A Scientific Approach to Estimate the Masonry Labour Productivity Using Human Physical Parameters

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ABSTRACT

The productivity problems are usually associated with the performance of construction workers involved in labour-intensive tasks. The measurement of labour productivity at task level masonry activities is defined as a Masonry Labour Productivity (MLP). While low productive masonry worker practices were not challenged, the causes of low masonry labour performances at site level have not been focused. In construction projects, workers perform vigorous activities such as lifting and carrying construction material, pushing, dragging and pulling, loading, carrying out difficult work positions and engaged in tiresome activities. Accordingly, workers should be physically strong to withstand these vigorous activities on the construction field. Since different people have different physical strength capabilities, analysing physical ability-productivity relationships could propose a way to estimate labour productivity that can further aid in improving the productivity of construction industry.

It is observed that even though there is a vast research on productivity and significant factors responsible for variation of labour productivity, there is less focus towards the assessment of labour productivity based on the worker's individual performance. The problem to be addressed in this research is the estimation of labour productivity, specifically in masonry construction with regard to physical capabilities, and how does these capabilities (i.e., human physical parameters) predict the task level labour productivity in masonry construction activities.

From the literature it is evident that utilization of human physical parameters in construction will help in determining the performance of the labour on site. The physical fitness of human body can be apparently assessed using isometric strength tests. These tests involve a maximum controlled contraction performed at a specified body joint angle of humans in stationary position. Therefore, to focus on effective application of human factors, present study selected four parameters such as age, Body Mass Index (BMI), Hand Grip Strength (HGS) and Upper Body Muscles Strength (UBMS) for measuring the labour performance on site.

In the present study, ongoing construction projects were selected in Warangal and Hyderabad of Telangana State, India. Survey was conducted on forty-five brick layers in which the data of thirty-eight workers is successfully recorded for the study. Therefore, the study is focussed on developing a scientific approach on a real time construction field for assessing labour productivity. The outcome of this research is expected to present a methodology that can be applied in construction industry.

Present research is specifically focused on masonry labour construction. An investigation on masonry workers in a real time building construction projects was carried out in India. Human

parameters are denoted in the form of categories. The parameters are combined in to a unified parameter using human parametric categorization. Sum of the weightages of respective performance classes corresponding to human parametric category (ca_n) of a worker will be the index of that worker which is termed as Human Parameter Index (HPI).

HPI is a non-dimensional and MLP is a dimensional parameter. MLP can be made in to non-dimensional parameter taking performance levels and physical abilities of labour in to consideration to form an indexed value, called as Productivity Index (PI). The HPI and PI of workers were calculated. From the relationship between HPI and PI of workers by regression analysis, a model to estimate MLP is developed.

The validity of the model was checked by conducting an independent survey. In a way it is proposed to apply the relationship model for a real time field construction activity and examine its level of prediction. Validation of model is carried out for workers involved in masonry construction activities. The newly developed parameter HPI is corroborated with the established heart rate parameter. It is found that as HPI increases heart rate of the workers decreased.

The influence of human parameters on MLP is examined in carrying out AAC block wall construction activity. All four human physical parameters together were found as good indicators in assessing MLP. The findings revealed that the subjects (masons) can be categorized with respect to human physical parameters based on their level of performance such as lower(ca_3), middle(ca_2) and upper(ca_1) categories. Human physical parameters when considered in category showed promising trends on MLP.

The study contributes to knowledge about the utilization of parameters related to physical strength in qualitative assessment of MLP in construction industry. It is concluded that the productivity of construction labour on site can be assessed from categorizing their performance.

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Notations

MLP	Masonry Labour Productivity
Norm(MLP)	Normalized MLP
MLP_{std}	Standard MLP
MLP_{avg}	Average MLP
LOCs	Labour Output Constants
SSR	Standard Schedule of Rates
IS	Indian Standard
TSSD	Telangana State Standard Data
DSR	Delhi Schedule of Rates
CPWD	Central Public Works Department
AAC	Autoclaved Aerated Concrete
RII	Relative Importance Index
TS	Telangana State
BMI	Body Mass Index
WHO	World Health Organization
HGS	Hand Grip Strength
UBMS	Upper Body Muscles Strength
HR	Heart Rate
HPI	Human Parameter Index
PI	Productivity Index
LH	Left Hand
RH	Right Hand
CP	Chest Pose
WP	Wall climb Pose
HP	Head Pose
LL	Lower Limit
UL	Upper Limit
LR	Lower Range
MR	Mid Range
UR	Upper Range
bw	before work
dw	during work
aw	after work
μ	mean
σ	standard deviation
s_x	percentage of sample
p	probability
S	variance
R^2	regression coefficient
$\hat{P}_{hp,ca}$	average productivity of workers for the respective category
$P_{hp,ca}$	individual productivity of worker
n_{ca}	no of workers in the respective parametric category
ca_n	parametric category
c_n	productivity class
$W^{i}{}_{c_n}$	productivity weightage based on human physical parameter
φ^i	relative importance of respective parameter

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Chapter-01

1. Introduction

1.1. General

Construction industry in India is buoyant due to huge demand from various real estate and infrastructure projects. Construction market accounts for fifteen percent of Gross Domestic Product, making India the third largest globally by 2030 (Construction 2019). To develop employment and encourage job prospects, most of the developing nations like India consider the manufacturing industry. However, India can still adopt the construction sector for supporting its economic growth.

