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Improving Labour Productivity on Construction Projects

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ABSTRACT

In order for businesses to succeed, management must keep a close eye on the bottom line. One of the many factors that directly affect a firm's profitability is employee productivity.

The purpose of this research is to study the productivity rates on construction projects and the role of project manager to improve the productivity rates by highlighting the techniques that can be used and applied to achieve a noticeable difference in the productivity.

Literature review is conducted through referred researches and journals to show different findings and theories related to the productivity rates and the methods of improvement. And then research instruments were used such as work sampling and interviews in order to reach to the final discussions and conclusions.

The study shows that the productivity rates of the construction workers vary from one project to another, taking into consideration the type of the activity to be carried out and the surrounding work environment. However, the study also highlights how the project manager can intervene in order to improve the productivity of his workers.

بسم الله الرحمن الرحيم

أهدي هذا العمل إلى من كانت حياتي و دراستي وعملي لنيل رضاهما ومباركتهما ....

والدي العزيز ... ليرحمك الله ويسكنك فسيح جناته

أمي الغالية ... ليحفظك الله لي تاجا فوق رأسي

كما وأهديه إلى زوجتي الحبيبة ... ليبارك الله لي بك

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CHAPTER ONE:

INTRODUCTION

1.1 Background

Labour productivity is of central importance to the economic health of the United Arab Emirates economy. Due to the size of the construction industry, productivity changes within it have significant direct effects on the national productivity and economic well-being.

Many researchers have expressed concern over productivity in the construction industry. Perceptions of productivity trends vary widely within engineering academia, industry, and economic academia, where many researches have influenced the belief that construction labor productivity has been decreasing for decades (Business Roundtable 1988). Economists are split, with many questioning the existence of any construction productivity decline, while others speculate as to the causes. Clearly there is a lack of agreement and understanding concerning this critical issue. Construction labor productivity remains one of the least understood factors in the economy (Eisner, 1994).

According to Faraday (1971), the problem of productivity and productivity measurement has been addressed for many years without coming to any conclusions. He claimed that the calculation of productivity has long been a field of controversy when attempts are made; little value is placed on the results because they seem to contain so many imperfections.

Productivity remains as one of the most elusive concepts in business and economic literature. It remains elusive because of a lack of definitive theoretical work –

mainly at the firm level (Taylor, 2007). However, the ever-rising customer requirements and expectations have increased demands for continually introducing improvements in the cost, timing and quality of the construction output. As world competition intensifies, leading construction organizations throughout the world continue to be more active in enhancing their competitive position by improving their performance. Thus, setting new operating targets and standards for national markets, this dynamic mechanism and the well-known fierce national competition have raised the awareness of performance measurement (benchmarking) among the majority of construction organizations.(Sherif, 1996)

There has been much work identifying the factors that affect productivity. Ineffective management has been cited as the primary cause of poor productivity rather than an unmotivated and unskilled workforce consequently, there has been significant research on how to make management more effective in supporting craftsworkers in the field. There is no doubt that management effectiveness ultimately determines profitability in most cases. Four primary ways of increasing productivity through management include: planning; resource supply and control; supply of information and feedback; and selection of the right people to control certain functions (Sanvido, 1988).

According to Hodgkinson (1999), productivity improvements lie at the core of economic restructuring process and strategies to improve productivity in the service sectors have been identified as essential for correcting the slowing growth rates in advanced economies. Furthermore, productivity is essentially a physical measure expressed as a ratio of outputs to inputs. This ratio can be readily converted into a value measure by converting outputs into revenue and inputs into labour and other costs. Thus improvements in productivity convert into improved profitability and generate a pool from which labour can be compensated for its contribution to this result in the form of pay rises.

1.2 Economic Growth & Productivity

Sharon (2004) defines productivity as the ratio of output to one or more of the inputs used in production - labour, land, capital (plant, machinery and equipment) etc. According to him, Total Factor Productivity (TFP) is defined as: output/total inputs. Labour productivity is defined as: output/labour inputs, and is therefore a partial productivity measure. Productivity provides us with a way of looking at how efficiently production inputs are used in an economy. It is important to bear in mind the distinction between labour productivity and TFP. An improvement in labour productivity (when defined as GDP (Gross Domestic Product) per hour worked) may not reflect an improvement in the efficiency of labour; it may result from the substitution of capital for labour, for example.

However, Sharon stated that it is also important to consider productivity over the long run. This is because, in the short run, productivity is strongly influenced by cyclical factors. So, for example, in the early part of a recession, labour productivity falls as output falls at a faster rate than labour is shed. During an economic upturn, labour productivity tends to rise, as labour is more fully utilized, and firms are able to expand with a less than proportional increase in employment.

According to Saari (2006), economic activity can be identified with production and consumption. Production is a process of combining various immaterial and material inputs of production so as to produce tools for consumption. The way of combining the inputs of production in the process of making output is called technology. Technology can be depicted mathematically by the production function which describes the function between input and output. The production function depicts production performance and productivity is the measure of it. By help of the production function, it is possible to describe simply the mechanism of economic growth. Economic growth is a production increase achieved by an economic community. It is usually expressed as an annual growth percentage depicting (real) growth of the national product. Economic growth is created by two factors so that it is appropriate to talk about the components of growth. These components are an increase in production input and an increase in productivity.

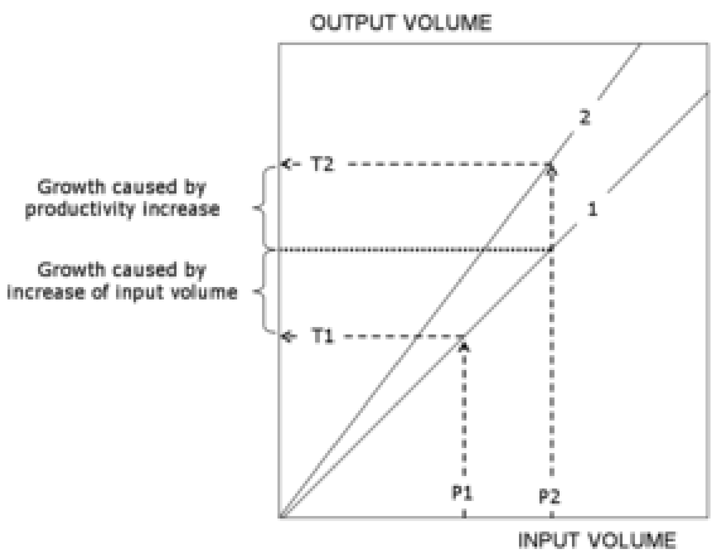

Figure 1.1: Components of economic growth (Saari 2006)

The figure presents an economic growth process. By way of illustration, the proportions shown in the figure are exaggerated. Reviewing the process in subsequent years (periods), one and two, it becomes evident that production has increased from Value T1 to Value T2. Both years can be described by a graph of production functions, each function being named after the respective number of the year, i.e., one and two. Two components are distinguishable in the output increase:

the growth caused by an increase in production input and the growth caused by an increase in productivity. Characteristic of the growth effected by an input increase is that the relation between output and input remains unchanged. The output growth corresponding to a shift of the production function is generated by the increase in productivity. (Saari 2006)

Accordingly, an increase in productivity is characterized by a shift of the production function and a consequent change to the output/input relation. The formula of total productivity is normally written as follows:

- Total productivity = Output quantity / Input quantity

1.3 Research Aim

The main aim of this research is to identify the factors that affect the productivity of the construction worker and how we can utilize these factors in order to improve the labour productivity on construction projects.

Among reaching to the aim of the research clear identification of the general concept of productivity and labour productivity will be studied. Throughout defining productivity, the relation between productivity and efficiency and effectiveness will be explained and the importance of productivity as a major factor of the economic growth.

However, it is essential to study the methods of measuring the productivity of construction worker and how do the difficulty and accuracy of these measurements vary from project to another, taking into consideration many factors like the type of the project, the size of the project, the volume of the workforce and others.

The research also will study the benchmarking of labour productivity and how to set up Target Productivity Rates that can be adopted for different types of tasks and activities, for example to find the target productivity rate of the shuttering carpenters throughout different activities like: Shuttering of foundation, columns, walls and slabs.. etc, and the same concept will be applied for the block mason and the steel fixer.

1.4 Research Objectives

In order to achieve the research aim, specific objectives were required:

1) To identify the most effective method to measure the productivity of the construction workers (Three categories were selected: Shuttering Carpenter, Steel Fixer and Block Mason).
2) To examine the variations in the productivity of the selected trades across the projects in order to determine the Target Productivity Rates of different major construction tasks as a benchmark.
3) To investigate the factors which influence the productivity of the construction worker.
4) Identify how the management can intervene to improve the productivity of their workers.

1.5 Research Methodology

The first methodology of the research is the literature review carried out and directed towards the research aim and objectives, the literature review should include different views and previous researches' findings from relevant books, journals and previous reports which had studied the topic, and this will be as starting point of the research.

Second step will be collecting data about construction worker productivity across several construction residential projects (case studies) through daily monitoring of their productivity and then process these data to determine productivity trend and the target productivity rates to be as benchmarks in order to enable evaluating the performance of the construction workers and examining the influence of the factors which would be obtained from the literature that could affect the improvement of the productivity.

Finally, to conduct interviews with the project managers and the key personnel of the case studies projects. The purpose of these interviews is to obtain direct information about the research topic and examine the validity of the results obtained from the literature in order to reach to final conclusions and recommendations.

1.6 Research Organisation

Chapter One consists of the research topic background and its importance and the need of this study to the construction industry, and then the aim and the objectives follow in addition to the research methodology.

Chapter Two includes literature review related to the definitions of the construction worker productivity and the productivity measurement and benchmarking.

Chapter Three consists of further literature related to the productivity improvement and the factors which influence the productivity of the construction worker.

Chapter Four presents the research methods obtained in this study and detailed explanation of the process of data collection from the case studies and then approach to the data processing.

Chapter Five consists of the results of analyzing the data collected from chapter four in order to reach to productivity benchmarks.

Chapter Six introduces the examination of the factors resulted from the literature through interviews conducted with the project managers of the case studies projects and then the final conclusions and recommendations.

CHAPTER TWO:

PRODUCTIVITY OF CONSTRUCTION WORKER

2.1 Defining Productivity

Productivity is a general indicator to measure performance taking into account efficiency. Productivity generally takes the form of output divided by input. Output may be any indicator of what a business is trying to produce, such as revenue, profit, units produced, etc. Common input measures are time, labour, and other recourses used in the production of goods or services, e.g. revenue per person. Productivity measures are also part of the balanced scorecard system and generally rely on some indicators of output per employee. (Litschka, 2006)

Productivity in economics refers to measures of output from production processes, per unit of input. Labour productivity, for example, is typically measured as a ratio of output per labour-hour, an input. Productivity may be conceived of as a measure of the technical or engineering efficiency of production. As such quantitative measures of input, and sometimes output, are emphasized. Productivity is distinct from measures of allocative efficiency, which take into account both the value of what is produced and the cost of inputs used, and also distinct from measures of profitability, which address the difference between the revenues obtained from output and the expense associated with consumption of inputs. (Saari, 2006)

In its simplest form, labour productivity could be defined as the hours of work divided by the units of work accomplished (Thomas, 1994). However, in reality, labour productivity is a much more complex phenomenon which largely depends on quite diverse factors such as site conditions, workers' competence, materials availability, weather, motivation, supervision, to name just a few. Management also affects labour productivity. Ganesan (1984), for example, reported that incompetent management of the industry and its construction agencies, whether these are public or private, is a prime cause of low productivity. Often, labour productivity is a key factor contributing to the inability of many contracting organizations to achieve their project goals, which include, most importantly, the profit margin. Therefore, it is paramount to understand the main determinants of labour productivity, and to keep and compare accurate records of productivity levels across projects.

Labour productivity is generally speaking held to be the same as the "average product of labour" (average output per worker or per worker-hour, an output which could be measured in physical terms or in price terms).

Labour productivity is defined by the OECD Manual (2002) to be "the ratio of a volume measure of output to a volume measure of input". Volume measures of output are normally gross domestic product (GDP) or gross value added (GVA), expressed at constant prices i.e. adjusted for inflation. The three most commonly used measures of input are: hours worked; workforce jobs; and number of people in employment. Measured labour productivity will vary as a function of both other input factors and the efficiency with which the factors of production are used (total factor productivity). So two firms or countries may have equal total factor productivity (productive technologies) but because one has more capital to use, labour productivity will be higher.

2.2 Efficiency & Effectiveness

Productivity studies analyze technical processes and engineering relationships such as how much of an output can be produced in a specified period of time. It is related to the concept of efficiency. While productivity is the amount of output produced relative to the amount of resources (time and money) that go into the production, efficiency is the value of output relative to the cost of inputs used. Productivity improves when the quantity of output increases relative to the quantity of input. Efficiency improves, when the cost of inputs used is reduced relative the value of output. A change in the price of inputs might lead a firm to change the mix of inputs used, in order to reduce the cost of inputs used, and improve efficiency, without actually increasing the quantity of output relative the quantity of inputs. A change in technology, however, might allow a firm to increase output with a given quantity of inputs; such an increase in productivity would be more technically efficient, but might not reflect any change in allocative efficiency.

Efficiency generally refers to increases in the output/input ratio and is thus consist with the cost-oriented concepts of productivity, which can be achieved by either expanding output or reducing inputs. Effectiveness, on the other hand, refers to improvement in the internal capacity of the unit to deliver services which meet the requirements of the clients or in the quality and targeting of that service towards, those clients most in need of those services. Effectiveness measures thus require the inclusion of quality of service factors, a concept well recognized in productivity analysis but which has been exceedingly difficult to measure. (Hodgkinson, 1999)

2.3 Productivity Measurement

Researchers have a long tradition of measuring productivity at the industry or macro-economic level, typically making a longitudinal study of productivity trends, but this high-level analysis does not provide an indication of firm level performance (El-Mashaleh et al., 2001). Other literature examined various influences on productivity through both longitudinal and cross-sectional studies among contemporaneous projects and/or activities. Man-hours employed and work produced get measured and compared to past records, or compared with other firms to obtain measurements of how efficient a firm is in undertaking its activities (Thomas and Napolitan, 1995; El-Mashaleh et al., 2001).

Enshassi et al. (2007) say that the scope of most construction productivity research has been on partial measures, principally labour. While useful at the activity level, partial factor metrics are limited. In particular, they do not address complex interactions between different factors both within and across projects.

El-Mashaleh et al. (2001) stated that productivity measure at the firm level has a host of benefits, as it supports:

- Management decisions regarding resource utilization across projects to achieve highest return;
- Management decisions about investment in resources and in mix of projects; benchmarking efforts, thus allowing contractors to better understand their competitive position and improve their performance; and. comparative research of various management policies.

According to Jaideep et al (1995), in the construction industry, productivity has always been very difficult to measure and control. All estimating professionals would agree that the quantity of work to be performed and the cost per hour for labour to perform that work can be established with considerable accuracy. However, he added that it is the identifying and evaluating of the critical factors which influence productivity that provides a challenge. Every error in productivity estimation causes an inverse effect in the actual cost of labour to perform a cope of work. Productivity improvement can be viewed as a continuous and orderly management process which implies change. Companies, and especially the estimators within the company, must learn to forecast scientifically a realistic productivity value in order to be competitive and to survive in today's bidding environment.

Baumol and Maddela, (1990) identified the changes in the quality of equipment, materials or labours as critical factors of productivity measurement. They state that quality changes in labour, materials or equipment are often confused as contributors to true labour productivity decline or advancements, and also suggest that quality must be looked at separately from the issue of true productivity improvements or decline.

Labour productivity is not the same as the marginal product of labour, which refers to the increase in output that results from a corresponding increase in labour input. Output per worker corresponds to the "average product of labour" and can be contrasted with the marginal product of labour, which refers to the increase in output that results from a corresponding (marginal) increase in labour input.

However, some aspects of labour productivity may be very difficult to measure exactly, or in an unbiased way, such as:

- The intensity of labour-effort, and the quality of labour effort generally.
- The creative activity involved in producing technical innovations.
- The relative efficiency gains resulting from different systems of management, organisation, co-ordination or engineering.
- The productive effects of some forms of labour on other forms of labour.

These aspects of productivity refer to the qualitative, rather than quantitative, dimensions of labour input. If one firm/country is using labour much more intensely, it does not necessary mean that this is due to greater labour productivity, since the output per labour-effort may be the same. This insight becomes particularly important when a large part of what is produced in an economy consists of services. Management may be very preoccupied with the productivity of employees, but the productivity gains of management itself might be very difficult to prove. Modern management literature emphasizes the important effect of the overall work culture or organizational culture that an enterprise has.

In this research, Chistester (1992) method of productivity measurement was adopted where he proposed the XYZ model of construction productivity. This model uses three key variables to analyze productivity – time, quantities and unit installation rate – and it can be applied to any project of any discipline that requires bulk quantity installation.

However, most of the researchers' productivity measurement theories can be summarized by the following formula:

Productivity = Output Quantity / Input Quantity

2.4 Benchmarking

Sherif (1996) stated that in construction, benchmarking is not a straightforward task due to both the very nature of the industry which lacks solid data gathering and the remarkable fluctuation in productivity. Benchmarking attempts in construction are bound to face certain difficulties such as incomplete or non-existent data. Even if data are well recorded and retrievable, it would be highly dependent on the special characteristics of the project, e.g. size, type and budget. Therefore, he added, it is difficult to use it effectively as a basis for comparison, the structure of the industry with its temporary nature in organizing the construction process, where a number of organizations get involved in designing and constructing a single project, adds to the complexity of the benchmarking task. Benchmarking only works if consistent methods of measuring the performance of operations can be developed and introduced. Sherif (1996) in his study claimed that such methods do not exist in the construction industry where the majority of the relatively limited number of studies devoted to construction productivity and performance measurement is concerned with identification of sources of delays, rather than with analysis of measuring systems and techniques.

Contractors lacking complete internal data use Benchmark values as reference values for purposes of cost estimation. These measures reflect two different types of productivity. Unit labour cost figures provide an indication of productivity as it relates to capital resources. Unit output figures measure efficiency of labour application on the job site. From a national perspective, output growth in the USA economy as a whole has varied in rate over the past several decades. During the expansion of the early post-WWII period, output per labour hour in the USA grew at an average rate of 2.8%. It slowed considerably during the 1970s, however, following this slowdown, output has only grown at an average of 1.1% yearly. In the late 1990s, output has grown more swiftly again, but it is difficult to determine if this will be a long-term trend. (US Bureau of Labour Statistics, 1998)

Planning engineers frequently maintain a library of basic productivity rates. These can be adjusted for each project, taking into consideration specific site factors and conditions which could impact the productivity of construction operations. Significantly, Christian & Hachey (1995) found there existed 'substantial agreement' between the average productivity rates measured in the field and of those used by planning engineers in his study of productivity rates. Where the above authors did find differences between productivity rates and actual output (between a number of sites for similar operations), it was established that such was caused mainly by waiting and idle times (an impact of improper and/or inadequate site supervision or management). However, Christian & Hachey (1995) reported that planners would very often modify their productivity rates for every specific estimate in order to reflect anticipated delay times. This latter point underlines the reliability of making any comparisons between contractors, using planned productivity rates. (Proverbs, 1998)

What is important to us in this research with regards to productivity benchmarking is the same what was approached by Oglesby (1989) in his study, where he suggested two methods to develop an approach for studying long-term construction labour productivity trends: (a) choose a limited number of representative tasks and (b) to use a long series of work sampling studies to track direct work rate. Selection of tasks to be studied was focused maintaining variety in terms of trade and tasks. A more thorough definition might account for other factors as well, such as complexity, skill level required, planning required, and interaction with other tasks.

Direct work rates are a measure of efficiency in terms of time, therefore increasing the direct work rate usually increases construction productivity.

CHAPTER THREE:

IMPROVING LABOUR PRODUCTIVIY

3.1 Introduction

Theories of improving construction labour productivity vary from project to project and from activity to another. Because of the variety of uncontrollable productivity influence factors it is hard to have one set plan.

Construction projects are mostly labour-based with basic hand tools and equipment, as labour costs comprise 30 to 50 % of overall projects costs (Guhathakurta and Yates, 1993). Lema (1995) observed that labour productivity data were not available from Tanzanian construction established on the basis of actual site observations. Accordingly, on the basis of limited data, it was concluded that labour utilization on construction sites was less than 30 % in Tanzania.

Olomolaiye et al (1998) briefly studied labour productivity on construction sites in Nigeria. Their study concluded that there was a need for establishing output figures on various construction sites through time study techniques. It was concluded that method studies and research results should be disseminated not only to large firms but also to small firms so the most productive working methods (or best practices) could be adopted by operatives, resulting in increased output without necessarily increasing physical efforts.

The above studies in regards to the labour productivity enhance the necessity of having more researches and information about utilizing the labours on construction projects in UAE and how to improve the productivity rates in order to increase the output with less cost.

According to Mohanty (1992), the starting-point for improving productivity is the application of techniques which help in the effective utilization of resources. We all know that the human resource is the most valuable resource in any organization; it is certainly the primary resource since it, in turn, plans and controls the application of all other resources. Yet, in many productivity management programmes, we attack productivity as if it was a completely mechanical entity capable of being subjected to the strict application of "scientific techniques"; as a result we get low output, high absenteeism, high turnover, high grievance rates — a sick rather than a healthy and high productivity organization. What is needed is to develop an approach that recognizes the importance of the people employed and ensures that:

- Employees are encouraged to develop an action-oriented point of view;
- Employees are trained to develop a commitment to and involvement in their work;
- the value system of employees is recognized when designing the technical components of the work system.

A poorly managed workforce can have adverse effects on organization operations. These include inefficiency, low productivity, low morale and absenteeism through covert conflict in the workplace, or overt conflict resulting in loss of working time through strikes, bans, go slows, etc. (Nankervis, 1996).

3.2 Factors affecting productivity of construction worker

According to Jaideep et al (1995), identifying and evaluating the factors which influence productivity are critical issues faced by construction managers; he claimed that companies must phase affirmative action into the total management of productivity through formalized, documented process as depicted in figure 3.1. The process should begin with a historical productivity analysis and then to utilize the knowledge gained to forecast and manage future productivity. He also added that supervisors involved in the process must implement and monitor the predetermined productivity values.

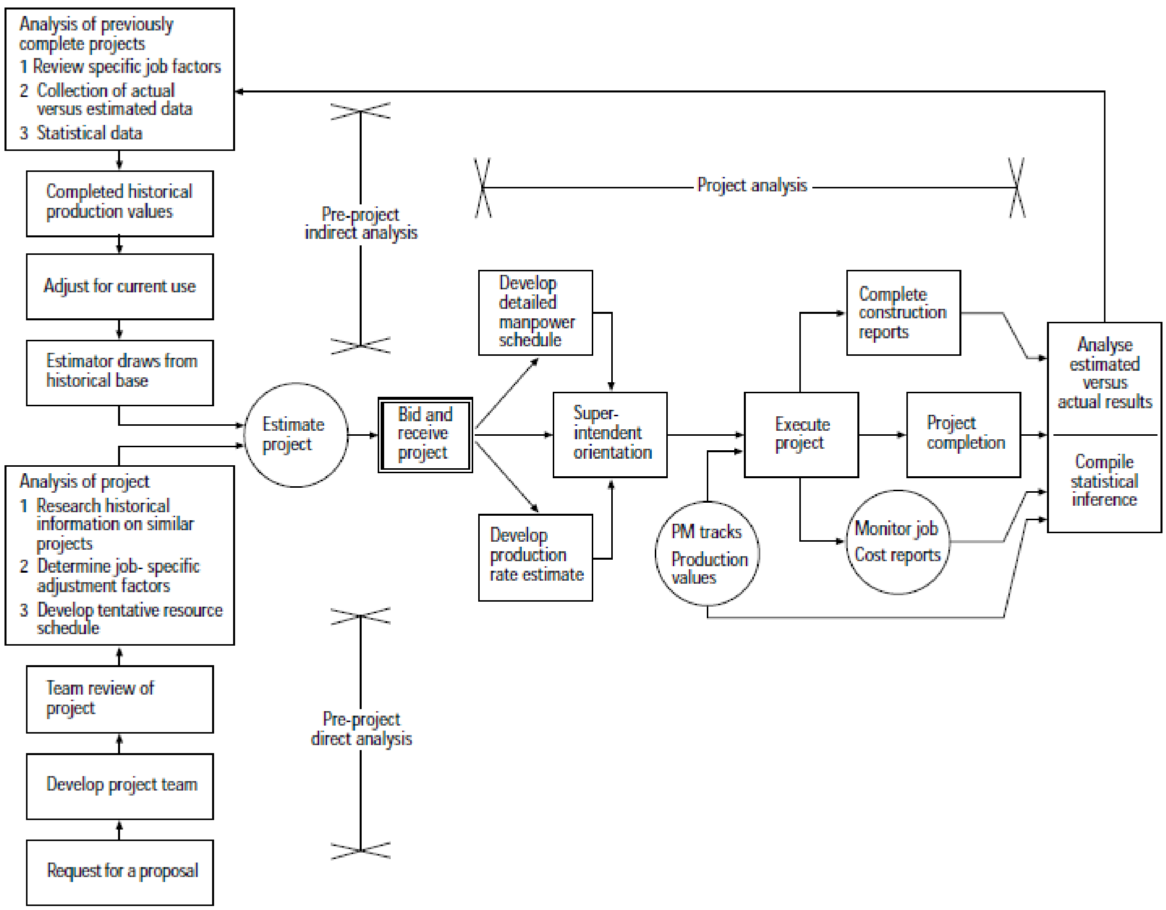

Figure 3.1 A model to manage construction productivity. (Jaideeb et al., 1995)

Lim et al (1995) studied factors affecting productivity in the construction industry in Singapore. His findings indicated that the most important problems affecting productivity were: difficulty with recruitment of supervisors; difficulty with recruitment of workers; high rate of labour turnover; absenteeism from the work site; and communication problems with foreign workers. Olomolaiye et al. (1998) studied factors affecting productivity of craftsmen in Indonesia, with their findings indicating craftsmen in Indonesia spent 75 % of their time working productively. Five specific productivity problems were identified: i.e. lack of materials; rework; absenteeism; lack of equipment; and tools.

