaks and valleys(Mendoza 1995).

2.7 CONCEPTUAL FRAMEWORK

The output of the detail literature review is the five key variables already discussed, driving the process of resource allocation. Most of the researchers focus their concept of resource allocation procedures to these variables (Klein 1999; Levy 2009; Lock 2004; Loosemore et al. 2003; PMI 2004; Reiss 2007). 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 scheduling of activities, competent skill required, realistic scheduling, internal targets, project performance and monitoring. 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. Project management involves from the inception until completion of project influencing the planning, scheduling and allocation of resources. Resource automation

system helps in planning, execution, record keeping and managing the resource allocation process in a systematic way. The graphical representation of this conceptual framework is illustrates below in Figure 2.6.

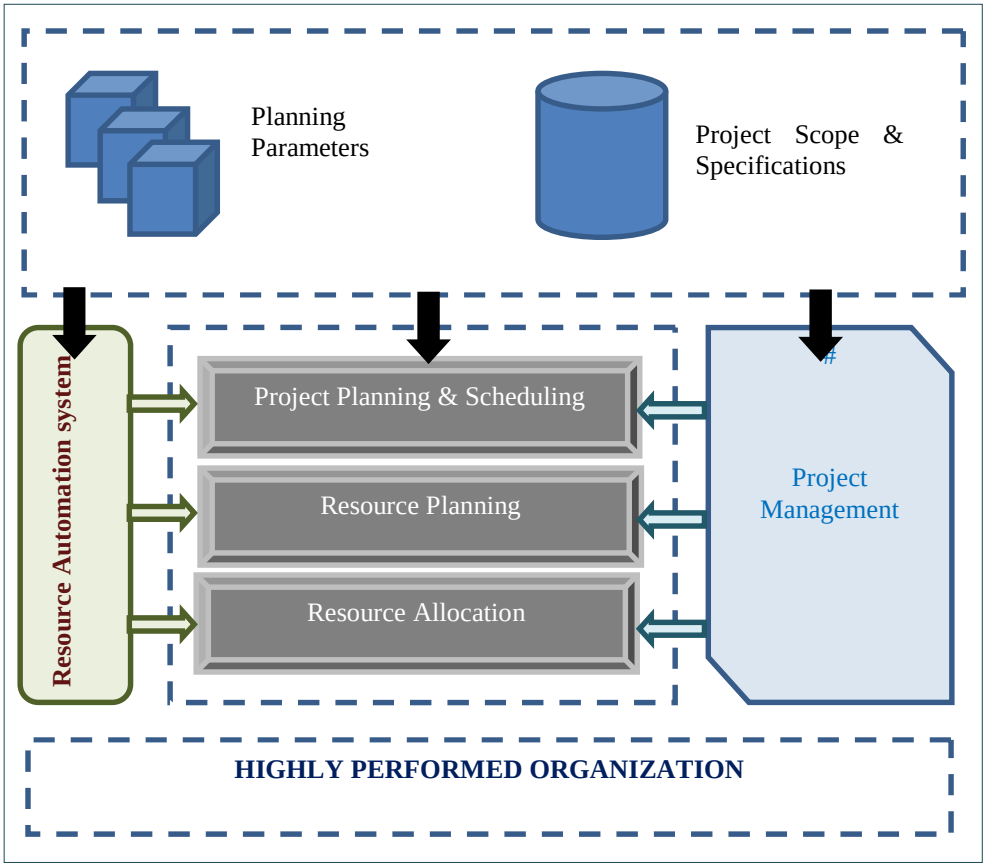

Figure 2.6. Conceptual Framework of Resource Allocation

2.8 SUMMARY

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. 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.

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 future, resource planning and resource allocation will still present considerable challenges and sources of frustration to researchers in applied mathematics and operations research.

Chapter 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter include the outline of the methodology planned and conducted. Detail of the sample size selected and computed is also mentioned. This is followed by the detail procedure for development of the questionnaire. The pilot study was also conducted to validate the questionnaire for the finalization of the developed questionnaire. The data collection strategy is mentioned in detail followed by the data analysis strategy.

The method used for this research is initially the literature review followed by the interview based survey of the contractor firms. This will identify the resource allocation policies, procedures and practices followed by the local contractor firms. The selection of such an interview based survey and ending up with qualitative data is a strategic option. Ordinary information about resource allocation and its terms is limited at construction projects. To avoid any misapprehension, having an interview while discussing the resource allocation issues rather than filling in the questionnaire, has been more significant. By using the semi-structured open-ended interviews(Powell 1998), the respondents were welcomed to add additional information. To examine the interview questions and the type of the interview, a pre-study consisting of four interviews were made. This pre-study included senior management level and the questions were focused on the allocation of resources they would actually deal in the operation and execution. An interview study carried out to answer the research questions. Detail analysis is carried out to formulate the useful conclusions of the study (Figure 3.1).

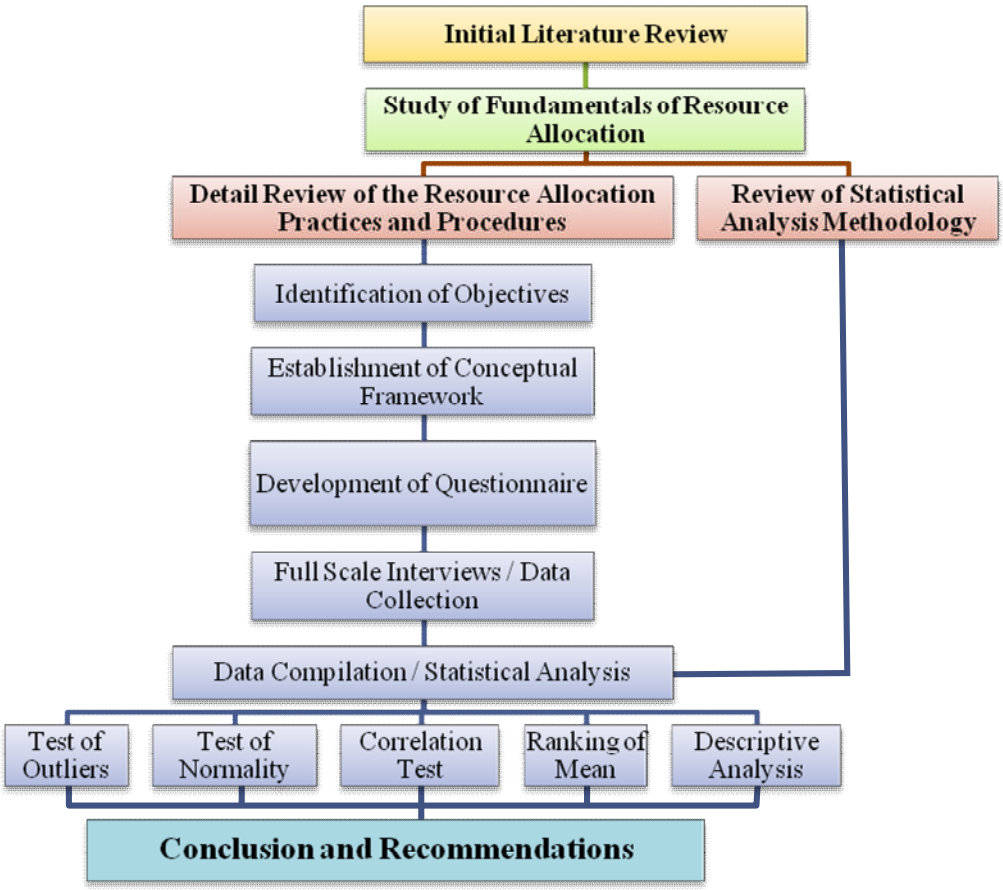

Figure 3.1. Flowchart Showing Process of Research

3.2 SAMPLING

In this study multiple sources of evidence were used, i.e. interviews, documentary studies and researchers background knowledge. The framework for analysis built up and suggestions are made for the methods and techniques involved in resource allocation practices in construction projects. The scope of the survey sample included only "*No Limit*"(CA Category) contractor firms of Province of Punjab and Capital (Islamabad). As per data available with PEC, there are total 78 "CA Category" contractor firms registered. Out of them, 55 are in Punjab and 23 in Islamabad.

From a statistical perspective, 30 is the minimum sample size to conduct the statistical analysis (Economists 2003). It will be difficult to obtain a significant statistic test if the sample size is smaller than 30(Saunders et al. 2009). In summary, the reason why all the above researchers view 30 (or a little bigger) as the smallest sample size is because according to these researchers, a sample size of 30 (or bigger) usually could result in a sampling distribution for the mean that is very close to a normal distribution. Therefore considering the above arguments, at least 30 contractor firms are to be considered to be the minimum number for this research. The choice of sample size depends on:

- The confidence required to have the data, i.e., the level of certainty that the characteristics of the data collected will represent the characteristics of the total population;
- The margin of error that can be tolerated, i.e., the accuracy required for the estimates made from the sample.

The empirical formula used here for calculating the sample size is as given below (Wilson 2010):

$$n = \frac{N}{[1 + N(e)^2]}$$

Where,
n = Sample Size
N = Population Size
e = Precision

CA category (No limit contractors firms registered with PEC, means contractor firms being eligible to establish the contract amounting to Rs 2,000 Million in Pakistan) from Province of Punjab and Capital Islamabad, that is total of 78 contractor firms (Appendix 1) are considered for this survey study, such that at ±5% precision level where, 95% of the sample values are within 2 standard deviations of the true population mean, the above formula would be as follows:

$$n = \frac{78}{[1 + 78(0.05)^2]}$$

n= 65

A sample size of 65 contractor firms will be the true representation of the population of 78. The sample of at least 65 contractor firms was required to conduct the analysis to study the population of 78 firms.

3.3 QUESTIONNAIRE DEVELOPMENT

Based on the literature review, a survey instrument in the form of a questionnaire was developed. A report on research conducted on *Resource Management Challenges* have been quite a good guideline to proceed ahead on the subject (CBP 2009). Five key variables have been identified through the literature review and researchers knowledge and further studied to comprehend the relevant indicators. Questionnaire was developed with the aimed to figure out the indicators with set of questions for elaboration (Powell 1998). Questionnaire was given to the researchers as well as colleagues for review and critique. The format and sequence was well framed to meet the requirement of interview based response for the questionnaire.

3.4 PILOT STUDY

Before using the questionnaire to collect data in the field, it is necessary to conduct few pilot studies for testing the questionnaire for its reliability, consistency and validity(Thompson 2010). Few contractor firms at city Lahore (Capital of Punjab Province) were selected basing on few senior managers interested for discussion and testing of the questionnaire. The questionnaire was filled in, and detailed discussions were made with the professionals as well as scholars. This small sample for pilot study was from the same population, which is under consideration for the purpose of this survey. The questionnaire was refined and the validity of the questionnaire is further

improved. In future data collection, the respondents should have less problems in answering the questions and there will be fewer problems in recording the data. Considering the above issues, four pilot studies were undertaken in this research. Meanwhile, discussion with the supervision team and colleagues was also helpful in improving the quality/validity of the questionnaire. After pilot studies, the questionnaire was finally ready for the formal data collection(Appendix 3).

3.5 DATA COLLECTION

The second objective of this research is to explore trends and practices in resource allocation by the Pakistani contractor firms in construction projects. Data collected was based on the interviews by firm owners / executives, general managers or senior project managers. These stakeholders were contacted to enquire whether they agreed to be involved in this research. The response was low but the good thing was that almost all were agreed that they might be available at the time of interview. The detail time schedule for the contractor firms were made to visit Rawalpindi, Lahore, Faisalabad, Multan and finally the Capital city of Pakistan, i.e., Islamabad to conduct the survey. In the interviews, they were invited to evaluate their resource allocation trends and practices with their project performance.

The identities of the respondent were kept anonymous and the related information was treated with the utmost confidentiality. Ethical standards does oblige that researchers must not put the participants in a situation where there might be any harm and risk to them because of their involvement in the survey. Almost all the researches guarantee the confidentiality of the participants. The principle of anonymous, which means that the participants will remain anonymous through the study even to the researchers themselves(Smith 2003; Trochim 2006).

All 78 firms are accessed and 68 Firms (87%) responded. The valid interviews accounted for the survey were 65 (83%) and 3 interviews (4%) were

declared invalid, due to either not justifying replies or unfilled questionnaires. Figure 3.2 below shows the statistics of the responses.

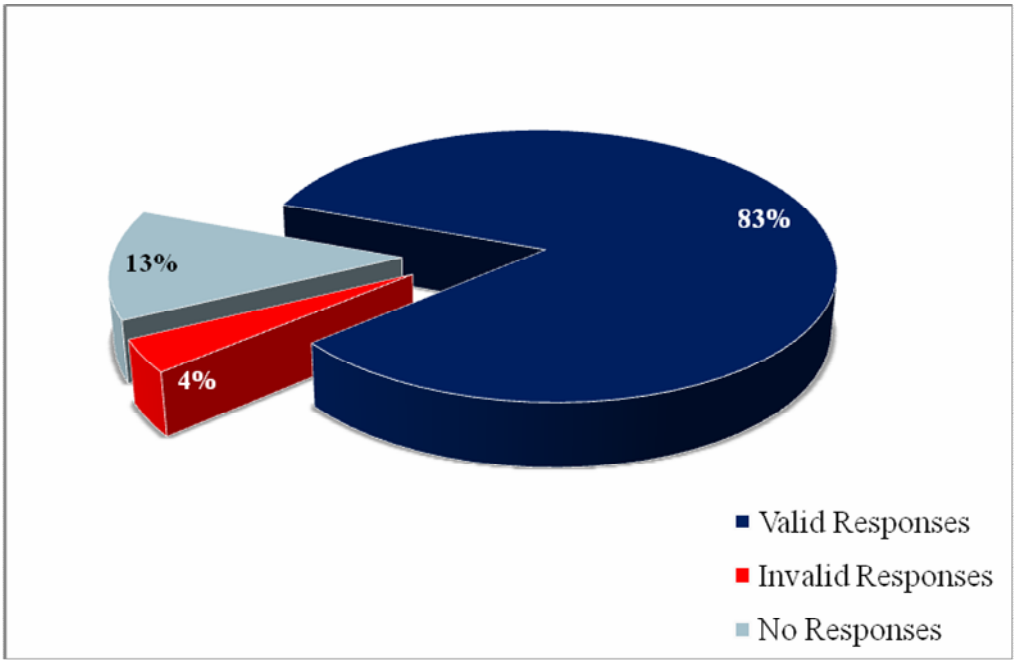

Figure 3.2. Percentage of Interview Responses

A cover letter (Appendix 2) about the intension and brief of the survey objectives has been attached with each questionnaire to help the respondent to have a summary view of this survey based research.

