Building Productivity Analysis: Tangible & Intangible Factors

Final Year Project UG 2015

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CERTIFICATION

This is to certify that thesis entitled

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DEDICATED

TO

OUR FAMILIES, TEACHERS AND FRIENDS

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ABSTRACT

Construction productivity helps us to judge the performance of a construction project. Construction industry is one of the largest industry in the world. It accounts for 13 % of the world's GDP. Since it holds so much significance, we need to analyze the factors that play a vital role in controlling its productivity.

Construction process is a combination of activities. There are various factors that affect the productivity of different construction activities; some are tangible and other are intangible. The study aims to establish a relationship of productivity of with its tangible and intangible factors. The study was done at the first (basic) level of productivity i.e. activity level. Activities selected were: concreting, rebar installation, brickwork and shuttering. The tangible factors were measured by calculating the direct work being performed at different construction sites and the intangible were measured through direct work, questionnaire and performas. Research was conducted at four different construction projects in the Islamabad region.

Firstly, we carried out the literature review to find out the details and research already done in this field. We went to the construction sites to collect the selected activities data in regard with our factors and recorded it on a data sheet. Once field data collection is complete, we plotted graphs of productivity against its factors to determine their relationship.

CHAPTER 1

INTRODUCTION

1.1 Background

Productivity is the relation between input and output. Input can be of various types i.e. energy, labor, capital, goods, services etc. Output is the product produced after utilizing the inputs. How efficiently the inputs are utilized is known as productivity. Larger the value of productivity, better the utilization of input resources.

The performance of a construction project is the measure of its productivity. To form a product (i.e. facility) you can pay millions or billions, but would that money be justified? Were the resources used, in the production of that product, at their optimum efficient level? The answer to such questions lies in the productivity. Productivity tells us how efficient were we to manage our resources.

A simple & basic example to describe productivity is, let say, you are a site supervisor on a project and you are given a task to build a wall of specific dimensions. You have the authority to place an ‘x’ number of labors to build that wall. Now you have two options: a) you can just build a wall or b) you can build a wall in an efficient manner i.e. using minimum resources & obtaining maximum output. In simply building a wall (of specific dimensions) you place any arbitrary amount of labor and can make at any time (day or night) you want. But, if you want to make it efficient, you’ll place an optimum number of labors; not too less which will consume a lot of time and not too much that it creates congestion. Moreover, you will see that, what time of day is suitable for the execution of that activity. Taking such measures to perform activities is called construction productivity.

1.2 Significance

Economy is divided into two industries: basic industry and non-basic. Mining, construction, manufacturing, transportation etc are considered as basic industries. Non-basic industry

includes small businesses e.g. stores, service companies, consulting companies etc. Economy is heavily dependent on basic industries as compared to non-basic industries. Basic industries generate new employment opportunities, increases foreign exchange earnings of a country, improves the purchasing power of a country & boosting the GDP of the whole economy.
Construction industry is a part of the basic industry, which means that how well does this industry performs creates an epidemic impact on the economy. For financial and economical progression of country, we need a strong and efficient construction industry.

Construction projects these days are very complicated and a project can only be a success if all resources and factors involved are managed properly. Since a country's economy is significantly dependent on its construction industry, therefore we need to make sure that it's performing at its maximal level. This is where productivity plays a significant role. Productivity is the measure of construction performance **(Menon & Varghese, 2018)**
Economic problems can be overcome by improving productivity.

1.3 Problem statement

Construction industry (CI) is focused on completing a project rather than completing it with efficient use of resources. If we compare the productivity of construction industry with manufacturing industry, we will see that the productivity of CI is less than that of manufacturing industry. There was a time, before 1968, when the productivity of CI was more than manufacturing, finance, retail trade & mining industry. As the time passed by, other industries started focusing on their respective productivities for e.g. they improved their productivities using automation techniques efficiently, and eventually surpassed CI in terms of productivity, whereas the CI remained sluggish in productivity growth. **(Allen, 1985)**

CI is more concerned about the outcome rather than the process it goes through to achieve that outcome. Productivity is one of the major problem of the CI. Research tells us that, "70% and

90% of projects exceed the original planned cost and that the overrun commonly varies between 50% and 100% of budget”

Construction process is a combination of activities. There are various factors that affect the productivity of different construction activities. For example, nowadays there is an increasing trend of day and night construction, and what civil engineers don’t realise is that there are certain activities, like concreting, steel sheet piling etc, which are more productive at night and other activities, like pavement cutting, timber piling etc, which are more productive at day **(Nguyen, Nguyen, Tran, & Villiers, 2014)**. Likewise, there are many activities, whose productivity depends upon several other factors. Activity wise judgement of productivity is quite rare in CI. Project managers cannot correlate the construction activities with its factors and this is one of the major reason why the productivity of the CI is so abysmal. CI has developed an axiom (hypothesis) about the construction process over the years and no one objects that axiom. There is unawareness that how some activities can be altered by correlating it certain factors.

1.4 Objectives

- To identify tangible and intangible factors that affect productivity
- To develop and determine strength of correlation between productivity of each activity and its factors
- To analyse the data and conclude each activities’ productivity with respect to its factors

Chapter 2

LITERATURE REVIEW

2.1 Construction productivity

The construction sector is one of the largest in the world economy, with about $10 trillion spent on construction-related goods and services every year. However, the industry's productivity has trailed that of other sectors for decades, and there is a $1.6 trillion opportunity to close the gap. The productivity growth is very slow in the construction industry which is creating a huge economic loss to the world economy. There is a dire need to revolutionize the construction industry. Construction industry accounts for 13 % of the world's GDP but the sector's annual productivity has only increased 1 % over the past 20 years. Whereas, productivity in manufacturing, retail, and agriculture has grown by as much as 1,500 percent.

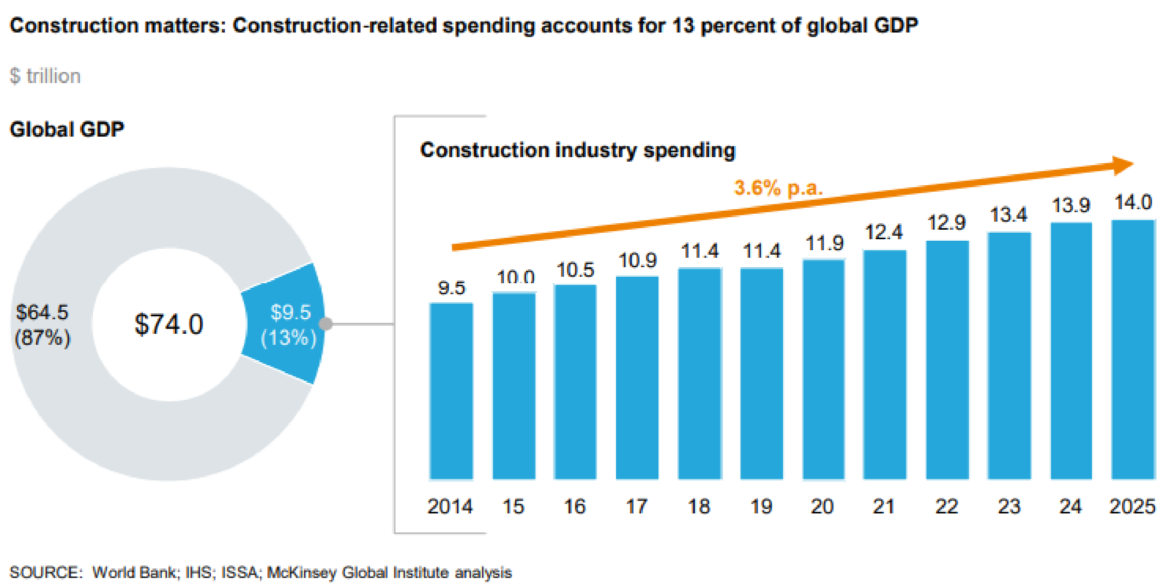


Fig 2.1 Construction industry spending

Construction productivity is far behind that of manufacturing and the total economy