The arrival of automation and mechanical advancements has been affecting the demand for manual labour in modern day construction industry. Manpower utilization in most of the Indian construction projects is essential for many basic activities such as brickwork, plastering, flooring, etc. Construction industry is labour-intensive and greatly depends on the productivity of workforce. Productivity of the workforce is the most important aspect that affects the performance of any construction firm.

Productivity problems are usually associated with the performance of workers involved in the construction activities. Construction industry normally defines productivity as effectiveness of labour employed with respect to the management skills, workers, materials, working area, tools and equipment or to produce a finished product of construction project at the lowest viable cost (Chui et al. 2011). Construction productivity enables the industry to maintain satisfied client, attract investment, remain feasible and contribute to the economic growth and well-being of the country (Durdyev and Mbachu 2011).

In today’s era, optimized labour productivity is most important aspect for any construction organization. Assessment of masonry labour work in the construction projects is an important part of management process (Nyando and Strasheim, 2012). As most of the construction activities are labour intensive, labour productivity is measured at activity/task level, which measures input as labour time and output as installed quantities (Oglesby et. al., 1989). The measurement of labour productivity at task level masonry activities is defined as Masonry Labour Productivity (MLP).

Thirty to fifty percent of the overall construction project’s cost is consumed by labour and is benchmarked as a true reflection of the financial success of the construction projects (Loganathan and Kalidindi 2015; Harmon and Cole 2006; Shea 1988). It can also be said that labour output is the only productive means in the construction process, hence construction productivity is mostly reliant on labour performance. While the low productive masonry worker practices were not challenged, the causes of low labour performances at site level have not been investigated.

Construction productivity is usually defined as the effective employment of manpower resources (inputs) in execution of services (output) (Thomas and Sudhakumar, 2014). In construction projects, workers perform vigorous activities such as lifting and carrying construction material, pushing, dragging and pulling, loading, carrying out work from difficult work positions and engaging themselves in tiresome activities. Accordingly, workers should be physically strong to withstand these vigorous activities on the construction field. Construction tasks involve such actions and lead to physical fatigue due to excessive physical strain of workers, which in turn leads to decrease in labour productivity ((Raisudeen et al., 2014; Brouha, 1967; Janaro, 1982; National Safety Council, 2000)). In case of similar project locations, labour productivity in construction does not vary (Odesola and Idoro, 2014). Umberto et al., (2013) found a relationship between a worker's physical strain and work productivity using heart rate as a human parameter. Loss of physical strength in humans causes physical strain. Since different people have different physical strength capacities, analyzing human strength-productivity relationships could propose a way to estimate labour productivity that can be very helpful in improving the growth of construction industry.

As a diversified sector contributing to the national economy, the construction industry contains a broad range of resources. Therefore, construction productivity is not only concerned with individual activities, but the industry as a whole. Even though there are numerous advancements in the construction industry, various types of constructions such as residential buildings largely depend on manual labour (Parthasarathy et al., 2017). The issue of developing the construction productivity has been researched since a long time. There are many basic and important areas that need to be discussed in detail. Three such areas are included:

1. Need for productivity measurement
2. Factors affecting MLP and
3. Methods of productivity measurement

1.2. Need for productivity measurement

Productivity is generally stated as a ratio of a measure of output to a measure of input use. Although there are no differences on this general notion, looking at the productivity studies and its various applications reveals that there is neither a unique reason for, nor a definite measure of productivity. The purposes of productivity measurement include:

1.2.1. Technology:

One of the main purposes of measuring productivity growth is to find the technological changes in the construction industry. In productivity, technology has been defined as “the renowned ways of converting resources into outputs desired by the economy” (Griliches 1987) and emerges either in its intangible form (such as new blueprints, scientific results, new organisational methods) or tangible form in outcomes.

1.2.2. Efficiency:

The pursuit of finding changes in efficiency is conceptually dissimilar from identifying technological change. Maximum efficiency in the sense of completing an engineering activity implies that a production activity has completed the maximum quantity of output that is physically feasible with current technology, with fixed quantity of inputs given (Diewert and Lawrence, 1999). Gains in technological efficiency are the efforts towards “best practice”, or the removal of technological and managerial inefficiencies. Where productivity measurement is concerned at the industry level, efficiency improvements can either be due to improved efficiency in specific establishments that forms the industry or production changes towards the more efficient establishments.