3.6 DATA ANALYSIS STRATEGY

To check the significance, hypothesis testing is the most common method being used (Chaudhry and Kamal 1999; Kanji 2006; Pallant 2007;Wilson 2010). It involves the making of the statement about the population in some aspect. To test this statement about the population, an assumption is formulated which is known as "*Null Hypothesis*" or H_0, which can or cannot be rejected. There is always an "*Alternate Hypothesis*" or H_1, which is accepted, if the H_0 is rejected. The probability of rejecting the H_0 is referred to as the significant level. If the significant level 5% ($\alpha = 0.05$), and probability $p<0.05$, H_0 is rejected, else it is not rejected and the assumption about the population stands true (Chaudhry and Kamal 1999; Kerr et al. 2002). Basing on the facts,

analysis and results, conclusions was drawn and certain recommendations were made.Once the statistics are calculated with the assumption that distribution is normal, it is called as *Parametric Statistics*. *Parametric Tests* are based on the assumption that the data is normally distributed. If this assumption is not true then the test loses its validity. However, when the data is not normally distributed, the statistics would be called as *Non-Parametric Statistics*. The statistical tests conducted with the assumption that the data is not normally distributed, are known as *Non-Parametric Tests*(Kanji 2006). The data was tested for its outliers, normality and correlation, then the detailed analysis was conducted using descriptive statistics to make out its behaviour.

Chapter 4

RESULTS ANALYSIS AND DISCUSSIONS

4.1 INTRODUCTION

There were five independent variables and one dependant variable in this research survey. Table 4.1 shows the descriptive statistics of the collected data. There are no missing values.*Skewness* and *kurtosis* show the shape of the curve formed. Hereskewness does not indicate any symmetry in the data, whereas kurtosis shows thepeakedness of the data. The values ofskewness and kurtosis are not equal to zero indicating the lack of normality in the data(Kanji 2006; Pallant 2007). However normality is confirmed in the test of normality.

Table 4.1. Descriptive Statistics

	N	Mean	Std. Deviation	Variance	Skewness	Kurtosis
Project Management	65	2.83	.993	.987	.253	.319
Project Planning & Scheduling	65	2.03	.661	.437	.303	.382
Resource Planning	65	2.34	.871	.759	.444	.347
Resource Allocation	65	2.48	.986	.972	.218	-.094
Resource Automation System	65	1.32	.752	.566	2.110	3.051
Valid N (list-wise)	65					

4.2 TEST FOR OUTLIERS

There are many statistical techniques which are sensitive to outliers (the values which are quite above or below the most of the values of the data). "*5% trimmed mean"* is the new mean which is attained after removing the top 5 and bottom of the data value and recalculating the mean. This new mean will be taken as "*5% trimmed mean*". If there is not much difference between the 5% trimmed mean and original mean values, than that means that outliers are not affecting the means of the data, therefore the outliers are not necessary to be removed and are retained (Pallant 2007). The result using SPSS 17.0 clearly

indicated here that there is not much difference in 5% trimmed mean and the original mean of all the variables (Appendix4).

4.3 TEST OF NORMALITY

The formal normality tests are very sensitive to the sample size of the variable concerned. The result is presented in "*Kolomogorov-Smirnov*" and "*Shapiro-Wilk*" Tests. Since N<2000, results of shapiro-wilk test was considered(Park 2008). The assumption about the population here was that the data is normally distributed, which became the null hypothesis or H_0. If H_0 is rejected than alternate hypothesis or H_1 would be required to be accepted. In this case following are hypothesis for the test of normality:

H_0 = Data is following the normally distribution

H_1 = Data is not following the normal distribution

The null hypothesis or H_0would not be rejected, if significance(sig.) value of "shapiro-wilk" is greater than 0.05 (level of significance). If significance (sig.) value of "shapiro-wilk" is less than 0.05 (level of significance), null hypothesis or H_0 would have to be rejected and alternate hypothesis or H_1 have to be accepted. Result of the test of normality is as per Table 4.2 below. Significance (sig.) value of "shapiro-wilk" is less than 0.05 (level of significance), we have to reject our null hypothesis or H_0 and accept our alternate hypothesis or H_1. Therefore the data is not normally distributed.

Table 4.2. Tests of Normality

	Shapiro-Wilk		
	Statistic	df	Sig.
Project Management	.875	65	.000
Project Planning & Scheduling	.800	65	.000
Resource Planning	.874	65	.000
Resource Allocation	.885	65	.000
Resource Automation System	.472	65	.000

As already discussed in the previous chapter, that if the data does not follow the normal distribution, it will go through the non-parametric statistics. Therefore, only non-parametric tests will be used for the data analysis in this research.

4.4 Correlation Test

Correlation describes the relationship between the variables depicting the type of relationship including the strength as well as direction of the relationship(Pallant 2007). Using SPSS 17.0, correlation coefficients between the pairs of variables listed, along with the level of significance was analysed. Spearman's Rho Test is being used for the said purpose being the non-parametric statistics. The results of the Spearman's Rho Correlation Test are shown in Appendix 5.

4.4.1 Information about the Sample

The first thing to be noted in the Spearman's Correlation Test result is the N (number of cases). If there is any missing value, the concerned variable is automatically removed by SPSS. Here we have total 65 cases under consideration in this research. Value of N here in the Spearman's Correlation Test here is 65, which is equal to the total cases under consideration, therefore there is no missing value found.

4.4.2 Direction of the Relationship

The second thing to be considered in the spearman's correlation test is the direction of the relationship. If there is any negative sign in front of the correlation coefficient value, shows the negative relationship between the variables. That means that higher value of one variable is associated with the lower value of other. Similarly positive sign shows the positive relationship between the variable. Here in the spearman's correlation Table we have all positive signs, showing the positive relationship between the variables.

4.4.3 Strength of the Relationship

The third thing to be noted is the strength of the relationship by considering the size of the correlation coefficient. It is ranged from -1.00 to 1.00. The value of -1.00 or 1.00 indicates the perfect negative and positive relationships respectively between the variable, whereas 0.00 dictates the absence of any relationship (no relationship) between the variables. Here in the spearman's correlation results we have correlation coefficient or value of rho mostly very high showing very strong relationship between the variables. However the strength of relationship of resource automation system is comparatively lesser than the other variable. That means that resource automation system is not common in practice or perceived to be of less significant variables.

4.4.4 Assessment of Significance Level

The next thing here is the assessment of the significant level of the relationship (two-tailed). Here the null hypothesis or $H_0$is that the variables under consideration are not correlated and their value would be "0", showing perfectly "no relationship" between the variables. Therefore the alternate hypothesis (H_1) would be that correlation coefficient $\neq$ 0 or existence of correlation between the variables. The two tailed test is always used once we try to compare the certain values with a fix value and in both directions. If the requirement is to check the value in one direction only that is greater than the fix value only or smaller than the fix value, than one tailed test can be used (Chaudhry and Kamal 1999).Here we are required to check on both direction whether positive or negative as well as to check the hypothesis if the coefficient values are equal to "0" or not equal to. The result shows that $p < .01$ for all the variables depicting the high significance value for the strong correlation among the variables under consideration.

4.5 Ranking of Mean

The friedman test is used for ranking of mean, when same sample is tested for different conditions or variables (Pallant 2007). The assumption for the test is that all the variables have the same mean, which would be the null hypothesis or H_0. Alternate hypothesis or H_1 would be that the variables under consideration have different means. The results of the friedman's test are shown below in Table 4.3 and Table 4.4 for ranked mean and friedman's statistics respectively. Significance value is less than 0.05, therefore our null hypothesis is rejected and we accept out alternate hypothesis, which is that the variables have not the same mean. Ranking of the mean shows that the *Project Management* has the highest ranking and *Resource Automation System* has the lowest ranked mean. X^2 (df: 4, n: 65) = 160.098, $p < 0.05$ value at significant difference of the means of the variables.

Table 4.3. Friedman Tests - Ranking of the Mean

Description	Mean Rank
Project Management	4.21
Resource Allocation	3.48
Resource Planning	3.24
Project Planning & Scheduling	2.60
Resource Automation System	1.47

Table 4.4. Friedman Test – Statistics

N	65
Chi-square	160.098
df	4
Asymp. Sig.	.000

a. Friedman Test

4.6 DESCRIPTIVE STATISTICAL ANALYSIS

Descriptive statistics summarises the patterns of the responses sample, which includes measures of central tendency, frequency, standard deviation and spread of the variables (Pallant 2007). In descriptive statistics, the analysis is univariate and mostly supported by diagrams like line, bar and pie chart and histograms. The spread of each variable, the range of each attribute

(collaborative working) and indicator (project performance), can be identified. The trends and traditions of the population would be deducted basing on their descriptive analysis. So far what has been found on the basis of preliminary analysis is as follows:

- The data is not following the normal distribution, rather it is not only skewed, but have kurtosis as well. skewness and kurtosis shows the lack of symmetry in the data.
- The outliers have no significant effect on the mean of the data.
- Variables are highly correlated and have positive correlation among them.
- The variables under consideration have different mean which is being ranked as that Project Management has the highest mean value whereas Resource Automation System being the lowest in rank for the mean value.

4.6.1 Project Management

Project management variable for the resource allocation aspect have several indicators, which include the management, executives, staffing policies of the organization, project management organization (PMO) along with the organization goals, objectives and the strategic plans. Interviewees were asked for rating for its significance, which was mostly on the lower side. Only 15-20% of the firms were of the opinion of significance of this variable.

Table 4.5. Percentage Perception of Project Management Indicators

Responses	Management/ Executives/ Stakeholder Responsibilities	Staffing Policies	PMO / Decision Making Policies & Effectiveness	Organization Goals / Objectives / Strategic Plans
Highly Insignificant	15.38	16.92	10.77	12.31
Insignificant	35.38	27.69	36.92	16.92
Neutral	36.92	41.54	35.38	49.23
Significant	10.77	6.15	13.85	13.85
Highly Significant	1.54	7.69	3.08	7.69

About 75-80% responses were of either have perceived this variable of no significant value or does not have any perception in this aspect. Details of the responses are as per Table 4.5 above. The firms have the opinion that stakeholders and management responsibilities concerning the stakeholders of the government departments can never be met in the current scenario, however non-government bodies may be iterated for the aspects, but that will take a long time. Staffing policies for the competent skill levels are not as organized and it is always followed with the requirement. Most of the organization does not have any specific policies for that matter. PMO is the most effective entity in the project for coordination and management of the project activities. Most of the management and coordination are done at the firm headquarters. There are very few professional firms, which have developed the proper system for PMO, which not only implement the organizational policies but take care of the objectives and effectiveness of the decision made. The graphical representation of the results is also shown as per Figure 4.1 below.

The mean results of the project management variable are also shown below in Figure 4.2. This shows the overall perception of the firms for project management factor. There are hardly 16.90% firms, who have the significance value of this variable. There is a need that indicators of the project management variable with the aspects of resource allocation be give attention. 31.3% of the contractor firms do not perceived project management as of significant importance for construction projects. This shows the poor perception of project management aspect of resource allocation in contractor firms. One third of the contractor firms need to give more emphasis on project management.