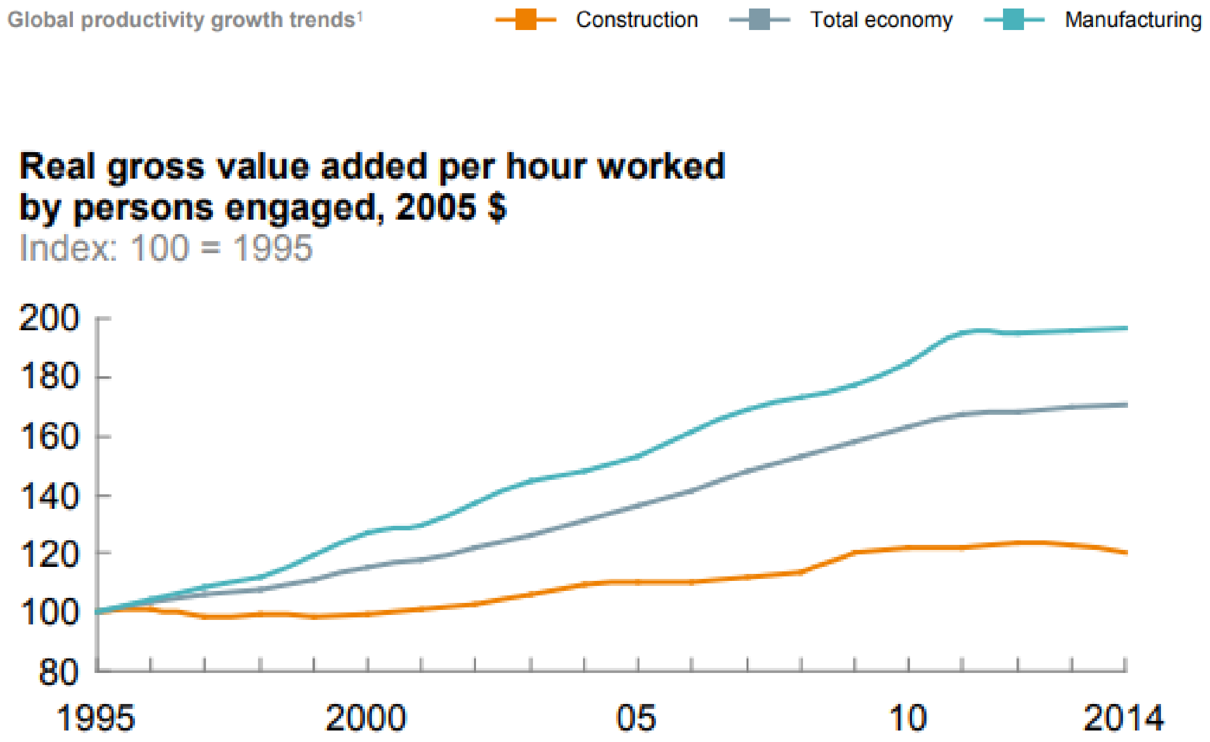


Fig 2.2 global productivity growth trends

On a global scale, each country has its own productivity rate. Construction productivity is a unique phenomenon. It doesn’t matter whether the country is developed or under developed, productivity rate is independent of the stature of a country.

Good productivity rates achieved by some small countries

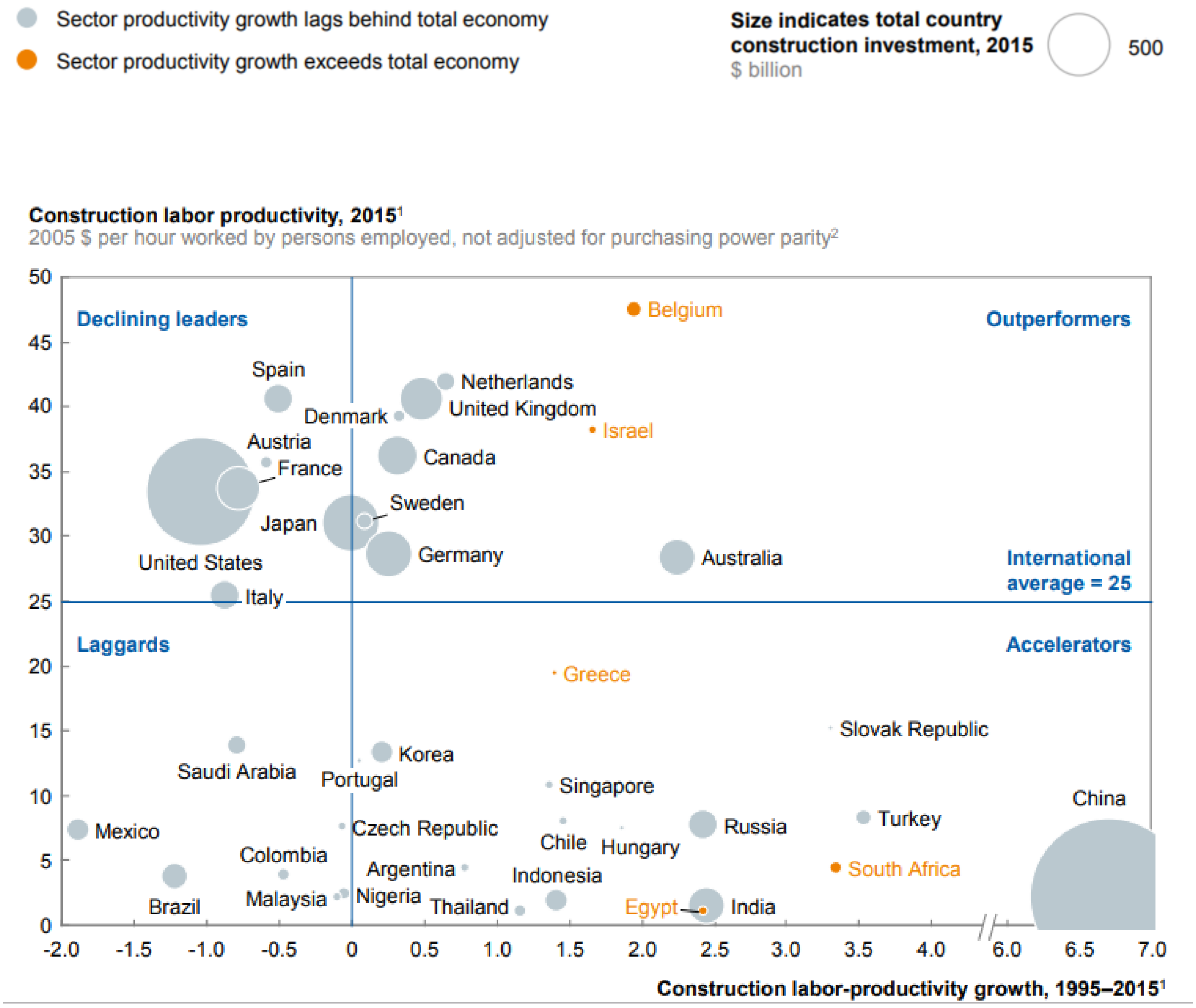


Fig 2.3 construction labor productivity growth 1995 - 2015

If the construction industry improves its productivity, it can surely add 1.6 trillion dollars to the world GDP, which is equivalent to 2% of the global economy.