It is the myriad of factors that exercise influence over construction worker productivity that creates the difficult nature of the problem. Further to the literature conducted through related researches, referred journals and books, the following factors were concluded that can be utilized in order to make major influence on construction worker productivity.

3.2.1 Motivation

Litschka et al (2006) proposed that it seems obvious for managers that job satisfaction, commitment and intrinsic motivation are extremely important factors for productivity and customer related contacts. Customer satisfaction and its close interrelation to human and organizational assets are seen as important factors for productivity and success of the organizations, while other factors, e.g. health, lack the attention of managers. There seems to be awareness that organizations have to actively promote their human and organizational assets – like investing in training and other employee- orientated activities, because these activities are perceived as beneficial for productivity and efficiency.

According to Ian (2006), although motivation is a critical factor in individual, group and organizational success there is some debate concerning its definition. In broad terms motivation can be considered to comprise an individual's effort, persistence and the direction of that effort. In simpler terms, motivation is the will to perform. It is, perhaps, of more value to identify the characteristics frequently associated with will-motivated individuals. Such people are commonly thought to consistently achieve at work to exhibit energy and enthusiasm in the process. They often work with people to overcome organizational problems, or obstacles to progress, and frequently demand and accept additional responsibilities. They may also be more willing to accept organizational change. In contrast, employees who are demotivated may appear apathetic and may tend consider problems and issue as insurmountable obstacles to progress. They may have poor attendance and time-keeping records and may appear uncooperative and resistance to change. Clearly organizations that can motivate their employees are more likely to achieve their organizational objectives.

Historically there have been two major approaches to solving the motivation puzzle. Management can motivate people to work by fear and being tough. Or it can motivate people by understanding and being good. The authors argue that in spite of some diversions, these two paths to motivation have been vying for manager's attention throughout the years. (Dayr, 2001)

According to Eguchi (2008), one of the best ways to improve employee productivity is to create a direct link between output and pay by implementing a piecework compensation plan. In a piecework compensation plan, there are no hourly wages. Instead, employees get paid according to how many parts they assemble, how many sales they make, how many hours they bill, etc. In the mean time, when you show employees that you are committed to promoting from within, you'll be giving them even more incentive to increase their productivity and improve their overall performance. Nobody likes to believe that they are stuck in a dead-end job or that their efforts will go unnoticed. If the workers can see that their hard work might pay off in the form of a promotion, they will be more inclined to give it their all day in and day out.

In addition to financial incentives, many employees are motivated by the need for social recognition., that's why giving achievement awards to outstanding employees is an excellent way to improve productivity, also achievement awards typically take the form of plaques, jackets, certificates, prizes, and are handed out to employees who meet certain performance standards (Eguchi, 2008). Furthermore, as counterintuitive as it may sound, providing employees with adequate breaks is essential for improving overall productivity, however, break time not only gives employees something to look forward to, but also gives them a chance to recharge their batteries before diving back into work and more often than not, they'll come back refreshed and ready to focus for another couple of hours until the next break. (Eguchi, 2008)

John Borcherding and Clarkson Oglesby (1974) discovered that productive job creates high job satisfaction while non-productive job (one which fall behind schedule) produce dissatisfaction at all levels of the management/worker chain. The relationship is believed to be due to the very nature of construction, thus different from the one found in an office or factory setting which states that high job satisfaction leads to greater productivity. In construction, a worker, through his own efforts produces a highly visible, physical structure in which great satisfaction comes from completion. Therefore, jobs that are well-planned and run smoothly produce great satisfaction while jobs with poor management (with scheduling and planning problems), create dissatisfaction. This illustrates the relationship between job satisfaction and productivity since; well-managed jobs are generally more productive. (Wellington and Lydia, 2007)

Kay et al. (2005) suggested that to empower successfully it is necessary to examine the role of managers/leaders, as they have considerable impact upon the psychological sense of empowerment held by the employee. The way in which managers/leaders can implement and maintain empowerment strategies is multi-dimensional, as outlined below. Johnson (1994) considered that it is necessary for managers to give people the power to do their job. However, Vogt and Murrell (1990) viewed the power relationship as a complex interactive process whereby empowerment is an act of developing and increasing power by working with others. Therefore, until power is shared (and employees perceive that power is shared) empowerment is not possible.

Communication within organizations, between employees and managers, is a vital ingredient of motivation. Powerful intrinsic rewards require communication to be apparent. For example, employees are likely to be motivated by recognition and constructive feed back by their line manager. It is not enough for employees to be doing a good job; more often than not, some recognition of that is important. What is more, communication needs to be two-way. Expectancy motivation theory suggests that people are motivated by attempts to achieve desired outcomes to their manager. Similarly, mis-communication, sending out inaccurate or misleading information, can cause motivational problems. Managers who promise the earth and do not deliver to employees will not be trusted again, while those who clearly and unambiguously communicate may be trusted and valued for their honesty. (Ian, 2006)

The dynamic relationship of the leader with employees is frequently cited as crucial in the empowerment literature. Honold (1997) and Johnson (1994) both argued that the leader is responsible for creating a common goal, which they communicate and share. Furthermore, the leader should continually monitor that their subordinates feel empowered. The leader may also play a part in recognizing the contributions made by employees by emphasizing efforts of an employee as important (Psoinos and Smithson, 2002). There may be limits to the rewards that leaders are able to offer, and so senior management may also need to consider the implementation of profit related incentive schemes (Cunningham et al., 1996). It is argued that managers/leaders must focus on team empowerment as well as individual empowerment if the organizational environment relies upon cohesive teams. (Dainty et al., 2002)

3.2.2 Planning

According to Thomas et al. (2001), project and site managers need to have complete job histories, educational records and other information relating to employees in order to make realistic decisions concerning the utilization of the workers under their control. Job-site managers and construction managers also need to have access to information and underlying work processes and functions controlled by HR department. Such information includes:

- Data pertaining to each person in the project or at the work location, including demographic data, employment history, qualifications, career plans and training/development completed/required.
- Data relating to contractor, consultants, part-timers and temporary workers.

- Information concerning peoples' time-off patterns/ preferences and desired work/location preferences.
- Information concerning the availability of others in the organization for job reassignment or redeployment.
- Operational data concerning the workforce itself such as workforce size, productivity ratios, resource allocation, both for site managers' organizational units and similar work organization-wide.
- Information such as time and attendance data, payroll, applicant data from an applicant tracking system, training records from the career development system, cost data from accounting.
- Information relating to wages, working hours, holidays, allowances, safety, disputes and for the proper management of industrial relations.
- Environmental data that impacts on the HRs managed by the site manager, supervisor, or team leaders such as salary surveys, skill shortages, new employment legislation, demographic trends, retirement trends, and changing attitudes and values of workers.
- The impact of on-site availability of operational HR data helps managers to know their people better and can help them find answers to such questions as: Can two tasks be handled by the same individual? And will that result in lower costs and provide similar or better results? And finally what skills are required for the tasks, and who has the skills to take both tasks in this organization or in other locations?

It is quite common for construction projects to be developed under a permanent fight to keep up with schedule and in many cases to accelerate schedule. However, the planning and scheduling practices are usually inadequate to deal with the uncertainties that affect the production system. In many cases the uncertainties are hidden within the system and the management of the schedule becomes contaminated by urgent requirements, for instance, the sequence of activities is chosen without a comprehensive analysis and usually depends on what resources are available first. Similarly, activities that are in sequence are started as soon as the previous activity starts, trying to accelerate the schedule, without consideration of how the uncertainties of the activities upstream could affect productivity of downstream activities. (Saari, 2006)

Jaideep et al (1995) see that companies should only track the important activities where his research shows that concentrating on productivity improvement in the larger portions of non-productive employee time would be more effective. He added that improving communication skills, preplanning and stricter management could help to raise the individual productivity rate from an average of 32 per cent productive time per hour to almost 60 per cent per hour. It is most interesting to note that in order to increase productivity by 10 per cent, all that must be done is to achieve an additional 15-16 minutes to the productive time each day for the average worker.

3.2.3 Specialization

Projects in construction are never designed or built exactly in the same manner as previous projects. Environmental factors such as the landscape, weather and physical location force every project to be unique from its predecessors. There are also aesthetic factors that create uniqueness from project to project. Such factors have a significant impact upon major project characteristics. While most construction personnel find this uniqueness to be an attractive element for a career in construction, it can have an adverse effect upon construction productivity. Project uniqueness requires modifications in the construction processes. These modifications require workers to go through a learning curve at the beginning stages of each project activity.

In small organizations where the variety of work is low, employees can move between jobs to build up their versatility and interchangeability. As organizations get bigger and as the nature of the work done diversifies, then it is more likely that employees start to specialize in the type of work that they do. Specialization is the extent to which there are different specialist roles in an organization: the higher the number of specialist roles the higher the degree of specialization. Specialization also refers to the extent to which employees engaged in similar or closely related tasks are grouped together. This is called routine specialization and occurs when jobs are split down such that employees only do one or a few parts of a job but not the whole job. High specialization has the advantage that employees reach high levels of efficiency, and control is simplified as jobs are tightly defined. Possible disadvantages include creating a climate of inflexibility, creating workers who do not see or who are not interested in the big picture, and creating work that, over time, becomes boring (Hage & Aiken, 1969).

In construction work, general contractors and specialized contractors are organized either vertically or horizontally. Thus improving the labour productivity of the construction sector overall requires the cooperation of many different operators. The vertical subcontracting relationships centered around large general contractors are symbiotic in nature and based on long-term business ties. However, these relationships have begun changing in recent years due to intense competition, and the number of equal relationships is growing. Even if the present division of functions persists, productivity improvements can be achieved through greater specialization and uniqueness. A new structure would emerge that effectively integrates these strengths and contributes to higher labour productivity in the construction sector. (Takashi, 1998)

3.2.4 Training

It is advantageous for the manager to have some awareness of how learning occurs both at individual level and overall in the organization. With an increasing number of organizations being dependent on 'knowledge workers', managers will benefit from having knowledge of cognitive styles. (Brooks, 2006)

However, there is currently a lack of formal training in construction - the lowest of any major sector of the economy. This lack of training is due to practical concerns such as employers completing the increased percentage of nonunion work (Arabian Business, 2008). In general, the workforce of contractors is highly mobile. For this reason, contractors in UAE are often reticent to invest capital to train those who may soon be someone else's employees. The result may be a decrease in the construction workforce average productivity rates.

Pastor (1996) says that the final area in which managers/leaders play a pivotal role is training, it is necessary that employees believe themselves to be ‘‘capable’’, and training can be a key mechanism that provides employees with this reassurance. He argues that the principal training focus should be on communication development so that they can engage in this new participative and facilitative management/leadership style.

According to Kenyon (2005), apprentices’ productivity tends to be higher compared to other employees as they undergo formalized training from the start of their apprenticeship, and this ensures the right expectations are set out and reinforced regularly. He added that BT Retail estimates their apprentices are 7.5 per cent more productive than non-apprentices, and apprentices are also usually more commercially aware and naturally follow the correct procedures for generating more revenue. As a result, the company believes apprentices are more profitable than non-apprentices based on the comparative labour cost, along with higher levels of productivity, quality of work and employee satisfaction, however, BT Retail has calculated apprentices generate a higher annual net profit of over £1,300 per apprentice when compared to non-apprentices.

An important key to improve productivity is to train the crew, especially construction supervisors, whose knowledge and skills can make or break a project, in sound management principles and techniques. Construction companies rarely hesitate to train employees in specific skills such as how to operate a new piece of equipment. The benefit of training is measurable almost immediately: the employee is more productive as soon as he has mastered new skills.

Supervisor training should be specifically related to how to improve productivity at the job site. Supervisors must be trained to look at the job not on a day-to-day basis, but as a work process with many discrete steps that must be completed over an extended, if limited, period of time. Supervisors should also explain what productivity means to all employees and show them how increased productivity leads to fewer hassles and greater profits. Once they have identified new, more productive ways of doing something, make sure everyone involved understands the change and why it is being implemented. Productivity training should always stress that the most productive workplaces are always the safest and produce the highest quality work, since accidents and rework are major drains on productivity. (Michael, 2002)

Sharon et al. (2004) stated that industry training is essentially an investment in human capital, the economic benefits of which can be thought of as being shared between:

• The individual trainee, through higher wages (a proxy for labour productivity)

• The firm, through enhanced profitability (a proxy for capital productivity)

• Society as a whole, through "externalities" (returns over and above the private returns to the individual trainee or firm who pays for the training).

They added that these benefits are difficult to measure. However, there is a weight of evidence from their literature relating to the positive wage effects of training that an industry training qualification is likely to increase the earnings of an individual by 5% to 20%.

3.2.5 Health & Safety

An improved productivity of the workforce translates into a more productive business. While various motivational factors have traditionally been applied to stimulate motivation of people in order to improve their productivity, the potential of improved productivity through health promotion has only recently become the subject of investigation. It has long been recognized that good health is an important factor in employee efficiency and productivity (Fielding, 1990), and can lead to a better performance, both physically and mentally. Healthy people are less likely to be absent from work through illness, are more likely to cope better with stress, are less likely to suffer from musculoskeletal injuries sustained in the workplace, and generally display more evidence of job satisfaction (Cooper & Smith, 1985; Chu & Forrester, 1992). It therefore makes good sense to explore avenues for improving employee health in order to reap the benefit of improved productivity. (Thomas, 1998)

Many scientific authors stress the importance of health and workability factors: The results from Karasek and Theorell (1990) showed a close correlation of the decision-latitude and health and productivity. Drucker (2002) underpins that it is actually more important today for organizations to pay close attention to the health and wellbeing of all their workers than it was 50 years ago. A knowledge-based workforce is qualitatively different from a less-skilled one. Today they are still a minority of the workforce, but they will become the major creators of wealth and jobs, because the success and the survival of every business will depend on the performance of its knowledge workforce

Bo¨ckerl (2000) stated that workability, health and well being. Physical health and psychological well being play a decisive role in the willingness for high efficiency, flexibility and innovativeness of a person. The subjective perception of health determines what kind of commitment to work is shown. It is rather obvious that employees' workability, health, and well being are intermediate steps on the pathway to profitability. Organizational structures, its management and the health of employees are interrelated. Health-promoting structures have to be enlarged by an employee-orientated management style and a culture of trust in an organization – the management is one of the most important factors regarding health in an organization. They are responsible for the structure and processes in the organization, they decide on the workload and the chances of development for their employees.

3.2.6 Technology & Innovation

Project manager role is to encourage innovation and try to find creative ideas to do the job in better ways that save efforts and time and increase production, furthermore, to ensure that the workers have good equipments. In many instances, labour productivity is limited by the equipment they are forced to use. If your plant is filled with 20-year-old machinery that constantly needs attention from the maintenance crew, or if your tools are slow or outdated, then you are not giving your workers a fair opportunity to be productive

Technology has had a tremendous effect on overall productivity. All but the most basic of tasks on a site have seen changes due to advances in technology over recent years. Tools and machinery have increased both in power and complexity. These advances in technology can significantly modify skill requirements. This can create difficulties in separating the contributions of technology, management, and labour to productivity.

Introducing new technology can be more difficult in the construction industry than in other industries. Innovation barriers such as diverse standards, industry fragmentation, business cycles, risk aversion, and other factors can create an inhospitable climate for innovations. In many regions in GCC, labour costs for many skills are relatively low. There is less motivation to automate a task when the labour associated with the task is not expensive. Due to such impediments, firms are naturally reluctant to try a new technology, especially if it amounts to putting the entire company on the line. Should the new technology prove effective, the firm gains only a temporary strategic advantage. Once it is proven, other bidders can quickly begin to adopt the technology. Gestation periods can vary widely depending on the market force behind the innovation and other factors. This cycle is typical, and is one reason for the step change nature of construction productivity for individual activities or tasks when technology is the main factor.

Michael (2002) stated that a construction company should therefore enlist all of its workers in the search for greater productivity, the company should communicate explicitly that suggestions are welcomed and should consider some type of reward system for suggestions that increase productivity. He added that one effect of involving the workers in improving productivity is that they will come to look on the goal as making progress, not finding blame. New technologies such as scheduling software and more efficient equipment can yield an immediate return on investment in increased productivity (Michael, 2002). His research shows that the construction industry spends fewer dollars for research and development than any other industries in the United States; however, the technological explosion that has revolutionized the U.S. has so far only affected the very largest construction companies. In implementing new technology, construction companies should learn from the mistakes made in other industries, too often companies have attempted to implement new technologies and equipment literally overnight, leading to a cataclysm of change that disorients and discourages workers. Finally he suggested that construction companies take a gradualist approach, introducing first the new software or equipment that will have the most immediate positive impact and to make sure the training that to be provided in new technologies not only details how to use the technology, but also how the company and the workers will benefit from it.

3.2.7 Monitoring & Control

Finally, careful monitoring of the implementation process is crucial to ensuring its sustained effectiveness. This should include activities such as obtaining measurable outcomes in order to provide a clear focus for monitoring and following through the process. Essential elements of this should include control and feedback in the form of both formal and informal mechanisms that allow the process of implementation to be monitored, the use of quick feedback such as customer satisfaction, which can encourage employees to continue with the change process, and failure to achieve the espoused objectives should be investigated and addressed. (Cheng, 2007)

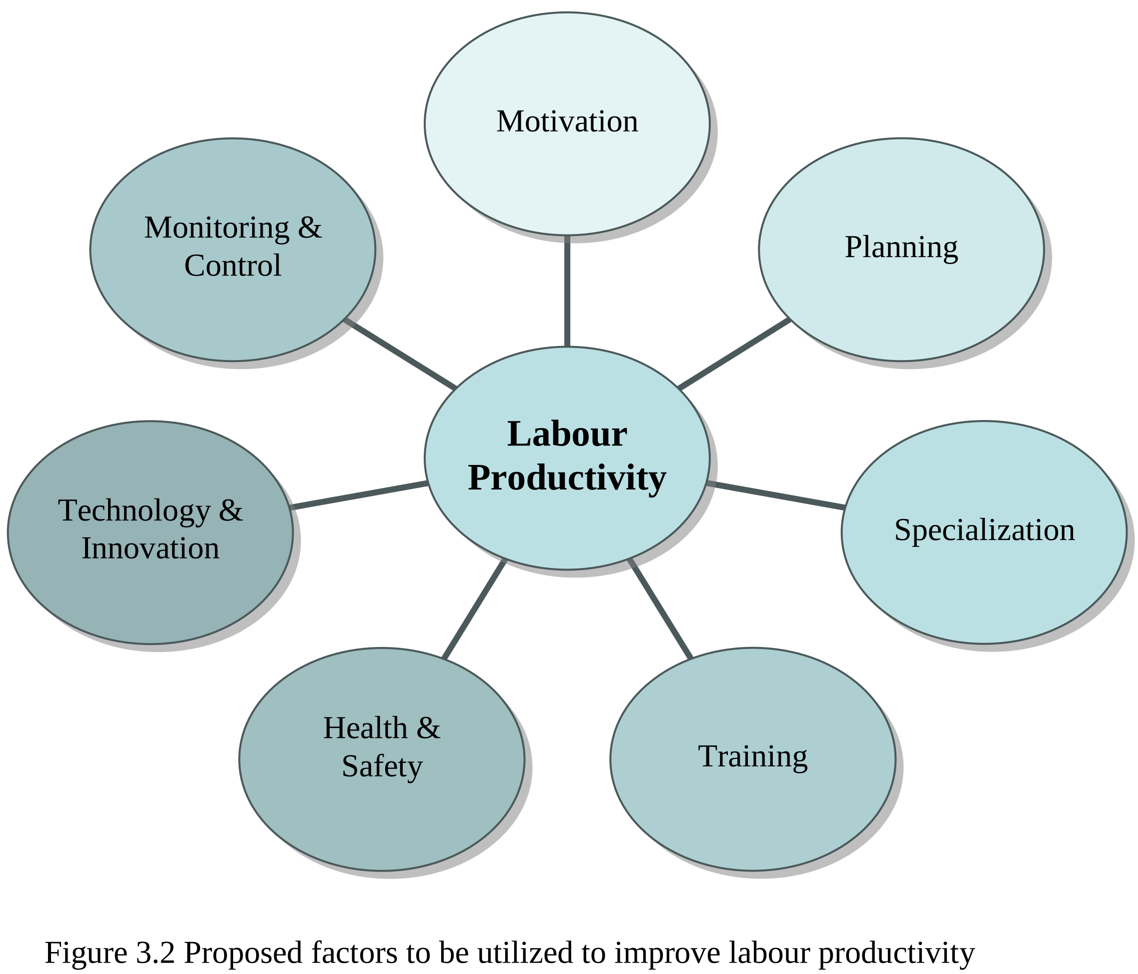

Figure 3.2 Proposed factors to be utilized to improve labour productivity

CHAPTER FOUR:

RESEARCH DESIGN

4.1 Research Methods

In order to achieve the research objectives the following research methods were used; First to collect data for different ongoing construction residential projects including the daily, weekly and monthly productivity of their workers (Carpenters, Steel Fixers & Block Masons). And then to analyze these data through MS Excel to determine the productivity trend and Target Productivity Rates (Benchmarks) for the major activities carried out by the workers' trades.

Next step is to examine the deviations of the actual productivity rates of these workers' trades for each project compared with the obtained Target Productivity Rates, in the meantime, to identify the factors that caused those deviations.

Finally to conduct interviews with the project managers and the key personnel of each project in order to identify how the management can utilize the factors obtained from the literature to improve the productivity of their workers.

4.2 Work Sampling Study

In the work sampling technique, observations of what each worker is doing at a particular instant are made and recorded. The trades of workers are typically divided into three categories: Steel Fixers, Carpenters and Masons Although the definition of each category can be dependent upon the craftsman performing the work, the type of work, and viewpoint of the observers, it is very important to set a clear definition of the categories for reliable data collection to take place (Business Roundtable, 1982).

The case studies of this research are ongoing five large residential construction projects belong to one building contractor in UAE. These five projects share to certain extent the type of the tasks to be carried out by the workers, where they are all construction projects of single or double storey residential villas (100 – 1000 villas) and they have the same type of structural concept and form works system (Tunnel Form) with different sizes and architectural designs, which make the results of the surveys are more comparable and can be used to obtain reasonable benchmarks.

Project name	**Project Description**	**Value (AED million)**	**Duration (days)**	**No. of villas types**	**Sizes of the villas (1000 ft^2)**
Project # 1	> 1000 villas	1,200	970	4	3.2-5.5
Project # 2	200 – 500 villas	330	730	9	2.5-6.0
Project # 3	500– 1000 villas	1,000	910	11	2.5-5.0
Project # 4	< 100 villas	520	1030	8	8.0-10.5
Project # 5	200 – 500 villas	370	760	6	3.5-4.2

Table 4.1 Case studies projects description

4.3 Productivity Measurement

Based on the literature conducted in the previous chapters, the measurement of the construction worker productivity can be measured according to the general formula of productivity measurement:

- Productivity = Output Quantity / Input Quantity

In this study the Input and the Output will be measured as follow:

1) The Input for labour productivity will be the total Man-Hours, in other words; the total hours consumed by the construction workers in order to achieve the Output.
2) The Output depends on the trade of the worker and the type of the tasks carried out by him, accordingly the Output measurement in this research will be:

WORKER TRADE	OUTPUT	UNIT
Shuttering Carpenter	The total area of formworks installed	Meter Square (Area)
Steel Fixer	The total quantities of steel fixed	Kilogram (Weight)
Block Mason	The total numbers of blocks built	Nos. (Numbers)

Table 4.2 The proposed output for each construction worker trade

However, there are several different tasks and activities to be carried out by one trade. For example, the productivity of the carpenter installing form works varies from the foundation form works to the columns or slab form works...etc.

Accordingly, it was essential to examine the productivity for each activity separately in order to reach to the most effective values which can be used as benchmarks in order to conduct proper and fair evaluation to the worker productivity.

The following table shows some major activities that could be carried out by each trade in order to be studied separately:

WORKER TRADE	**MAJOR ACTIVITIES**
Shuttering Carpenter	1) Installation of strip foundation form works 2) Installation of roof parapet form works
Steel Fixer	3) Installation & fixing of strip foundation steel 4) Installation & fixing of tunnel steel (columns & slabs)
Block Mason	5) Masonry works of building 200,150 or 100mm block works

Table 4.3: The proposed major construction activities to be studied WRT each trade

In order to collect the data which are required to calculate the daily productivity rates for these activities, the project managers of the five case studies projects (see table 4.1) were approached to have access to the direct supervisors (site engineers or foremen) of the workers groups carrying out the selected activities.