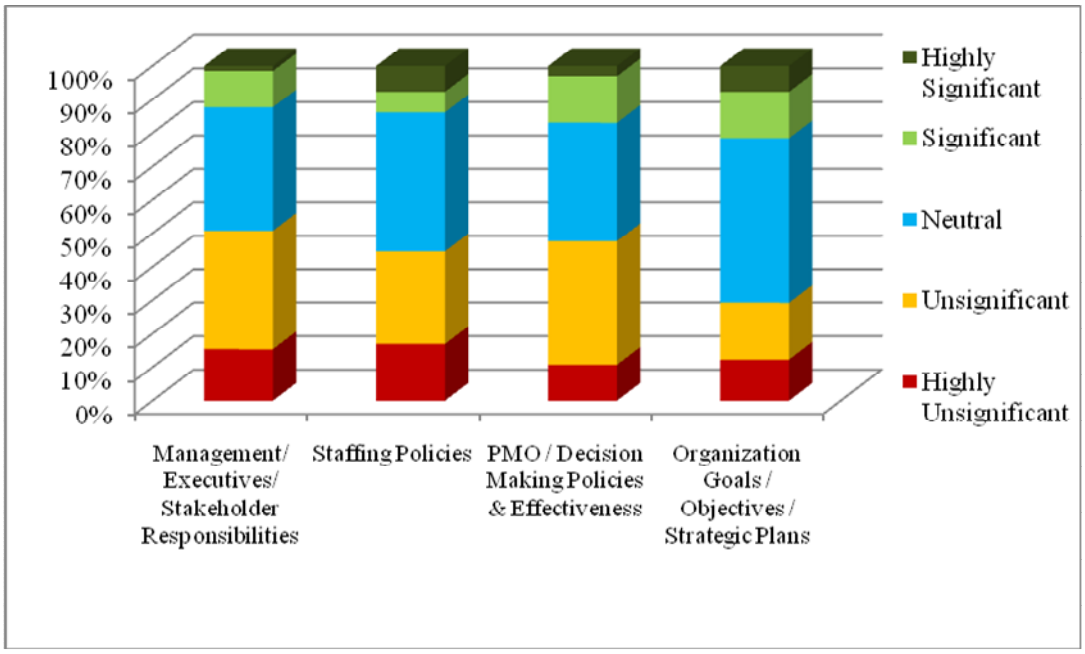

Figure 4.1. Percentage Perception of Project Management Indicators

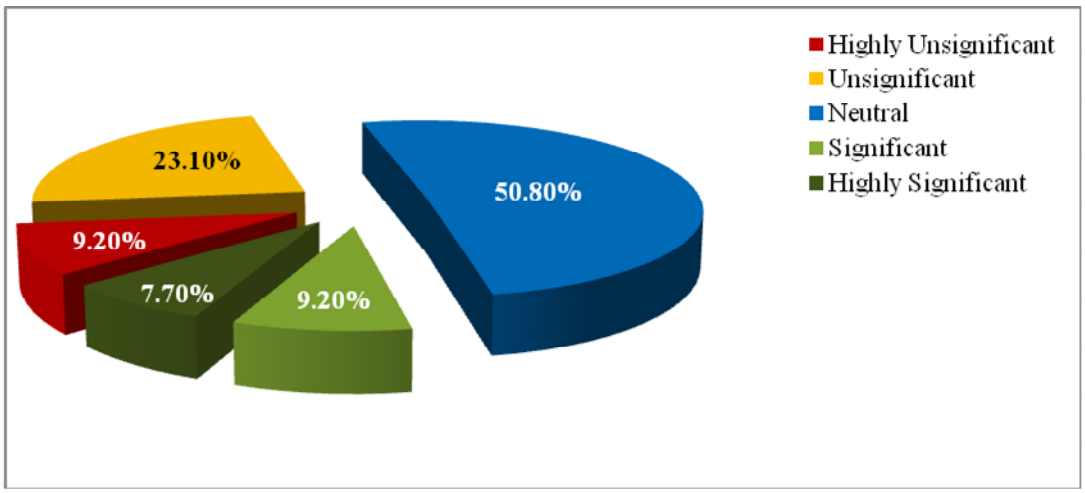

Figure 4.2. Percentage of Mean Perception for Project Management

4.6.2 Project Planning and Scheduling

Planning and scheduling is the foundation of the resource scheduling. The schedules are always developed before the start of the project and project plan is based on the schedule. The quality of schedule varies project to project. The perception generally says that most of the firms go for the realistic scheduling as

per client requirement. Dead-lines for the milestones are hardly planned by most of the construction firm in Pakistan.

Table 4.6. Percentage Perception of Project Planning & Scheduling Indicators

Responses	Activity/ Skills Required	Realistic Schedules / Dead-lines / Internal Targets	Performance & Monitoring	Scheduling & Planning Techniques
Never	15.38	12.31	18.46	98.46
Seldom	24.62	36.92	41.54	1.54
Sometimes	36.92	30.77	29.23	-
Often	13.85	12.31	9.23	-
Always	9.23	7.69	1.54	-

There are hardly 10% of the firms, which have due concerned about the performance and monitoring to follow the schedule in a true letter and spirit. There are seldom any planning techniques used for the scheduling. The details of the responses are shown in Table 4.6 above. The graphical representation of the responses is also shown in Figure 4.3.

The mean of the responses for overall picture of the project planning and scheduling perception is shown below in Figure 4.4. About 1.50% of the contractor firms are involved in the planning and scheduling their projects. 18.50% contractor plan and schedule their project sometimes, whereas 61.50% contractor firms seldom plan and schedule. 18.50% contractor firms never plan and schedule their projects or they do not plan and schedule on traditional techniques. They are in a view that construction activities are plan on site. This aspect of planning and scheduling need quite a lot attention.

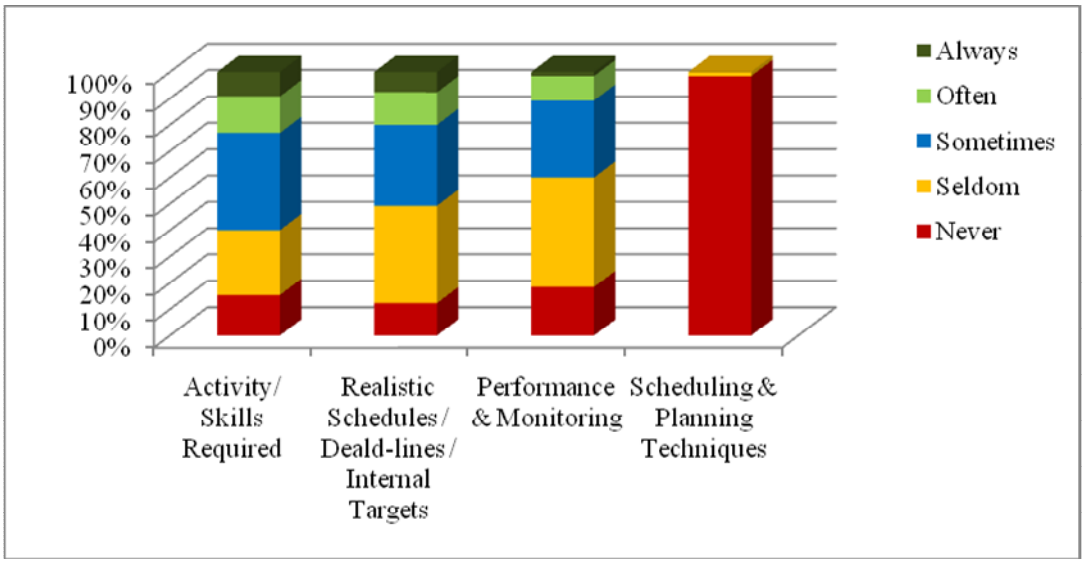

Figure 4.3. Percentage Perception of Project Planning & Scheduling Indicators

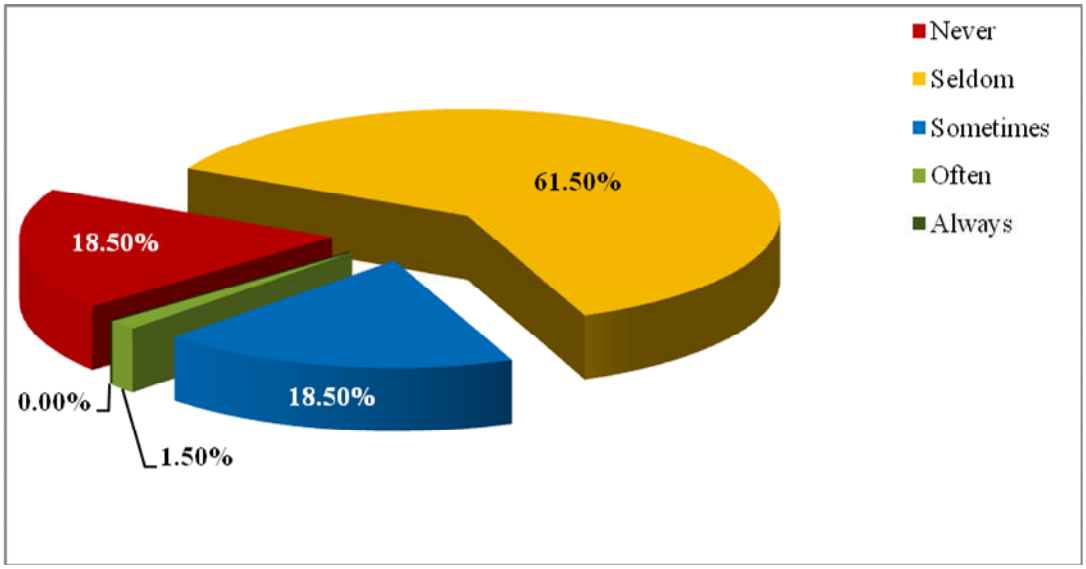

Figure 4.4. Percentage of Mean Perception forProject Planning & Scheduling

4.6.3 Resource Planning

Resource planning is the most important aspect of the resource allocation. Unless and until the project schedule is not loaded with the resources, resources can never be optimally utilized. There are number of aspects and indicators for the basis of resource planning. There are certain processes to plan for

the resources. The first basic step is the resource breakdown structure to develop the hierarchical list of all the project resources. Loading of the resources and developing the resource calendars and management plans is the key for making the resource plan. Mostly firms (above 50%) are not even agreed to the feature of the resource planning. The do agree with the work breakdown structure, but the resource breakdown structure. Use of Resource Histograms and Calendars are limited to even less than 2% of the contractor firms. Details of the responses of Resource planning are as per Table 4.7 below.

Table 4.7. Percentage Perception of Resource Planning Indicators

Responses	Resource Handling Standards/ Procedures	Resource Breakdown Structure	Resource Availability / Adequacy/ Capacity Planning	Resource Loading	Histogram /Calendar	Resource Management Plan
Strongly Disagree	15.38	15.38	21.54	20.00	75.38	12.31
Disagree	52.31	35.38	38.46	38.46	10.77	36.92
Neutral	24.62	32.31	29.23	29.23	12.31	36.92
Agree	6.15	13.85	9.23	6.15	1.54	12.31
Strongly Agree	1.54	3.08	1.54	6.15	-	1.54

Graphical representation of the resource planning variables along with the indicators shows the weak perception of the contractor firms of this country (Figure 4.5).The overall picture of the mean perception of resource planning features is shown below in Figure 4.6.

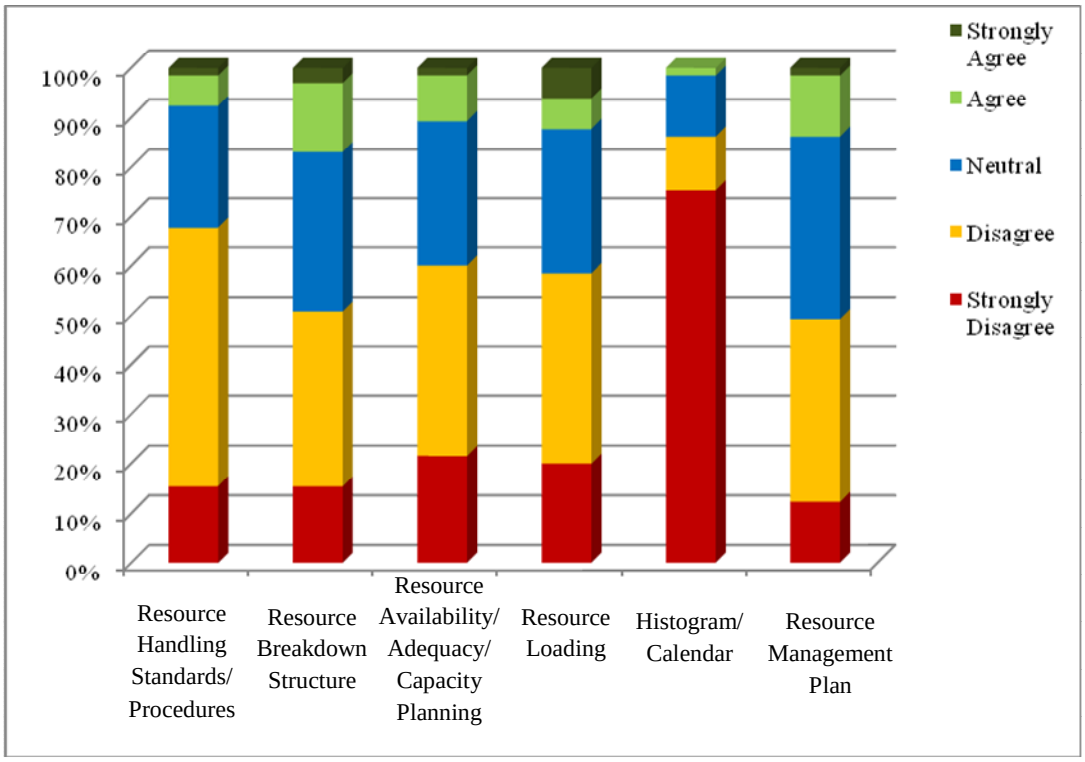

Figure 4.5. Percentage Perception of Resource Planning Indicators

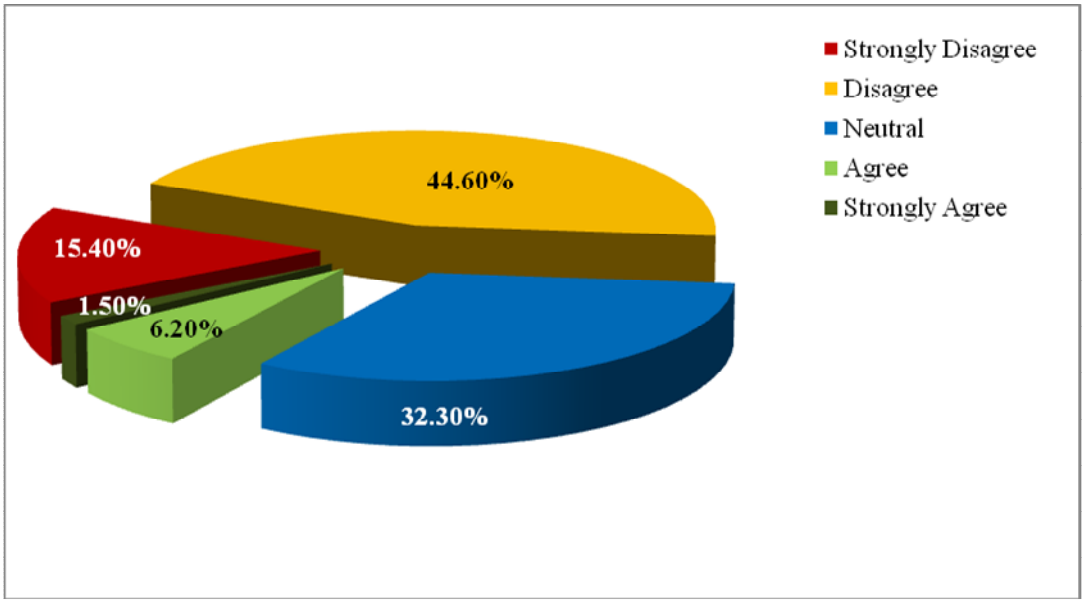

Figure 4.6. Percentage of Mean Perception for Resource Planning

4.6.4 Resource Allocation

This is the most important aspect itself. The process of resource allocation involves several key indicators including the resource levelling, time-cost trade-offs, resource constraint scheduling and resource scheduling across multiple projects. Not more than 15% of the contractor firms are of the opinion of any significance to the process of resource allocation. There are slightly more trend of managing the resource across multiple projects, however still there huge portion of the contractor firms, which are either do not agree to levelling and time-cost trade-off techniques or do not even know about them. Few top professionals contractor firms, have the complete standing procedures in their planning departments for resource allocation, levelling and time-cost trade-off tasks. Details of the responses for resource allocation aspects are given in Table 4.8 below.