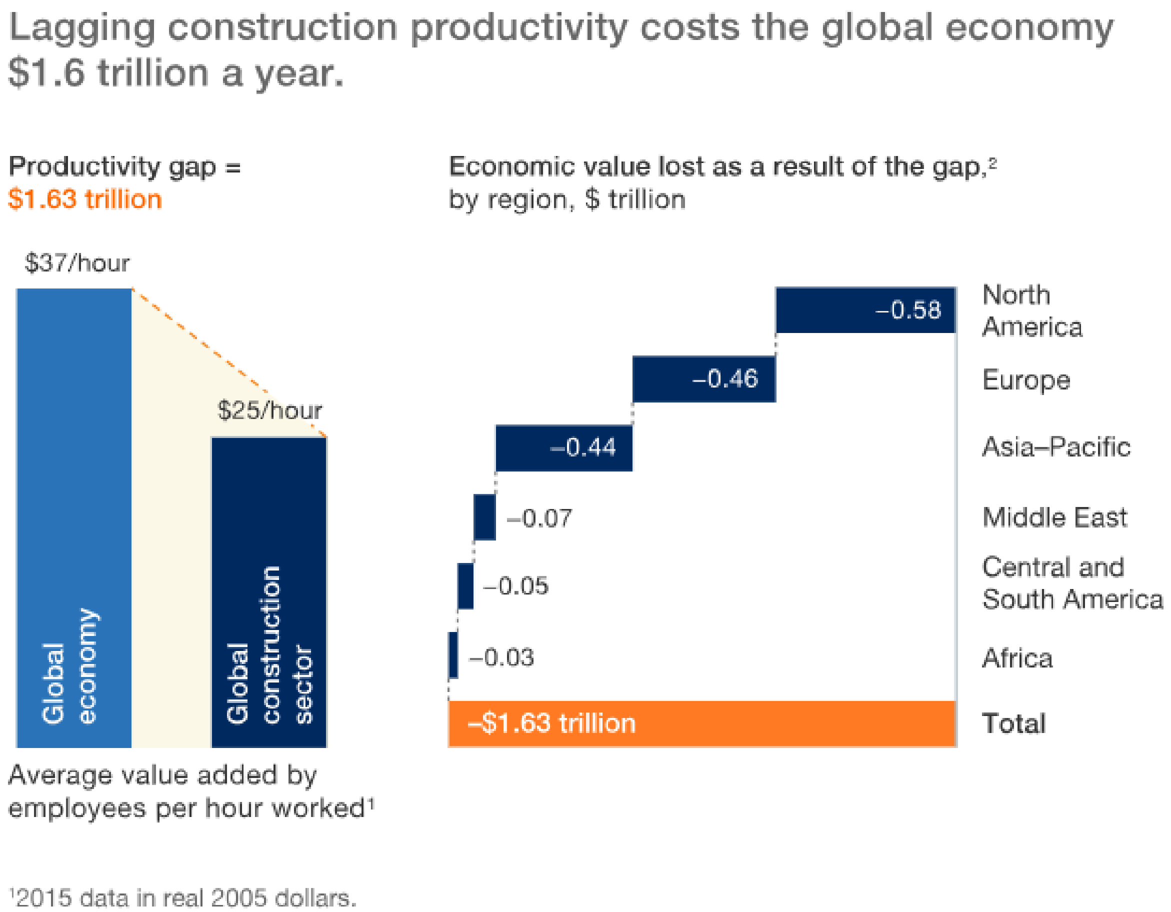


Fig 2.4 Decrease in economic value

2.2 Total factor & Labor productivity

As stated in the introduction, construction productivity is the relation between input and output. This relation is further divided into two categories: total factor productivity (TFP) and partial factor productivity (PFP). **(Robles, Stifi, Ponz-Tienda, & Gentes, 2014)**

Total factor productivity (TFP) is the summation of all the outputs and inputs, where as partial factor productivity (PFP) is one in which output is obtained using selective inputs.

$$TFP = \frac{Total\ Output}{\sum of\ all\ input\ resources}$$

Or

$$TFP = \frac{Total\ Output}{Labor + Materials + Equipment + Energy + Capital}$$

Measurement of all the inputs to determine an output is not feasible, therefore it is impossible to accurately calculate TFP. To counter this, we use, partial factor productivity (PFP), also known as labor productivity.

$$Labor\ Productivity = \frac{Output\ Quantity}{Labor\ hours}$$

2.3 Levels of Productivity:

Construction productivity has been studied from different perspectives. Construction productivity is the amount of work per unit of time that an engineering or project team can comp(Robles et al., 2014)**.** To understand productivity we divide it into 3 segments or levels: activity, project & industry. Studying productivities at activity level help us to judge the performance of a project, studies at the project level aids in the assessment of the industry productivity & studies at the industry level shows the long term productivity trends. **((Pan, Chen, & Zhan, 2018)).**

2.4 Misconception about Productivity:

There is a misinterpretation that productivity is doing more at a very faster pace; to clarify this, there’s a better definition i.e. productivity means "producing better" and not necessarily "producing more". For e.g. To concrete a slab of 150 m^3 by 7 labour takes 5 hours in Project A and in another project (say project B) same volume of slab is concreted in 5 hours by 5 labours. The quantity of work stayed same which tells us that no project produced more quantity of work and the labour at project B was better at completing the work in the same amount of time, while being lesser in number. **(Loughborough, 1996)**

2.5 Green buildings & productivity:

Nowadays, productivity plays an important role in the increasing trend of green buildings in the construction industry. Green building poses a great challenge because its design & construction is more complex than those of conventional buildings, which usually leads to high design and construction costs. So, the contractor receives less profit from green buildings projects which demotivates him to opt such projects. This is where productivity comes into play. Improved productivity helps firm to maximize profits from green constructions. Moreover, long-term profitability and competitiveness can be obtained by the organizations & countries through increasing productivity. Long-term profitability and competitiveness can be obtained by the organizations & countries by increasing productivity.

2.6 Quality management & productivity:

Both quality and productivity go side by side. Quality work is obtained when it meets the customers' demands while there is less wastage, fewer reworks, lower resources (capital) etc. and productivity concept is built on such principles. Edosomwan (1987) defined productivity and quality management as an integrated process. **(Loughborough, 1996)**

2.7 Factors affecting productivity:

Many factors affect productivity. Factors has been divided in various categories depending upon the similarities among them.

Category	**Factor**	**Relevant literature**
Project	• Construction method • Complexity of the design • Drawings clarity • Project scale	Enshassi, Abushaban (2009), Durdyev, Ismail, Nurmurat (2018), G. Robles, Tienda, S and Gentes (2014)
Human	• Level of Skill and experience Human category • Ability to adapt to changes and new • environments • Labour motivation • Working overtime • Number of breaks and duration • Worker´s integrity	Enshassi, Abushaban (2009), Durdyev, Ismail, Nurmurat (2018), G. Robles, Tienda, S and Gentes (2014)
Environment	• Performing work at night • Influence of working at height category • Motion´s limitation in the jobsite • Air humidity • High/low temperatures • Rain • High winds	Enshassi, Abushaban (2009), Durdyev, Ismail, Nurmurat (2018), G. Robles, Tienda, S and Gentes (2014)

	• Distance between construction sites and cities	
Finance	• Inadequate supply or high cost of resources: workers (overtime work), materials, machinery, and money • Level of staff turnover/churn rate and Love and Edwards (2005) • Reworks because of on-site construction errors • Inflation/fluctuations in material prices • Fluctuations in exchange rate • Late Payments	Forsberg (2007), Page (2010), Jarkas and Bitar (2012), Durdyev and Mbachu (2017), and Love and Edwards (2005)
Management	• Supervision, performance monitoring, and control • Competencies of the project manager • Loss in productivity caused from change orders • Lack of capability of contractor's site management to organize on-site works • Adequacy of planning and risk management process	Doloi et al. (2012), Dai et al. (2009), Huang et al. (2008), Ibbs and McEniry (2008), Dainty et al. (2005), Bernold and AbouRizk (2010), and Ghoddousi and Hosseini (2012)

	• Adequacy of method of construction • Project management style • Lack of coordination among the construction parties	
Material & Tools	• Lack of tool and equipment in the market • Adequacy of technology used • Late supply of construction materials • Material shortage at project site	Alonso et al. (2007), Pratibha and Gaikwad ME2 Suitability or adequacy of the plant and equipment used (2015), Kazaz et al. (2008), and Page (2010)

Table 2.0 factors effecting productivity

We have divide the above factors into two categories: tangible and intangible, for our study.

Tangible factors are those which can be measured at site. Intangible factors are those which can't be measured physically or which will be measured through questionnaires.