Then each supervisor was asked to fill and submit a daily productivity sheet (see table 4.4) for his group on a daily basis for a period of three months. The researcher explained in details how the form should be filled and this form consists of:

1) The crew size which means the total number of worker available on that day for that specific activity (INPUT).
2) The working hours consumed in that day (INTPUT). And this can be obtained from the daily time sheets for each group of workers which supposed to be filled by their foreman.
3) The total quantities produced in that day by the same group of workers, and this can be obtained by multiplying the quantity of each type of villas by the number of villas produced of the particular type in that day (OUTPUT).
4) Productivity rate = $\dfrac{\text{The total quantities produced}}{\text{The crew size * The working hours (Man-hours)}}$

One of the positive factors to make the process of data collection succeed is that the contracting company adopted the policy to maintain monitoring the productivity rates which makes the supervisors familiar with the process of calculating and filling the productivity monitoring sheet which is the same research sheet required by the researcher, and they don't have to spend more time to fill it where it is part of their ordinary daily paper works.

During the data collection period the researcher was visiting the concerned supervisors in order to ensure that the data collection process is going well and the required sheets are filled properly, in the meantime he also interviewed them about any difficulties or obstructions that may affected their workers' productivity or even the success factors that could have positive influence on the same.

After all the sheets have been collected from the concerned people of the five activities at the five projects, the data have been tabled for each activity (see Appendix B), and then processed through MS Excel and the results will be shown in the next chapter.

However, based on the supervisor's feedback during the researcher's visits and the literature review, the researcher have established the interviews questions with the projects managers in order to perform further analysis to the work sample results and reach to the final conclusions.

Project Name: **Engineer Name**:

#	Date	Activity	Crew Size			Working Hours	Total Quantities Produced	Unit	Productivity Rate	Remarks
			S/F	C	M					

Where: S/F = Steel Fixer, C= Carpenter, M= Mason

Table 4.4: Daily Productivity Monitoring Sheet

CHAPTER FIVE

RESULTS

After monitoring the daily productivity of the workers of the case studies for 3 months the following results were obtained:

5.1 Project # 1 :

5.1.1 Productivity of Steel Fixers for tunnel steel works

The daily productivity rates of tunnel steel at project # 1 have not shown major deviations from the average productivity rate where the number of workers and their daily target were almost consistent during the study period:

TOTAL MANHOURS	153600
TOTAL QUANTITIES PRODUCED (*kg*)	4140220
AVERAGE PRODUCTIVITY RATE (*kg/man-hours)*	26.95
STANDARD DEVIATION	1.01

Table 5.1 Results summary of tunnel steel activity at project # 1

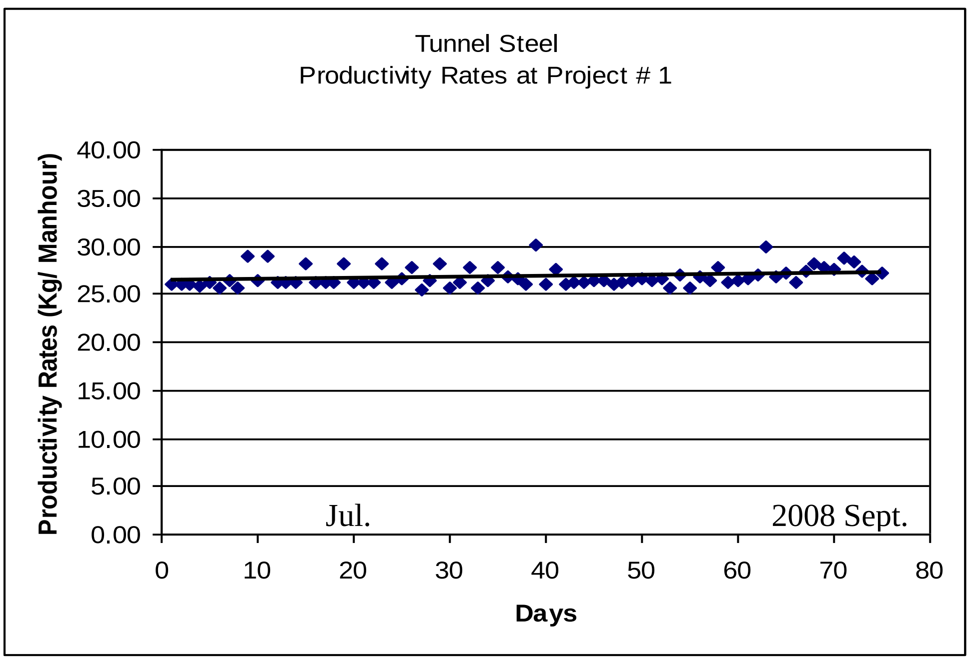

Figure 5.1 Monitoring of daily average productivity rates of tunnel steel activity at project # 1.

5.1.2 Productivity of Steel Fixers for strip foundation steel works

The average daily productivity rates have shown lower values during the second month (day 34 – day 64) in this case because of new steel fixers joined the group until they get enough training and learning to approach the average productivity rates in the last 10 days:

TOTAL MANHOURS	60400
TOTAL QUANTITIES PRODUCED (*kg*)	1702508
AVERAGE PRODUCTIVITY RATE (*kg/man-hours)*	28.19
STANDARD DEVIATION	1.11

Table 5.2 Results summary of footing steel activity at project # 1

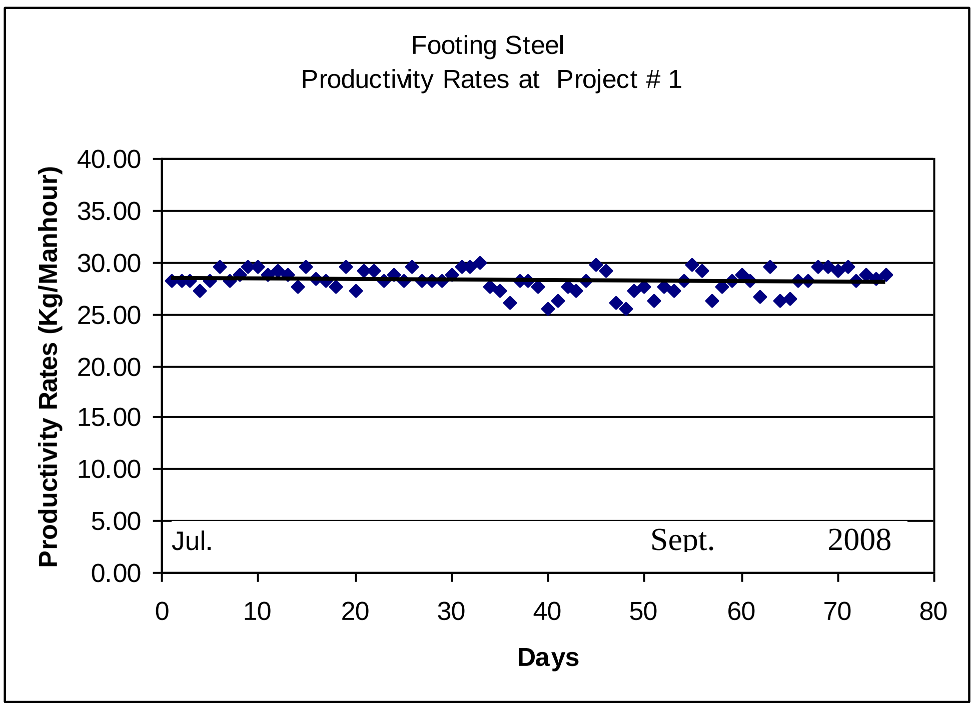

Figure 5.2 Monitoring of daily average productivity rates of footing steel activity at project # 1.

5.1.3 Productivity of Carpenters for strip foundation formworks

This activity started with a 1 villa target per day then increased to 2 villas after 12 days by increasing the group size to an average of 85 carpenters per day and their productivity have shown improvement in accordance with the type of the villas executed where in the first period of this activity the carpenters were not familiar with executing such types of villas and then they were enforced by more professional carpenters which caused noticeable improvement and then reduced because of providing additional 10 new arrival carpenters for training purpose.

TOTAL MANHOURS	58380
TOTAL QUANTITIES PRODUCED (*m²*)	57618
AVERAGE PRODUCTIVITY RATE (*m²/manhour)*	0.99
STANDARD DEVIATION	0.12

Table 5.3 Results summary of footing formworks activity at project # 1

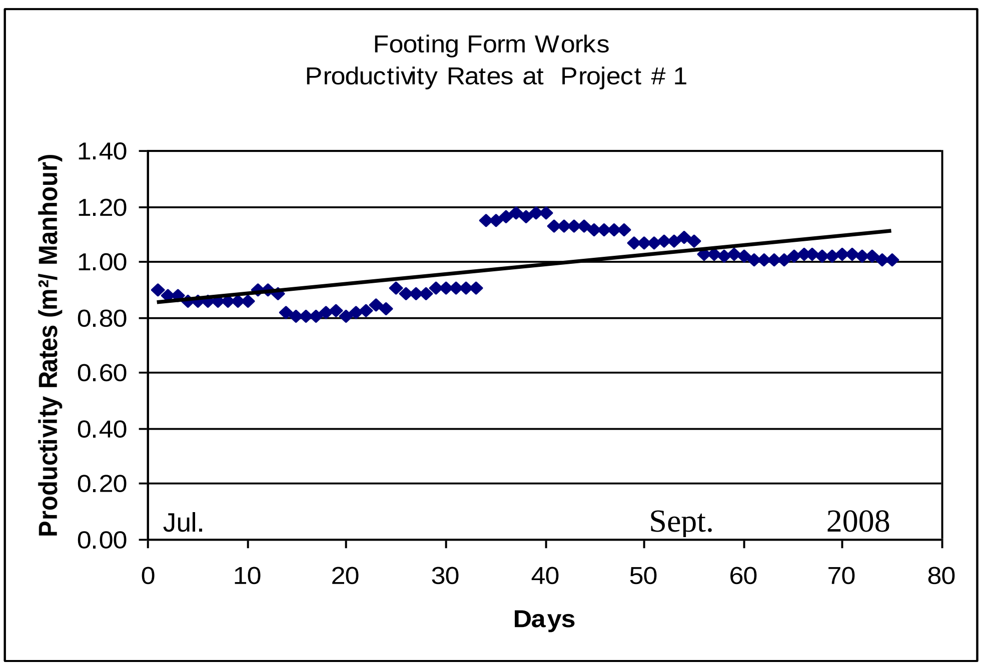

Figure 5.3 Monitoring of daily average productivity rates of footing form work activity at project # 1.

5.1.4 Productivity of Carpenters for roof parapet form works:

The values obtained from the parapet carpenters group have shown variations from day to day where the standard deviation value is considered high in relative to the mean value and that could be due to the differences of the complexity level from villa type to another:

TOTAL MANHOURS	67240
TOTAL QUANTITIES PRODUCED (*m²*)	66862
AVERAGE PRODUCTIVITY RATE (*m²/manhour)*	0.99
STANDARD DEVIATION	0.14

Table 5.4 Results summary of roof parapet activity at project # 1

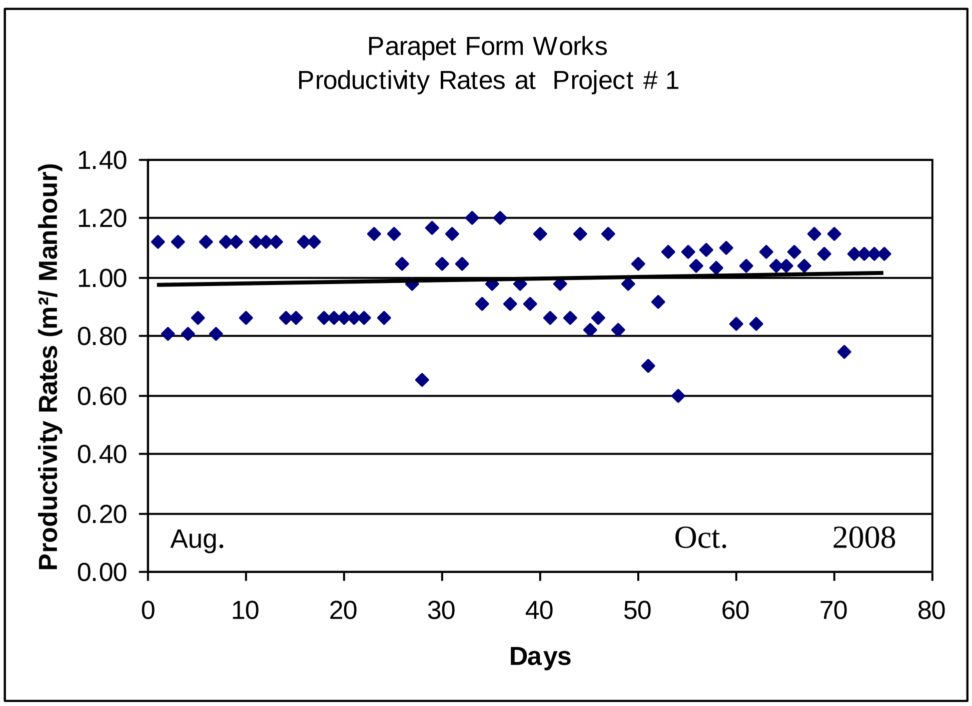

Figure 5.4 Monitoring of daily average productivity rates of roof parapet activity t project # 1.

5.1.5 Productivity of Mason for Block works:

The daily average productivity rates of this group have shown noticeable variances from day to day and decreasing in the productivity rates especially in the last two weeks and that could be due to the type of the villas or other obstructing factors will be discussed in the next chapter:

TOTAL MANHOURS	18014
TOTAL QUANTITIES PRODUCED (*Nos*)	225063
AVERAGE PRODUCTIVITY RATE (*Nos/man-hours)*	12.5
STANDARD DEVIATION	0.88

Table 5.5 Results summary of block work activity at project # 1

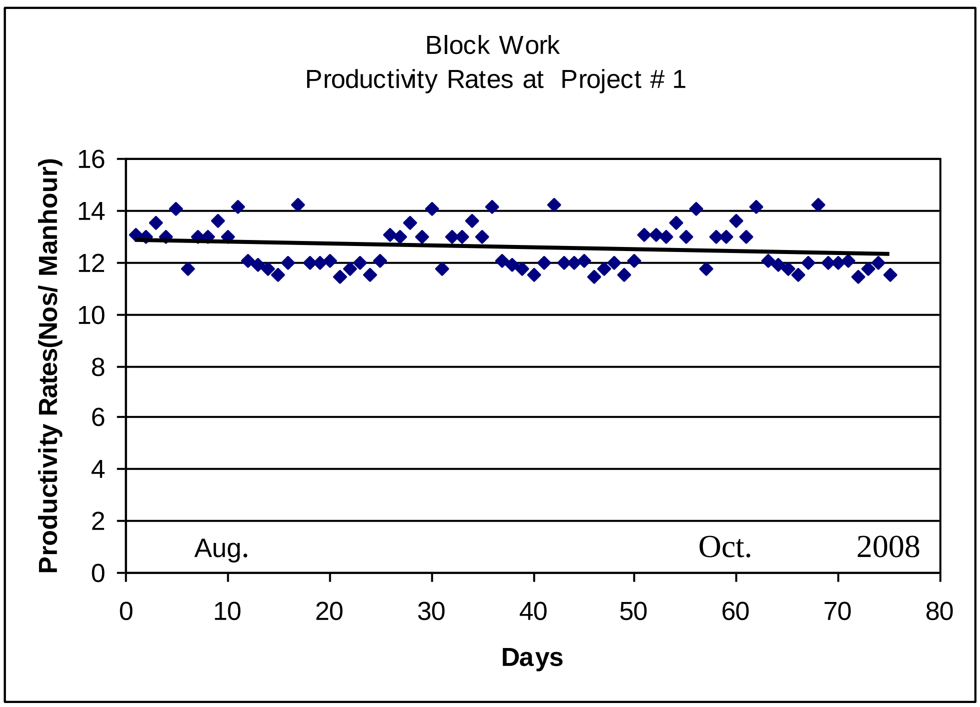

Figure 5.5 Monitoring of daily average productivity rates of block work activity at project # 1.

5.2 Project # 2:

5.2.1 Productivity of Steel Fixers for tunnel steel works

Figure 5.6 shows ideal case of productivity improvement and this can be justified by the consistency in daily target and the learning curve of the workers and further factors will be discussed in the interviews section.

TOTAL MANHOURS	88670
TOTAL QUANTITIES PRODUCED (*kg*)	2256120
AVERAGE PRODUCTIVITY RATE (*kg/man-hours)*	25.44
STANDARD DEVIATION	1.37

Table 5.6 Results summary of tunnel steel activity at project # 2

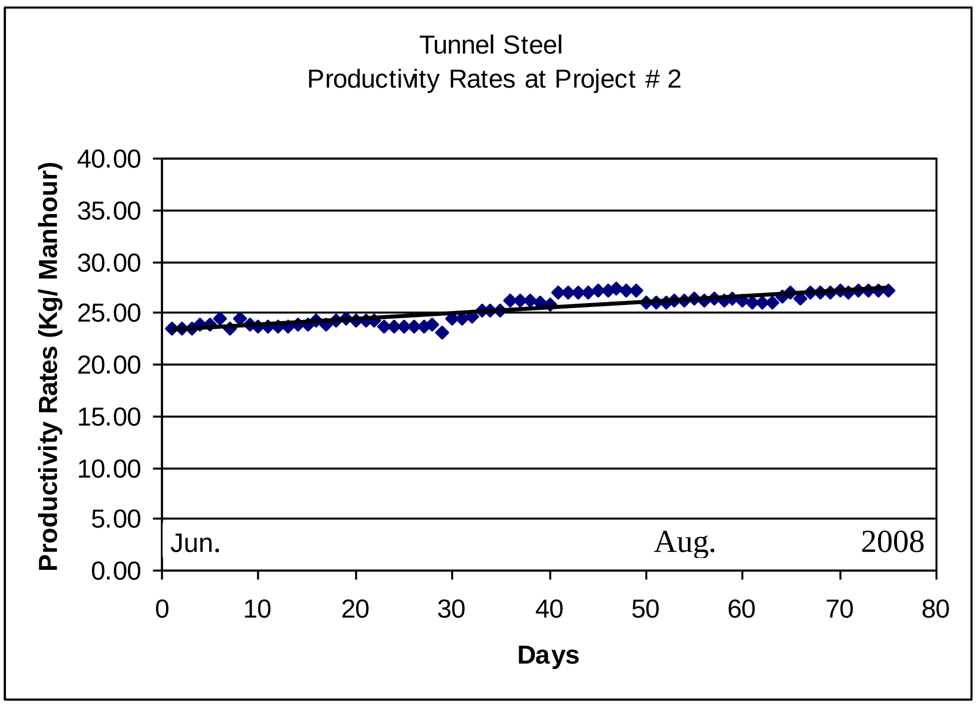

Figure 5.6 Monitoring of daily average productivity rates of tunnel steel activity at project # 2.

5.2.2 Productivity of Steel Fixers for strip foundation steel works

This group of steel fixers has shown high productivity rates in general compared to the other four projects in the study:

TOTAL MANHOURS	57270
TOTAL QUANTITIES PRODUCED (*kg*)	1774081
AVERAGE PRODUCTIVITY RATE (*kg/man-hours)*	30.98
STANDARD DEVIATION	1.78

Table 5.7 Results summary of footing steel activity at project # 2

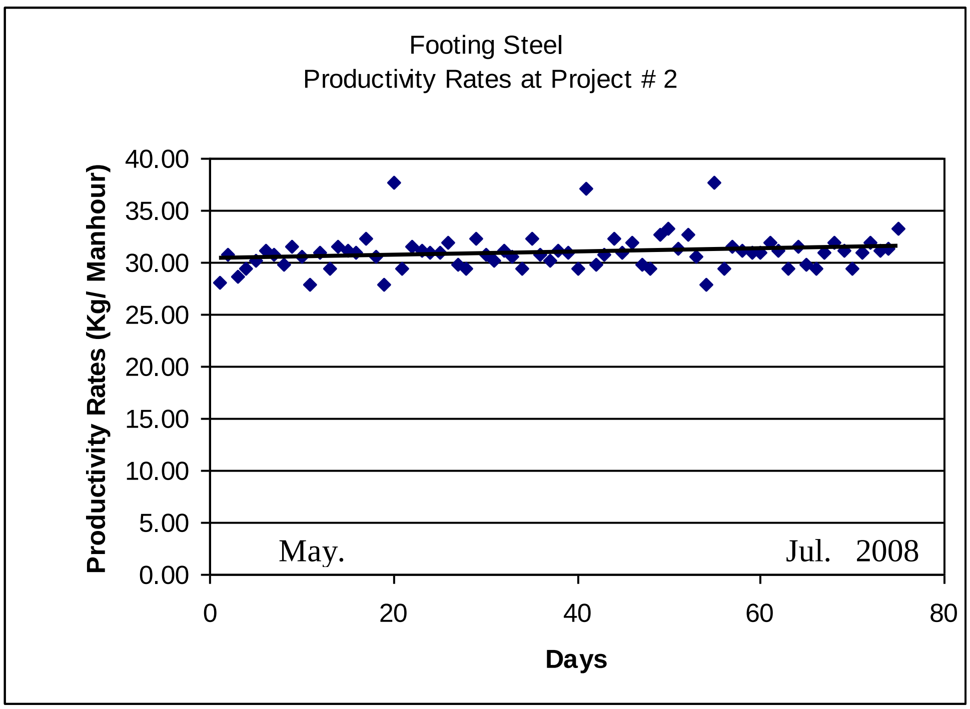

Figure 5.7 Monitoring of daily average productivity rates of footing steel activity at project # 2.

5.2.3 Productivity of Carpenters for strip foundation formworks

The productivity rates have shown little improvement during the study period with very little deviations:

TOTAL MANHOURS	38190
TOTAL QUANTITIES PRODUCED (m^2)	26879
AVERAGE PRODUCTIVITY RATE ($m^2/manhour$)	0.70
STANDARD DEVIATION	0.03

Table 5.8 Results summary of footing formwork activity at project # 2

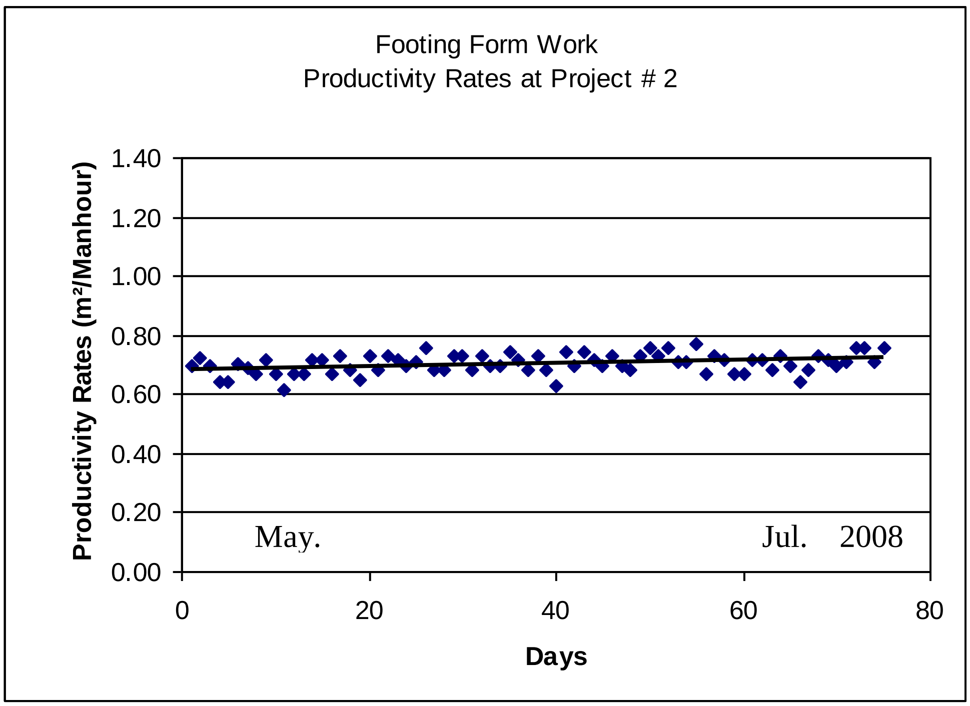

Figure 5.8 Monitoring of daily average productivity rates of footing formwork activity at project # 2.

5.2.4 Productivity of Carpenters for roof parapet form works:

The productivity rates have shown little improvement during the study period with very little deviations:

TOTAL MANHOURS	56750
TOTAL QUANTITIES PRODUCED (m^2)	44031
AVERAGE PRODUCTIVITY RATE ($m^2/manhour$)	0.78
STANDARD DEVIATION	0.05

Table 5.9 Results summary of roof parapet activity at project # 2

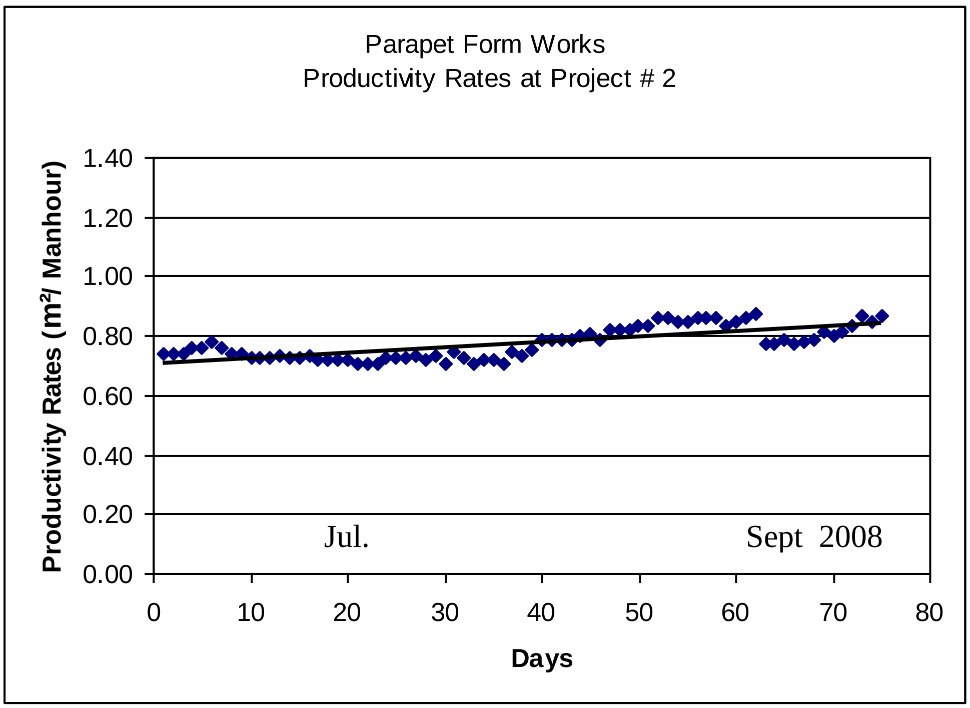

Figure 5.9 Monitoring of daily average productivity rates of parapet form works activity at project # 2.