Table 4.8. Percentage Perception of Resource Allocation Indicators

Responses	Resource Allocation as per Schedule	Resource Levelling	Resource Time-cost Trade-off / Crashing	Resource Constraint Scheduling	Resource Scheduling across Multiple-Projects
Strongly Disagree	26.15	20.00	18.46	18.46	1.54
Disagree	41.54	36.92	30.77	27.69	20.00
Neutral	23.08	33.85	35.38	44.62	47.69
Agree	4.62	7.69	9.23	9.23	23.08
Strongly Agree	4.62	1.54	6.15	-	7.69

Graphical representation of the overall view of Resource Allocation can be seen in Figure 4.7 below. The overview of the picture for resource allocation trends can be seen in Figure 4.8. Lack of the trends in resource allocation would not have the positive effect on the firm’s performance and productivity.

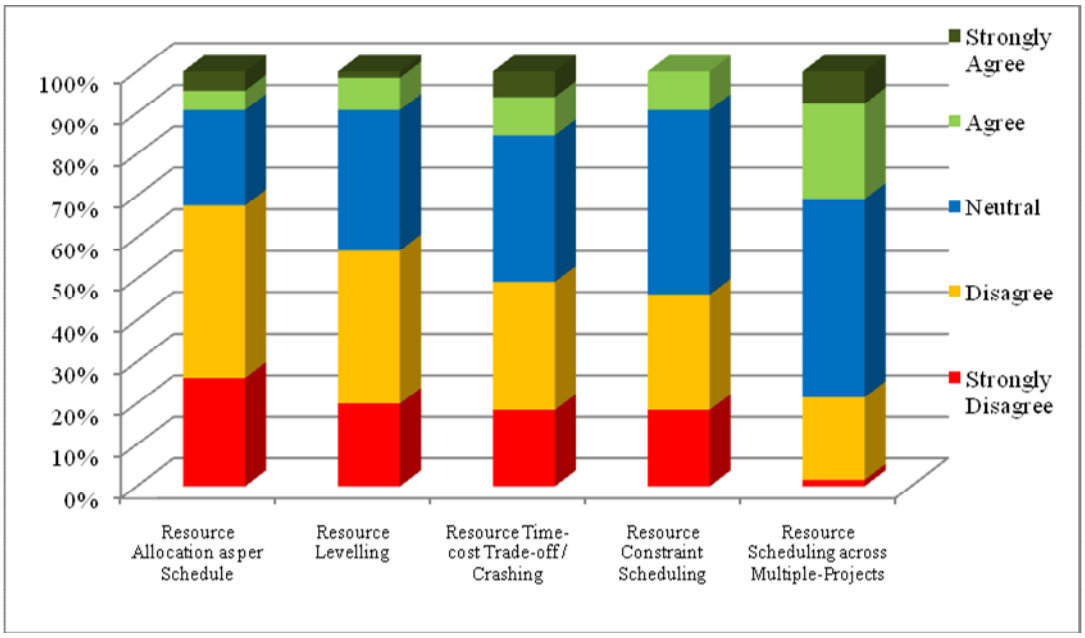

Figure 4.7. Percentage Perception of Resource Allocation Indicators

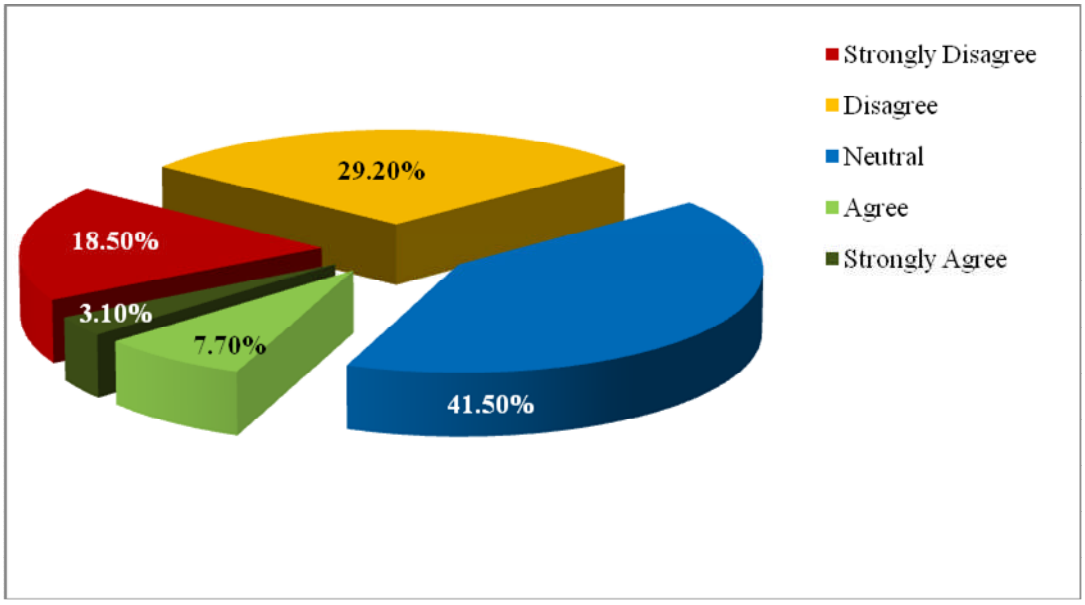

Figure 4.8. Percentage of Mean Perception for Resource Allocation

4.6.5 Resource Automation System

Uses of project management software not only enhance the productivity but also help in managing the resources efficiently. World-wide, it is even almost all the contractor firms have incorporated the project management software in their businesses. Use of sophisticated software helps in managing the huge database of the resources and making the effective schedules by incorporating the progress and monitoring the progress. More than 80% of the contractor firms in this country are using MS Project as their primary scheduling softwares, however still there are 20% firms, who are using primavera. There are about 10% to 13% contractor firms, which have incorporated the complete project management and resource planning and scheduling softwares. The detail of the responses in this regard is given as per Table 4.9.

Table 4.9. Percentage Perception for Use of Project Management Software.

Responses	MS Project	Primavera	Sure Track	Other Softwares
No	18.46	80.00	100.00	86.15
Yes	81.54	20.00	.00	13.85

The overview of the comparison for use of various project management softwares are shown below in Figure 4.9.Use of automation system in Pakistan is somewhat discouraged. About 86.20% contractor firms do not agree to incorporate resource automation system in their internal system. 1.50% of contractor firms agree to incorporate the resource automation system in their organization. These firms have their automation modules to look after various aspects of project management, planning and scheduling, resource planning, resource automation etc.

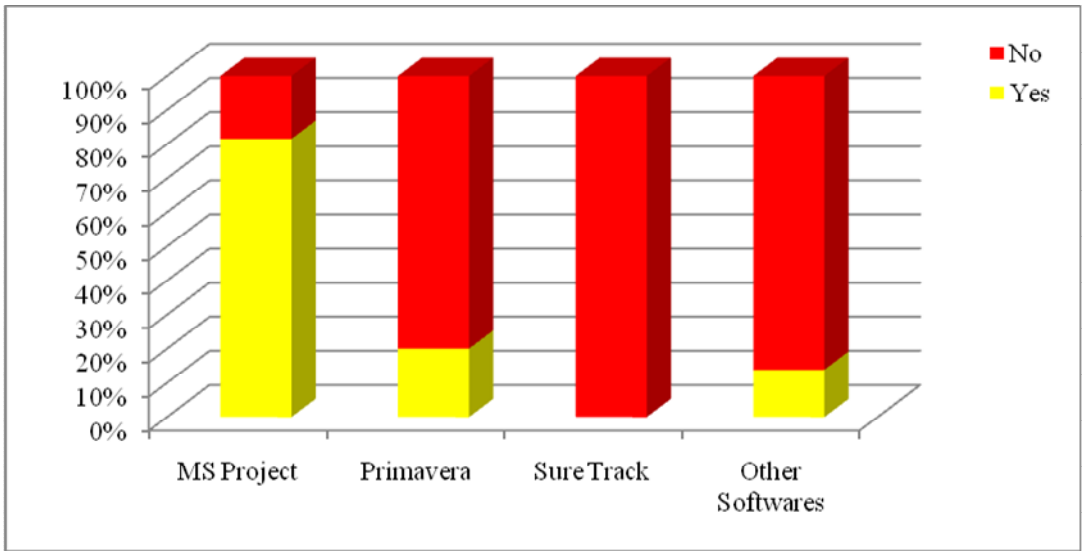

Figure 4.9. Percentage PerceptionforUse of Project Management Software

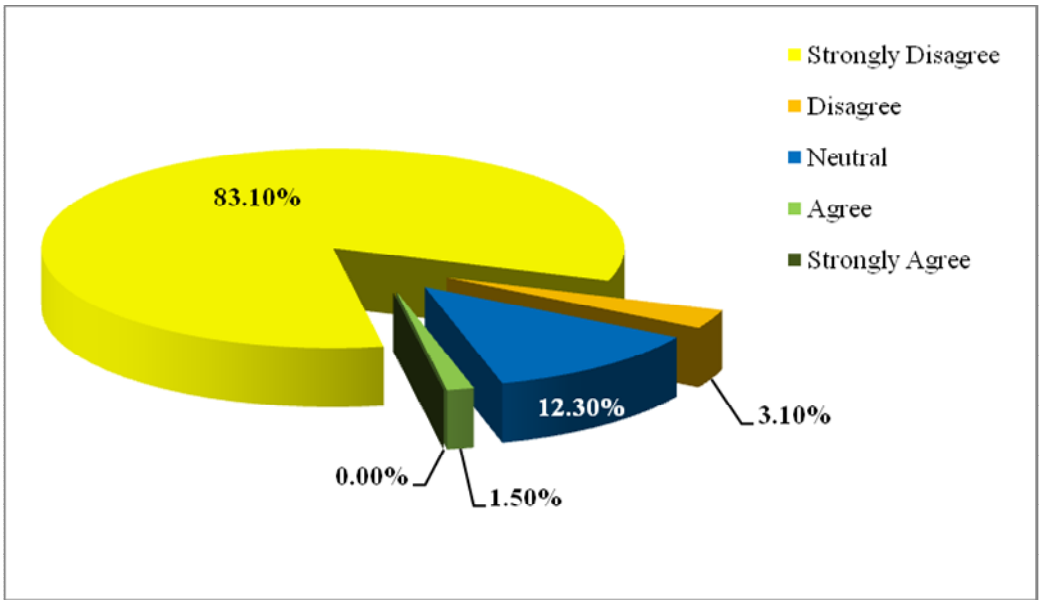

Figure 4.10. Percentage Perception for Resource Automation System

4.6.6 Resource Allocation and Perceived Performance

The entire variables have the significantly high influence on the organizational behaviour. Interviewees were also invited to comment and give the details of their project performance. The performance criteria are taken,

which are used by most of the researchers and are related to resource allocation (Costa et al. 2004). The mean values of the variables of conceptual framework have the positive behaviour with the organizational performance. Organizations having more mean score have high perceived performance. The graphical representation of the relation is shown in line-chart below as Figure 4.11.On comparison of the responses of the high and low performing organization, it is revealed that the more the value of the performance of an organization or high organizational performance, more value of the mean is linked with it in all the key variables. They are more likely to practicing the resource allocation procedures. They are managing their resources on standard procedures (CBP 2009).