2.7.1 Tangible factors:

- Project category: Complexity of the design
- Human category: Level of Skill and experience
- Environment category: Day & night work
- Finance category: Working overtime

We have shortlisted one (tangible) factor from each category.

2.7.2 Intangible factors

- Management category

  Supervision, performance monitoring, and control
  Competencies of the project manager
  Loss in productivity caused from change orders
  Lack of capability of contractor’s site management to organizeon-site works
  Adequacy of planning and risk management process
  Adequacy of method of construction
  Project management style
  Lack of coordination among the construction parties
  Relationship management degree of harmony, trust, and cooperation

- Materials & Tools category

  Lack of tool and equipment in the market
  Suitability or adequacy of the plant and equipment used
  Adequacy of technology used
  Late supply of construction materials
  Material shortage at project site

2.7.3 Activities:

Factors of productivity varies from task to task. Construction project is a combination of several activities.

Following are the activities we selected: a) these are common in every project b) they are easy to measure

- Form installation
- Rebar installation
- Concreting
- Excavation
- Brickwork
- Painting
- Plastering
- Pipe fitting / Installation of pipes
- Flooring (tiling)

2.8 Work done in construction productivity:

Long D. Nguyen, did work on one aspect i.e. Environment category: Day and Night. He did research on the labor productivity of 10 activities typically performed in both day and night shifts in urban sewer construction. Following are those activities:

- Pavement cutting
- Excavation
- Timber piling
- Steel sheet piling
- Form installation
- Manhole concreting
- Rebar installation
- Pipe laying
- Sand filling
- Asphalt paving

The purpose of this research was to check how productivity of day time & night time affects various activities in site. His research was based on the suggestions by **(Ellis Jr & Kumar,**

1993). The methodology for the research had two shifts: 9 hours (7 am to 5 pm) morning shift & 8 hours (8 pm to 4 am) night shift.

His research concluded that *pavement cutting* and *timber piling* had more productivity in daytime, whereas *steel sheet piling* and *manhole concreting* had higher productivity in nighttime. There was no significant difference in productivity between

day and night shifts for the rest 6 activities. Lastly, this research helped us to prioritize which activity is to be performed and at what time of the day. Graphical representation of the results is shown in the following graph. **(Nguyen et al., 2014)**

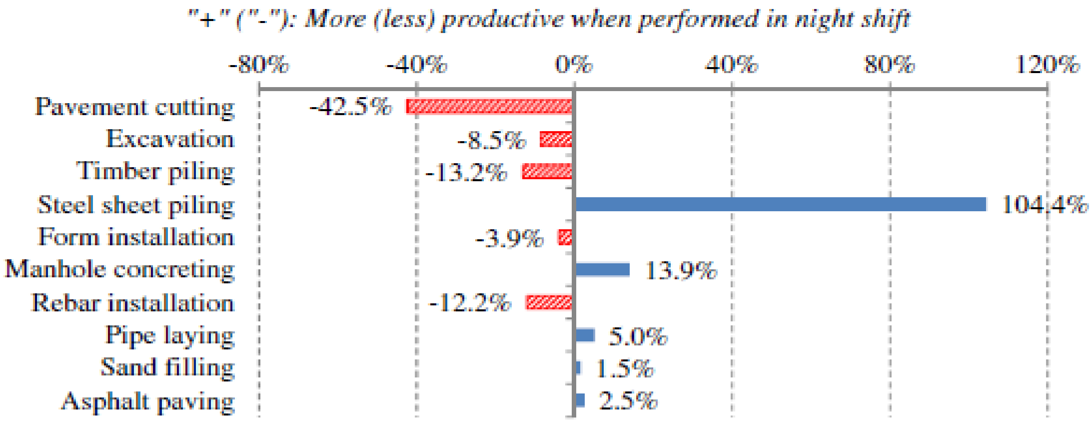


Fig 2.5 Productivity difference (%) between day and night shifts

Chapter 3

RESEARCH METHODOLOGY

3.1 Theoretical background:

The methodology we are opting has parts:

a) Questionnaire
b) Correlation
c) Likert scale **(Rami Huges, 2014)**
d) Relative importance indices (RII)

Correlation:

Correlation coefficient has two types:

i. Spearman's rank (correlation) coefficient
ii. Pearson’s (correlation) coefficient.

Several authors (Abubakar, Omran, & Hussin, 2017)have used Spearman's rank coefficient for the data analysis of construction-related surveys. (Lim, 1996) used spearman’s coefficient to form a correlation between the responses he received from local and foreign contractors.

3.1.1 Spearman's rank (correlation) coefficient:

$r_s = 1 - \frac{6\sum d^2}{n(n^2-1)}$

Where $\sum d^2$ is the sum of the squared differences between the pairs of ranks and n is the number of pairs of ranks.

Pearson's (correlation) coefficient is a bit different from Spearman's rank coefficient, but the basic function of both coefficients is same i.e. determining a statistical relationship between two variables.

3.1.2 Pearson's (correlation) coefficient:

$$r = \frac{N\Sigma XY - (\Sigma X)(\Sigma Y)}{\sqrt{N\Sigma X^2 - (\Sigma X)^2}\ \sqrt{N\Sigma Y^2 - (\Sigma Y)^2}}$$

Pearson's correlation coefficient between the ranked variables is used to establish a relation between the productivity. The value of Pearson's coefficient (r) is always between -1 and 1. The value of r indicates the strength of the correlation. If the value is -1 it means that there is a negatively strong relation between the values and if the value is +1 it means a positively strong relation between the values is present. A zero value of r is the sign of no relation at all in the activities.

3.1.3 Likert scale:

It tells us the level of significance of a specific subject, on a point scale of 5 or 7.
The level of significance, i.e. the impact and influence of a particular matter on a specific subject can be categorize in various forms, such as defined below:

1. No effect
2. Less effect
3. Minor effect
4. Serious effect
5. Very serious effect

3.1.4 Relative importance indices (RII):

It is the process of ranking the specific factors (on likert chart) on the basis of the significance

$$Rii = \frac{\sum_{r=1}^{5} r * n_r}{5N}$$

- **r** is the rating on a Likert scale (1-5) as for the impact on construction efficiency for a specific element influencing construction profitability.
- **nr** is the quantity of respondents giving a specific Likert scale rating r.
- **N** is the aggregate number of respondents to a specific inquiry

(Dixit, Pandey, Mandal, & Bansal, 2017)

3.2 Methodology

Research methodology is descriptive, observation and interviews. After a comprehensive literature review, we divided our methodology into two components: tangible and intangible.

In first phase, we made a questionnaire which consisted of intangible factors from management and material category. Conducted a pilot survey by distributing the questionnaire to more than 30 civil engineering experts. Using relative importance index, shortlisted one factor from each category.

3.2.1 Intangible factors & their relative importance indices (RII):

Factors	**RII**
Management category:	
Supervision, performance, mnitoring, and control	0.89
Competencies of the project manager	**0.9**
Loss in productivity caused from change orders	0.72
Lack of capability of contractor’s site management to organize on-site works	0.83
Adequacy of planning and risk management process	0.76
Adequacy of method of construction	0.76
Project management style	0.75
Lack of coordination among the construction parties	0.84
Relationship management degree of harmony, trust, and cooperation	0.74
Materials & Tools category:	
Lack of tool and equipment in the market	0.75

Suitability or adequacy of the plant and equipment used	0.81
Adequacy of technology used	0.77
Late supply of construction materials	0.89
Material shortage at project site	**0.94**

Table 3.0 Intangible factors & their RII

3.2.2 Shortlisted intangible factors:

<u>Management:</u> Supervision, performance, monitoring, and control (0.9)

<u>Materials & Tools:</u> Material shortage at project site (0.94)

In second phase, we performed a preliminary survey in twin cities (Rawalpindi-Islamabad) to select construction sites. Construction sites we chose were:

1. Nust Science & Technology Park (NSTP)
2. Female Faculty Hostel
3. Swimming Pool & Gymnasium
4. Pakistan Housing Authority Apartments

Construction sites were chosen by keeping in mind, the ease of access, cooperation from the construction company staff, distance from our residency etc.