5.2.5 Productivity of Mason for Block works:

Almost consistent productivity rates were obtained of this group of worker through the study period where the group size was large (around 125 masons compared to the other four projects where the block works groups' sizes range between 25-65 masons), so the differences in the individual productivity are hardly to be observed on the average productivity rates for the whole group and the absentees can be compensated easily:

TOTAL MANHOURS	88590
TOTAL QUANTITIES PRODUCED (*Nos*)	975785
AVERAGE PRODUCTIVITY RATE (*Nos/man-hours)*	11.0
STANDARD DEVIATION	0.51

Table 5.10 Results summary of block work activity at project # 2

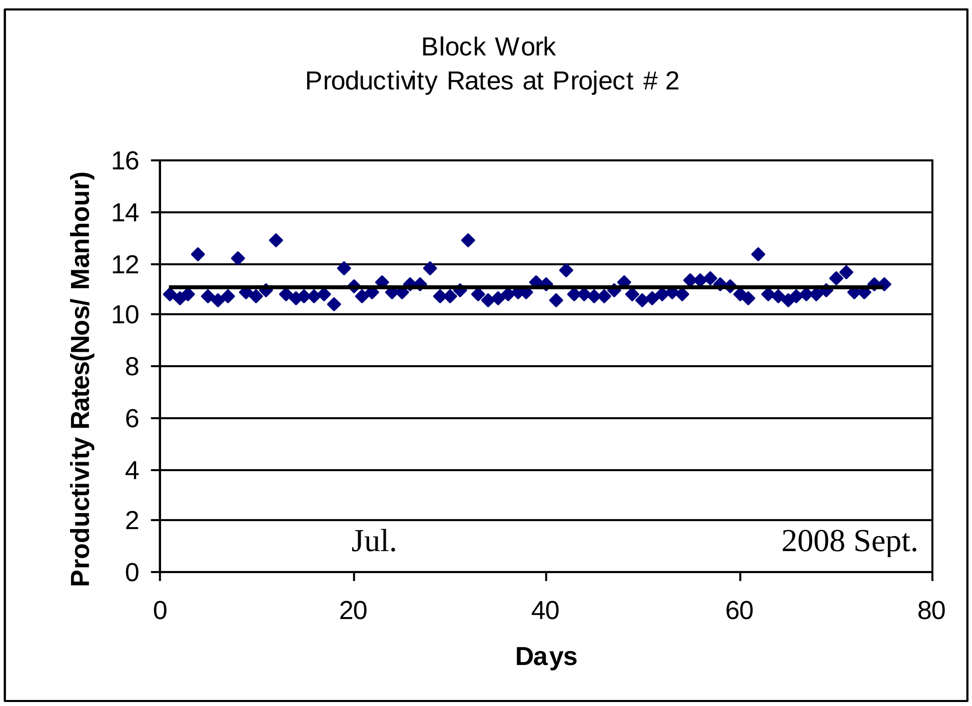

Figure 5.10 Monitoring of daily average productivity rates of block works activity at project # 2.

5.3 Project # 3:

5.3.1 Productivity of Steel Fixers for tunnel steel works:

In this project there were some difficulties to procure the required manpower in the first 40 days but then the group was settled to reach to an average of 105 steel fixers who achieved a daily target of 3 villas per day:

TOTAL MANHOURS	44750
TOTAL QUANTITIES PRODUCED (*kg*)	1361920
AVERAGE PRODUCTIVITY RATE (*kg/man-hours)*	30.43
STANDARD DEVIATION	2.10

Table 5.11 Results summary of tunnel steel activity at project # 3

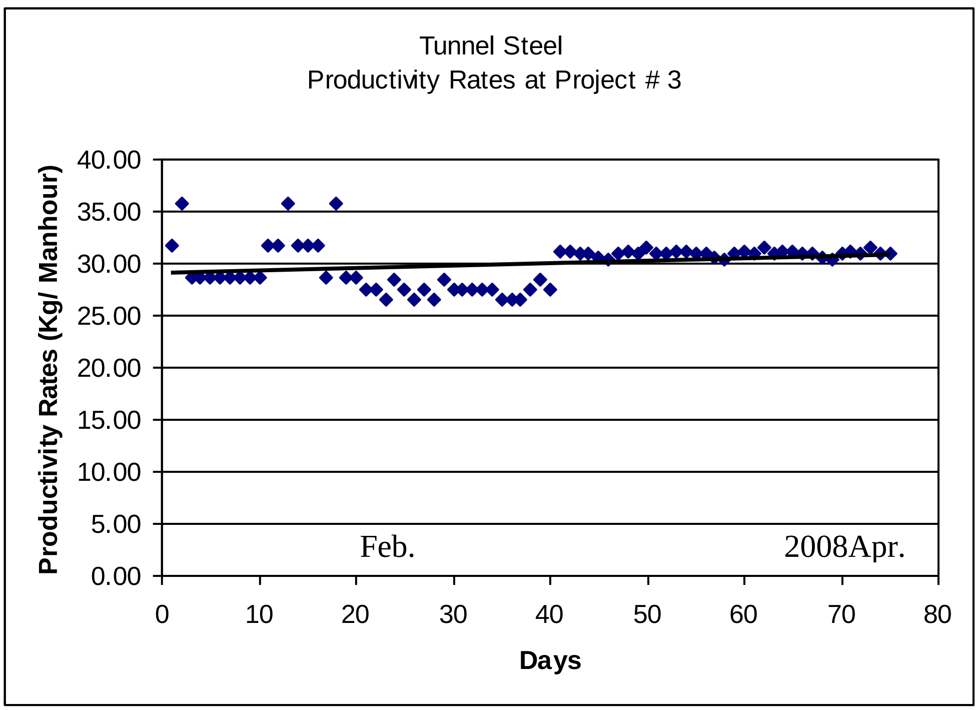

Figure 5.11 Monitoring of daily average productivity rates of tunnel steel activity at project # 3.

5.3.2 Productivity of Steel Fixers for strip foundation steel works:

The group size in this activity was very small (10-14 steel fixers) which caused high variations in the daily productivity rates where 1 or 2 absentees had major influence on the whole group and further to the supervisors comments of this group that they had to maintain the same target production although they suffered from high percentage of absentees which will cause higher productivity rates in those days.

TOTAL MANHOURS	8730
TOTAL QUANTITIES PRODUCED (*kg*)	219117
AVERAGE PRODUCTIVITY RATE (*kg/man-hours)*	25.10
STANDARD DEVIATION	2.94

Table 5.12 Results summary of footing steel activity at project # 3

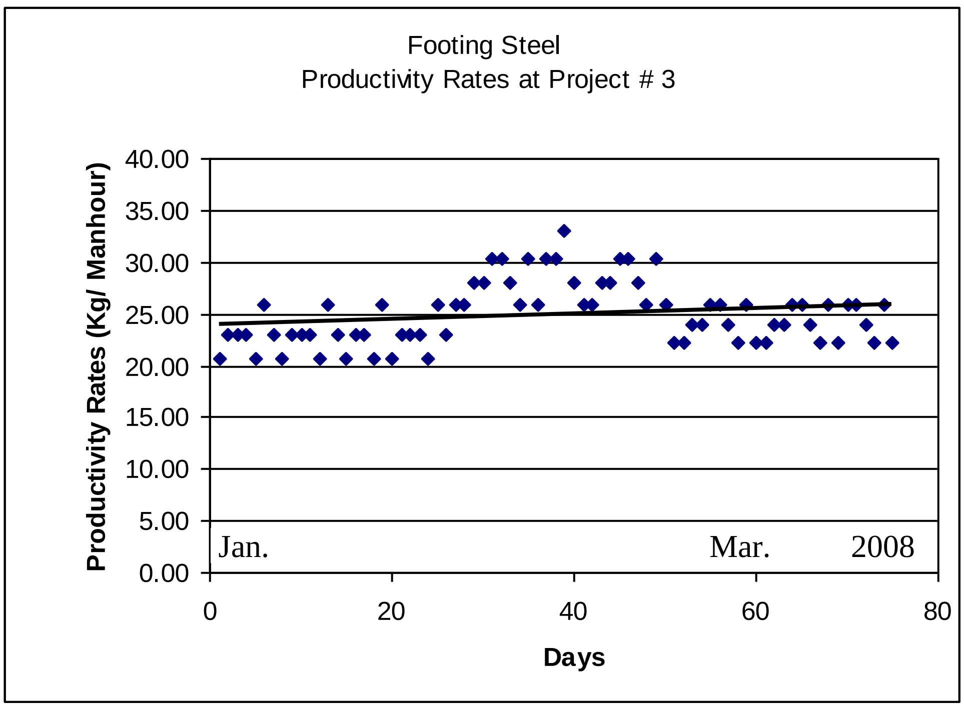

Figure 5.12 Monitoring of daily average productivity rates of footing steel activity at project # 3.

5.3.3 Productivity of Carpenters for strip foundation formworks:

Relative uniformity has been shown in this case with low average productivity rate and low standard deviation:

TOTAL MANHOURS	23960
TOTAL QUANTITIES PRODUCED (m^2)	14727
AVERAGE PRODUCTIVITY RATE (m^2/*manhour*)	0.61
STANDARD DEVIATION	0.05

Table 5.13 Results summary of footing formwork activity at project # 3

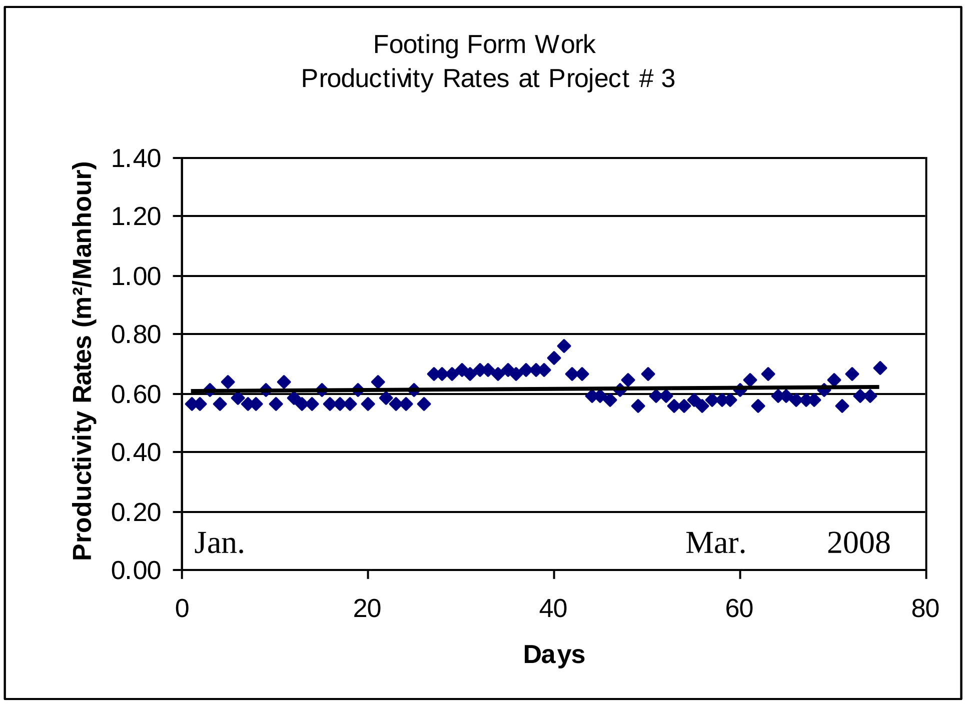

Figure 5.13 Monitoring of daily average productivity rates of footing form works activity at project # 3.

5.3.4 Productivity of Carpenters for roof parapet form works:

In this case the variety of villas types executed from day to day had major affect on the productivity rates where the carpenters performed very well in some types in the contrary of their performance on other types:

TOTAL MANHOURS	41140
TOTAL QUANTITIES PRODUCED (*m²*)	29970
AVERAGE PRODUCTIVITY RATE (*m²/manhour)*	0.73
STANDARD DEVIATION	0.08

Table 5.14 Results summary of roof parapet activity at project # 3

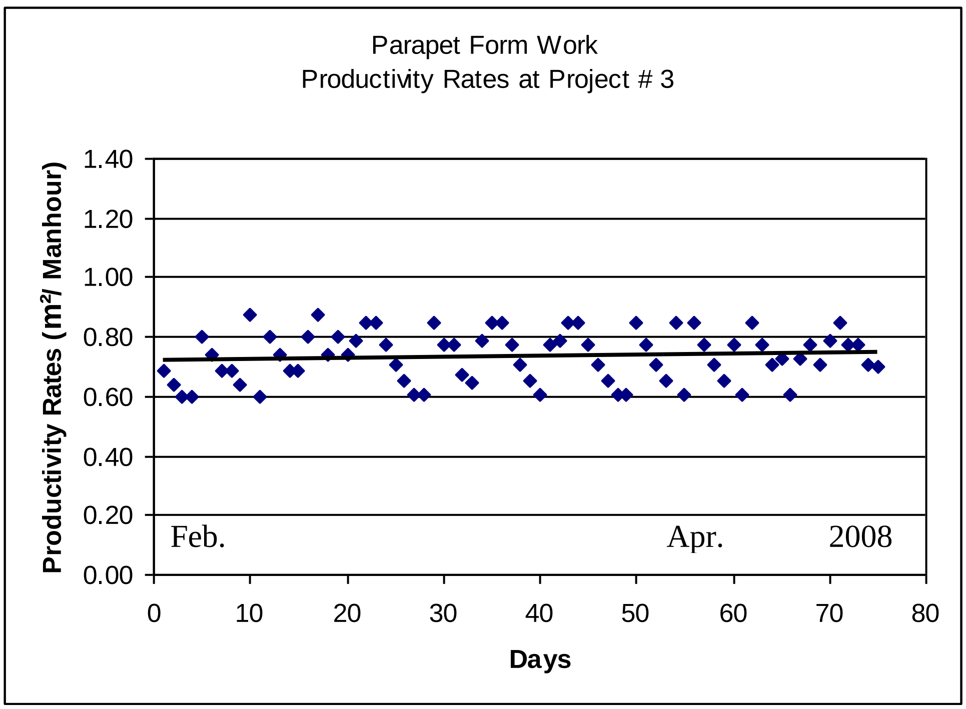

Figure 5.14 Monitoring of daily average productivity rates of parapet form works activity at project # 3.

5.3.5 Productivity of Mason for Block works:

A uniformity of good productivity values is clearly observed in this group of block masons:

TOTAL MANHOURS	47640
TOTAL QUANTITIES PRODUCED (*Nos*)	599475
AVERAGE PRODUCTIVITY RATE (*Nos/man-hours)*	12.60
STANDARD DEVIATION	0.29

Table 5.15 Results summary of block work activity at project # 3

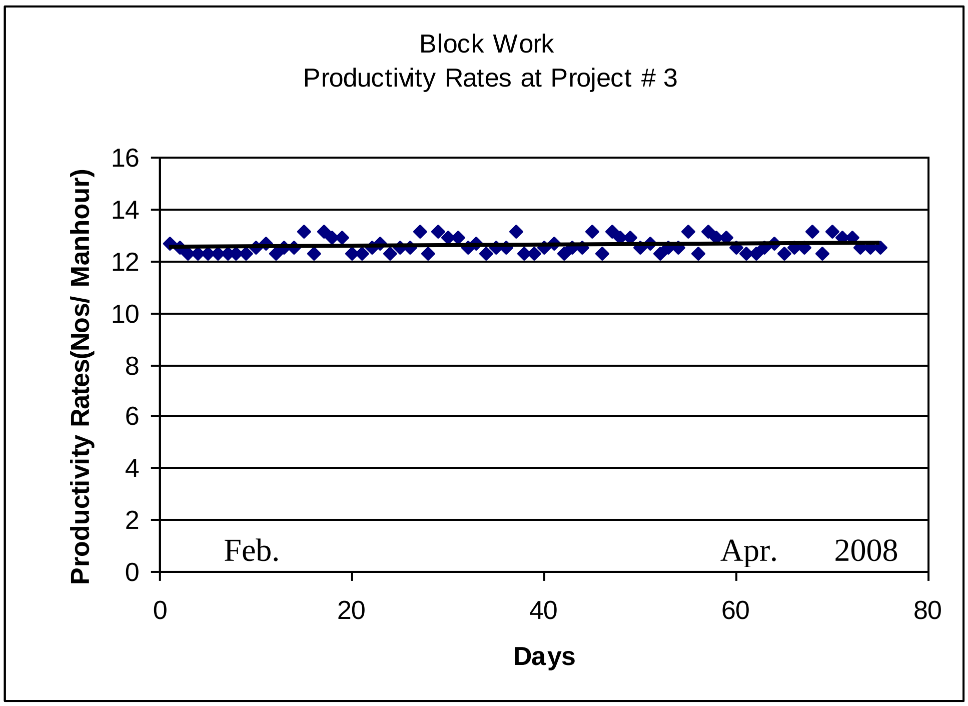

Figure 5.15 Monitoring of daily average productivity rates of block works activity at project # 3.

5.4 Project # 4:

5.4.1 Productivity of Steel Fixers for tunnel steel works

In this case some difficulties took place in the first 10 days until the group has been set up to reach to the required target which were 1 villa per day and the group size was established in accordance to the size of the targeted villa of that particular day and this can be considered as the learning curve period:

TOTAL MANHOURS	83630
TOTAL QUANTITIES PRODUCED (*kg*)	1800922
AVERAGE PRODUCTIVITY RATE (*kg/man-hours)*	21.53
STANDARD DEVIATION	2.77

Table 5.16 Results summary of tunnel steel activity at project # 4

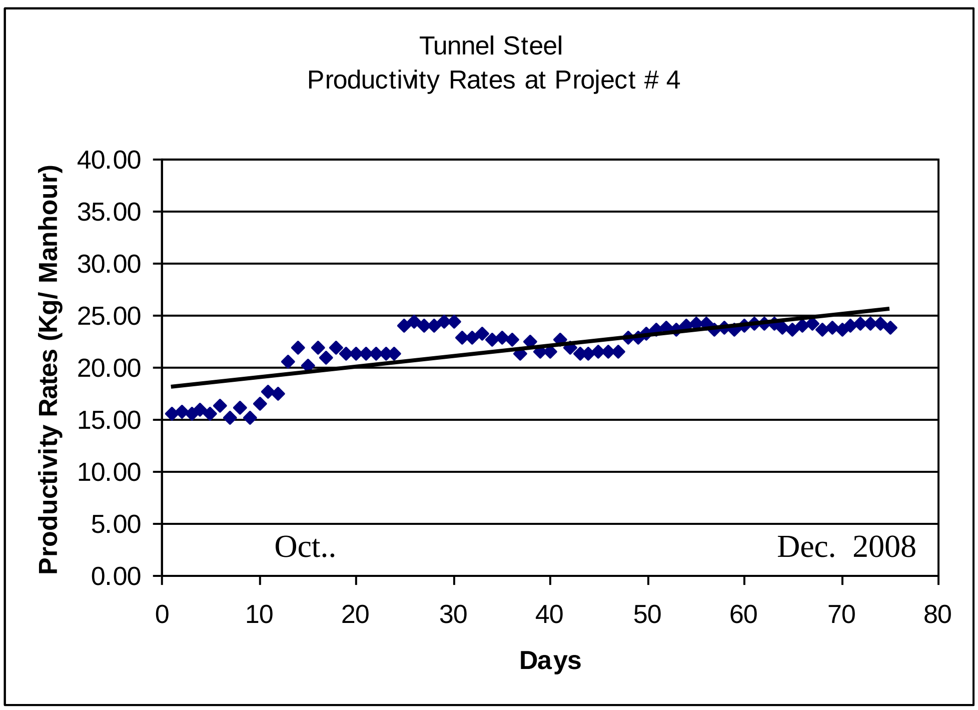

Figure 5.16 Monitoring of daily average productivity rates of tunnel steel activity at project # 4.

5.4.2 Productivity of Steel Fixers for strip foundation steel works:

The footing steel fixers' productivity rates in this project are considered low and could be due to the high complexity of the villas design which will be discussed in the next section:

TOTAL MANHOURS	19040
TOTAL QUANTITIES PRODUCED (*kg*)	395312
AVERAGE PRODUCTIVITY RATE (*kg/man-hours)*	20.10
STANDARD DEVIATION	1.86

Table 5.17 Results summary of footing steel activity at project # 4

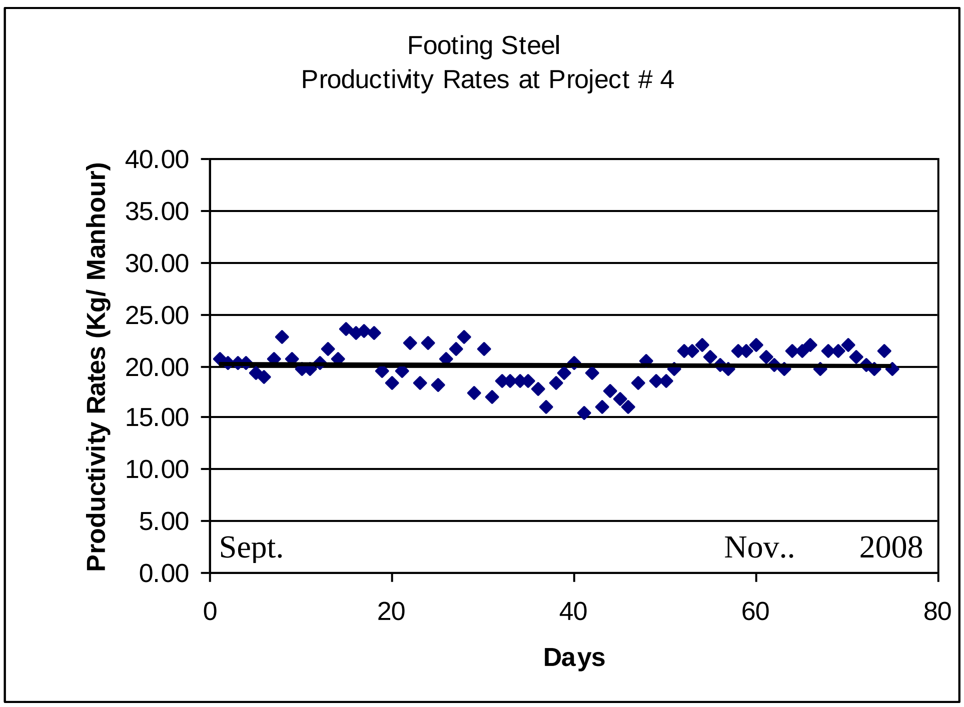

Figure 5.17 Monitoring of daily average productivity rates of footing steel activity at project # 4.

5.4.3 Productivity of Carpenters for strip foundation formworks:

The footing formwork carpenters' productivity rates in this project are also considered low and have relatively high standard deviation compared to the average productivity rates where the values range between 0.40 to 0.90 and here the complexity and the size of the villas could be also considered the main causing factor:

TOTAL MANHOURS	9030
TOTAL QUANTITIES PRODUCED (*m²*)	5594
AVERAGE PRODUCTIVITY RATE (*m²/manhour)*	0.62
STANDARD DEVIATION	0.11

Table 5.18 Results summary of footing formwork activity at project # 4

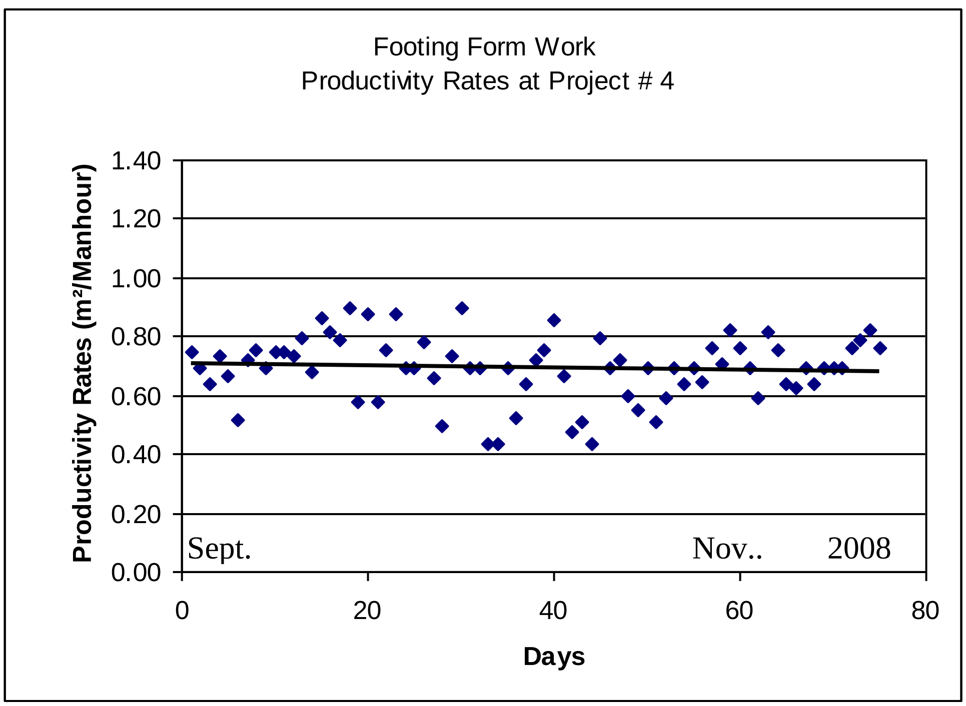

Figure 5.18 Monitoring of daily average productivity rates of footing form works activity at project # 4.