1.2.3. Cost Savings:

A practical way of describing the essence of productivity change is cost savings. Though various types of changes in terms of efficiency, technological and economies were possible to separate in principle, the same task remains difficult to achieve in real practice. Harberger (1998) reaffirmed the point that there are many sources behind improvement of productivity and regarded cost savings as one such source. In this manner, measurement of productivity practically might be seen as a pursuit to ensure cost savings in production.

1.2.4. Benchmarking:

Productivity is a crucial factor contributing to the ability of many construction firms in achieving their planned targets. Therefore, it is vital to recognize the main elements of productivity, and to keep and link to exact archives of productivity levels in construction projects. This method is denoted as benchmarking and this has been accepted in many industries. In simple manner, benchmarking is defined as a systematic approach to continuous measurement process. Benchmarking is not a direct job in construction industry due to lack of solid data collection in the industry and the remarkable variation in productivity. Benchmarking efforts are bound to meet certain difficulties such as incomplete or imaginary data. Though the data is well documented and recoverable, it would be greatly reliant on the exceptional characteristics of the project such as size, type and budget which makes it difficult to use effectively. (Mohamed, 1996).

1.2.5. Standards:

Measurement of productivity is a significant element towards assessing the industry standards of labour productivity. A simple example is the labour cost incurred, probably the most common measure of standards: wages per labour in an economy differs directly from amount of labour productivity. In this manner, measuring productivity aids in better understanding of the development of industry standards.

There are several productivity measures. The choice between them depends on the objective of the productivity measurement. In most cases, productivity measurement depends on the availability of data. Generally, productivity measurement can be categorized as single factor productivity measurement (measurement of output to a single input) or multifactor productivity measurement (measurement of output to more than one input). Another distinction, particularly at the firm or industry level is amongst productivity trials that are related to some of the gross output to one or numerous inputs and those which use the idea of value addition to take the movements of output.

1.3. Factors affecting MLP

The main goal of construction is to build and a major part of the building is crafted by masonry workers onsite with support from the project management team in a construction firm. The performance of labour is primarily influenced by factors such as time, cost, and quality of the construction projects (Ulubeyli 2014). Past studies have showed a broad range of factors affecting labour productivity at various levels such as industry, company, project and field level (Thomas and Sudhakumar 2013; Soham and Rajiv 2013; Kaming et al. 1997). In case of masonry construction, productivity of onsite workers will be a major concern. The focus of the present research is on labour productivity in masonry construction in which the labour ability is directly involved. The assessment of labour ability has to be done by human physical parameters

The concept of developing task level productivity (i.e., masonry labour productivity in construction projects) has been overlooked in construction industry when compared to the manufacturing industry that has been reaping benefits from established production management procedures. Task level labour productivity in building construction is commonly measured by their physical performance i.e., predetermined motion time systems. In this regard, identification of significant factors for development of MLP in building construction projects was inadequate. Improvement of MLP is not possible without identifying the critical factors that play a major role.

Therefore, a precise assessment of factors influencing MLP will enable proper allocation of workforce on site and provide workers with support or development towards productivity improvement. Assessment of labour issues on construction site considering the influence of crucial MLP factors will assist construction engineers, supervisors and managers in making timely decisions on construction projects.

1.4. Methods of productivity measurement

Measurement of construction productivity is a complex issue and there is no standard formula to determine it under all conditions. Certainly, there still exist functional areas in construction industry where the methods of measuring labour productivity have to be established. A proper measuring method for labour productivity must have these essential characteristics:

a. Simple, clear and well identified;
b. Utilizable for various levels of construction projects; and
c. Hold a reliable database information and allow periodical tracking

Measurement of construction productivity at task level has both direct and indirect objectives. Control of cost, scheduling, targets, and motivating the labour are some of the direct objectives. Management need labour productivity data as feedback on their performance, which may be used for further evaluations. There are two different methods of developing labour productivity standards, estimation and improvement purposes. Estimation based standards rely on the assessment of historical data to establish man-hour requirements for specific type of construction activity whilst improvement-based standards involve dividing the complex construction work processes into small controllable activities and evaluating these activities for the amount of time needed to complete the respective construction work processes (Gilleard 1992). There are four productivity measurement approaches frequently utilised for measuring construction labour productivity in projects. These approaches are activity sampling, time study, questionnaire survey, and delay surveys.