Following four activities are selected to evaluate the construction labor productivity with its factors:

1. Brickwork
2. Rebar installation
3. Concreting
4. Shuttering/formwork.

Our project is focused on labor productivity so we considered only those activities which are labor intensive and the main variable in the productivity is human. One can find many such activities going on in any construction site, but we made sure that the selected 4 activities were common in all our sites.

- **Brickwork** is one of the major activity, usually used as a non-bearing material. At some place block masonry is also used instead of brickwork, but in Pakistan brickwork is found more often at construction sites. It is labor intensive activity which is performed by masons and helpers. We measured it in 'no of bricks' being placed in a 'unit hour'.

- **Rebar installation** steel bar or mesh of steel wires installed as a tension device in reinforced concrete and reinforced masonry structures to strengthen and aid the concrete under tension. Anywhere where steel is being placed, whether in slab or column, it's considered in rebar installation. It is labor intensive activity which is performed by steel fixers and helpers. We measured it in 'tons/hr'

- **Concreting** is one of the most frequent activity on site. It's a major process in construction and is also easy to measure. This labor intensive activity is measured in m^3/hr.

- **Shuttering and Formwork** is quite a technical task to carry out. Arrangement of shuttering needs to be accurate to ensure that concrete attains proper strength in right orientation. This labor intensive task is measured in 'sft/hr'.

Before going to the field to measure physical factors, a standard form was developed which was used throughout the field work to take measurements from the site work. Since our project involves measuring four activities in relation to four different physical factors, therefore we made sure that the form we devise is kept as generic as possible. It included details like, activity name, site name, site supervisor, time (on hourly basis), work done, number of labours, date, observer, labour experience, labour details, observation number, temperature and productivity in (unit/hr/labour). Following is our designed form:

Activity name				
Site Name				
Site Supervisor				
Time	Work Done (in sqft/tons etc.)	Number of labors	Productivity (workdone/labor)	Temperature
7:00-8:00				
8:00-9:00				
9:00-10:00				
10:00-11:00				
11:00-12:00				
12:00-01:00				
01:00-02:00				
02:00-03:00				
03:00-04:00				
04:00-05:00				
05:00-06:00				
06:00-07:00				
Date:				
Observer:				
Observation Number:				
Labour experience				
Labour details				

Fig 3.1 Data collection form

3.3 Data Collection:

A very comprehensive data collection was performed at construction sites. Took assistance from the site supervisor to compute data as precise as possible. There were four members in our group; each member was assigned a site. We used to go to the site at least 3 times in a week for a period of 2 months. Since we had our classes as well on the week days, so we taught the site supervisor to help us measure data in the hours we weren't available. Being undergrad students we had 6-7 hours available for project on daily basis (except for the project day). Since site work is minimum of 8 hours, which at times exceeds to 10-11 hours (overtime work) and we could only manage 6-7 hours, so the extra hours measurements were taken by the site supervisor on our behalf, and later we counter checked those measurements using our own activity analysis. We remained vigilant while collecting data.

The scope of our project includes four tangible factors, hence the data we acquired touched all four aspects. For the first factor, '**level of experience of labour'** we looked for sites that had labours with various years of working experience in the specified activities. On construction site there were labours with a ranging work experience i.e. from a few months to years of experience. To bring uniformity and reliability in our results, we categorized experience into parts i.e. 0-5 years, 5-10 years, 10-15 years etc and cases like labour having experience of 23 years or 30 years were very rare, hence we ignored those cases.

'**Complexity of a project'** was our second aspect. To cover this aspect we chose two sites with 'higher complexity' and two sites with lower complexity. To define a project as complex, we had to go through literature review. The construction process is always made up of a multitude of interacting parts. Therefore, in simple terms, this may suggest that construction is generally complex in nature. However, the dictionary definition adds another interesting property, i.e. `being difficult to understand or carry out, intricate, involved'. Since not all construction production processes satisfy this property, it may then be acceptable to consider it as a meaningful cut-off point that makes a distinction between a `complex' construction process and a simple or `non-complex' one.

Many experts and researchers have defined a complex process in quite a number of specific ways. Perrow (1965) defined the complexity of a task as the *degree of difficulty* of the search process in performing the task, the amount of thinking time required to *solve work-related problems* and the body of knowledge that may provide guidelines for performing the task. Thompson (1981) considered complexity as the measure of the *difficulty of coordinating* a production process comprising of activities that *lack uniformity of work*. Malzio *et al*. (1988) suggested that a complex process is that which comprises of operations that are *innovative* and conducted in an *uncertain situation.*

Experts consider project complexity in a number of ways. They see a complex project as follows.

1. That having a large number of different systems that need to be put together and/or that with a large number of interfaces between elements.
2. When a project involves construction work on a confined site with access difficulty and requiring many trades to work in close proximity and at the same time.
3. That with a great deal of intricacy which is difficult to specify clearly how to achieve a desired goal or how long it would take.
4. That which requires a lot of details about how it should be executed.
5. That which requires efficient coordinating, control and monitoring from start to finish.
6. That which requires a logical link because a complex project usually encounters a series of revisions during construction and without interrelationships between activities it becomes very difficult to successfully update the programme in the most effective manner.

Keeping in mind all these points, we rated our four site projects on a complexity scale. For which we used the method of Likert scale (on a scale of 1 to 5). 1 representing fulfilment of the condition at a very small extent & 5 representing fulfilment of the condition at a very high extent. Sites were rated by observing the site and interviewing the staff.

	Sites			
	Swimming pool	Female Faculty	NSTP	PHA Apartments
1. Having a large number of different systems that need to be put together and/or that with a large number of interfaces between elements	1	2	3	5
2. project involves construction work on a confined site with access difficulty and requiring many trades to work in close proximity and at the same time.	3	2	1	3
3. a great deal of intricacy which is difficult to specify clearly how to achieve a desired goal or how long i	1	2	3	4
4. That which requires a lot of details about how it should be executed	1	2	4	5
5. That which requires efficient coordinating, control and monitoring from start to finish.	2	3	4	4
6. That which requires a logical link because a complex project usually encounters a series of revisionsd	1	1	3	4
	9	**12**	**18**	**25**
	Least complex	**Less complex**	**More complex**	**Most complex**

Fig 3.2 Complexity of a project

Or even cost wise, PHA Apartments is most costly project, whereas swimming pool site is least in terms of cost of project, as well.

Our third factor is '**temperature**', literature review says that studies on '*temperature effect on productivity are not consistent'***.** We used to note hourly data of temperature whenever we were working at site. We took data during winters therefore there weren't many fluctuations in the temperature.

'**Overtime**' is our fourth factor. Overtime in this research is defined as the hours worked beyond the typical 40 h scheduled per week or 8 hours of work per week days. Extended overtime is frequently used to:

- Meet tight project targets from owners
- Make up for late changes and project delays
- Attract skilled labor to a project

Some owners and contractors consider extended overtime as necessary and required to meet the demands for faster schedules or to staff their projects. For them, extended overtime is the norm, their standard approach to projects.

In our case, the numbers of hours exceeding 8 hours work in a day, is equal to the number of overtime hours. In our sites, it ranged from 1 hr to 5 hrs.

3.4 Process of acquiring data on field with respect to its factors:

3.4.1 Tangible:

Steps:

1. Reach site, and see what activities are being performed.
2. Start noting data of those activities on the designed site performa, at one hour intervals.
3. If you reach the site late or leaves a bit early, take the assistance of foreman or site supervisor to fill the remaining hours data. In order to make sure that data of whole day at construction site is noted in the performa.
4. Labour skill level: It was measured by taking readings of labour with a particular experience. For e.g. one day, work done by labour having experience of 0-5 years, working on a particular activity (let's say concreting), was measured. And on another day, work done by labour having experience of 5-10 years, working on the similar

activity (concreting), was measured. Same goes for labour having experience 10-15 years.