5.4.4 Productivity of Carpenters for roof parapet form works:

The daily productivity rates of the parapet carpenters ranges between (0.7-0.9) *m²/manhour* according to the type of villas performed:

TOTAL MANHOURS	44480
TOTAL QUANTITIES PRODUCED (*m²*)	35402
AVERAGE PRODUCTIVITY RATE (*m²/manhour)*	0.80
STANDARD DEVIATION	0.07

Table 5.19 Results summary of roof parapet activity at project # 4

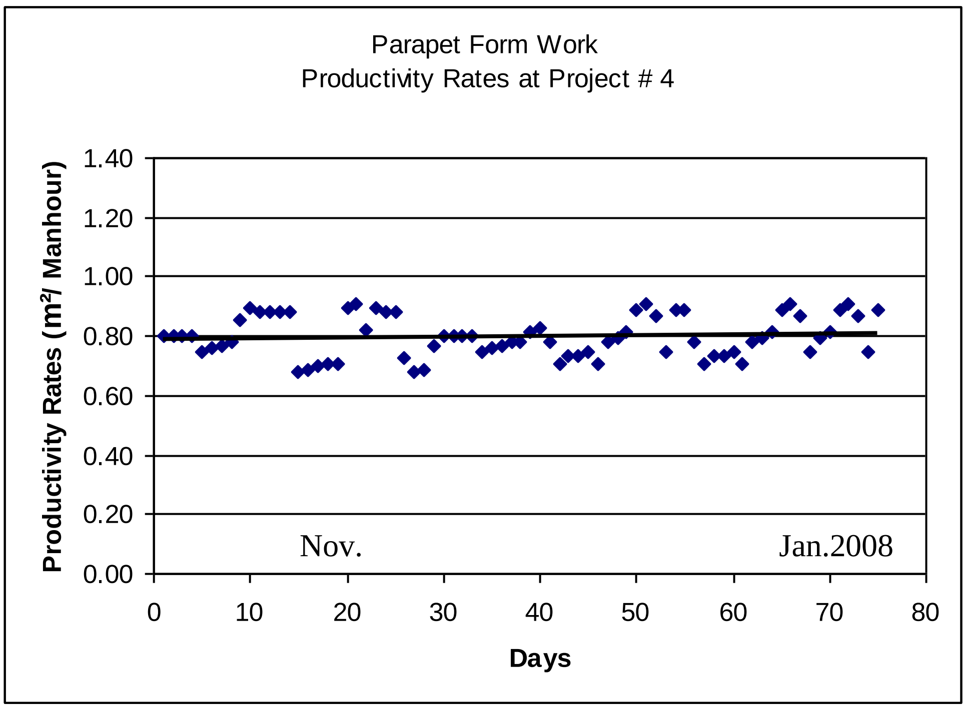

Figure 5.19 Monitoring of daily average productivity rates of parapet form works activity at project # 4.

5.4.5 Productivity of Mason for Block works:

The large size of the villas (see table 4.1) allow the block mason to lay more blocks as plain walls, in the other hand his productivity would go down in the tight spaces and corners and this can be observed in figure 5.20:

TOTAL MANHOURS	25630
TOTAL QUANTITIES PRODUCED (*Nos*)	363490
AVERAGE PRODUCTIVITY RATE (*Nos/man-hours)*	14.2
STANDARD DEVIATION	1.55

Table 5.20 Results summary of block work activity at project # 4

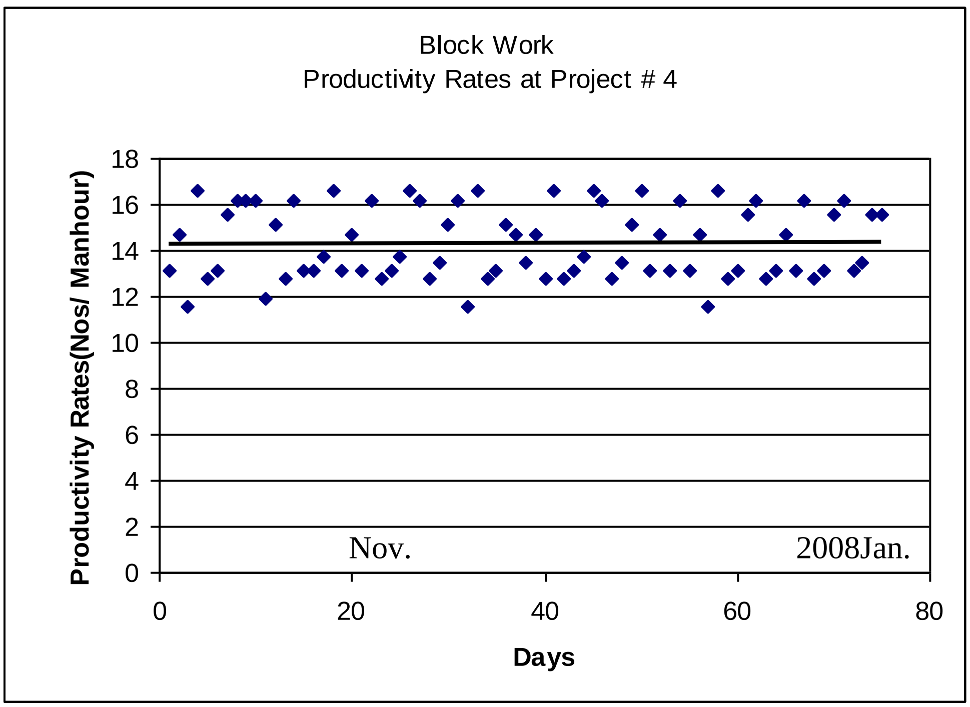

Figure 5.20 Monitoring of daily average productivity rates of block works activity at project # 4.

5.5 Project # 5:

5.5.1 Productivity of Steel Fixers for tunnel steel works

High level of consistency in this group productivity rates was observed along the three months:

TOTAL MANHOURS	106800
TOTAL QUANTITIES PRODUCED (*kg*)	2706900
AVERAGE PRODUCTIVITY RATE (*kg/man-hours)*	25.35
STANDARD DEVIATION	0.38

Table 5.21 Results summary of tunnel steel activity at project # 5

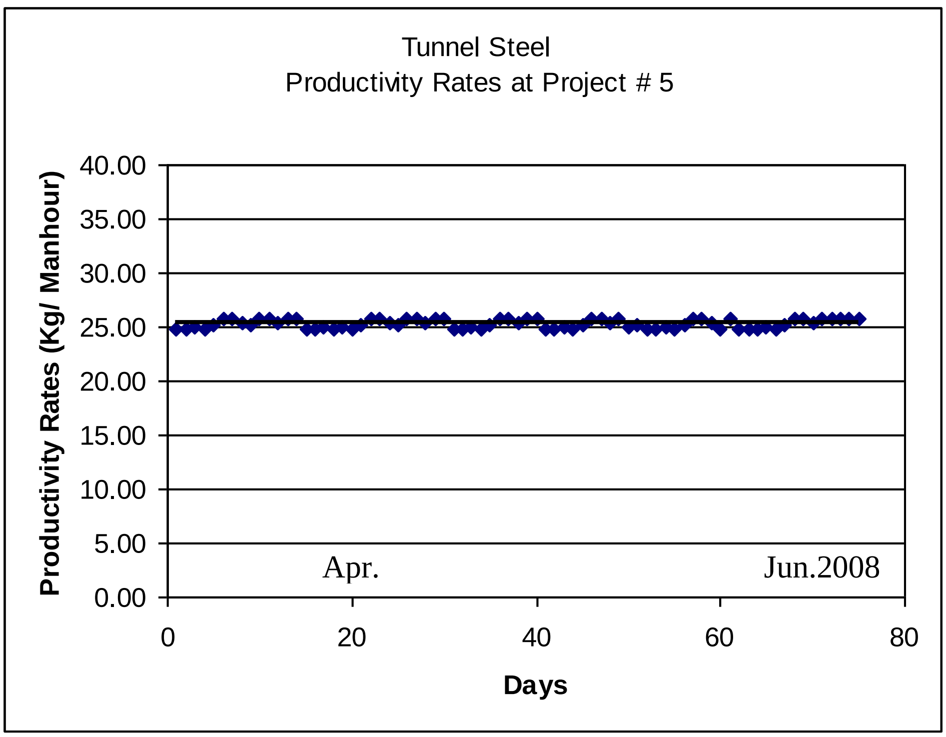

Figure 5.21 Monitoring of daily average productivity rates of tunnel steel activity at project # 5

5.5.2 Productivity of Steel Fixers for strip foundation steel works

The productivity rates have shown continuous improvements and reached to high average and high standard deviations:

TOTAL MANHOURS	18410
TOTAL QUANTITIES PRODUCED (*kg*)	495375
AVERAGE PRODUCTIVITY RATE (*kg/man-hours)*	26.91
STANDARD DEVIATION	2.19

Table 5.22 Results summary of footing steel activity at project # 5

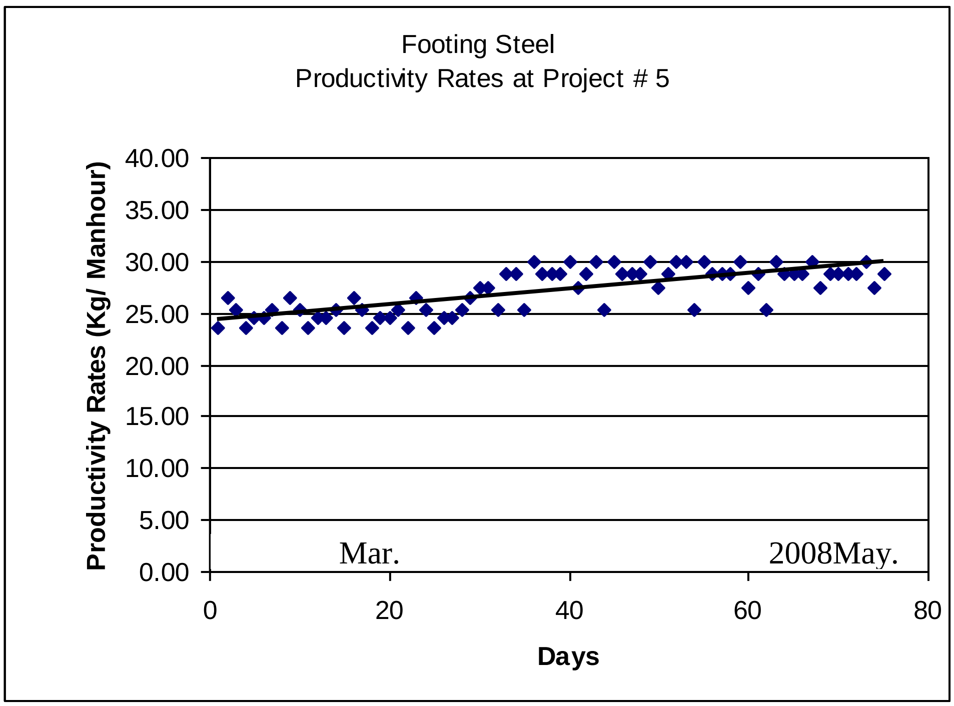

Figure 5.22 Monitoring of daily average productivity rates of footing steel activity at project # 5.

5.5.3 Productivity of Carpenters for strip foundation formworks

The formwork carpenters of this group have not shown much variations from the average productivity rates which ranges between (0.80 – 0.90) *m²/manhour:*

TOTAL MANHOURS	34371
TOTAL QUANTITIES PRODUCED (m^2)	29567
AVERAGE PRODUCTIVITY RATE ($m^2/manhour$)	0.86
STANDARD DEVIATION	0.04

Table 5.23 Results summary of footing formwork activity at project # 5

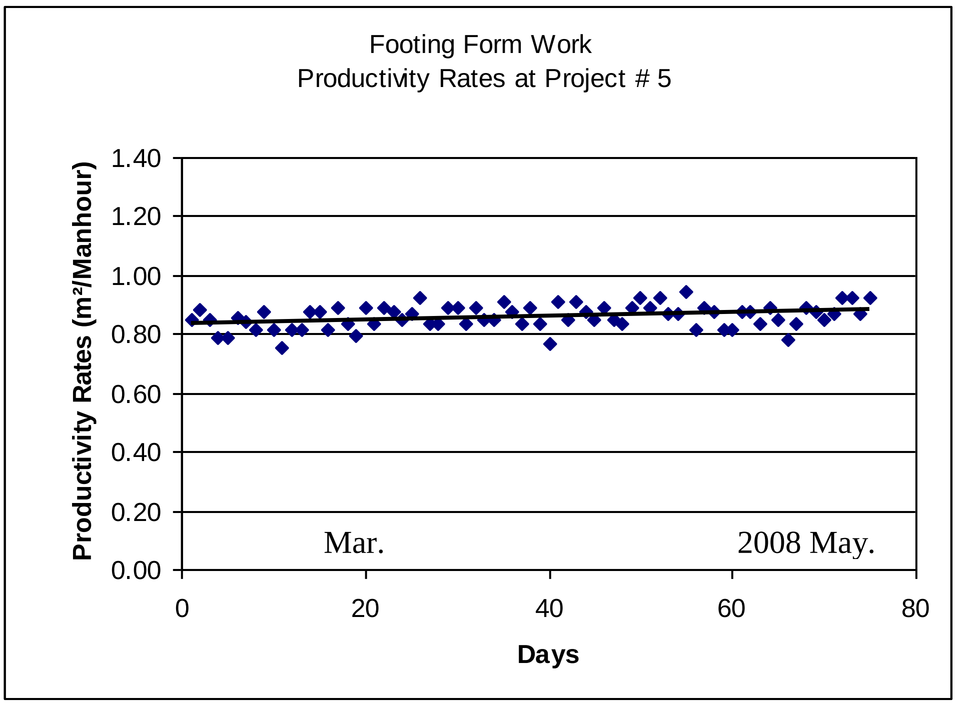

Figure 5.23 Monitoring of daily average productivity rates of footing form works activity at project # 5.

5.5.4 Productivity of Carpenters for roof parapet form works

New unskilled carpenters were involved in the parapet activity in this project which affected the average productivity rates in the first few weeks until they get trained and reach to a reasonable productivity rates:

TOTAL MANHOURS	45550
TOTAL QUANTITIES PRODUCED (m^2)	37275
AVERAGE PRODUCTIVITY RATE ($m^2/manhour$)	0.82
STANDARD DEVIATION	0.07

Table 5.24 Results summary of roof parapet activity at project # 5

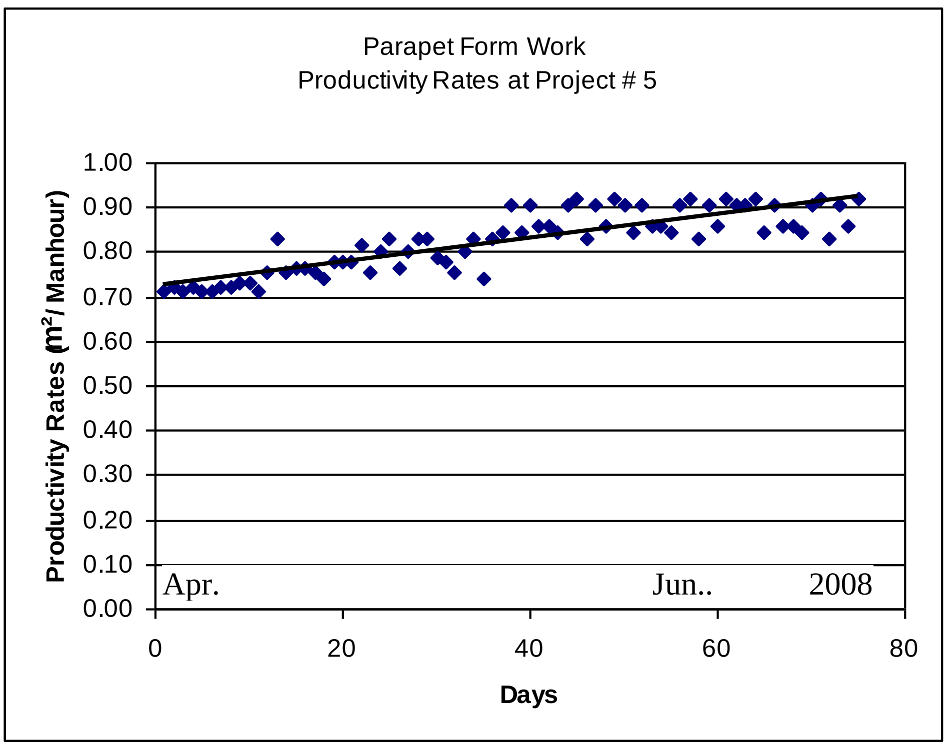

Figure 5.24 Monitoring of daily average productivity rates of parapet form works activity at project # 5.

5.5.5 Productivity of Mason for Block works

The learning curve is also clearly observed in this case of block masons because of the new unskilled masons who were involved in this group where it started with 55 new arrival masons and after two months they were gradually reduced to 40 masons producing the same daily output :

TOTAL MANHOURS	36810
TOTAL QUANTITIES PRODUCED (*Nos*)	399825
AVERAGE PRODUCTIVITY RATE (*Nos/man-hours)*	10.86
STANDARD DEVIATION	1.51

Table 5.25 Results summary of block work activity at project # 5

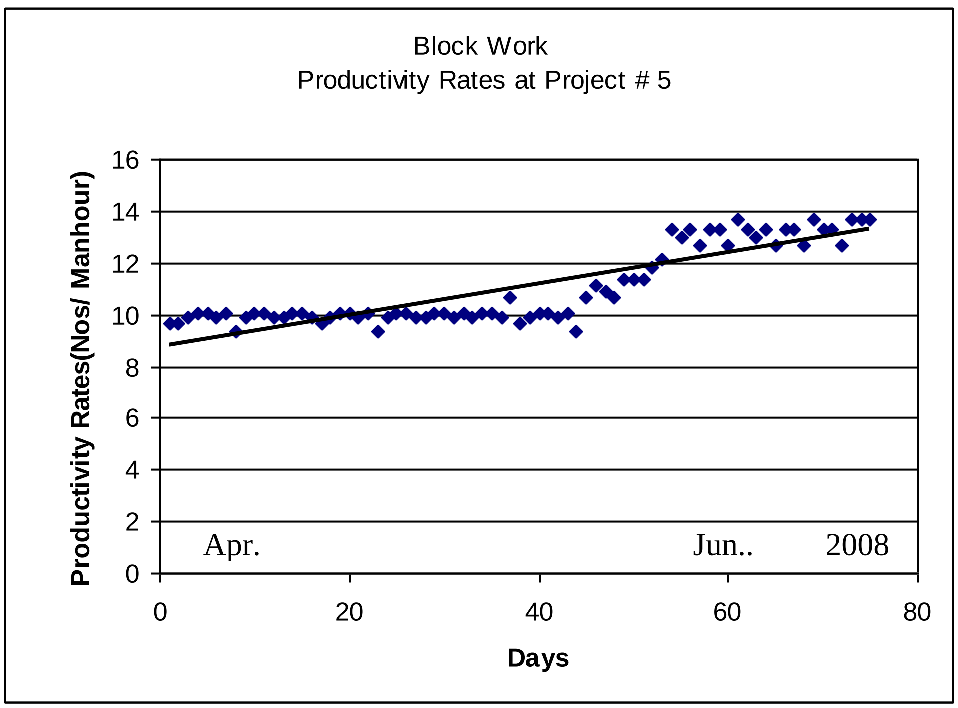

Figure 5.25 Monitoring of daily average productivity rates of block works activity at project # 5.

5.6 Results Summary

	TUNNE STEEL	FOOTING STEEL	FOOTING FORMWORK	PARAPET FORMWORK	BLOCK WORK
Project # 1	26.95	28.19	0.99	0.99	12.50
Project # 2	25.44	30.98	0.70	0.78	11.00
Project # 3	30.43	25.10	0.61	0.73	12.60
Project # 4	21.53	20.10	0.62	0.80	14.20
Project # 5	25.35	26.91	0.86	0.82	10.86

Table 5.26 Summary of average productivity rates across the projects

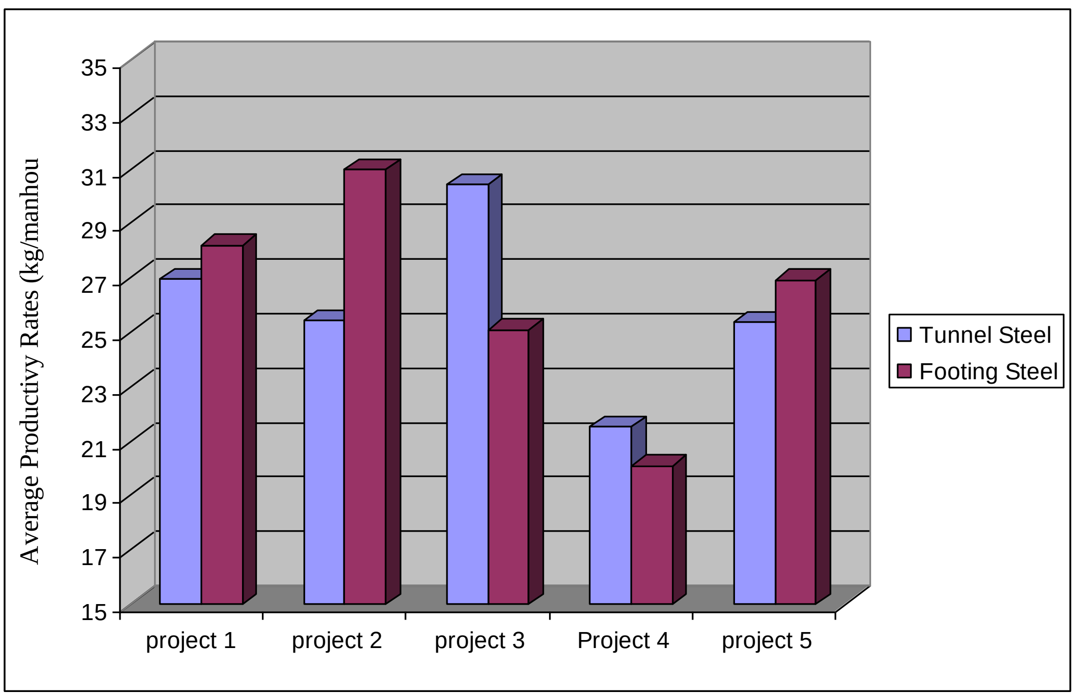

Figure 5.26 Variances of average productivity rates for steel fixers

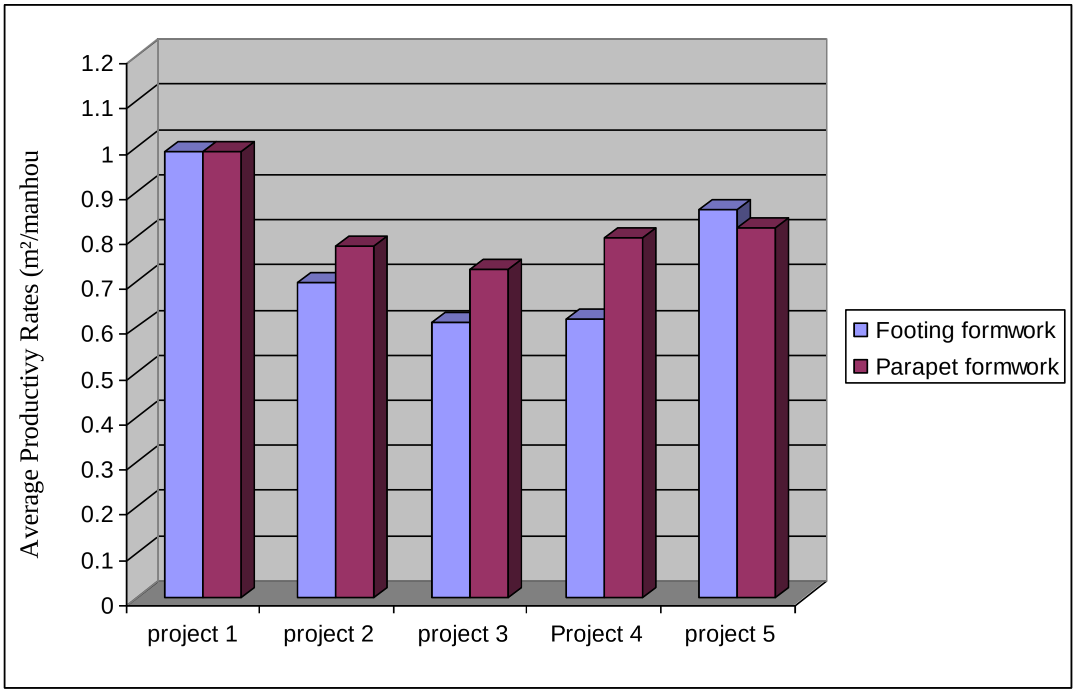

Figure 5.27 Variances of average productivity rates for carpenters

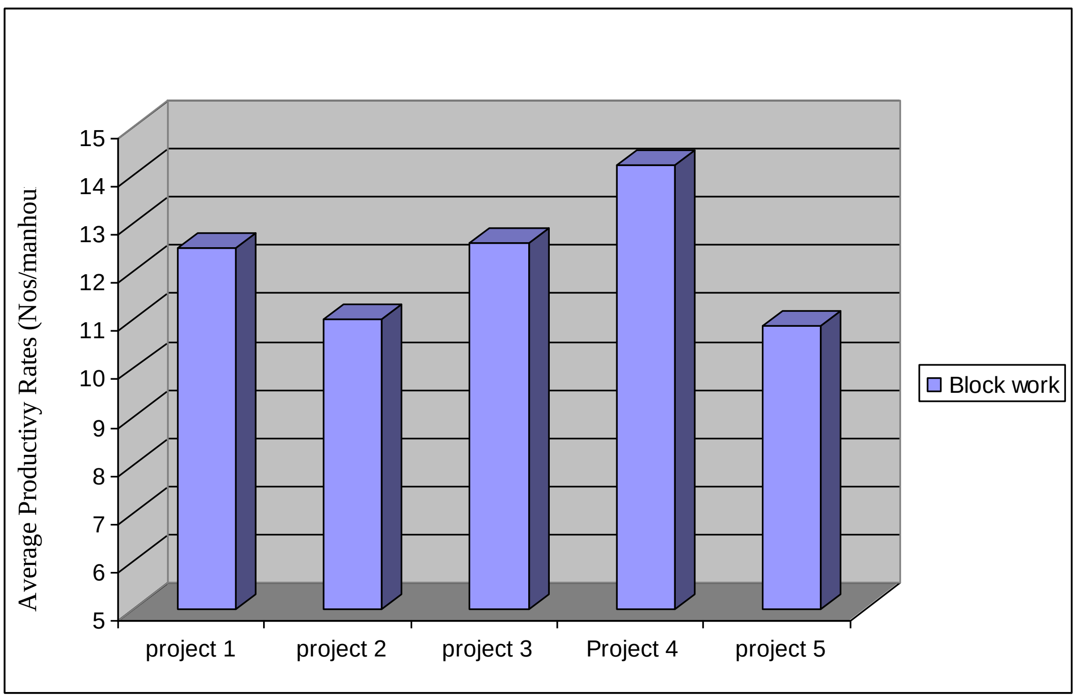

Figure 5.28 Variances of average productivity rates for block masons

	TUNNE STEEL	FOOTING STEEL	FOOTING FORMWORK	PARAPET FORMWORK	BLOCK WORK
Project # 1	1.01	1.11	0.12	0.14	0.88
Project # 2	1.37	1.78	0.03	0.05	0.51
Project # 3	2.10	2.94	0.05	0.08	0.29
Project # 4	2.77	1.86	0.11	0.07	1.55
Project # 5	0.38	2.19	0.04	0.07	1.51