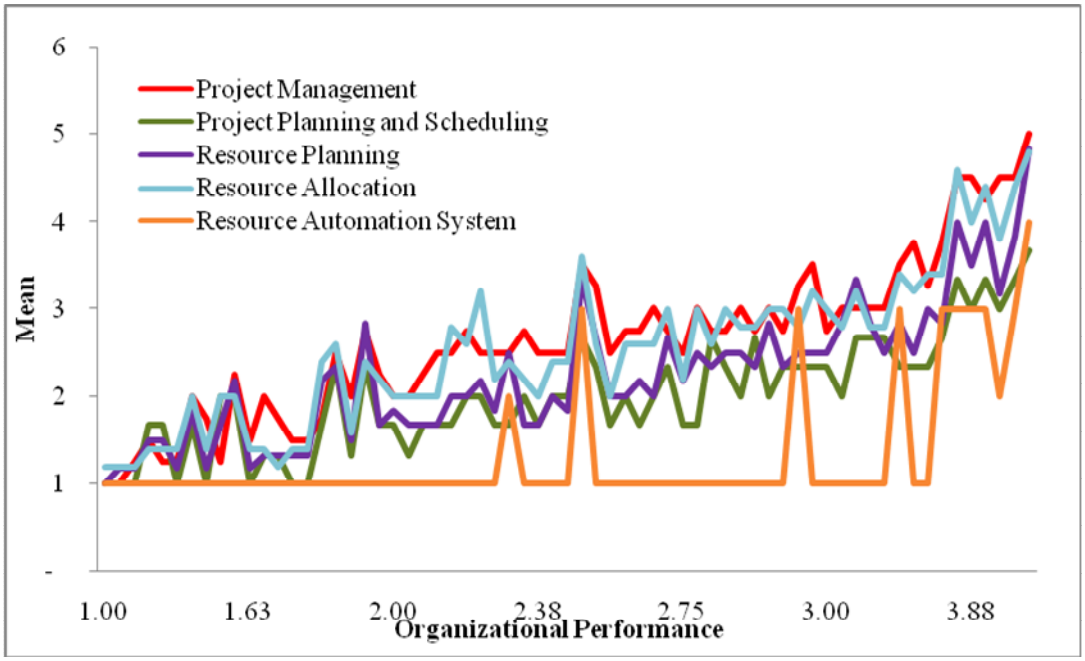

Figure 4.11. Project Performance vs Mean of the Resource Allocation variables

4.6.7 Resource Allocation Maturity Level

Organization's mean scoring of variables concerning conceptual framework for resource allocation, can be measured in terms of maturity level. Researchers have used various methodologies to compare the level of maturity. (CBP 2009; Zou et al. 2010). In this study maturity level is spread on a scale between 1 and 5 for comparison purpose. The meaning of each maturity level is

described in Table 4.10below. Following criteria is selected to assess the maturity levels of the organization for various aspects of conceptual framework:

- Maturity Level 1 - Mean Score 0.00 to 1.00
- Maturity Level 2 - Mean Score 1.01 to 2.00
- Maturity Level 3 - Mean Score 2.01 to 3.00
- Maturity Level 4 - Mean Score 3.01 to 4.00
- Maturity Level 5 - Mean Score 4.01 to 5.00

Table 4.10. Description of Resource Allocation Maturity Levels

Maturity Level	Descriptions
Level 1: (Preliminary)	The organization may identify the need for resource allocation process; however, there may not any established practices or standards in place. The average maturity level of all the variables of Conceptual framework is 1.
Level 2: (Managed)	The organization has standard procedures and may have potentials to use those on some projects. Process performance may be shared with senior management. The average maturity level of all the variables of Conceptual framework is between 1 and 2.
Level 3: (Definite)	All resource allocation processes are in place. The processes are being used by nearly all projects. Here processes are described more rigorously than maturity level 2. Average maturity level of all the variables of Conceptual framework is between 2 and 3.
Level 4: (Quantitatively Managed)	Resource allocation processes and standards, used by nearly all projects, are integrated with other corporate processes and systems.The average maturity level of all the variables of Conceptual framework is between 3 and 4.
Level 5: (Optimizing)	Resource allocation processes and standards, used by all projects, are integrated with other corporate processes and systems. Resource management improvement processes are in place and used. Lessons learned are regularly examined and used to improve documented processes. Processes are in place to measure resource allocation effectiveness and efficiency. Organization is concerned with overall performance. The average maturity level of all the variables of Conceptual framework is between 4 and 5.

These maturity levels may be help in assessing the standing of the organization. The flaw can be assessed as where the shortfall lies and measures can be taken to overcome the flaws. The perceived information about the key variables of conceptual framework can be graphically analysed to assess the level of maturity of an organization as shown below as radar graph (Figure 4.12). Five contractor firms from the collected data are selected randomly one from each maturity level. Their data is plot on the radar diagram, which has range of each maturity level from 0-1, 1-2, 2-3, 3-4 and 4-5. The general perception of overall maturity of the organization can be obtained by analysing the diagram. The shortfall can be given due attention for the betterment and improvement.

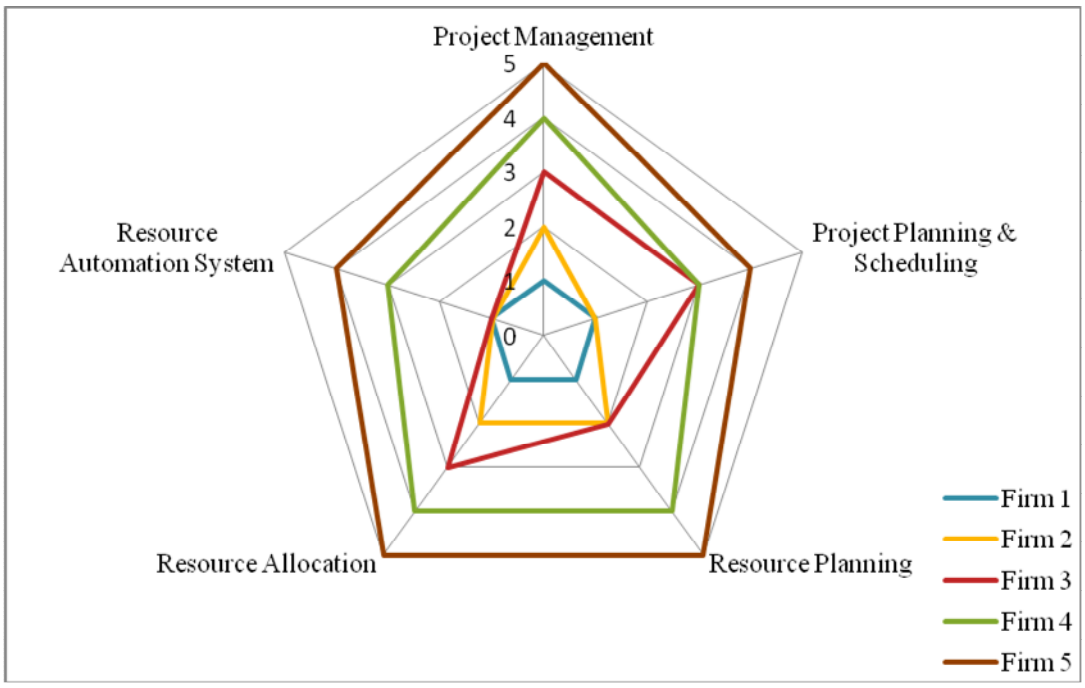

Figure 4.12.Examples of Firms' Resource Allocation Maturity Levels

Each of the five variables has their own maturity levels, which presents the specific characteristics of an organization as well as the overall maturity level of the organization. Project management found to be mostly at maturity level 2 and 3 (73.90%). There are 9.20% firms at maturity level 4 and only 7.70% at maturity level 5(Figure 4.13). Project planning and scheduling

found to be worse than the project management. The bulk is at maturity level 2 (61.5%). There are 18.50% firms at maturity level 3 and 1.50% at level 4. Unfortunately there is not a single firm in maturity level 5 (Figure 4.14). Probably the reason must be that most of the time, in the current scenario of this country, the projects are delayed or mostly not on the schedules. Resource planning is almost similar at the level of project management. Mostly firms are at maturity level 2 and 3 (76.90%). However, there are fewer contractors at higher maturity level, i.e., is 6.20% at level 4 and 1.50% at level 5. The area need to be emphasized too (Figure 4.15). Resource allocation has got the same situation. Most of the firms are at maturity level 2 and 3 (70.70%). There are only 7.70% firms at level 4 and 3.10% firms at level 5 (Figure 4.16). Resource automation system has the worst situation. The bulk is at maturity level 1 (83.10%). There are 3.10% at level 2, 12.30% at level 3 and only 1.50% at level 4. No firm seems to be in maturity level 5. These really need to be emphasized (Figure 4.17).