5. Overtime: Work done in the hours after 8 working hours was noted as overtime work.
6. Temperature: Since we were taking readings at intervals of 1 hour, hence we noted temperature for 1 hour intervals
7. Complexity: Since we rated each project on a complexity scale, so the productivity data for each site was calculated in hourly average format.

3.4.2 Intangible:

Steps:

1. Developed a project management process performa
2. Interviewing construction site staff and observing management system
3. Verifying our performa results with readings obtained from site

Following is the sample of project management process performa

Project Management Process Performa

1. **Site name:**
2. **Competency & Number of foreman (years of experience):**
3. **Documentations:**
4. **Company SOPs:**
5. **Safety Management:**
6. **Company SOPs communicated to the administrative body (till forem level):**
7. **Tools, Techniques & Policies regarding quality management:**
8. **Number of complete projects:**

Fig 3.3 Project management process performa

CHAPTER 4

RESULTS & DISCUSSION

4.1 Discussion

The data collection was the longest phase of this project which lasted about three months i.e. February 2019 to April 2019 (spring season). Data collection took place on four building construction projects. We gathered data from the field (construction sites), by going to the site at least 3 times a week and also contacted other members of engineering and construction community to assist us to collect the mentioned data for us. The whole data for labor productivity was cross checked by the members of final year project in order to accurately interpret and analyse the data. Data analysis of all the observations, related discussions and findings of all five projects are explained below in detail.

4.2 Human Category: Labour Skill level

Labour skill level is related to the number of years the person has worked in the construction field. At construction site, variety of labour having different years of experience is working. Now matter what activity is being performed at site you will find labour having various years of experience. We categorized the labour skill level into 3 categories: 0-5 years, 5-10 years & 10-15 years. Following are the results of productivity of each activity against labour skill.

Field results

Fig 4.1 Productivity vs Labor skill level (concreting)

Fig 4.2 Productivity vs Labor skill level (brickwork)

Fig 4.3 Productivity vs Labor skill level (shuttering)

Fig 4.4 Productivity vs Labor skill level (rebar installation)

4.2.1 General trend from graph (Productivity vs Labour Skill Level):

Productivity increases as labour skill level increases up till an optimum level i.e. 5-10 years experience. Beyond that productivity starts to decrease. The same trend is being followed by all the four activities graphs.

4.3Finance Category: Working Overtime

Overtime is the time when a labour works beyond the standard set of working hours. The labour are paid hourly at a fix rate. The same rate is fixed for the working overtime hours. Working long hours has become a routinized part of life in Asia. Overtime is utilized to speed up the construction process. It is working more than forty hours per week, i.e. working more than eight hours per day. When the project is behind schedule, overtime work is done to increase the performance of a project. Following are the results of productivity of each activity against working overtime.

Field results

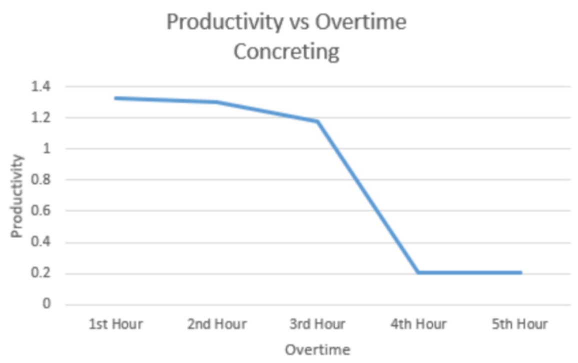


Fig 4.5 Productivity vs overtime (concreting)

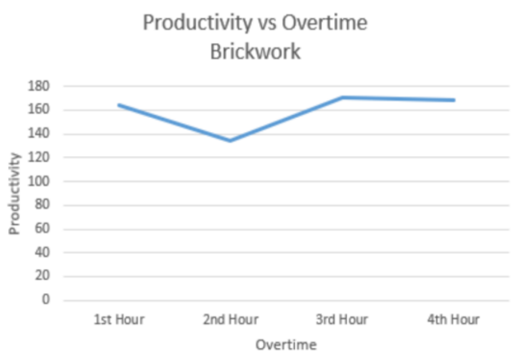


Fig 4.6 Productivity vs overtime (brickwork)

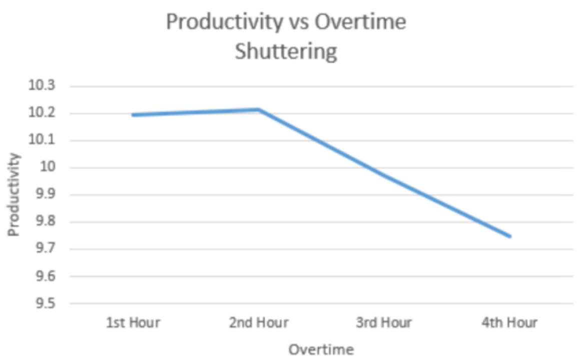


Fig 4.7 Productivity vs overtime (shuttering)

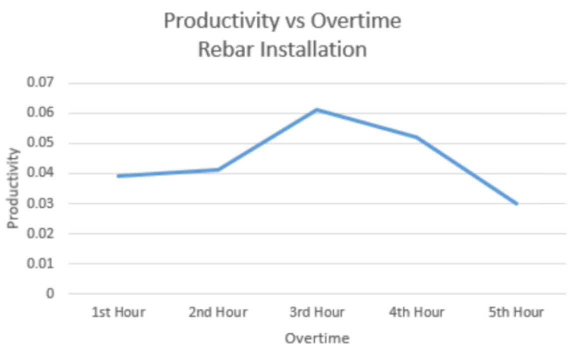


Fig 4.8 Productivity vs overtime (rebar installation)

4.3.1 General trend from graph (Productivity vs Working Overtime):

As the overtime extends, productivity starts to decrease. Peculiar results are seen at 2nd & 3rd hours of brickwork and Rebar installation.

4.4 Environment Category: Temperature

Temperature has physiological effect on labours, hence it effects how effective a labour will work. All the four construction sites were in the Islamabad region, therefore all the sites had similar temperature on any given day, which made it easier for us to analyse and compare the data.

Field results

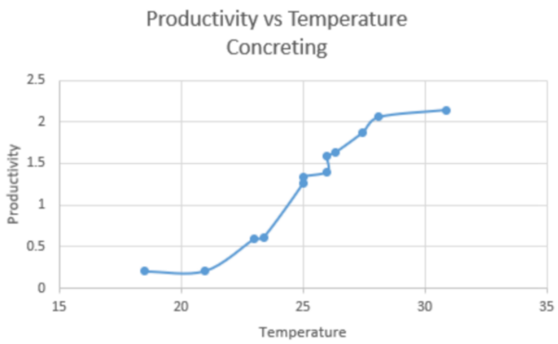


Fig 4.9 Productivity vs temperature (concreting)

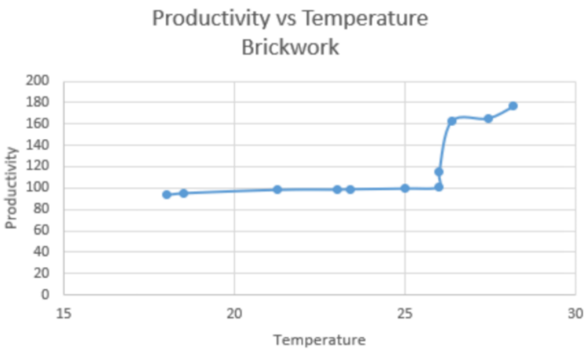


Fig 4.10 Productivity vs temperature (brickwork)

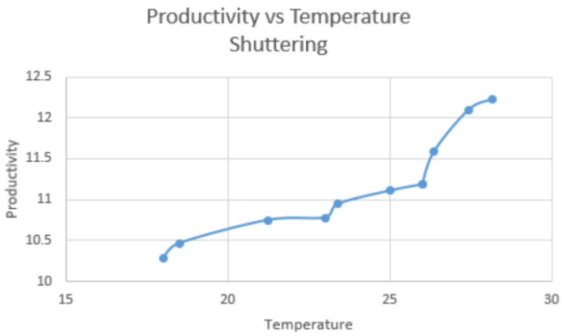


Fig 4.11 Productivity vs temperature (shuttering)

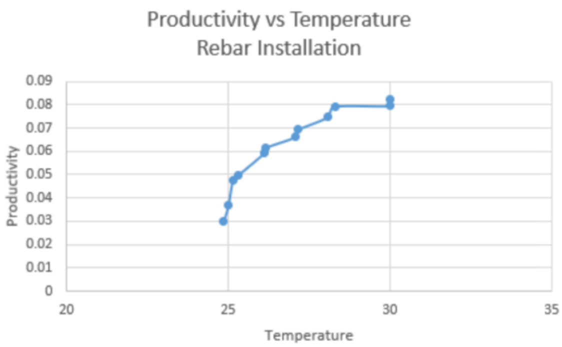


Fig 4.12 Productivity vs temperature (rebar installation)

4.4.1 General trend from graph (Productivity vs Temperature):

The temperature range is of months February 2019 to April 2019. Not a linear trend, but a gradual increase is being shown by the graphical line, which concludes that productivity increases with the rise in temperature during the span of months mentioned above.