Table 5.27 Summary of standard deviations of productivity rates across the projects

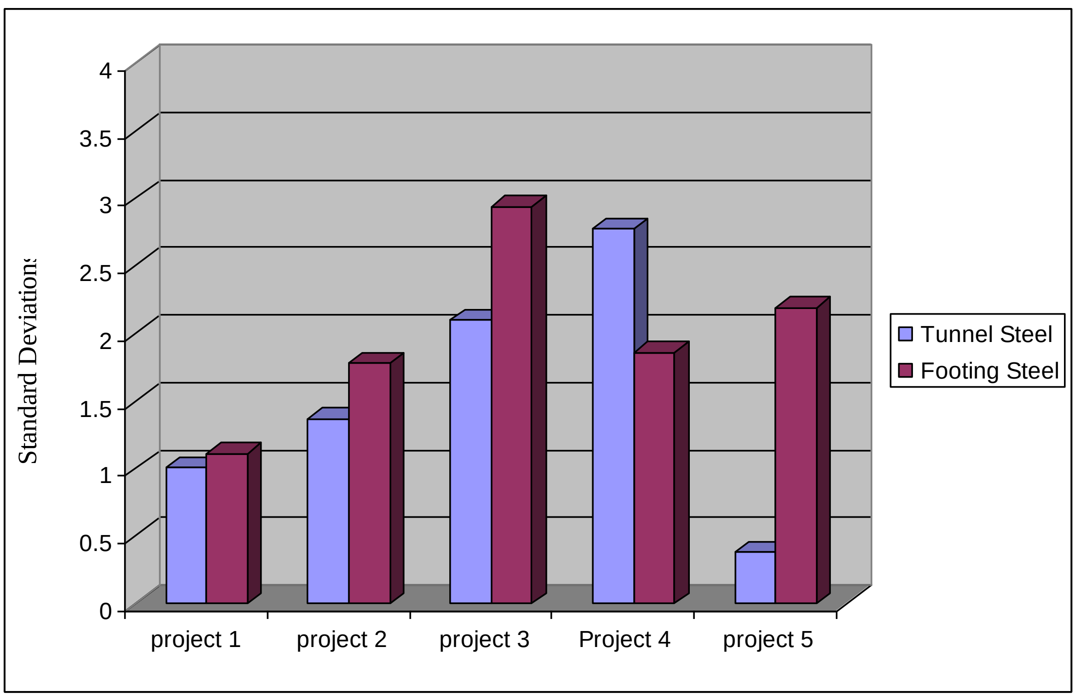

Figure 5.29 Variances of standard deviations for steel fixers

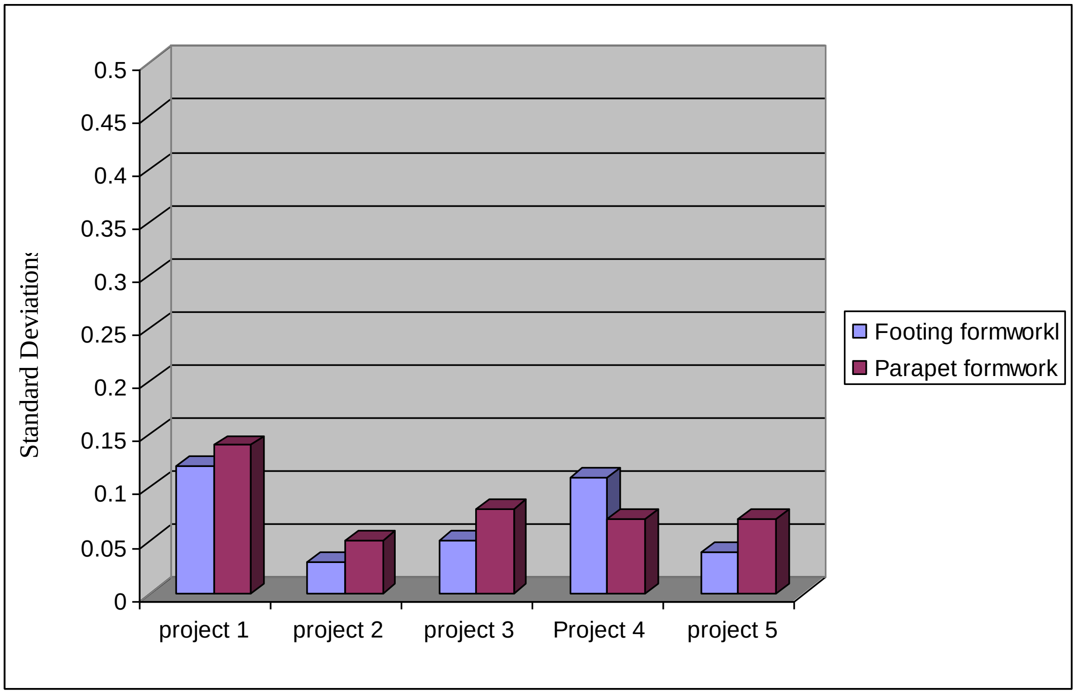

Figure 5.30 Variances of standard deviations for shuttering carpenters

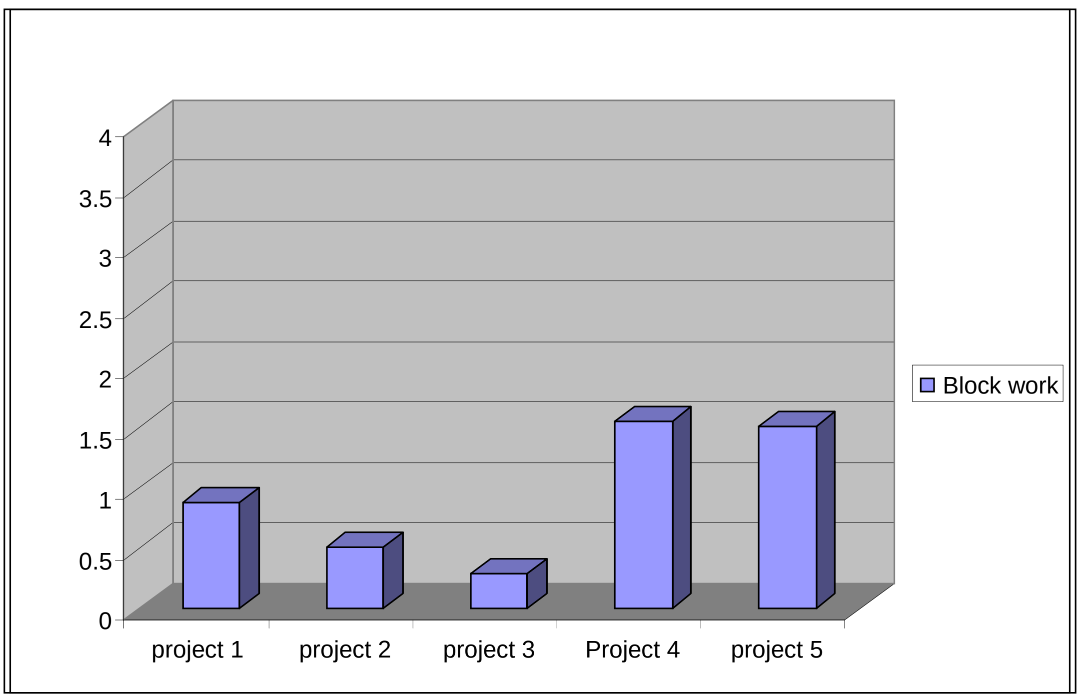

Figure 5.31 Variances of standard deviations for block masons

Further to section 2.4 and in order to establish Target Productivity Rates to be considered as benchmarks which would be useful for planning of further projects and evaluation of labours performance, the following figures were obtained as the Target Productivity Rates for each activity using the weighted average method*:

#	Activity	Target Productivity Rates	Unit
1	Installation & fixing of tunnel steel (columns & slabs)	25.5	Kg /man-hours
2	Installation & fixing of strip foundation steel	28.0	Kg /man-hours
3	Installation of strip foundation form works	0.80	m^2/manhour
4	Installation of roof parapet form works	0.85	m^2/manhour
5	Masonry works of building 200,150 or 100mm block works	12	Nos /man-hours

Table 5.29: the Target Productivity Rates to be considered as benchmarks for each construction activity in the study

*** Target Productivity Rates =**

$$\frac{\sum \text{the average productivity rate} * \text{the total man-hours consumed}}{\sum \text{the total man-hours}}$$

CHAPTER SIX

STUDY ANALYSIS

6.1 Results Analysis

After the data have been collected from the 25 work samples of this study, the results have been processed through excel sheets and illustrations which indicate the following observations:

Table 5.26 and figures 5.26, 5.27 and 5.28 show noticeable variations of the productivity rates of each worker trade with respect to the type of activities to be carried out and to the project as well, where the steel fixers average productivity rates range between 20.0 kg/man-hour to 31.0 kg/man-hour for both tunnel and footing steel activity which can be considered significant (around 40% variance), and in regards to the carpenters range: 0.61-0.99 m^2/man-hour for footing and parapet formwork activity which also can be considered relatively significant (around 40% variance) and finally block work masons productivity rates vary between 10.8 to 14.2 Nos/man-hour (around 20% variance). Furthermore the standard deviations values of the daily productivity rates (illustrated in figures 5.29, 5.30 and 5.31) are relatively high and these variations can be justified by considering the following:

1) The size, the complexity and the constructability of the villa structural and architectural design.
2) The size and the number of villas of the project.
3) The crew size and the quantity of production required to be achieved by one group of workers.

4) The external factors surrounding the work environment such as the weather conditions, the obstructions from other parties.

And finally, the influence of the management of the project and how they intervene to improve the productivity by applying the factors which have been discussed in the literature (section 3.2). Further discussion will be addressed through the interviews conducted with the project managers in the next section.

"Work sampling gives information about time spent on activities and therefore gives indirect information about productivity. However, direct work time does not necessarily correlate with unit rate productivity. In other words, a high percentage of direct work time would not always indicate an equally high level of unit rate productivity because of variation in skill levels of the workers sampled, work methods and types of tools and equipment used. For example, a skilled worker may produce more than an unskilled worker performing the same task even though both have the same direct work rate. A carpenter utilizing a skill saw will out-produce a carpenter with a handsaw even though the direct work percentage may be the same. Even considering these constraints, work sampling can be useful as a diagnostic tool for productivity improvement programs." (Business Round Table, 1982)

6.2 Interviews

In order to perform further analysis of the results obtained from the case studies of this research, interviews were conducted with the project managers of those projects where the study was conducted, and they are all working in the same contracting company. The interviews questions were directed towards the objectives of this study in order to obtain the project managers' opinions about the productivity rates of the workers and the factors that cause the variations of the productivity rates from one project to another and from one activity to another, And then the interviews were directed to receive the project managers' views about their roles towards improving the productivity rates and how they can intervene to influence the productivity of their workers.

INERVIEWEE NAME	PROJECT NAME	DESIGNATION	EXPERIENCE
PM-1	Project # 1	Sr. Project Manager	> 15 years
PM-2	Project # 2	Project Manager	> 10 years
PM-3	Project # 3	Sr. Projects Manager	> 20 years
PM-4	Project # 4	Deputy Project Manager	> 5 years
PM-5	Project # 5	Project Manager	> 10 years

Table 6.1 Interviewees' Overview

6.2.1 Project # 1

PM-1 sees that the size of the project and the total villas to be constructed have a direct effect on labour productivity, and this project includes the construction of more than one thousand villas distributed on ten different types of structural and architectural design which makes the number of repetitive work is very big. This would help the worker to improve his productivity among the project duration. Furthermore, he added that all the villas designs are not highly complicated and they are in the same concept of previous projects villas carried out by the same groups of workers which would enhance their productivity rates.

About climate changes, he talked about the high temperature and humidity during summer time and the regulations of work stoppage during the noon time (12:30-15:00), and this had negative effect on the continuity of the works where the labour productivity would not be the same after taking long break. In this regards he added that the site engineers and the foremen were instructed to increase their attendance with their workers in order to ensure that they start their work immediately after the break and make sure to complete their target.

In regards to the other external factors, PM-1 claimed that there were no major obstructions or disturbances took place during the project duration, where the infrastructure contractors have started their works after one year of the commencement of the building contractor works.

PM-1 emphasizes the role of the project manager for improving the labour productivity and he concludes his role in the following: first he enhances the importance of building proper communication lines between all the project team members including the management, engineers, supervisors and the labours taking into consideration the cultural and the language issues where he suggested to make language courses for the team member to communicate with the labours in their language. He added that having qualified team in all the department of the project such as: planning, design, quality control, site engineers and reaching to the direct supervisor would be a major factor for improving the productivity of the worker, where their duty is to facilitate his work and provide all the requirements on time before commencing the work and this includes; cleared drawings, approved materials and adequate tools.

He also confirmed that proper hand over between the preceding and the subsequent activities have been be maintained in order to ensure that the working area is safe, clean and ready to commence the new activity without the need of further rectification or repairing due to poor quality from preceding activity.

Finally, PM-1 stated that after providing the adequate environment for the worker to work, he applied a direct incentive action to motivate the worker to produce more, and this can be through using the over time tool or what is called contract piece work, and this is done be assigning each group of workers with specific target to be achieved in accordance with specific productivity rates obtained from previous projects. And also he said that he did not ignore the social recognition to the worker and enhancing his self satisfaction through making him feels that he is important to the company by providing proper facilities like adequate accommodation, transportation, providing cold water and sufficient number of toilets.

6.2.2 Project # 2

PM-2 sees that having the same concept of structural design for all the villas types of his project and even of previous projects of the company is a major factor of getting high productivity rates of the company's workers by reducing the learning curve period at the beginning of every new activity of each project. However he added that his project contains nine different types of the villas that can be considered more complex than other projects' villas, and this would affect the productivity rates, but this effect varies from one activity to another. Further more the daily target as per the baseline of this project is approximately two villas per day and the sizes of the villas are considered relatively big which makes the number of workers to be procured for each activity is high, but this is not affecting their productivity because they have enough space to work as he said.

In regards to the external factors, he said that there was no touchable influence from external factors on the performance of his workers, where the weather was stable most the time and the working times been altered during the summer in order to avoid working under high humidity and temperature, and we have not faced any obstructions from other contractors such as infrastructure and road works.

PM-2 emphasizes the role of the project manager to improve the productivity rates of his workers by procuring sufficient and efficient supervisors who are qualified to monitor and control their workers and ensuring that they have adequate tools and materials in order to avoid idle time, he added that initiative supervisor will make noticeable difference in the performance of his group day after day.

He said that the workers should work in a safe environment to give their best efforts especially in the activities of high level such as parapet form works and this will ensure the continuity of work.

Finally, he stated that conducting a risk management before the commencement of the project and even on the major milestones of the project would have great assistance for improving the productivity of the workers by learning from previous mistakes and deficiencies and then make proper planning to avoid them in future and find the appropriate corrective actions.

6.2.3 Project # 3

PM-3 sees that before asking the worker for production the management should make sure that all the surrounding and the related circumstances are set up and allowing him to give his best efforts.

He said that adopting the people-oriented leadership style have great influence on the labour productivity, where management must build a qualified and homogeneous team and enhance their loyalty and dedication to the project success and the whole company benefits, and this team has many tasks to provide the facilities for the workers to work without distraction.

Before commencing the work of any activity the project team has to ensure that all the drawings and the method of statements are clear and approved from the consultant and then provide the sufficient tools and materials for the workers. He added that this team should act as trouble shooter and tackle the problems or the discrepancies even before they took place, furthermore the project team should make sure that the working area is safe and the preceding activities have been completed properly without deficiencies which could affect the work progress of the new activity and this would lead to avoid any abortive work.

About the characteristics of his project, PM-3 stated that although the complexity level of the eleven different design types of the project villas is considered relatively high, but its effect on the productivity of the workers have been overcome because most of the workers have carried out hundreds of the same villas on previous project which makes them familiar with such type of work.

However, he mentioned that because of many client changes, the sequence of work have been disturbed and the daily target have been altered many times in some critical activities as recovery program (the groups have been enforced by new workers), which caused some variances in some activities workers' daily productivity rates.

Finally, PM-3 emphasizes the effect of the financial incentives such as bonuses, additional over time, and promotions' opportunities. And also he mentioned the non-financial incentives such as monthly awards and parties.

6.2.4 Project # 4

PM-4 stated that that the complexity of carrying out the construction works of these villas is considered very high due to the multitudinous types of features in the architectural elevations, either internally or externally, which contain many projections and corners, and the influence of this factor varies from one activity to another, for example the productivity of roof parapet formwork carpenters would be highly affected by the numerous design details of cornices and these details vary from one villa type to another. However, the complexity of the structural designs has a great effect as well, where the tunnel steel distribution in the beams, slabs, walls and columns contains more details compared to the other projects villas' designs.

In regards to the daily target of progress, PM-4 claimed that it started with one villa per day for all the activities but due to some conflicts with the client, the target has been reduced to 0.5 villas per day, and this certainly affected the productivity of the workers because of the sudden reallocation of the tasks.

PM-4 highlighted the effect of weather changes on the productivity in his project which is surrounded by desert, where some days we faced work stoppage due to sand storms or fog in addition to the high temperature and humidity as he said.

PM-4 pointed out the effect of mechanical and electrical subcontractor which is considered as a major cause of delays and affected the main contractor's workers productivity. Furthermore, he empathized that the uniqueness of his project villas compared to the other company's current and previous project has forced a long learning curve for commencing every new activity.
In order to improve the productivity of the labours, he stated that proper planning was done sufficient data were collected about the productivity rates of the company workers from previous projects in order to assign adequate number of workers in each activity and then keep monitoring them daily and then while this activity is on the track, gradual reduction of the labours in the same group have been done and maintained the same target which resulted increasing in the productivity rates.

He also added that the supervisors to workers ratio must be reasonable and not less that 10% in order to maintain proper monitoring and controlling of workers progress and quality as well. In the meantime, the team work and establishing good relation between the workers and the other staff would enhance the work environment and improve the worker's commitment towards the success of the project.

6.2.5 Project # 5

PM-5 sees that there were no characteristics of the project that had negative influence on the productivity rates in general, where all the workers were familiar with the procedure of building the project's villas since they are similar to several previous projects, and the sizes of the villas are normal and the daily target was constant of two villas per day, which makes the group sizes stable through the whole project duration. Furthermore, he stated that they have not faced any major obstruction from external factors.

In order to get higher productivity rates from the workers PM-5 confirmed that high safety standards were not compromised in all aspects, starting from the house keeping and reaching to the scaffolding in high level, where he said that the worker will never give his best efforts unless he feels safe while he is working. And he also connected the safety of the labour with his loyalty to the project and to the whole company as well, because he will feel that the management is taking care of him and considering his life precious.

PM-5 stated that periodic toolbox and different types of training was maintained in order to enhance the labour performance and knowledge towards important issues like safety and quality, in addition “we always do our best to provide proper and advanced tools to the labours and conduct inductions to teach them how to use” as he said.

In regards to the motivation, PM-5 said that the workers were motivated to increase their productivity by offering more bonus overtime hours to the labours who achieve more than the standard target which has been obtained from the planning engineers.

Finally, PM-5 sees that applying sufficient monitoring system with qualified supervising team has great influence on improving productivity, where the project manager needs this team to observe and control the labours’ performance.

6.3 Discussions & Conclusions

Productivity has become now an everyday word. In the last few decades academic researchers and economists have all stressed the importance of productivity because its relationship with the general economic health of a nation.

"Productivity rates rank amongst the most essential data needed in the study of construction productivity. One of the most important applications of these data is in the area of construction planning and scheduling. Other uses include estimating, accounting and cost control. Indeed, Koehn & Brown (1986) used productivity rates to generate international labour productivity factors and also suggested ways in which these could subsequently be applied to determine comparative international construction costs." (Proverbs et al,1998)

However, accurate measurement of the construction worker productivity has been always a puzzle because of the numerous different tasks involved the construction process including steel fixing, carpentry and masonry works. In order to measure the productivity the input and the output need to be specified. In this study and as per most of the related researches, the input is considered as the man-hours consumed, but the challenge is how to quantify the output for each trade with respect to the type of task to be carried out, in this study five different construction tasks were specified to be studied through work sampling.

"Work sampling is a system for indirectly measuring productivity on construction sites, which has been used for more than 30 years. Work sampling measures how time is utilized by the labor force." (Thomas et al., 1984)

The results of the work sampling were processed to determine the productivity trend and productivity benchmarks in order to conduct further examination of the causes of the variations of productivity rates.

The results have shown high variations of productivity rates of each trade with respect to the tasks and between the five projects. And these variations must be justified in two directions:

1) The existing characteristics of each project and their direct and indirect effects on the labour productivity including: the constructability of the villas, the uniqueness, the sizes of the project and the villas as well, the required daily target, in addition to other external factors such as the climate conditions and the any possible obstructions from other parties involved.

2) The role of the project managers of how they intervene to overcome and resolve the negative factors or to utilize the positive factors in order to improve the productivity rates of their workers.

Further to the literature and to the interviews, the project manager can intervene to make noticeable improvement of the worker productivity rates, and his role can be summarized as follow:

- The project manager to assign qualified project team to provide the entire technical and logistic requirements to the workers in order to create proper environment for them to work.

- The project manager to have sufficient data of the achieved productivity rates through previous projects in order to assign the tasks in accordance with the ability of his workers.
- The project manager to study the characteristics of his project in comparison with previous and current projects and then to determine the success factors that could have positive effect on the productivity.
- Safety issues should not be ignored, where one of the main project manager duties is to ensure that his workers are working in safe conditions.
- The project manager to encourage his team to be initiative and create better methods to carry out the works, such as adopting new tools or machineries which may ease and fasten the works.
- The project manager to apply financial and non-financial incentive plans to motivate the workers to achieve more.
- Finally, the project manager must have sufficient supervising teams including engineers and foremen in order to apply proper monitoring and controlling system that allow him to have sufficient feedback about the performance of the workers and then to examine the influence of the factors and the techniques applied for improving their productivity rates.

APPENDIX

Appendix A: Interview Questions Sample

Interview # **Date:**

___/___/_____

Interviewee Information

Name:
Career Position:
Experience:

Project Information

Title:
Budget:
Duration:

Interview Questions:

1) Give general description about your project taking into consideration the following:
   a) the type and the size of the villas
   b) the complexity of the architectural & the structural design of the villas
   c) the daily target to be achieved
   d) the climate changes through out the project duration
   e) any obstructions been faced from other contractors

2) How do the above characteristics affect the productivity of the workers?