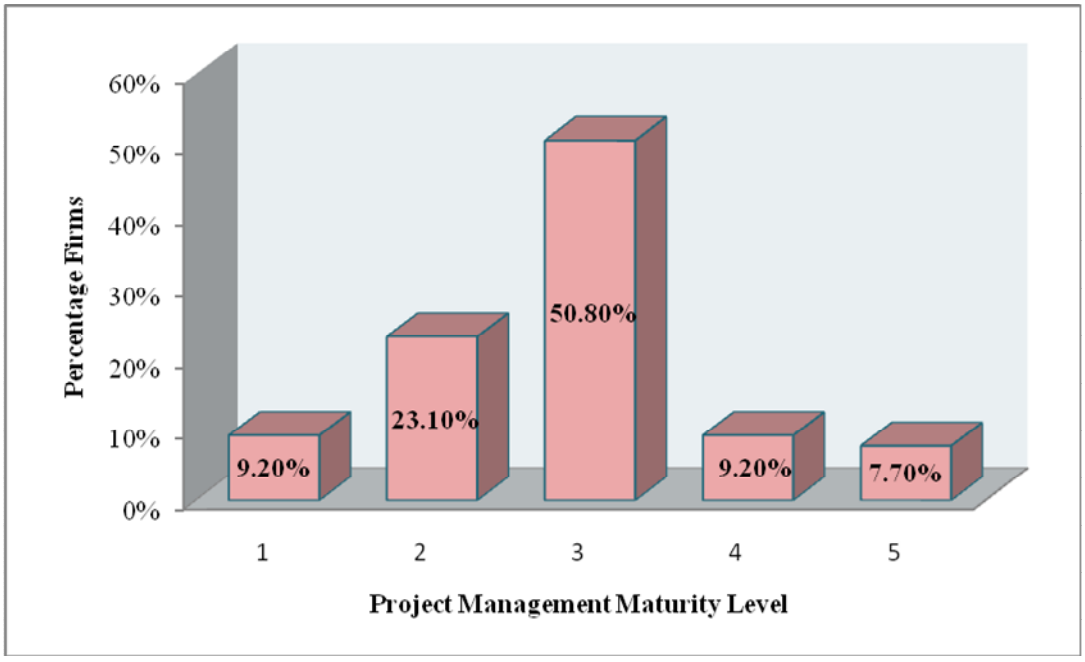

Figure 4.13. Percentage of Project Management Maturity Level

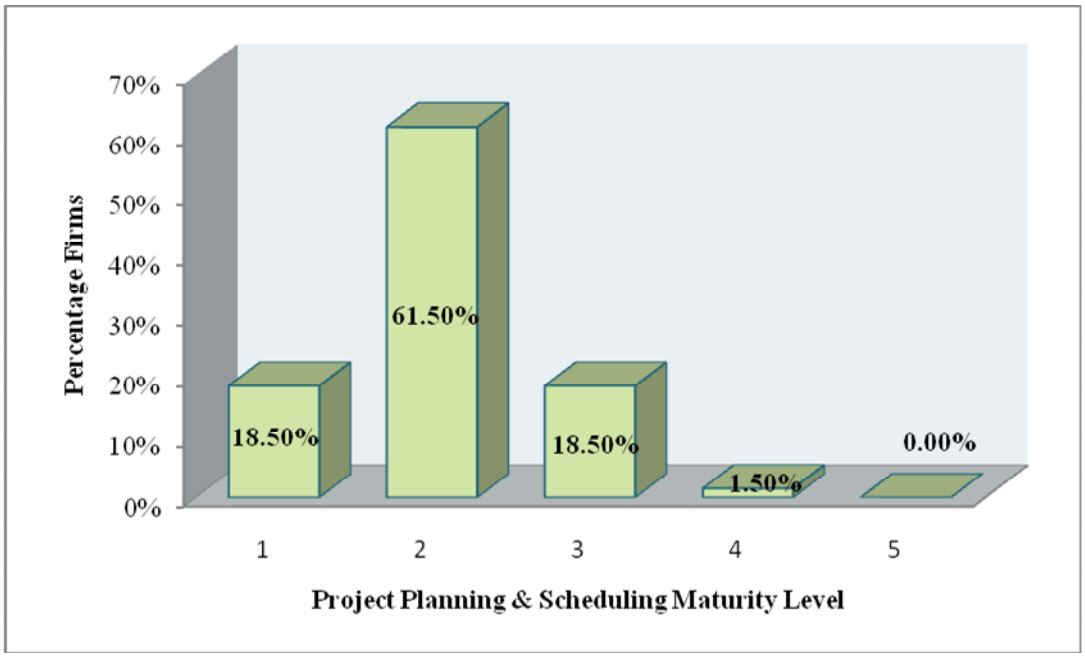

Figure 4.14. Percentage of Project Planning & Scheduling Maturity Level

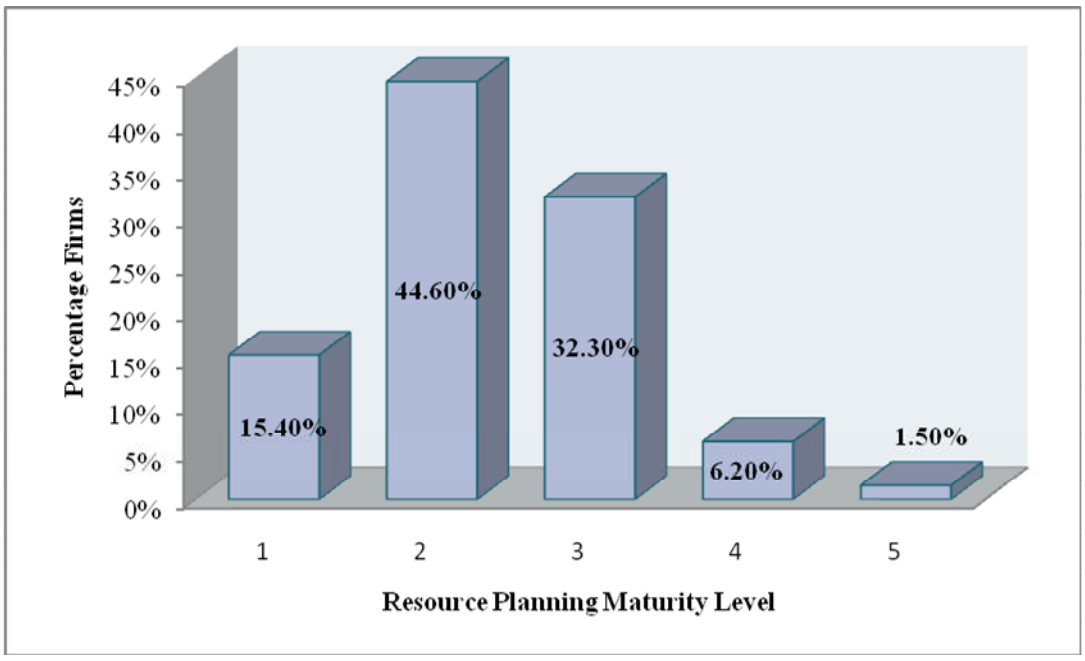

Figure 4.15. Percentage of Resource Planning Maturity Level

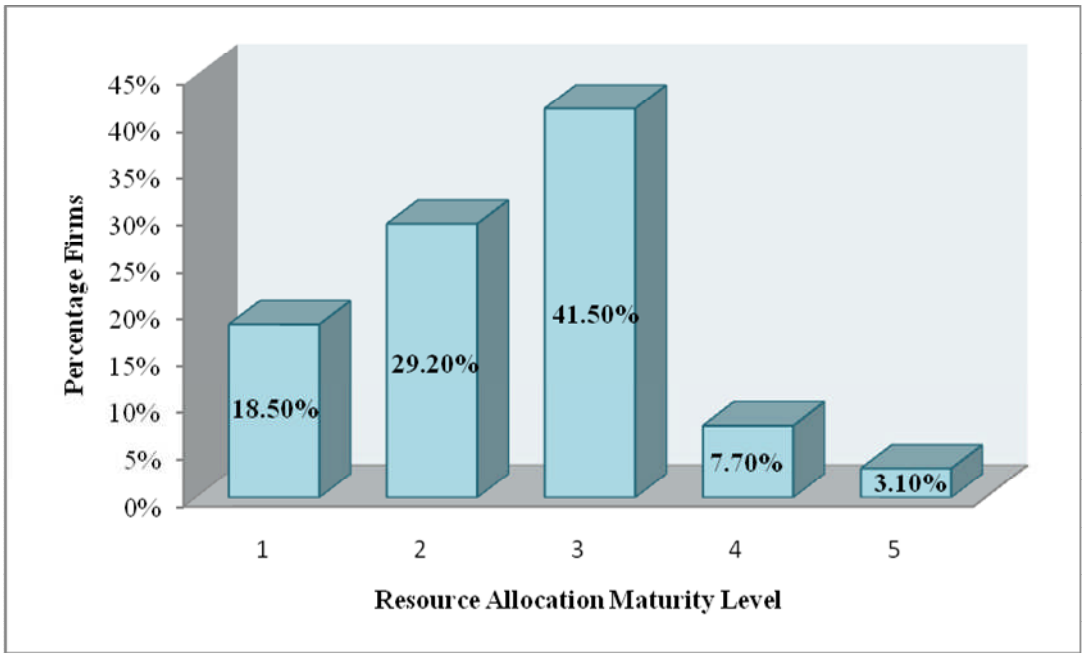

Figure 4.16. Percentage of Resource Allocation Maturity Level

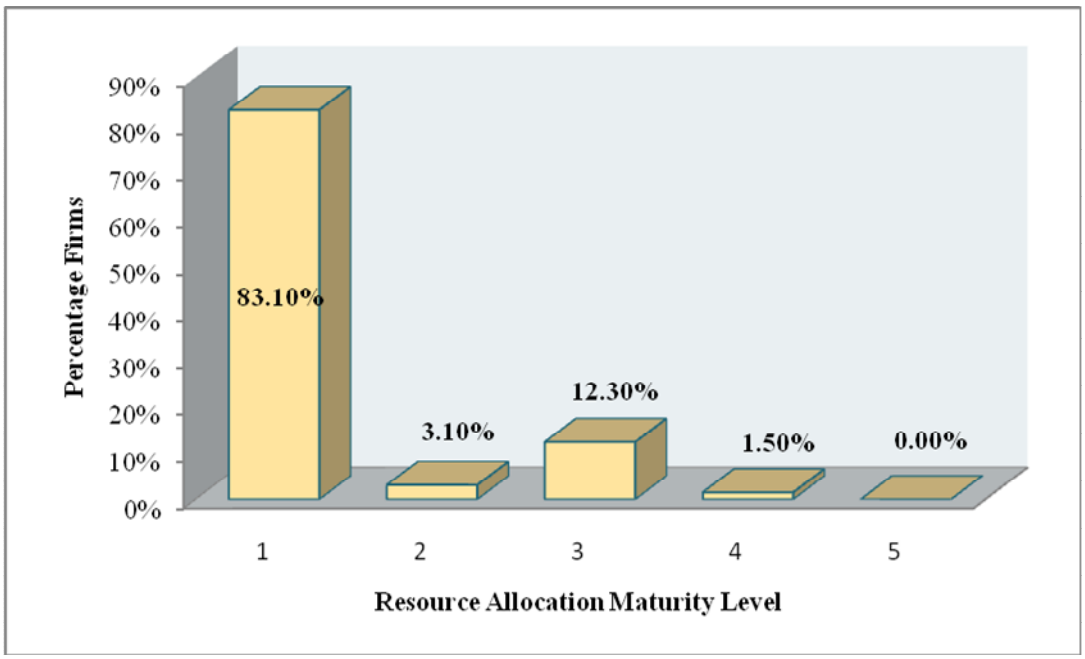

Figure 4.17. Percentage of Resource Automation System Maturity Level

The mean scoring of all the variables are scaled between 1 and 5 to get the maturity level. Most of the firms (44.70%) are at maturity level 2 or below, where there are no established procedures and policies. Software is hardly used unless required by the contract. Only scheduling is done and there are no trends of resource loading, levelling and allocation in a systematic way. A large percentage is at maturity level 3 (43.10%), where there are defined process and policies as well as a system to plan resources on a schedule. Proper record and database maintenance for resource utilization and capacity planning is not done as required by the process of resource allocation. There are only 10.80% of the firms with maturity level 4 and only 1.50% firms are at maturity level 5. They have well defined process, supporting standards, templates and software for scheduling, resource allocation, project management, resource database and capacity planning. Graphical representation of the facts and figures is also illustrated in Figure 4.18 below.

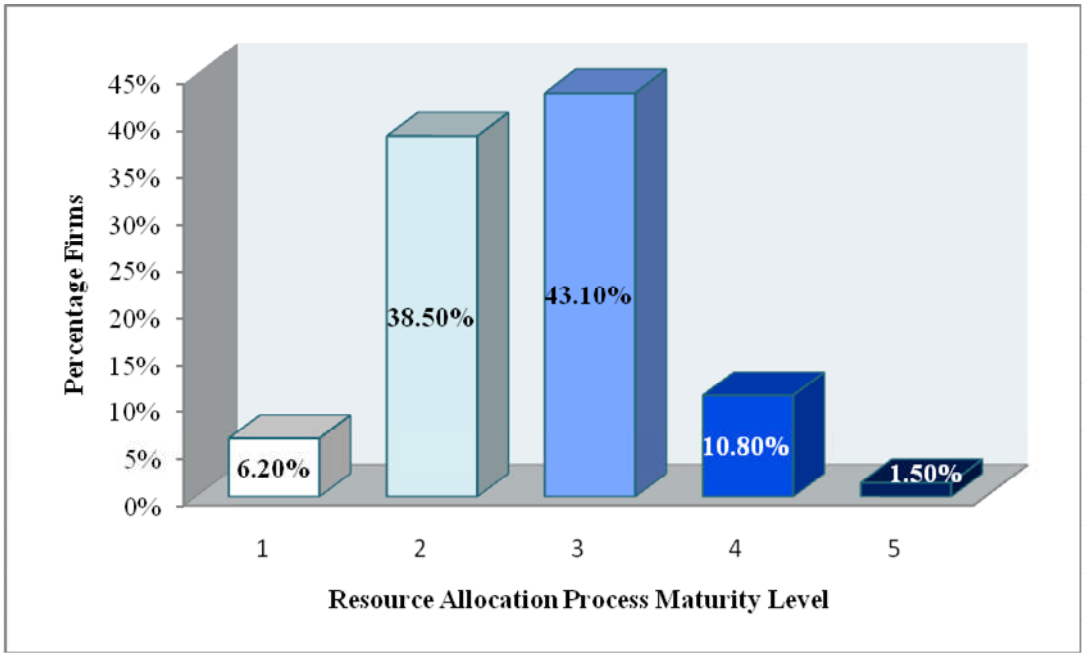

Figure 4.18. Percentage of Maturity Level of Resource Allocation Process

Chapter 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSIONS

Results of this study show that large percentage of contractor firms are not agreed to procedural aspects of the resource allocation practices. They are even not ready to accept any opinion to incorporate *Automation System* for project management or allocation of resources within the current environment of this country. They are used to with the old trends and need more time and effort to make a change to follow the latest trends and techniques. Qualitative analysis of the resource allocation procedures found five fundamental variables including project management, project planning and scheduling, resource planning, resource allocation and resource automation system. These variables have significant impact on resource allocation process and practices.

5.1.1 To overcome the lack of procedural aspects of resource allocation procedure, this research study has proposed a conceptual framework for resource allocation procedures based on the identified key fundamental variables through extensive literature review. A survey based interviews of the contractor firms was conducted and itis revealed that the five key fundamental variables including project management, project planning and scheduling, resource planning, resource allocation and resource automation system have significant influence on organization performance.

5.1.2 Organizations with high mean scoring or resource allocation maturity level have high performance as well. Based on the maturity levels of different organizations, this study also proposes the maturity levels for resource allocation. The shortfalls in resource allocation process can be assessed. Radar graph can be utilized to plot the five key variables of the conceptual work and analysis can be made to assess the direction of effort required to improve the resource allocation maturity level.

5.1.3 Researchers have recognized that enhanced resource allocation practices in any organization can sustain and advance their competitiveness. Understanding responsibilities, coordination ability, effective monitoring and feedback. Most of the contractors do not agree to allocate the resources with the push of few buttons (software based applications). Yet top performed companies have incorporated the automation system in their resource allocation system. They have not only created the complete database of their resources electronically but also keeping the allocation and utilization records for future learning and analysis.

5.1.4 Scheduling and planning procedures may lead to unreliable programs unless resource constraint scheduling is conducted. Resource constraint scheduling is mostly ignored and few firms agreed to its significant value in allocation of resources, that is not more than 8% of the contractor firms in Pakistan.

5.1.5 Ranking of mean shows the perception of contractor firms about the fundamental variables. Project management being the highest ranked mean perceived to be of significant importance by most of the contractors whereas resource automation system with lowest ranked mean is perceived to be the lowest significant.

5.2 RECOMMENDATIONS

5.2.1 Organization should consider the conceptual framework for resource allocation in construction projects. This research shows the potential effects of conceptual framework for resource allocation procedure. The conceptual framework ensures that resources are scheduled in a justified manner that impacts the improvements in organization performance. The outcome of analysis has shown significance importance of the variables basis for the conceptual framework. The conceptual framework with its five fundamental variables of resource allocation procedures are recommended to be considered as standard practices.

5.2.2 Resource allocation maturity levels are proposed to be implemented to assess the shortfalls in the resource allocation process in an organization. The

measures can be taken for betterment and improvement in the organization performance and strategy.

5.2.3 Resource automation system must be emphasized being absent in most of the organization. It not only enhances the departmental procedures of the organization but also improve planning efficiency and speedy decision making. Resource automation system is recommended for resource allocation as already in use by the top performed organizations. It helps in optimizing the resource allocation process in a more sophisticated and systematic manner. Maintaining the electronic database of the resource not only enhance the resource planning capacity but also speedup the decision making process.

5.2.4 The contractor must conduct resource constraint scheduling instead of simple schedules. Allocating the resources followed by scheduling will allow consideration of trade-off between schedule length and stability. Many project activities are potentially uncertain, lead to schedule disruption and crashing. Optimizing the allocation of resources by resource levelling and time-cost trade-off is recommended as the major factor for decision making process.

5.3 FUTURE DIRECTIONS

5.3.1 The conceptual framework for resource allocation has potentials for establishment of a model, which can be further studied and analysed for its maturity. Analysis should also be conducted to study the effectiveness of the five key fundamental factors and its comparison with the organizational performance on complex projects.

5.3.2 The scope of this thesis included the survey of capital city (Islamabad) and Punjab province. In total 78 contractor firms of CA Category (PEC Registered) were selected. Total CA category contractor firms in all provinces of Pakistan are about 117 in number. Although the figure 78 (66.67%) is a large representation of the population, however further survey study should be carried out to include the other provinces to make the entire representation of Pakistan.

REFERENCES

ADA (2010). "Resource Breakdown Structure." *Resource Management*, <www.brighthub.com/office/project-management/articles/32864.aspx>. (Jan 30, 2011).

Ammar, M. A. (2011). "Optimization of Project Time-Cost Trade-Off Problem with Discounted Cash Flows." *Journal of Construction Engineering and Management*, 137(1), 65-71.

APCA (2010). "Construction Industry Vital for Economic Growth and Infrastructure Development." <http://www.apca.org.pk/pages/news.html>. (Feb 25, 2011).