4.5 Project Category: Complexity of Project

What is a complex project and how did we rate our construction sites on a complexity scale is mentioned in the 'chapter 3 - data collection' section.

Field results

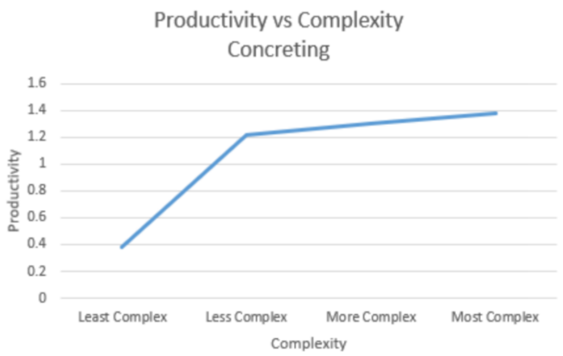


Fig 4.13 Productivity vs complexity (concreting)

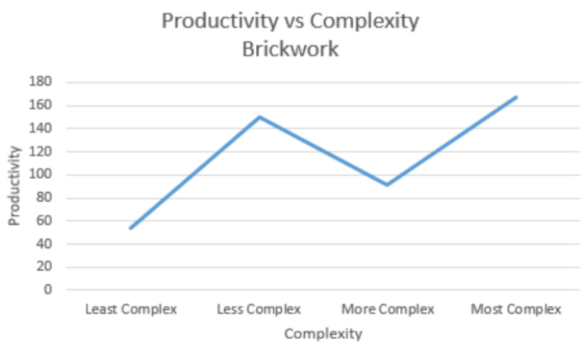


Fig 4.14 Productivity vs complexity (brickwork)

Fig 4.15 Productivity vs complexity (shuttering)

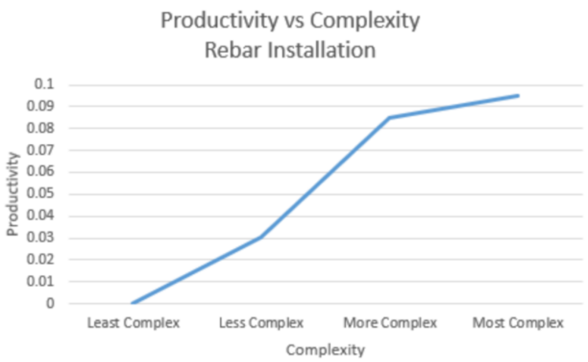


Fig 4.16 Productivity vs complexity (rebar installation)

4.5.1 General trend from graph (Productivity vs Complexity of Project):

Our constructions site were, ‘Swimming pool’, ‘Female Faculty’, ‘NSTP’ and ‘PHA Apartments’. After performing the complexity criteria check, our construction sites were rated as:

- Swimming pool – least complex
- Female Faculty – less complex
- NSTP – more complex
- PHA Apartments – most complex

For all the activities we see a similar trend. More complex the project, higher will be the productivity.

4.6 Material & Tools Category: Shortage of Material

Complete material shortage is very rare at construction sites. Back-up material is always there to cope up with the material shortage. Whereas, a limited supply or availability of a material was observed. Following are the two graphs: series 2 represent a normal routine day when the bricks were readily available. Series 1, represents when the brick weren’t readily available and there were a limited number of bricks at site

Field results

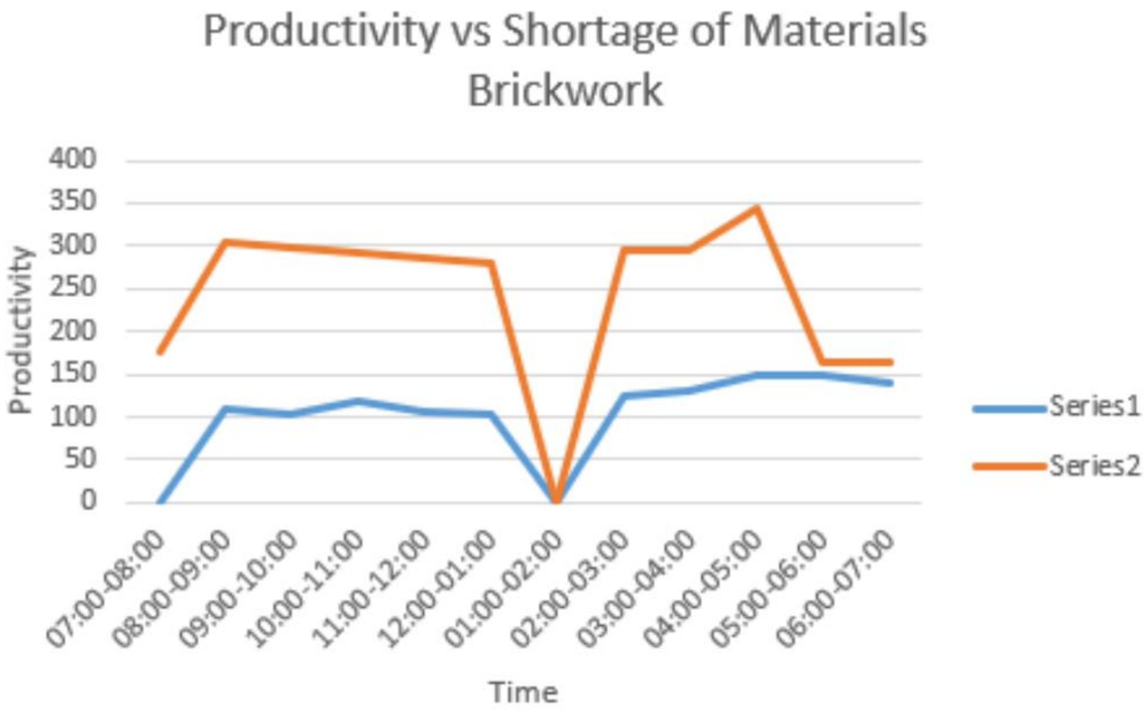


Fig 4.17 Productivity vs Shortage of material (brickwork)

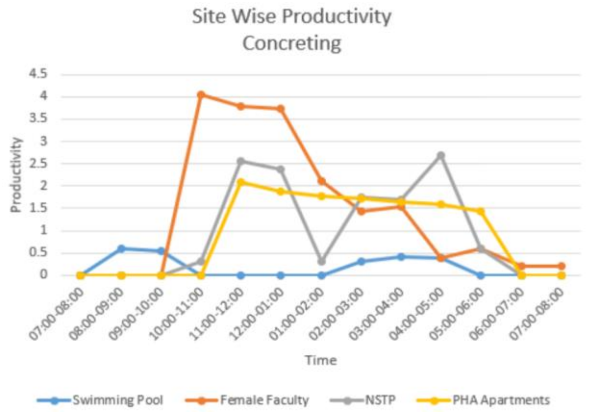
4.6.1 General trend from graph (Productivity vs Shortage of Material):

When material is readily available, productivity is high (trend shown by series 2) and when the material supply gets limited, productivity gets reduced. The sharp decline between 1pm to 2pm is due to lunch break, since no work is being done.