3) How can you as a project manager influence the productivity rates of the construction workers?

Appendix B: Daily Productivity Rates Data

Monitoring Daily Productivity Rates of the tunnel steel works at Project # 1

Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates	Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates
1	2020	52722	26.10	38	2200	57200	26.00
2	2060	53766	26.10	39	2100	63336	30.16
3	2100	54810	26.10	40	2020	52742	26.11
4	2040	52836	25.90	41	2060	56815	27.58
5	2060	54178	26.30	42	2100	54642	26.02
6	2000	51200	25.60	43	2040	53285	26.12
7	1960	51646	26.35	44	2060	53890	26.16
8	1980	50688	25.60	45	2000	52680	26.34
9	2200	63646	28.93	46	1960	51705	26.38
10	2100	55440	26.40	47	2020	52641	26.06
11	2120	61332	28.93	48	2060	53951	26.19
12	2120	55396	26.13	49	2100	55272	26.32
13	2100	54999	26.19	50	2040	54080	26.51
14	2040	53448	26.20	51	2060	54487	26.45
15	2060	58092	28.20	52	2000	53120	26.56
16	2000	52380	26.19	53	1960	50117	25.57
17	1960	51548	26.30	54	2040	55162	27.04
18	1980	51856	26.19	55	2020	51874	25.68
19	2100	59157	28.17	56	2060	55229	26.81
20	2040	53326	26.14	57	2100	55545	26.45
21	2060	53951	26.19	58	2040	56508	27.70
22	2000	52280	26.14	59	2060	54054	26.24
23	1960	55233	28.18	60	2000	52680	26.34
24	1980	51757	26.14	61	1960	52097	26.58
25	2060	54796	26.60	62	1980	53460	27.00
26	2100	58191	27.71	63	2200	65670	29.85
27	2040	51898	25.44	64	2100	56301	26.81
28	2060	54260	26.34	65	2120	57706	27.22
29	2000	56420	28.21	66	2120	55629	26.24
30	1960	50078	25.55	67	2100	57393	27.33
31	2060	54075	26.25	68	2040	57344	28.11
32	2100	58317	27.77	69	2060	57103	27.72
33	2040	52102	25.54	70	2000	55300	27.65
34	2060	54549	26.48	71	1960	56428	28.79
35	2000	55640	27.82	72	1980	56074	28.32
36	1960	52626	26.85	73	2200	60148	27.34
37	1980	52668	26.60	74	2100	55860	26.60

Monitoring Daily Productivity Rates of the footing steel works at Project # 1

Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates	Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates
1	730	20593	28.21	38	800	22568	28.21
2	730	20593	28.21	39	800	22160	27.70
3	740	20875	28.21	40	830	21165	25.50
4	750	20400	27.20	41	830	21746	26.20
5	740	20875	28.21	42	830	22991	27.70
6	740	21830	29.50	43	830	22576	27.20
7	740	20875	28.21	44	830	23414	28.21
8	740	21290	28.77	45	870	25839	29.70
9	740	21830	29.50	46	870	25404	29.20
10	730	21535	29.50	47	870	22620	26.00
11	720	20736	28.80	48	870	22185	25.50
12	700	20440	29.20	49	870	23664	27.20
13	700	20160	28.80	50	870	24099	27.70
14	700	19390	27.70	51	870	22794	26.20
15	700	20650	29.50	52	870	24099	27.70
16	690	19665	28.50	53	870	23664	27.20
17	690	19465	28.21	54	870	24543	28.21
18	680	18836	27.70	55	860	25542	29.70
19	680	20060	29.50	56	860	25112	29.20
20	680	18496	27.20	57	860	22532	26.20
21	680	19856	29.20	58	870	24099	27.70
22	740	21608	29.20	59	870	24543	28.21
23	740	20875	28.21	60	840	24192	28.80
24	740	21253	28.72	61	870	24543	28.21
25	790	22286	28.21	62	860	22876	26.60
26	830	24485	29.50	63	850	25075	29.50
27	830	23414	28.21	64	880	23056	26.20
28	830	23414	28.21	65	870	23055	26.50
29	830	23414	28.21	66	870	24543	28.21
30	820	23591	28.77	67	860	24261	28.21
31	820	24190	29.50	68	850	25075	29.50
32	830	24485	29.50	69	860	25370	29.50
33	820	24518	29.90	70	870	25404	29.20
34	800	22080	27.60	71	860	25370	29.50
35	800	21760	27.20	72	860	24261	28.21
36	810	21060	26.00	73	860	24768	28.80
37	810	22850	28.21	74	860	24510	28.50

Monitoring Daily Productivity Rates of footing formworks at project # 1

Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates	Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates
1	400	360	0.90	38	780	906	1.16
2	410	360	0.88	39	770	906	1.18
3	410	360	0.88	40	770	906	1.18
4	420	360	0.86	41	800	906	1.13
5	420	360	0.86	42	800	906	1.13
6	420	360	0.86	43	800	906	1.13
7	420	360	0.86	44	800	906	1.13
8	420	360	0.86	45	810	906	1.12
9	420	360	0.86	46	810	906	1.12
10	420	360	0.86	47	810	906	1.12
11	400	360	0.90	48	810	906	1.12
12	400	360	0.90	49	850	906	1.07
13	820	726	0.89	50	850	906	1.07
14	890	726	0.82	51	850	906	1.07
15	900	726	0.81	52	840	906	1.08
16	900	726	0.81	53	840	906	1.08
17	900	726	0.81	54	830	906	1.09
18	890	726	0.82	55	840	906	1.08
19	880	726	0.83	56	880	906	1.03
20	900	726	0.81	57	880	906	1.03
21	890	726	0.82	58	890	906	1.02
22	880	726	0.83	59	880	906	1.03
23	860	726	0.84	60	890	906	1.02
24	870	726	0.83	61	900	906	1.01
25	800	726	0.91	62	900	906	1.01
26	820	726	0.89	63	900	906	1.01
27	820	726	0.89	64	900	906	1.01
28	820	726	0.89	65	890	906	1.02
29	800	726	0.91	66	880	906	1.03
30	800	726	0.91	67	880	906	1.03
31	800	726	0.91	68	890	906	1.02
32	800	726	0.91	69	890	906	1.02
33	800	726	0.91	70	880	906	1.03
34	790	906	1.15	71	880	906	1.03
35	790	906	1.15	72	890	906	1.02
36	780	906	1.16	73	890	906	1.02
37	770	906	1.18	74	900	906	1.01

Monitoring Daily Productivity Rates of parapet formwork at project # 1

Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates	Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates
1	900	1008	1.12	38	880	862	0.98
2	920	745	0.81	39	860	783	0.91
3	910	1019	1.12	40	900	1035	1.15
4	880	713	0.81	41	900	774	0.86
5	860	740	0.86	42	900	882	0.98
6	900	1008	1.12	43	920	791	0.86
7	900	729	0.81	44	900	1035	1.15
8	900	1008	1.12	45	920	754	0.82
9	920	1030	1.12	46	910	783	0.86
10	900	774	0.86	47	880	1012	1.15
11	920	1030	1.12	48	860	705	0.82
12	910	1019	1.12	49	900	882	0.98
13	880	986	1.12	50	900	945	1.05
14	860	740	0.86	51	920	644	0.70
15	900	774	0.86	52	910	837	0.92
16	900	1008	1.12	53	880	959	1.09
17	900	1008	1.12	54	860	516	0.60
18	920	791	0.86	55	900	981	1.09
19	920	791	0.86	56	900	936	1.04
20	920	791	0.86	57	900	984	1.09
21	860	740	0.86	58	920	952	1.04
22	870	748	0.86	59	920	1012	1.10
23	900	1035	1.15	60	920	773	0.84
24	900	774	0.86	61	860	894	1.04
25	920	1058	1.15	62	870	731	0.84
26	910	956	1.05	63	920	1003	1.09
27	880	862	0.98	64	910	946	1.04
28	860	559	0.65	65	880	915	1.04
29	900	1053	1.17	66	860	937	1.09
30	900	945	1.05	67	900	936	1.04
31	900	1035	1.15	68	900	1035	1.15
32	920	966	1.05	69	900	975	1.08
33	920	1104	1.20	70	920	1058	1.15
34	920	837	0.91	71	920	690	0.75
35	860	843	0.98	72	920	996	1.08
36	870	1044	1.20	73	860	929	1.08
37	910	828	0.91	74	870	940	1.08

Monitoring Daily Productivity Rates of block work at project # 1

Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates	Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates
1	240	3135	13.06	38	281	3345	11.91
2	240	3116	12.98	39	281	3293	11.73
3	230	3116	13.55	40	292	3365	11.54
4	240	3126	13.02	41	281	3365	11.98
5	220	3097	14.08	42	238	3386	14.25
6	260	3050	11.73	43	281	3365	11.98
7	240	3116	12.98	44	281	3365	11.98
8	240	3116	12.98	45	281	3376	12.02
9	230	3135	13.63	46	292	3345	11.47
10	240	3116	12.98	47	281	3293	11.73
11	220	3116	14.16	48	281	3365	11.98
12	260	3126	12.02	49	292	3365	11.54
13	260	3097	11.91	50	281	3386	12.06
14	260	3050	11.73	51	280	3657	13.06
15	270	3116	11.54	52	192	2508	13.06
16	260	3116	11.98	53	192	2493	12.98
17	220	3135	14.25	54	184	2493	13.55
18	260	3116	11.98	55	192	2500	13.02
19	260	3116	11.98	56	176	2478	14.08
20	260	3126	12.02	57	208	2440	11.73
21	270	3097	11.47	58	192	2493	12.98
22	260	3050	11.73	59	192	2493	12.98
23	260	3116	11.98	60	184	2508	13.63
24	270	3116	11.54	61	192	2493	12.98
25	260	3135	12.06	62	176	2493	14.16
26	259	3386	13.06	63	208	2500	12.02
27	259	3365	12.98	64	208	2478	11.91
28	248	3365	13.55	65	208	2440	11.73
29	259	3376	13.02	66	216	2493	11.54
30	238	3345	14.08	67	208	2493	11.98
31	281	3293	11.73	68	176	2508	14.25
32	259	3365	12.98	69	208	2493	11.98
33	259	3365	12.98	70	208	2493	11.98
34	248	3386	13.63	71	208	2500	12.02
35	259	3365	12.98	72	216	2478	11.47
36	238	3365	14.16	73	208	2440	11.73
37	281	3376	12.02	74	208	2493	11.98

Monitoring Daily Productivity Rates of the tunnel steel works at Project # 2

Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates	Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates
1	500	11740	23.48	38	1440	37756	26.22
2	500	11740	23.48	39	1450	37756	26.04
3	500	11740	23.48	40	1460	37756	25.86
4	490	11740	23.96	41	1400	37756	26.97
5	490	11740	23.96	42	1400	37756	26.97
6	480	11740	24.46	43	1400	37756	26.97
7	500	11740	23.48	44	1400	37756	26.97
8	480	11740	24.46	45	1390	37756	27.16
9	490	11740	23.96	46	1390	37756	27.16
10	1200	28528	23.77	47	1380	37756	27.36
11	1200	28528	23.77	48	1390	37756	27.16
12	1200	28528	23.77	49	1390	37756	27.16
13	1200	28528	23.77	50	1100	28528	25.93
14	1190	28528	23.97	51	1100	28528	25.93
15	1190	28528	23.97	52	1100	28528	25.93
16	1180	28528	24.18	53	1090	28528	26.17
17	1190	28528	23.97	54	1090	28528	26.17
18	1180	28528	24.18	55	1080	28528	26.41
19	1170	28528	24.38	56	1090	28528	26.17
20	1180	28528	24.18	57	1080	28528	26.41
21	1550	37756	24.36	58	1090	28528	26.17
22	1560	37756	24.20	59	1080	28528	26.41
23	1600	37756	23.60	60	1090	28528	26.17
24	1600	37756	23.60	61	1100	28528	25.93
25	1590	37756	23.75	62	1100	28528	25.93
26	1600	37756	23.60	63	1100	28528	25.93
27	1590	37756	23.75	64	1070	28528	26.66
28	1580	37756	23.90	65	1060	28528	26.91
29	1630	37756	23.16	66	1080	28528	26.41
30	1540	37756	24.52	67	1060	28528	26.91
31	1540	37756	24.52	68	1060	28528	26.91
32	1530	37756	24.68	69	1060	28528	26.91
33	1500	37756	25.17	70	1050	28528	27.17
34	1500	37756	25.17	71	1060	28528	26.91
35	1490	37756	25.34	72	1050	28528	27.17
36	1440	37756	26.22	73	1050	28528	27.17
37	1440	37756	26.22	74	1050	28528	27.17

Monitoring Daily Productivity Rates of the footing steel works at Project # 2

Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates	Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates
1	440	12356	28.08	38	790	24565	31.09
2	440	13526	30.74	39	760	23538	30.97
3	430	12356	28.73	40	760	22356	29.42
4	800	23538	29.42	41	770	28598	37.14
5	780	23538	30.18	42	790	23538	29.79
6	790	24565	31.09	43	800	24565	30.71
7	800	24565	30.71	44	760	24565	32.32
8	790	23538	29.79	45	760	23538	30.97
9	780	24565	31.49	46	770	24565	31.90
10	770	23538	30.57	47	790	23538	29.79
11	800	22356	27.95	48	800	23538	29.42
12	760	23538	30.97	49	750	24565	32.75
13	800	23538	29.42	50	740	24565	33.20
14	780	24565	31.49	51	750	23538	31.38
15	790	24565	31.09	52	750	24565	32.75
16	760	23538	30.97	53	770	23538	30.57
17	760	24565	32.32	54	800	22356	27.95
18	770	23538	30.57	55	760	28598	37.63
19	800	22356	27.95	56	800	23538	29.42
20	760	28598	37.63	57	780	24565	31.49
21	800	23538	29.42	58	790	24565	31.09
22	780	24565	31.49	59	760	23538	30.97
23	790	24565	31.09	60	760	23538	30.97
24	760	23538	30.97	61	770	24565	31.90
25	760	23538	30.97	62	790	24565	31.09
26	770	24565	31.90	63	800	23538	29.42
27	790	23538	29.79	64	780	24565	31.49
28	800	23538	29.42	65	790	23538	29.79
29	760	24565	32.32	66	760	22356	29.42
30	800	24565	30.71	67	760	23538	30.97
31	780	23538	30.18	68	770	24565	31.90
32	790	24565	31.09	69	790	24565	31.09
33	770	23538	30.57	70	800	23538	29.42
34	800	23538	29.42	71	760	23538	30.97
35	760	24565	32.32	72	770	24565	31.90
36	800	24565	30.71	73	790	24565	31.09
37	780	23538	30.18	74	750	23538	31.38

Monitoring Daily Productivity Rates of footing formworks at project # 2

Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates	Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates
1	270	188	0.70	38	520	379	0.73
2	270	195	0.72	39	520	355	0.68
3	270	188	0.70	40	520	326	0.63
4	550	355	0.65	41	520	387	0.74
5	550	355	0.65	42	510	355	0.70
6	540	379	0.70	43	510	379	0.74
7	550	379	0.69	44	530	379	0.72
8	530	355	0.67	45	510	355	0.70
9	530	379	0.72	46	520	379	0.73
10	530	355	0.67	47	510	355	0.70
11	530	326	0.62	48	520	355	0.68
12	530	355	0.67	49	520	379	0.73
13	530	355	0.67	50	500	379	0.76
14	530	379	0.72	51	520	379	0.73
15	530	379	0.72	52	500	379	0.76
16	530	355	0.67	53	500	355	0.71
17	520	379	0.73	54	500	355	0.71
18	520	355	0.68	55	500	387	0.77
19	500	326	0.65	56	530	355	0.67
20	530	387	0.73	57	520	379	0.73
21	520	355	0.68	58	530	379	0.72
22	520	379	0.73	59	530	355	0.67
23	530	379	0.72	60	530	355	0.67
24	510	355	0.70	61	530	379	0.72
25	500	355	0.71	62	530	379	0.72
26	500	379	0.76	63	520	355	0.68
27	520	355	0.68	64	520	379	0.73
28	520	355	0.68	65	510	355	0.70
29	520	379	0.73	66	510	326	0.64
30	520	379	0.73	67	520	355	0.68
31	520	355	0.68	68	520	379	0.73
32	520	379	0.73	69	530	379	0.72
33	510	355	0.70	70	510	355	0.70
34	510	355	0.70	71	500	355	0.71
35	510	379	0.74	72	500	379	0.76
36	530	379	0.72	73	500	379	0.76
37	520	355	0.68	74	500	355	0.71

Monitoring Daily Productivity Rates of parapet formwork at project # 2

Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates	Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates
1	390	288	0.74	38	770	567	0.74
2	390	288	0.74	39	750	567	0.76
3	390	288	0.74	40	720	567	0.79
4	380	288	0.76	41	720	567	0.79
5	380	288	0.76	42	720	567	0.79
6	370	288	0.78	43	720	567	0.79
7	380	288	0.76	44	710	567	0.80
8	390	288	0.74	45	700	567	0.81
9	390	288	0.74	46	720	567	0.79
10	780	567	0.73	47	690	567	0.82
11	780	567	0.73	48	690	567	0.82
12	780	567	0.73	49	690	567	0.82
13	770	567	0.74	50	680	567	0.83
14	780	567	0.73	51	680	567	0.83
15	780	567	0.73	52	660	567	0.86
16	770	567	0.74	53	660	567	0.86
17	790	567	0.72	54	670	567	0.85
18	790	567	0.72	55	670	567	0.85
19	790	567	0.72	56	660	567	0.86
20	790	567	0.72	57	660	567	0.86
21	800	567	0.71	58	660	567	0.86
22	800	567	0.71	59	680	567	0.83
23	800	567	0.71	60	670	567	0.85
24	780	567	0.73	61	660	567	0.86
25	780	567	0.73	62	650	567	0.87
26	780	567	0.73	63	1130	876	0.78
27	770	567	0.74	64	1130	876	0.78
28	790	567	0.72	65	1110	876	0.79
29	770	567	0.74	66	1130	876	0.78
30	800	567	0.71	67	1120	876	0.78
31	760	567	0.75	68	1110	876	0.79
32	780	567	0.73	69	1080	876	0.81
33	800	567	0.71	70	1090	876	0.80
34	790	567	0.72	71	1080	876	0.81
35	790	567	0.72	72	1050	876	0.83
36	800	567	0.71	73	1010	876	0.87
37	760	567	0.75	74	1030	876	0.85

Monitoring Daily Productivity Rates of block work at project # 2

Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates	Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates
1	1200	12989	10.82	38	1190	12985	10.91
2	1220	12985	10.64	39	1150	12955	11.27
3	1200	12955	10.80	40	1160	12977	11.19
4	1050	12977	12.36	41	1220	12900	10.57
5	1200	12900	10.75	42	1100	12888	11.72
6	1220	12888	10.56	43	1200	12978	10.82
7	1210	12978	10.73	44	1200	12956	10.80
8	1060	12956	12.22	45	1200	12856	10.71
9	1180	12856	10.89	46	1220	13065	10.71
10	1220	13065	10.71	47	1200	13111	10.93
11	1200	13111	10.93	48	1200	13555	11.30
12	1050	13555	12.91	49	1200	12977	10.81
13	1200	12985	10.82	50	1220	12900	10.57
14	1220	12955	10.62	51	1210	12888	10.65
15	1210	12977	10.72	52	1200	12978	10.82
16	1200	12900	10.75	53	1190	12956	10.89
17	1190	12888	10.83	54	1190	12856	10.80
18	1250	12978	10.38	55	1150	13065	11.36
19	1100	12956	11.78	56	1160	13111	11.30
20	1160	12856	11.08	57	1190	13555	11.39
21	1220	13065	10.71	58	1150	12900	11.22
22	1210	13111	10.84	59	1160	12888	11.11
23	1200	13555	11.30	60	1200	12978	10.82
24	1190	12977	10.91	61	1220	12985	10.64
25	1190	12900	10.84	62	1050	12955	12.34
26	1150	12888	11.21	63	1200	12977	10.81
27	1160	12978	11.19	64	1200	12900	10.75
28	1100	12956	11.78	65	1220	12888	10.56
29	1200	12856	10.71	66	1210	12978	10.73
30	1220	13065	10.71	67	1200	12956	10.80
31	1200	13111	10.93	68	1190	12856	10.80
32	1050	13555	12.91	69	1190	13065	10.98
33	1200	12977	10.81	70	1150	13111	11.40
34	1220	12900	10.57	71	1160	13555	11.69
35	1210	12888	10.65	72	1190	12978	10.91
36	1200	12978	10.82	73	1190	12956	10.89
37	1190	12956	10.89	74	1150	12856	11.18

Monitoring Daily Productivity Rates of the tunnel steel works at Project # 3

Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates	Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates
1	90	2858	31.76	38	290	7950	27.41
2	80	2858	35.73	39	280	7950	28.39
3	100	2858	28.58	40	290	7950	27.41
4	100	2858	28.58	41	1050	32736	31.18
5	100	2858	28.58	42	1050	32736	31.18
6	100	2858	28.58	43	1060	32736	30.88
7	100	2858	28.58	44	1060	32736	30.88
8	100	2858	28.58	45	1070	32736	30.59
9	100	2858	28.58	46	1080	32736	30.31
10	100	2858	28.58	47	1060	32736	30.88
11	90	2858	31.76	48	1050	32736	31.18
12	90	2858	31.76	49	1060	32736	30.88
13	80	2858	35.73	50	1040	32736	31.48
14	90	2858	31.76	51	1060	32736	30.88
15	90	2858	31.76	52	1060	32736	30.88
16	90	2858	31.76	53	1050	32736	31.18
17	100	2858	28.58	54	1050	32736	31.18
18	80	2858	35.73	55	1060	32736	30.88
19	100	2858	28.58	56	1060	32736	30.88
20	100	2858	28.58	57	1070	32736	30.59
21	290	7950	27.41	58	1080	32736	30.31
22	290	7950	27.41	59	1060	32736	30.88
23	300	7950	26.50	60	1050	32736	31.18
24	280	7950	28.39	61	1060	32736	30.88
25	290	7950	27.41	62	1040	32736	31.48
26	300	7950	26.50	63	1060	32736	30.88
27	290	7950	27.41	64	1050	32736	31.18
28	300	7950	26.50	65	1050	32736	31.18
29	280	7950	28.39	66	1060	32736	30.88
30	290	7950	27.41	67	1060	32736	30.88
31	290	7950	27.41	68	1070	32736	30.59
32	290	7950	27.41	69	1080	32736	30.31
33	290	7950	27.41	70	1060	32736	30.88
34	290	7950	27.41	71	1050	32736	31.18
35	300	7950	26.50	72	1060	32736	30.88
36	300	7950	26.50	73	1040	32736	31.48
37	300	7950	26.50	74	1060	32736	30.88

Monitoring Daily Productivity Rates of the footing steel works at Project # 3

Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates	Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates
1	100	2077	20.77	38	120	3635	30.29
2	90	2077	23.08	39	110	3635	33.05
3	90	2077	23.08	40	130	3635	27.96
4	90	2077	23.08	41	140	3635	25.96
5	100	2077	20.77	42	140	3635	25.96
6	80	2077	25.96	43	130	3635	27.96
7	90	2077	23.08	44	130	3635	27.96
8	100	2077	20.77	45	120	3635	30.29
9	90	2077	23.08	46	120	3635	30.29
10	90	2077	23.08	47	130	3635	27.96
11	90	2077	23.08	48	140	3635	25.96
12	100	2077	20.77	49	120	3635	30.29
13	80	2077	25.96	50	140	3635	25.96
14	90	2077	23.08	51	140	3115	22.25
15	100	2077	20.77	52	140	3115	22.25
16	90	2077	23.08	53	130	3115	23.96
17	90	2077	23.08	54	130	3115	23.96
18	100	2077	20.77	55	120	3115	25.96
19	80	2077	25.96	56	120	3115	25.96
20	100	2077	20.77	57	130	3115	23.96
21	90	2077	23.08	58	140	3115	22.25
22	90	2077	23.08	59	120	3115	25.96
23	90	2077	23.08	60	140	3115	22.25
24	100	2077	20.77	61	140	3115	22.25
25	80	2077	25.96	62	130	3115	23.96
26	90	2077	23.08	63	130	3115	23.96
27	140	3635	25.96	64	120	3115	25.96
28	140	3635	25.96	65	120	3115	25.96
29	130	3635	27.96	66	130	3115	23.96
30	130	3635	27.96	67	140	3115	22.25
31	120	3635	30.29	68	120	3115	25.96
32	120	3635	30.29	69	140	3115	22.25
33	130	3635	27.96	70	120	3115	25.96
34	140	3635	25.96	71	120	3115	25.96
35	120	3635	30.29	72	130	3115	23.96
36	140	3635	25.96	73	140	3115	22.25
37	120	3635	30.29	74	120	3115	25.96