Bailey, C. (2010). "Resource Loading." *Resource Management*, <www.brighthub.com/office/project-management/articles/69522.aspx>. (Jan 31, 2011).

Baker, K. R., and Trietsch, D. (2009). *Principles of Sequencing and Scheduling: Network Methods for Project Scheduling*, John Wiley & Sons Inc, New Jersey.

CBP (2009). "Resource Management Challenges." *A Benchmark of Current Business Practices*, Ther Centre for Business Practices, 18.

Chan, W.-T.,Chua, D. K. H., and Kannan, G. (1996). "Construction Resource Scheduling with Genetic Algorithms." *J. Constr. Engrg. and Mgmt*, 122(2), 125-132.

Chaudhry, S. M., and Kamal, S. (1999). *Introduction to Statistical Theory*, 7th Ed, Markazi Kutub Khana Urdu Bazar, Lahore.

Costa, D. B.,Formoso, C. T.,Kagioglou, M., and Alarcon, L. F. (2004)"Performance Measurement Systems for Benchmarking in the Construction Industry." *Proc., 12th Annual Conference on Lean Construction*, IGLC, Denmark.

Doulabi, S. H. H.,Seifi, A., and Shariat, S. Y. (2010). "An Efficient Hybrid Genetic Algorithm for Resource Leveling via Activity Splitting." *Journal of Construction Engineering and Management*.

Easa, S. M. (1989). "Resource Levelling in Construction by Optimization." *J. Constr. Engrg. and Mgmt*, 115(2), 302-316.

Economists, T. (2003). *The Economicist Numbers Guide: the essentials of Business Numeracy*, 3rd Ed, London.

Eldosouky, A. I. (2001). *Principles of Construction Project Management: Planning and Scheduling*, Reprinted, Tanta University.

Farooqui, R. U., and Ahmed, S. M. (2008)"Assessment of Constructability Practices among General Contractors in Pakistan's Construction Industry." *Proc., CIB W107 Construction in Developing Countries International Symposium*, Trinidad & Tobago, West Indies.

Forman, E. H., and Selly, M. A. (2001). *Decision by Objectives: Resource Allocation*, World Scientidfic Publishing Co, Singapore.

Geem, Z. W. (2010). "Multiobjective Optimization of Time-Cost Trade-Off Using Harmony Search." *Journal of Construction Engineering and Management*, 136(6), 711-716.

Hariga, M., and El-Sayegh, S. M. (2011). "Cost Optimization Model for the Multiresource Leveling Problem with Allowed Activity Splitting." *Journal of Construction Engineering and Management*, 137(1), 56-64.

He, J.,Wan, Z. P., and Tang, G. (2005). "Construction Project Scheduling Problem with Uncertain Resource Constraint." *Chinese J. Engrg Maths*, 3, 12.

Ibbs, W., and Nguyen, L. D. (2007). "Schedule Analysis under the Effect of Resource Allocation." *J. of Constr. Engrg. and Mgmt.*, 133(2), 131-138.

IPS (2011). "WTO and Pakistan's Construction Sector." <http://www.ips.org.pk/pakistanaffairs/economy/1110.html>. (Mar 25, 2011).

Jiang, G., and Shi, J. (2005). "Exact Algorithm for Solving Project Scheduling Problems under Multiple Resource Constraints." *J. Constr. Engrg. and Mgmt*, 131(9), 986-992.

Kanji, G. K. (2006). *100 Statistical Tests*, 3rd, SAGE Publications Ltd, London.

Kelleher, A. H. (2004). "An Investigation of the Expanding Role of the CPM by Engineer's Top 400 Contractors." M.S. Thesis, Virginia Polytechnic Institute and State University.

Kerr, A. W.,Hall, H. K., and Kozub, S. A. (2002). *Doing Statistics with SPSS*, SAGE Publications Ltd, London.

Klein, R. (1999). *Scheduling of Resource-Constrained Projects*, Kluwer Academic Publishers, Assinippi Park, Norwell.

Le, H. Q. (2008)"Resource Constrianed Multi-Project Scheduling with Resource Moving Time for construction Projects in Vietnam." *Proc., First International Conference on Construction In Developing Countries (ICCIDC–I)*, Karachi.

Levy, S. M. (2009). *Construct Process Planning & Management*, Elsevier Inc, Burlington.

Liu, Y.,Zhao, S. l.,Du, X. K., and Li, S. Q. (2005)"Optimization of Resource Allocation in Construction Using Genetic Algorithms." *Proc., 4th International Conference on Machine Learning and Cybernetics*, IEEE Press, Guangzhou.

Lo, W., and Chen, Y.-T. (2007)"Optimization of Contractor's S-Curve." *Proc., 24th International Symposium on Automation & Robotics in Construction (ISARC 2007)*, Madras.

Lock, D. (2004). *Project Management in Construction*, Gower Publishing Limited, Aldershot.

Loosemore, M.,Dainty, A., and Lingard, H. (2003). *Human Resource Management in Construction Projects*, Spon Press, London.

Mendoza, C. E. (1995). "Resource Planning and Resource Allocation in the Construction Industry." M.Engg. Thesis, University of Florida, Gainesville.

Menesi, W. (2010). "Construction Scheduling Using Critical Path Analysis with seperate Time Segments." Doctoral Dissertation, University of Waterloo, Ontario.

Mingozzi, A.,Maniezzo, V.,Ricciardelli, S., and Bianco, L. (1998). "An Exact Algorithm for the Resource Constrained Project Scheduling Problem based on a New Mathematical Formulation." *Mgmt. Sciences*, 44(5), 714-729.

Moder, J. J.,Philips, C. R., and Davis, E. W. (1983). *Project Management with CPM, PERT and Precedence Diagramming*, 3rd Ed, Van Nostrand Reinhold Company Inc, New York.

Neumann, K., and Zimmermann, J. (1999). "Resource Levelling for Projects with Schedule-Dependent Time Windows." *Eur. J. Oper. Research*, 117(3), 591-605.

Neumann, K., and Zimmermann, J. (2000). "Procedures for Resource Leveling and Net Present Value Problems in Project Scheduling with General Temporal and Resource Constraints." *Eur. J. Oper. Research*, 127, 425-443.

Pallant, J. (2007). *SPSS Survival Manual: A Step by Step Guide to Data Analysis using SPSS for Windows*, 3rd Ed, Open University Press Mc Graw-Hill, Maidenhead.

Park, H. M. (2008). "Univariate Analysis and Normality Test Using SAS, Stata and SPSS." *Working Paper*, The University Information Technology Services (UITS) Center for Statistical and Mathematical Computing, Indiana University.

PMI (2004). *A Guide to Project management Body of Knowledge (PMBOK® Guide)*, 3rd Ed, Project Management Institute, Inc, Pennsylvania.

PMSolutions (2009). "Resource Management and the PMO." *Project Management Solutions White Paper Series*.

Powell, E. T. (1998). "Questionnaire Design: Asking Questions with a Purpose." *Program Development and Evaluation*, University of Wisconsin-Extension, Texas, 20.

Rees, A. (1963). "The Effects of Unions on Resource Allocation." *J. Law & Eco*, 6, 69-78.

Reiss, G. (2007). *Project Management Demystified*, 3rd Ed, Taylor & Francis, Abingdon.

Saunders, M.,Lewis, P., and Thornhill, A. (2009). *Research Methods for Business Students*, 5th Ed, Prentice Hall, Harlow.

Schwendt, C. (2005). *Resource Allocation in Project Management*, GOR Publications, Berlin.

Sengupta, H., and Guha, H. (1995). *Construction Management and Planning*, 6th Reprint, Tata McGraw-Hill Publishing Company Limited, New Delhi.

Smith, D. (2003). "Five Principles for Research Ethics." *Monitor on Psychology*, American Psychological Association, Washington, pp56.

Spencer, D. L. (1969). "An Investigation of the Relationships between the Sequencing and Scheduling Problems." Doctoral Dissertation, Texas Technological College.

Thompson, K. N. (2010). "Servant Leadership: An Effective Model for Project Management." Doctoral Dissertation, Capella University, Minneapolis.

ToolWatch (2006). "Construction Resource Management." *Improving Contractor Business Performance*, ToolWatch Corporation, Englewood.

Trochim, W. M. K. (2006). "Ethics in Research." *Research Methods*, <http://www.socialresearchmethods.net/>. (Feb 24, 2011).

Tutor, C. (2007). "A Practical Guide to Construction Scheduling." <www.cpmtutor.com/index.html>. (Dec 22, 2010).

Vanhoucke, M. (2005). "New Computational Results for the Discrete Time/Cost Trade-Off Problem with Time-Switch Constraints." *European Journal of Operational Research*, 165(2), 359-374.

Wilson, J. (2010). *Essentials of Business Research: A Guide to Doing Your Research Project*, 1st Ed, SAGE Publications Ltd, London.

Yang, J.,Shen, G. Q.,Drew, D. S., and Ho, M. (2010). "Critical Success Factors for Stakeholder Management: Construction Practitioners' Perspectives." *Journal of Construction Engineering and Management*, 136(7), 778-786.

Zou, P. X. W.,Chen, Y., and Chan, T.-Y. (2010). "Understanding and Improving Your Risk Management Capability: Assessment Model for Construction Organizations." *J. Constr. Eng. Manage.*, 136(8), 854-863.

APPENDICES

Appendix 1

LIST OF CONTRACTOR FIRMS

1.1 CA CATEGORY CONTRACTOR FIRMS (PEC REGISTERED) IN ISLAMABAD (CAPITAL CITY OF PAKISTAN)

Ser	Contractor Firms
1.	Khyber Grace (Pvt) Ltd
2.	Ch. A. Latif& Sons (Pvt) Ltd
3.	Exceed (Pvt) Ltd
4.	Matracon Pakistan Private Limited
5.	National Construction Limited
6.	Hajaviry Associates (Pvt) Ltd
7.	Ashers Trading & Construction Co
8.	Expertise (Pvt) Ltd
9.	Recent Construction Company
10.	Muhammad Ayub& Brothers
11.	Petrosin Engineering (Pvt) Ltd
12.	Anser Brothers (Pvt) Ltd (New Name)
13.	Techno Engineering Services (Pvt) Ltd
14.	Universal Corporation (Pvt) Ltd
15.	Mumtaz Construction Company (Pvt) Ltd
16.	Skyways Construction (Pvt) Ltd
17.	M.A. Aleem Khan & Sons (Pvt) Ltd
18.	Arshad& Co
19.	Qavi Engineers (Pvt) Ltd
20.	Moinsons (Pvt) Ltd
21.	Sachal Engineering Works (Pvt) Ltd
22.	Karcon Private Limited
23.	Hakas (Pvt) Ltd

1.2 CA CATEGORY CONTRACTOR FIRMS (PEC REGISTERED) IN PUNJAB (PROVINCE OF PAKISTAN)

Ser	Contractor Firms
1.	NPI Construction and Engineering
2.	KKP (Pvt) Ltd
3.	Echo West International (Pvt) Ltd
4.	IVCC Engineering (Pvt) Ltd
5.	Technical Associates Pakistan (Pvt) Ltd
6.	H.A. Construction
7.	ICC (Pvt) Limited
8.	Uni-Build Associates (Pvt) Ltd
9.	Interhome (Pvt) Ltd
10.	Guarantee Engineers
11.	Sadaat Enterprises
12.	Khalid Rauf& Co (Pvt) Ltd
13.	National Power Const Corporation (Pvt) Ltd
14.	HabibRafiq (Pvt) Ltd
15.	MCC Ruba International Real Estate Holding(Pvt)Ltd
16.	Saadullah Khan & Brothers
17.	Choudhry Engineers Associates
18.	Izhar Construction (Pvt)Ltd
19.	HusnainCotex Ltd
20.	Izhar (Pvt) Ltd
21.	Builders Associates (Pvt) Ltd
22.	Mass Constructors
23.	Sarwar& Co (Pvt) Ltd
24.	Habib Construction Services (Pvt) Ltd
25.	Descon Engineering (Pvt) Ltd
26.	Mughals Pakistan (Pvt) Ltd

Continued

Ser	Contractor Firms
27.	RMC Construction Co (New Name)
28.	IBEX Engineering (Pvt) Ltd
29.	Principal Builders
30.	H.M. Associates (Pvt) Ltd
31.	Associated Technologies (Pvt) Ltd
32.	Sinaco Engineers (Pvt) Ltd
33.	Hassan Sarwar Associates
34.	Tanveer Corporation (Pvt) Ltd
35.	Sh. AbdurRazzaq& Co (Pvt) Ltd
36.	A.M. Construction Co. (Pvt) Ltd
37.	GhulamRasool& Company (Pvt) Ltd
38.	Kingcrete Builders
39.	Zahir Khan & Brothers
40.	MIDJAC (Pvt) Ltd
41.	L.A.C (Pvt) Ltd (New Name)
42.	Taameer Associates
43.	S.A.Z. Co (Pvt) Ltd
44.	Pakistan Oilfields Limited
45.	Gammon Pakistan Ltd
46.	Royal Construction Co.(Pvt) Ltd
47.	Simcon Construction Co.
48.	Choudhry Construction Co
49.	Hidayatullah Khan & Co
50.	Nazir& Company (Pvt) Ltd
51.	Malik Abdul Salam & Co
52.	Pak Elektron Limited
53.	PressonDescon International (Pvt) Ltd.
54.	Parco Construction Company
55.	Nissan Engineers Pvt(Ltd)

Appendix 2

COVER LETTER

(RESOURCE MANAGEMENT RESEARCH QUESTIONNAIRE)

To: _____

Subject: **RESOURCE MANAGEMENT RESEARCH QUESTIONNAIRE**

Respected Sir,

Department of **Construction Engineering and Management** at **School of Civil and Environmental Engineering** (NUST) Islamabad is conducting a **Research Survey** to discover the root causes of our **Resource Management** challenges as well as the trends and techniques followed by the Construction Industry of Pakistan.