4.7 Management Category: Project Management Process

To judge this process, we took an average of all the particular activity that took place at a specific site for the span of 3 months – site wise productivity.

Field results



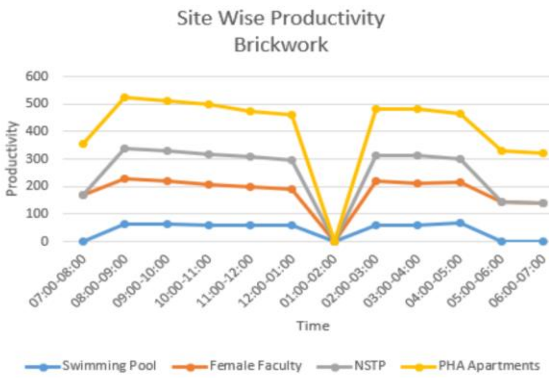
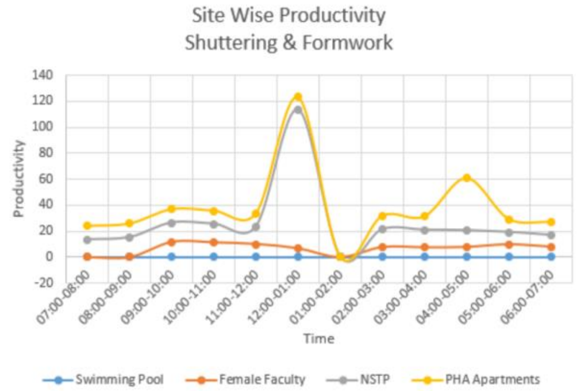


Fig 4.18 Site wise productivity (concreting)

Fig 4.19 Site wise productivity (brickwork)



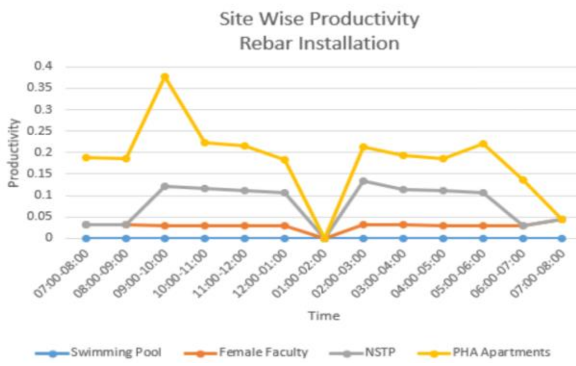


Fig 4.20 Site wise productivity (shuttering)

Fig 4.21 Site wise productivity (rebar installation)

4.7.1 General trend from graph (Productivity vs Project Management Process):

Each colour line represents the total average of activity at the particular site. Through the project management performa, we generalised the perception that project management process was very highly effective at PHA apartments, highly effective at NSTP, less effective at female faculty and least effective at swimming pool. From graphs, if we look at the yellow line (PHA apartments), we will notice that its productivity value remained high in each activity and the blue line of swimming pool showed that productivity of each activity remained least. Hence our graphs backed our project management performa results. Bottom line, better the project management process, greater the productivity.

CHAPTER 5

CONCLUSION

5.1 Conclusions

- Productivity with respect to labour skill was maximum at an optimum point, in our case 5-10 years.
- General trend of productivity with overtime was decreasing with increase in overtime hours
- Productivity increased with rise in temperature
- More complex the project, higher will be the productivity
- Rare occurrence of material shortage caused sharp decrease in productivity
- Better the project management process, greater the productivity

5.2 Recommendations

5.2.1 Industry related:

- Labour must be utilized for 8 hours, for work more than 8 hours, there should another shift of different workers.

- Foreman (Junior staff) experience creates a large impact on construction productivity, while hiring them take this into account.

- For a project to work at its optimum productivity level one should avoid hiring labour with experience 10 – 15 years.

5.2.2 Research related:

- Our research was limited to six factors with four activities each, and in future do consider other activities as well.

- Our research was based on *activity level* of productivity, in order to further analyse the productivity it is recommended that research should be conducted at *project level.*

CHAPTER 6

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APPENDIX

Survey Questionnaire

Factors affecting Construction Productivity

We are carrying out a survey to evaluate the non-physical factors that affect construction productivity. This questionnaire is intended to collect data regarding final year project. All the information will be kept confidential.
Thank you for taking the time to fill in this questionnaire; it should only take 10 minutes.

* Required

1. **Name** *

____

2. **Company** *

____

3. **Contact (Optional)**

____

4. **Please indicate your current position** *

Mark only one oval.

- ◯ Project manager
- ◯ Construction manager
- ◯ Site Engineer
- ◯ Cost Estimator/Quantity Analyst
- ◯ Site Supervisor
- ◯ Designer (Soil/Structure)
- ◯ Other: ______________________________

5. **How long have you worked for the company?** *

Mark only one oval.

- 0-5 years
- 5-10 years
- 10-15 years
- More than 15 years

Skip to question 6.

Management factors

Using Likert scale, to determine level of importance of non physical factors, on a point scale of 5 i.e.

1. Very less effect
2. Less effect
3. Moderate effect
4. High effect
5. Very high effect

Rate the effect of following factors on the construction productivity, on a scale of 1 to 5.

6. **Supervision, performance monitoring, and control** *

Mark only one oval.

	1	2	3	4	5	
Very less effect	◯	◯	◯	◯	◯	Very high effect

7. **Competencies of the project manager** *

Mark only one oval.

	1	2	3	4	5	
Very less effect	◯	◯	◯	◯	◯	Very high effect

8. **Loss in productivity caused from change orders** *

Mark only one oval.

	1	2	3	4	5	
Very less effect	◯	◯	◯	◯	◯	Very high effect

9. **Lack of capability of contractor's site management to organize on-site works** *

Mark only one oval.

	1	2	3	4	5	
Very less effect	◯	◯	◯	◯	◯	Very high effect

10. **Adequacy of planning and risk management process** *

Mark only one oval.

	1	2	3	4	5	
Very less effect	◯	◯	◯	◯	◯	Very high effect

11. **Adequacy of method of construction** *

Mark only one oval.

	1	2	3	4	5	
Very less effect	◯	◯	◯	◯	◯	Very high effect

12. **Project management style** *

Mark only one oval.

	1	2	3	4	5	
Very less effect	◯	◯	◯	◯	◯	Very high effect

13. **Lack of coordination among the construction parties** *

Mark only one oval.

	1	2	3	4	5	
Very less effect	◯	◯	◯	◯	◯	Very high effect

14. **Relationship management/degree of harmony, trust, and cooperation** *

Mark only one oval.

	1	2	3	4	5	
Very less effect	◯	◯	◯	◯	◯	Very high effect

Materials & Tools Factors

Using Likert scale, to determine level of importance of non physical factors, on a point scale of 5 i.e.

1. Very less effect
2. Less effect
3. Moderate effect
4. High effect
5. Very high effect

Rate the effect of following factors on the construction productivity, on a scale of 1 to 5.

15. **Lack of tool and equipment in the market** *

Mark only one oval.

	1	2	3	4	5	
Very less effect	◯	◯	◯	◯	◯	Very high effect

16. **Suitability or adequacy of the plant and equipment used** *

Mark only one oval.

	1	2	3	4	5	
Very less effect	◯	◯	◯	◯	◯	Very high effect

17. **Adequacy of technology used** *

Mark only one oval.

	1	2	3	4	5	
Very less effect	◯	◯	◯	◯	◯	Very high effect

18. **Late supply of construction materials** *

Mark only one oval.

	1	2	3	4	5	
Very less effect	◯	◯	◯	◯	◯	Very high effect

19. **Material shortage at project site** *

Mark only one oval.

	1	2	3	4	5	
Very less effect	◯	◯	◯	◯	◯	Very high effect