Monitoring Daily Productivity Rates of footing formworks at project # 3

Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates	Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates
1	250	141	0.56	38	370	252	0.68
2	250	141	0.56	39	370	252	0.68
3	230	141	0.61	40	350	252	0.72
4	250	141	0.56	41	330	252	0.76
5	220	141	0.64	42	380	252	0.66
6	240	141	0.59	43	320	213	0.67
7	250	141	0.56	44	360	213	0.59
8	250	141	0.56	45	360	213	0.59
9	230	141	0.61	46	370	213	0.58
10	250	141	0.56	47	350	213	0.61
11	220	141	0.64	48	330	213	0.65
12	240	141	0.59	49	380	213	0.56
13	250	141	0.56	50	320	213	0.67
14	250	141	0.56	51	360	213	0.59
15	230	141	0.61	52	360	213	0.59
16	250	141	0.56	53	380	213	0.56
17	250	141	0.56	54	380	213	0.56
18	250	141	0.56	55	370	213	0.58
19	230	141	0.61	56	380	213	0.56
20	250	141	0.56	57	370	213	0.58
21	220	141	0.64	58	370	213	0.58
22	240	141	0.59	59	370	213	0.58
23	250	141	0.56	60	350	213	0.61
24	250	141	0.56	61	330	213	0.65
25	230	141	0.61	62	380	213	0.56
26	250	141	0.56	63	320	213	0.67
27	380	252	0.66	64	360	213	0.59
28	380	252	0.66	65	360	213	0.59
29	380	252	0.66	66	370	213	0.58
30	370	252	0.68	67	370	213	0.58
31	380	252	0.66	68	370	213	0.58
32	370	252	0.68	69	350	213	0.61
33	370	252	0.68	70	330	213	0.65
34	380	252	0.66	71	380	213	0.56
35	370	252	0.68	72	320	213	0.67
36	380	252	0.66	73	360	213	0.59
37	370	252	0.68	74	360	213	0.59

Monitoring Daily Productivity Rates of parapet formwork at project # 3

Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates	Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates
1	140	96	0.69	38	720	510	0.71
2	150	96	0.64	39	780	510	0.65
3	160	96	0.60	40	840	510	0.61
4	160	96	0.60	41	660	510	0.77
5	120	96	0.80	42	650	510	0.78
6	130	96	0.74	43	600	510	0.85
7	140	96	0.69	44	600	510	0.85
8	140	96	0.69	45	660	510	0.77
9	150	96	0.64	46	720	510	0.71
10	110	96	0.87	47	780	510	0.65
11	160	96	0.60	48	840	510	0.61
12	120	96	0.80	49	840	510	0.61
13	130	96	0.74	50	600	510	0.85
14	140	96	0.69	51	660	510	0.77
15	140	96	0.69	52	720	510	0.71
16	120	96	0.80	53	780	510	0.65
17	110	96	0.87	54	600	510	0.85
18	130	96	0.74	55	840	510	0.61
19	120	96	0.80	56	600	510	0.85
20	130	96	0.74	57	660	510	0.77
21	650	510	0.78	58	720	510	0.71
22	600	510	0.85	59	780	510	0.65
23	600	510	0.85	60	660	510	0.77
24	660	510	0.77	61	840	510	0.61
25	720	510	0.71	62	600	510	0.85
26	780	510	0.65	63	660	510	0.77
27	840	510	0.61	64	720	510	0.71
28	840	510	0.61	65	700	510	0.73
29	600	510	0.85	66	840	510	0.61
30	660	510	0.77	67	700	510	0.73
31	660	510	0.77	68	660	510	0.77
32	760	510	0.67	69	720	510	0.71
33	790	510	0.65	70	650	510	0.78
34	650	510	0.78	71	600	510	0.85
35	600	510	0.85	72	660	510	0.77
36	600	510	0.85	73	660	510	0.77
37	660	510	0.77	74	720	510	0.71

Monitoring Daily Productivity Rates of block work at project # 3

Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates	Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates
1	630	7993	12.69	38	650	7993	12.30
2	640	7993	12.49	39	650	7993	12.30
3	650	7993	12.30	40	640	7993	12.49
4	650	7993	12.30	41	630	7993	12.69
5	650	7993	12.30	42	650	7993	12.30
6	650	7993	12.30	43	640	7993	12.49
7	650	7993	12.30	44	640	7993	12.49
8	650	7993	12.30	45	610	7993	13.10
9	650	7993	12.30	46	650	7993	12.30
10	640	7993	12.49	47	610	7993	13.10
11	630	7993	12.69	48	620	7993	12.89
12	650	7993	12.30	49	620	7993	12.89
13	640	7993	12.49	50	640	7993	12.49
14	640	7993	12.49	51	630	7993	12.69
15	610	7993	13.10	52	650	7993	12.30
16	650	7993	12.30	53	640	7993	12.49
17	610	7993	13.10	54	640	7993	12.49
18	620	7993	12.89	55	610	7993	13.10
19	620	7993	12.89	56	650	7993	12.30
20	650	7993	12.30	57	610	7993	13.10
21	650	7993	12.30	58	620	7993	12.89
22	640	7993	12.49	59	620	7993	12.89
23	630	7993	12.69	60	640	7993	12.49
24	650	7993	12.30	61	650	7993	12.30
25	640	7993	12.49	62	650	7993	12.30
26	640	7993	12.49	63	640	7993	12.49
27	610	7993	13.10	64	630	7993	12.69
28	650	7993	12.30	65	650	7993	12.30
29	610	7993	13.10	66	640	7993	12.49
30	620	7993	12.89	67	640	7993	12.49
31	620	7993	12.89	68	610	7993	13.10
32	640	7993	12.49	69	650	7993	12.30
33	630	7993	12.69	70	610	7993	13.10
34	650	7993	12.30	71	620	7993	12.89
35	640	7993	12.49	72	620	7993	12.89
36	640	7993	12.49	73	640	7993	12.49
37	610	7993	13.10	74	640	7993	12.49

Monitoring Daily Productivity Rates of the tunnel steel works at Project # 4

Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates	Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates
1	1580	24665	15.61	38	780	17505	22.44
2	1570	24665	15.71	39	810	17505	21.61
3	1580	24665	15.61	40	810	17505	21.61
4	1550	24665	15.91	41	770	17505	22.73
5	1580	24665	15.61	42	800	17505	21.88
6	1510	24665	16.33	43	820	17505	21.35
7	1630	24642	15.12	44	820	17505	21.35
8	1530	24642	16.11	45	810	17505	21.61
9	1630	24642	15.12	46	810	17505	21.61
10	1490	24642	16.54	47	810	17505	21.61
11	1500	26666	17.78	48	810	18576	22.93
12	1520	26666	17.54	49	810	18576	22.93
13	1100	22567	20.52	50	800	18576	23.22
14	1030	22567	21.91	51	1360	32104	23.61
15	1120	22567	20.15	52	1350	32104	23.78
16	1030	22567	21.91	53	1360	32104	23.61
17	1080	22567	20.90	54	1340	32104	23.96
18	1030	22567	21.91	55	1330	32104	24.14
19	660	14137	21.42	56	1320	32104	24.32
20	660	14137	21.42	57	1360	32104	23.61
21	660	14137	21.42	58	1350	32104	23.78
22	660	14137	21.42	59	1360	32104	23.61
23	660	14137	21.42	60	1340	32104	23.96
24	660	14137	21.42	61	1330	32104	24.14
25	820	19746	24.08	62	1320	32104	24.32
26	810	19746	24.38	63	1330	32104	24.14
27	820	19746	24.08	64	1350	32104	23.78
28	820	19746	24.08	65	1360	32104	23.61
29	810	19746	24.38	66	1340	32104	23.96
30	810	19746	24.38	67	1330	32104	24.14
31	810	18576	22.93	68	1360	32104	23.61
32	810	18576	22.93	69	1350	32104	23.78
33	800	18576	23.22	70	1360	32104	23.61
34	820	18576	22.65	71	1340	32104	23.96
35	810	18576	22.93	72	1330	32104	24.14
36	820	18576	22.65	73	1320	32104	24.32
37	820	17505	21.35	74	1330	32104	24.14

Monitoring Daily Productivity Rates of the footing steel works at Project # 4

Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates	Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates
1	220	4565	20.75	38	210	3851	18.34
2	220	4465	20.30	39	200	3851	19.26
3	220	4444	20.20	40	190	3851	20.27
4	220	4444	20.20	41	250	3851	15.40
5	230	4444	19.32	42	200	3851	19.26
6	240	4565	19.02	43	240	3851	16.05
7	210	4345	20.69	44	220	3851	17.51
8	200	4565	22.83	45	230	3851	16.74
9	220	4564	20.75	46	240	3851	16.05
10	220	4354	19.79	47	210	3851	18.34
11	220	4354	19.79	48	200	4087	20.43
12	220	4454	20.25	49	220	4087	18.58
13	230	4965	21.59	50	220	4087	18.58
14	240	4965	20.69	51	360	7063	19.62
15	210	4965	23.64	52	330	7063	21.40
16	200	4656	23.28	53	330	7063	21.40
17	190	4434	23.34	54	320	7063	22.07
18	200	4656	23.28	55	340	7063	20.77
19	160	3110	19.44	56	350	7063	20.18
20	170	3110	18.30	57	360	7063	19.62
21	160	3110	19.44	58	330	7063	21.40
22	140	3110	22.22	59	330	7063	21.40
23	170	3110	18.30	60	320	7063	22.07
24	140	3110	22.22	61	340	7063	20.77
25	240	4344	18.10	62	350	7063	20.18
26	210	4344	20.69	63	360	7063	19.62
27	200	4344	21.72	64	330	7063	21.40
28	190	4344	22.86	65	330	7063	21.40
29	250	4344	17.38	66	320	7063	22.07
30	200	4344	21.72	67	360	7063	19.62
31	240	4087	17.03	68	330	7063	21.40
32	220	4087	18.58	69	330	7063	21.40
33	220	4087	18.58	70	320	7063	22.07
34	220	4087	18.58	71	340	7063	20.77
35	220	4087	18.58	72	350	7063	20.18
36	230	4087	17.77	73	360	7063	19.62
37	240	3851	16.05	74	330	7063	21.40

Monitoring Daily Productivity Rates of footing formworks at project # 4

Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates	Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates
1	120	90	0.75	38	115	83	0.72
2	120	83	0.69	39	110	83	0.75
3	120	77	0.64	40	105	90	0.86
4	120	88	0.73	41	135	90	0.67
5	125	83	0.66	42	110	52	0.47
6	130	67	0.52	43	130	66	0.51
7	115	83	0.72	44	120	52	0.43
8	110	83	0.75	45	125	99	0.79
9	120	83	0.69	46	130	90	0.69
10	120	90	0.75	47	115	83	0.72
11	120	90	0.75	48	110	66	0.60
12	120	88	0.73	49	120	66	0.55
13	125	99	0.79	50	120	83	0.69
14	130	88	0.68	51	130	66	0.51
15	115	99	0.86	52	140	83	0.59
16	110	90	0.82	53	120	83	0.69
17	105	83	0.79	54	130	83	0.64
18	110	99	0.90	55	130	90	0.69
19	90	52	0.58	56	140	90	0.64
20	95	83	0.87	57	130	99	0.76
21	90	52	0.58	58	140	99	0.71
22	110	83	0.75	59	120	99	0.83
23	95	83	0.87	60	130	99	0.76
24	120	83	0.69	61	130	90	0.69
25	130	90	0.69	62	140	83	0.59
26	115	90	0.78	63	120	98	0.82
27	110	72	0.66	64	130	98	0.75
28	105	52	0.50	65	130	83	0.64
29	135	99	0.73	66	140	88	0.63
30	110	99	0.90	67	120	83	0.69
31	130	90	0.69	68	130	83	0.64
32	120	83	0.69	69	120	83	0.69
33	120	52	0.43	70	130	90	0.69
34	120	52	0.43	71	130	90	0.69
35	120	83	0.69	72	130	99	0.76
36	100	52	0.52	73	140	110	0.79
37	130	83	0.64	74	120	99	0.83

Monitoring Daily Productivity Rates of parapet formwork at project # 4

Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates	Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates
1	670	538	0.80	38	690	538	0.78
2	670	538	0.80	39	660	538	0.82
3	670	538	0.80	40	650	538	0.83
4	670	538	0.80	41	500	390	0.78
5	720	538	0.75	42	550	390	0.71
6	710	538	0.76	43	530	390	0.74
7	700	538	0.77	44	530	390	0.74
8	690	538	0.78	45	520	390	0.75
9	690	590	0.86	46	550	390	0.71
10	660	590	0.89	47	500	390	0.78
11	670	590	0.88	48	490	390	0.80
12	670	590	0.88	49	480	390	0.81
13	670	590	0.88	50	440	390	0.89
14	670	590	0.88	51	430	390	0.91
15	720	489	0.68	52	450	390	0.87
16	710	489	0.69	53	520	390	0.75
17	700	489	0.70	54	440	390	0.89
18	690	489	0.71	55	440	390	0.89
19	690	489	0.71	56	500	390	0.78
20	660	590	0.89	57	550	390	0.71
21	650	590	0.91	58	530	390	0.74
22	720	590	0.82	59	530	390	0.74
23	660	590	0.89	60	520	390	0.75
24	670	590	0.88	61	550	390	0.71
25	670	590	0.88	62	500	390	0.78
26	670	489	0.73	63	490	390	0.80
27	720	489	0.68	64	480	390	0.81
28	710	489	0.69	65	440	390	0.89
29	700	538	0.77	66	430	390	0.91
30	670	538	0.80	67	450	390	0.87
31	670	538	0.80	68	520	390	0.75
32	670	538	0.80	69	490	390	0.80
33	670	538	0.80	70	480	390	0.81
34	720	538	0.75	71	440	390	0.89
35	710	538	0.76	72	430	390	0.91
36	700	538	0.77	73	450	390	0.87
37	690	538	0.78	74	520	390	0.75

Monitoring Daily Productivity Rates of block work at project # 4

Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates	Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates
1	370	4846	13.10	38	370	4993	13.49
2	330	4846	14.68	39	330	4846	14.68
3	380	4410	11.61	40	380	4846	12.75
4	300	4993	16.64	41	300	4993	16.64
5	380	4846	12.75	42	380	4846	12.75
6	370	4846	13.10	43	370	4846	13.10
7	320	4993	15.60	44	320	4410	13.78
8	300	4846	16.15	45	300	4993	16.64
9	300	4846	16.15	46	300	4846	16.15
10	300	4846	16.15	47	380	4846	12.75
11	370	4410	11.92	48	370	4993	13.49
12	330	4993	15.13	49	320	4846	15.14
13	380	4846	12.75	50	300	4993	16.64
14	300	4846	16.15	51	370	4846	13.10
15	380	4993	13.14	52	330	4846	14.68
16	370	4846	13.10	53	380	4993	13.14
17	320	4410	13.78	54	300	4846	16.15
18	300	4993	16.64	55	370	4846	13.10
19	370	4846	13.10	56	330	4846	14.68
20	330	4846	14.68	57	380	4410	11.61
21	380	4993	13.14	58	300	4993	16.64
22	300	4846	16.15	59	380	4846	12.75
23	380	4846	12.75	60	370	4846	13.10
24	370	4846	13.10	61	320	4993	15.60
25	320	4410	13.78	62	300	4846	16.15
26	300	4993	16.64	63	390	4993	12.80
27	300	4846	16.15	64	370	4846	13.10
28	380	4846	12.75	65	330	4846	14.68
29	370	4993	13.49	66	380	4993	13.14
30	320	4846	15.14	67	300	4846	16.15
31	300	4846	16.15	68	380	4846	12.75
32	380	4410	11.61	69	370	4846	13.10
33	300	4993	16.64	70	320	4993	15.60
34	380	4846	12.75	71	300	4846	16.15
35	370	4846	13.10	72	380	4993	13.14
36	320	4846	15.14	73	370	4993	13.49
37	300	4410	14.70	74	320	4993	15.60

Monitoring Daily Productivity Rates of the tunnel steel works at Project # 5

Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates	Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates
1	1450	36092	24.89	38	1420	36092	25.42
2	1450	36092	24.89	39	1400	36092	25.78
3	1440	36092	25.06	40	1400	36092	25.78
4	1450	36092	24.89	41	1450	36092	24.89
5	1430	36092	25.24	42	1450	36092	24.89
6	1400	36092	25.78	43	1440	36092	25.06
7	1400	36092	25.78	44	1450	36092	24.89
8	1420	36092	25.42	45	1430	36092	25.24
9	1430	36092	25.24	46	1400	36092	25.78
10	1400	36092	25.78	47	1400	36092	25.78
11	1400	36092	25.78	48	1420	36092	25.42
12	1420	36092	25.42	49	1400	36092	25.78
13	1400	36092	25.78	50	1440	36092	25.06
14	1400	36092	25.78	51	1430	36092	25.24
15	1450	36092	24.89	52	1450	36092	24.89
16	1450	36092	24.89	53	1450	36092	24.89
17	1440	36092	25.06	54	1440	36092	25.06
18	1450	36092	24.89	55	1450	36092	24.89
19	1440	36092	25.06	56	1430	36092	25.24
20	1450	36092	24.89	57	1400	36092	25.78
21	1430	36092	25.24	58	1400	36092	25.78
22	1400	36092	25.78	59	1420	36092	25.42
23	1400	36092	25.78	60	1450	36092	24.89
24	1420	36092	25.42	61	1400	36092	25.78
25	1430	36092	25.24	62	1450	36092	24.89
26	1400	36092	25.78	63	1450	36092	24.89
27	1400	36092	25.78	64	1450	36092	24.89
28	1420	36092	25.42	65	1440	36092	25.06
29	1400	36092	25.78	66	1450	36092	24.89
30	1400	36092	25.78	67	1430	36092	25.24
31	1450	36092	24.89	68	1400	36092	25.78
32	1450	36092	24.89	69	1400	36092	25.78
33	1440	36092	25.06	70	1420	36092	25.42
34	1450	36092	24.89	71	1400	36092	25.78
35	1430	36092	25.24	72	1400	36092	25.78
36	1400	36092	25.78	73	1400	36092	25.78
37	1400	36092	25.78	74	1400	36092	25.78

Monitoring Daily Productivity Rates of the footing steel works at Project # 5

Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates	Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates
1	280	6605	23.59	38	230	6605	28.72
2	250	6605	26.42	39	230	6605	28.72
3	260	6605	25.40	40	220	6605	30.02
4	280	6605	23.59	41	240	6605	27.52
5	270	6605	24.46	42	230	6605	28.72
6	270	6605	24.46	43	220	6605	30.02
7	260	6605	25.40	44	260	6605	25.40
8	280	6605	23.59	45	220	6605	30.02
9	250	6605	26.42	46	230	6605	28.72
10	260	6605	25.40	47	230	6605	28.72
11	280	6605	23.59	48	230	6605	28.72
12	270	6605	24.46	49	220	6605	30.02
13	270	6605	24.46	50	240	6605	27.52
14	260	6605	25.40	51	230	6605	28.72
15	280	6605	23.59	52	220	6605	30.02
16	250	6605	26.42	53	220	6605	30.02
17	260	6605	25.40	54	260	6605	25.40
18	280	6605	23.59	55	220	6605	30.02
19	270	6605	24.46	56	230	6605	28.72
20	270	6605	24.46	57	230	6605	28.72
21	260	6605	25.40	58	230	6605	28.72
22	280	6605	23.59	59	220	6605	30.02
23	250	6605	26.42	60	240	6605	27.52
24	260	6605	25.40	61	230	6605	28.72
25	280	6605	23.59	62	260	6605	25.40
26	270	6605	24.46	63	220	6605	30.02
27	270	6605	24.46	64	230	6605	28.72
28	260	6605	25.40	65	230	6605	28.72
29	250	6605	26.42	66	230	6605	28.72
30	240	6605	27.52	67	220	6605	30.02
31	240	6605	27.52	68	240	6605	27.52
32	260	6605	25.40	69	230	6605	28.72
33	230	6605	28.72	70	230	6605	28.72
34	230	6605	28.72	71	230	6605	28.72
35	260	6605	25.40	72	230	6605	28.72
36	220	6605	30.02	73	220	6605	30.02
37	230	6605	28.72	74	240	6605	27.52

Monitoring Daily Productivity Rates of footing formworks at project # 5

Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates	Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates
1	243	207	0.85	38	468	417	0.89
2	243	215	0.88	39	468	391	0.83
3	243	207	0.85	40	468	359	0.77
4	495	391	0.79	41	468	426	0.91
5	495	391	0.79	42	459	391	0.85
6	486	417	0.86	43	459	417	0.91
7	495	417	0.84	44	477	417	0.87
8	477	391	0.82	45	459	391	0.85
9	477	417	0.87	46	468	417	0.89
10	477	391	0.82	47	459	391	0.85
11	477	359	0.75	48	468	391	0.83
12	477	391	0.82	49	468	417	0.89
13	477	391	0.82	50	450	417	0.93
14	477	417	0.87	51	468	417	0.89
15	477	417	0.87	52	450	417	0.93
16	477	391	0.82	53	450	391	0.87
17	468	417	0.89	54	450	391	0.87
18	468	391	0.83	55	450	426	0.95
19	450	359	0.80	56	477	391	0.82
20	477	426	0.89	57	468	417	0.89
21	468	391	0.83	58	477	417	0.87
22	468	417	0.89	59	477	391	0.82
23	477	417	0.87	60	477	391	0.82
24	459	391	0.85	61	477	417	0.87
25	450	391	0.87	62	477	417	0.87
26	450	417	0.93	63	468	391	0.83
27	468	391	0.83	64	468	417	0.89
28	468	391	0.83	65	459	391	0.85
29	468	417	0.89	66	459	359	0.78
30	468	417	0.89	67	468	391	0.83
31	468	391	0.83	68	468	417	0.89
32	468	417	0.89	69	477	417	0.87
33	459	391	0.85	70	459	391	0.85
34	459	391	0.85	71	450	391	0.87
35	459	417	0.91	72	450	417	0.93
36	477	417	0.87	73	450	417	0.93
37	468	391	0.83	74	450	391	0.87

Monitoring Daily Productivity Rates of parapet formwork at project # 5

Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates	Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates
1	700	497	0.71	38	550	497	0.90
2	690	497	0.72	39	590	497	0.84
3	700	497	0.71	40	550	497	0.90
4	690	497	0.72	41	580	497	0.86
5	700	497	0.71	42	580	497	0.86
6	700	497	0.71	43	590	497	0.84
7	690	497	0.72	44	550	497	0.90
8	690	497	0.72	45	540	497	0.92
9	680	497	0.73	46	600	497	0.83
10	680	497	0.73	47	550	497	0.90
11	700	497	0.71	48	580	497	0.86
12	660	497	0.75	49	540	497	0.92
13	600	497	0.83	50	550	497	0.90
14	660	497	0.75	51	590	497	0.84
15	650	497	0.76	52	550	497	0.90
16	650	497	0.76	53	580	497	0.86
17	660	497	0.75	54	580	497	0.86
18	670	497	0.74	55	590	497	0.84
19	640	497	0.78	56	550	497	0.90
20	640	497	0.78	57	540	497	0.92
21	640	497	0.78	58	600	497	0.83
22	610	497	0.81	59	550	497	0.90
23	660	497	0.75	60	580	497	0.86
24	620	497	0.80	61	540	497	0.92
25	600	497	0.83	62	550	497	0.90
26	650	497	0.76	63	550	497	0.90
27	620	497	0.80	64	540	497	0.92
28	600	497	0.83	65	590	497	0.84
29	600	497	0.83	66	550	497	0.90
30	630	497	0.79	67	580	497	0.86
31	640	497	0.78	68	580	497	0.86
32	660	497	0.75	69	590	497	0.84
33	620	497	0.80	70	550	497	0.90
34	600	497	0.83	71	540	497	0.92
35	670	497	0.74	72	600	497	0.83
36	600	497	0.83	73	550	497	0.90
37	590	497	0.84	74	580	497	0.86

Monitoring Daily Productivity Rates of block work at project # 5

Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates	Days	Man-hours	Quantity Produced (Kg)	Daily Productivity Rates
1	550	5331	9.69	38	550	5331	9.69
2	550	5331	9.69	39	540	5331	9.87
3	540	5331	9.87	40	530	5331	10.06
4	530	5331	10.06	41	530	5331	10.06
5	530	5331	10.06	42	540	5331	9.87
6	540	5331	9.87	43	530	5331	10.06
7	530	5331	10.06	44	570	5331	9.35
8	570	5331	9.35	45	500	5331	10.66
9	540	5331	9.87	46	480	5331	11.11
10	530	5331	10.06	47	490	5331	10.88
11	530	5331	10.06	48	500	5331	10.66
12	540	5331	9.87	49	470	5331	11.34
13	540	5331	9.87	50	470	5331	11.34
14	530	5331	10.06	51	470	5331	11.34
15	530	5331	10.06	52	450	5331	11.85
16	540	5331	9.87	53	440	5331	12.12
17	550	5331	9.69	54	400	5331	13.33
18	540	5331	9.87	55	410	5331	13.00
19	530	5331	10.06	56	400	5331	13.33
20	530	5331	10.06	57	420	5331	12.69
21	540	5331	9.87	58	400	5331	13.33
22	530	5331	10.06	59	400	5331	13.33
23	570	5331	9.35	60	420	5331	12.69
24	540	5331	9.87	61	390	5331	13.67
25	530	5331	10.06	62	400	5331	13.33
26	530	5331	10.06	63	410	5331	13.00
27	540	5331	9.87	64	400	5331	13.33
28	540	5331	9.87	65	420	5331	12.69
29	530	5331	10.06	66	400	5331	13.33
30	530	5331	10.06	67	400	5331	13.33
31	540	5331	9.87	68	420	5331	12.69
32	530	5331	10.06	69	390	5331	13.67
33	540	5331	9.87	70	400	5331	13.33
34	530	5331	10.06	71	400	5331	13.33
35	530	5331	10.06	72	420	5331	12.69
36	540	5331	9.87	73	390	5331	13.67
37	500	5331	10.66	74	390	5331	13.67

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