The construction industry is one of the most important sectors in any nation's development plan. The volume of construction is an indicator of a nation's progress and economic prosperity. This means that what is happening to the construction industry must be a matter of national concern. That is the reason for this study, which have made this area of research an important field for future improvement in the construction sector of this country.

The current economic condition has influenced both contractors and Pakistani government agencies to change their business attitude to a more competitive and a more conservative business approach. A contractor's success is dependent on his ability to accomplish projects in the most economical manner. They can achieve this objective by managing their available resources effectively and efficiently. **Resource Management** is among the nine critical areas whose standard practices are well defined in the **PMBOK® Guide** and other standards. Numerous articles, books and papers are dedicated to "***Best Practices***" on the theme as well. Still **Resource Management** issues are among the top challenges for the organizations practicing professionalism in **Project Management**.

We are conducting number of confidential surveys, aimed at the senior management levels, to discover the key issues of resource allocation and management challenges as well as the trends and techniques followed. To help with this task, we would like you to complete the attached questionnaire – confidentiality is assured. All responses will be treated in strict confidence. The questionnaire is relatively simple to complete and ask about your attitudes to resource allocation and management issues; as well as any suggestion you might have to improve the things in your work place.

We appreciate your participation in this survey in true letter and spirit. This will be a positive contribution towards study for the improvement in the construction sector.

Yours Sincerely,

MUHAMMAD JAWAD ANSARI
Post Graduate Student
Construction Engineering & Management

DR. RAFIQ MUHAMMAD CHOUDHRY (Ph D)
Head of Department
Construction Engineering & Management
National Institute of Transportation (NIT)
School of Civil & Environmental Engineering (SCEE)
Sector H-12, NUST, Islamabad.

Appendix 3

SURVEY QUESTIONNAIRE

2.1 RESPONDENT PROFILE

Org Name / PEC
Address
Name / Designation
PEC Category
Construction Types

2.2 QUESTIONNAIRE

2.2.1 PROJECT MANAGEMENT

(Best-to-Worst)

a. **MANAGEMENT / EXECUTIVES / STAKEHOLDER RESPONSIBILITIES**

		5	4	3	2	1
Q-016	Stakeholder responsibilities, authorities doesn't conflict					
Q-025	Management clearly understands its responsibility to provide the resources needed to succeed.					
Q-063	Executive managers are supportive of project culture.					
Q-066	Project stakeholders comply with PM policies/procedures.					

b. **STAFFING POLICIES**

Q-022	Organization staffing policies are considered in activity resource estimating.					
Q-010	Competency levels needed are well defined.					

c. **PMO / DECISION MAKING POLICIES AND EFFECTIVENESS**

Q-001	Resource management processes and standards, used by nearly all projects, are integrated with other corporate processes and systems.					
Q-004	Processes are in place to measure resource management effectiveness and efficiency.					
Q-060	The organization has a strong, effective PMO.					
Q-067	Decision-making policies/procedures are clear / effective.					

d. **ORGANIZATION GOALS / OBJECTIVES / STRATEGIC PLAN**

Q-068	Organizational goals/objectives are clear and understood.					
Q-030	Projects are prioritized.					

2.2.2 PROJECT PLANNING & SCHEDULING (Best-to-Worst)

a. ACTIVITIES / SKILLS REQUIRED

		5	4	3	2	1
Q-009	Activities \ Skills needed are well defined.					

b. REALISTIC SCHEDULES / DEAD-LINES / INTERNAL TARGETS

Q-006	Projects are given an internal completion date as well, based on the scope.					
Q-013	Schedules, deadlines are not unrealistic.					
Q-015	Individual schedules are always considered when building the project schedule					

c. PERFORMANCE & MONITORING

Q-037	Performance measurement tool (comparing actual to planned charges).					

d. SCHEDULING & PLANNING TECHNIQUES

Q-043	Program Evaluation and Review Technique (PERT)					
Q-044	Multi-Agent Resource Allocation (MARA)					
Q-045	Critical Path Method (CPM)					
Q-046	Line of Balance (LOB)					
Q-047	Generic Algorithms (GA)					
Q-048	Other					

2.2.3 RESOURCE PLANNING & SCHEDULING (Best-to-Worst)

a. RESOURCE HANDLING STANDARDS / PROCEDURES

		5	4	3	2	1
Q-002	Resource management improvement processes are in place and used.					
Q-003	Lessons learned are regularly examined and used to improve documented processes.					
Q-065	Std processes are used for managing & leading change.					
Q-020	Resource utilization is adequately documented.					
Q-033	Utilization of extended hours/overtime (if needed) is considered to reduce the durations of critical activities.					
Q-035	Resource utilization is recorded for the work performed.					
Q-041	How often you update your records and information 5(daily), 4(weekly), 3(fortnightly), 2(monthly), 1(quarterly/annually)					
Q-069	Resource utilization is tracked effectively.					
Q-007	Resource risks are assessment.					
Q-024	Resource risk is considered in developing a risk management plan.					

b. RESOURCE BREAKDOWN STRUCTURE (RBS)

		5	4	3	2	1
Q-021	Project plans include resource breakdown structures					
Q-039	Resource breakdown structure.					

c. RESOURCE AVAILABILITY/ADEQUACY/CAPACITY PLANNING

Q-023	Information for approximating the costs of the resources is available and used.					

Continued

Q-028	In schedule activity durations, the organization uses various information with resource availabilities.					
Q-036	Resource assignment database (what resources are working on).					
Q-070	Resource information is reported effectively.					
Q-071	Project information is visible to the entire organization.					
Q-029	The resources required to complete each activity are considered to determine the duration of each activity					
Q-072	Project resources are adequate to complete the work.					
Q-074	There are enough appropriately equipment/material resources to perform the work scheduled.					
Q-008	Resource capacity planning is conducted.					
Q-019	There is always capacity flexibility (overtime, subcontracting).					
Q-026	The centralized pool of project resources.					
Q-061	Resources have a consistent place and time to meet.					
Q-014	Planned time off/out for resources is factored into the schedule.					
Q-017	There are mostly planned requests for resources					
Q-073	Project resources communicate effectively.					

d. **RESOURCE LOADING**

Q-051	Resource Loading / Resource Allocation					

e. **RESOURCE HISTOGRAM / CALENDAR**

Q-040	Resource calendar / Resource histogram.					
Q-049	Multiple Calendars					

f. **RESOURCE MANAGEMENT PLAN**

Q-005	There is a mandate to comply with all documented and repeatable resource management processes.					
Q-038	Resource management plan.					

2.2.4 RESOURCE ALLOCATION (Best-to-Worst)

a. **RESOURCE ALLOCATION AS PER SCHEDULE** 5 4 3 2 1

Q-012	Resources are allocated according to schedule rather than by percentage of time.					

b. **RESOURCE LEVELLING**

Q-027	When resources are assigned and resource over-allocations exist, resource levelling is used.					
Q-031	Resource levelling is used to keep selected resource usage at a constant level.					
Q-052	Resource Levelling					

c. **RESOURCE TIME-COST TRADE-OFF / CRASHING**

Q-050	Schedule Crashing					
Q-032	Resource reallocation from non-critical to critical activities is used to bring projects back on track.					

Continued

	Q-034	The project schedule repeatedly gets recalculated due to missed deadlines.					

d. **RESOURCE CONSTRAINTS SCHEDULING**

Q-053	Resource Constraints Scheduling					
Q-018	Shifting resources to respond to problems is easy.					
Q-062	Resources are shared effectively.					
Q-064	There is clear Org culture for sharing resources.					
Q-011	Resource allocation are optimized					

e. **RESOURCE SCHEDULING ACROSS MULTIPLE PROJECTS**

Q-054	Scheduling Across Multiple Projects					

2.2.5 RESOURCE AUTOMATION SYSTEM (Best-to-Worst)

			5	4	3	2	1
a.	Q-042	Does your organization have an automated information system to assist you in your resource management functions (enterprise resource planning, project management, project portfolio management or related software)?					
b.	Q-055	MS Project					
c.	Q-056	Primavera					
d.	Q-057	Sure Track					
e.	Q-058	Integrated Management System					
f.	Q-059	Other					

ORGANIZATIONAL PERFORMANCE (Best-to-Worst)

		5	4	3	2	1
Q-075	The organization's strategies are executed according to plan.					
Q-076	The organization's shareholders are satisfied.					
Q-077	The organization is financially successful.					
Q-078	Projects are completed on schedule and on budget.					
Q-079	Project customers are satisfied.					
Q-080	Project resources are allocated optimally.					
Q-081	Projects are aligned to the organization's business strategy.					
Q-082	The organization works on the right projects.					

Muhammad Jawad Ansari
Department of Construction Engineering and Management
NIT (SCEE), NUST, Sector H-12, Islamabad

Appendix4

TEST OF NORMALITY

			Statistic	Std. Error
Project Management	Mean		2.83	.123
	95% Confidence Interval for Mean	Lower Bound	2.58	
		Upper Bound	3.08	
	5% Trimmed Mean		2.81	
	Median		3.00	
Project Planning & Scheduling	Mean		2.03	.082
	95% Confidence Interval for Mean	Lower Bound	1.87	
		Upper Bound	2.19	
	5% Trimmed Mean		2.02	
	Median		2.00	
Resource Planning	Mean		2.34	.108
	95% Confidence Interval for Mean	Lower Bound	2.12	
		Upper Bound	2.55	
	5% Trimmed Mean		2.30	
	Median		2.00	
Resource Allocation	Mean		2.48	.122
	95% Confidence Interval for Mean	Lower Bound	2.23	
		Upper Bound	2.72	
	5% Trimmed Mean		2.44	
	Median		3.00	
Resource Automation System	Mean		1.32	.093
	95% Confidence Interval for Mean	Lower Bound	1.14	
		Upper Bound	1.51	
	5% Trimmed Mean		1.23	
	Median		1.00	

Appendix 5

SPEARMAN'S RHO CORRELATION

			Project Management	Project Planning & Scheduling	Resource Planning	Resource Allocation	Resource Automation System
Spearman's rho	Project Management	Correlation Coefficient	1.000	.744	.794	.859	.615
		Sig. (2-tailed)	.	.000	.000	.000	.000
		N	65	65	65	65	65
	Project Planning & Scheduling	Correlation Coefficient	.744	1.000	.749	.787	.534
		Sig. (2-tailed)	.000	.	.000	.000	.000
		N	65	65	65	65	65
	Resource Planning	Correlation Coefficient	.794	.749	1.000	.825	.595
		Sig. (2-tailed)	.000	.000	.	.000	.000
		N	65	65	65	65	65
	Resource Allocation	Correlation Coefficient	.859	.787	.825	1.000	.537
		Sig. (2-tailed)	.000	.000	.000	.	.000
		N	65	65	65	65	65
	Resource Automation System	Correlation Coefficient	.615	.534	.595	.537	1.000
		Sig. (2-tailed)	.000	.000	.000	.000	.
		N	65	65	65	65	65

Appendix 6

CHI-SQUARE DISTRIBUTION TABLE

df\Area	0.95	0.5	0.1	0.05	0.025	0.01
1	0.00393	0.45494	2.70554	3.84146	5.02389	6.6349
2	0.10259	1.38629	4.60517	5.99146	7.37776	9.21034
3	0.35185	2.36597	6.25139	7.81473	9.3484	11.34487
4	0.71072	3.35669	7.77944	9.48773	11.14329	13.2767
5	1.14548	4.35146	9.23636	11.0705	12.8325	15.08627
6	1.63538	5.34812	10.64464	12.59159	14.44938	16.81189
7	2.16735	6.34581	12.01704	14.06714	16.01276	18.47531
8	2.73264	7.34412	13.36157	15.50731	17.53455	20.09024
9	3.32511	8.34283	14.68366	16.91898	19.02277	21.66599
10	3.9403	9.34182	15.98718	18.30704	20.48318	23.20925
11	4.57481	10.341	17.27501	19.67514	21.92005	24.72497
12	5.22603	11.34032	18.54935	21.02607	23.33666	26.21697
13	5.89186	12.33976	19.81193	22.36203	24.7356	27.68825
14	6.57063	13.33927	21.06414	23.68479	26.11895	29.14124
15	7.26094	14.33886	22.30713	24.99579	27.48839	30.57791
16	7.96165	15.3385	23.54183	26.29623	28.84535	31.99993
17	8.67176	16.33818	24.76904	27.58711	30.19101	33.40866
18	9.39046	17.3379	25.98942	28.8693	31.52638	34.80531
19	10.11701	18.33765	27.20357	30.14353	32.85233	36.19087
20	10.85081	19.33743	28.41198	31.41043	34.16961	37.56623
21	11.59131	20.33723	29.61509	32.67057	35.47888	38.93217
22	12.33801	21.33704	30.81328	33.92444	36.78071	40.28936
23	13.09051	22.33688	32.0069	35.17246	38.07563	41.6384
24	13.84843	23.33673	33.19624	36.41503	39.36408	42.97982
25	14.61141	24.33659	34.38159	37.65248	40.64647	44.3141
26	15.37916	25.33646	35.56317	38.88514	41.92317	45.64168
27	16.1514	26.33634	36.74122	40.11327	43.19451	46.96294
28	16.92788	27.33623	37.91592	41.33714	44.46079	48.27824
29	17.70837	28.33613	39.08747	42.55697	45.72229	49.58788
30	18.49266	29.33603	40.25602	43.77297	46.97924	50.89218

(STATSOFT: www.statsoft.com)