1.4.1. Activity sampling:

Activity sampling is a procedure in which a large number of direct observations of workers are made over a period of time. Each observation registers what is happening at that moment of an activity progress and the percentage of observations or delay is recorded for the same and this determines the percentage of time when the activity or delay occurs (Thomas et al. 1984; Thomas 1991). This method provides necessary data to define the time spent by the worker, find the issue regarding delay in work, and establish a base line measure for productivity growth. The main advantage of using this approach is that it allows a great number of workers to be observed at a time that can be carried out using continuous time data recording. This gives wider essence of the productivity of a particular task that is acquired from a more focussed but continuous study on a limited crew (Pilcher 1992). This concept is mainly based on two facts; the first fact is that a working task is divided into three parts: productive work, supporting work, and unproductive work time (Handa and Abdalia 1989; Oglesby 1989). Productive work time is that time which is directly involved in the actual process of a construction activity. Supporting work time involves performing contributing work that are indirectly required to finish the activity. Unproductive work time means idle time which is not useful to the activity. The second fact is the small number of possible events that tends to form the same output model as the whole activity operation. Thus, this approach is a mathematical method thoroughly coupled with probability and statistics (Ralph 1980).

1.4.2. Time study:

A fundamental approach to productivity development presented by Taylor and Gilbreth, is the standard technique of work measurement since ages (Olomolaiye et al. 1998). This method is used to establish the time needed by a well experienced person working at regular speed to perform a particular task (Ralph 1980). Therefore, this technique involves: acquaintance with the task to be observed; finding out the time consumed from various tasks; assessment of observed labour by rating in regard to norm; and developing time standards with appropriate allowances and relaxations (Pilcher 1997; Kaming et al. 1997). Time study offers a rational base for estimating and managing labour productivity. It can aid in productivity growth by allocating standards against performances that were planned, supervised and improved (Armstrong 2006). The complexity in utilizing the time study approach for construction labour productivity investigations in developing countries like India is the lack of practice in construction industry (Armstrong 2006).

1.4.3. Questionnaire survey:

Questionnaire surveys from construction personnel were used to study the factors that adversely affect labour productivity. The approach typically requires workers to avoid or eliminate loss of time due to various obstacles, ranking the significance of the factors and suggest possible solutions to increase productivity (Olomolaiye et al. 1998). The questions prepared in the questionnaire were usually related to specific type of construction project.

1.4.4. Delay surveys

This is a method in which labour productivity issues are exposed by foremen through the identification of reasons for delay and quantifying them regularly. The main objective of this approach is to emphasize issues that are outside the control of supervisor or foreman in the construction projects (Handa and Abdalia 1989; Oglesby 1989).

1.5. Importance of human physical strength in construction productivity

Physical efficiency with regard to the workers physical strength can be measured by human physical parameters. Human physical strength is taken as an indicator to quantify workers' strength in performing continuous tasks which in turn aids in estimating the construction labour productivity. Physically demanding activities require certain amount of physical strength which can be measured by these human physical parameters. Though the past studies have explained the relationship between labour productivity and physical strain in order to overcome the safety and human fatigue during work process, assessment of labour productivity with respect to human strength has not been studied. The concepts presented so far were based on improving/monitoring the worker performance from physiological parameters such as:

1. Variation in work performance due to decrease in human ability to carry out the work. (Oglesby et. al., 1989)
2. Worker fatigue which will decrease the performance of worker. (Abdelhamid and Everett, 1999)

Researchers in the past have inferred that the performance of labour is influenced by physical strain or capacity to do work (Oglesby et al., 1989; Abdelhamid and Everett, 2002). A relationship between worker's physical strain and construction task productivity of labour is developed (Umberto et. al., 2013). Similarly, past studies were focused on human factors such as ability to do work, physical fatigue and physical strain which depended on human efficiency i.e., physical strength. Numerous studies in the past utilized various human parameters such as age, BMI, isometric strength tests, heart rate, relative heart rate, oxygen intake and calorie count to assess the labour productivity thereby increasing the productivity growth.

1.6. Thesis organization

The chapters presented in this thesis are organized as follows. Chapter 1 gives the introduction of the study. Chapter 2 exhibits preliminary study findings. Chapter 3 communicates literature review. Chapter 4 states the objectives. Chapter 5 illustrates the case study conducted to collect masonry labour data. Chapter 6 presents the statistical analysis of the collected labour data from the case study. Chapter 7 determines the relationship between human physical parameters and MLP. Chapter 8 validates the research model and Chapter 9 concludes the thesis and provides recommendations for future research.

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Chapter - 02

2. Preliminary Study

2.1 General

Construction enterprises are one of the major industries in India that engage about 50-100 million workers throughout the country. Most of these workers were temporarily hired to work in various parts of the country. Workers usually migrate from their home state to various other states in the country. Workers employed on farms move to construction industry during off season in search of jobs (Doddamani, 2014). Construction industry is the most disorganized sector and consists mainly of unskilled labour. From both human energy and mental skills, labour is an important factor in producing the economic output of a construction firm. The price for the labour is paid on the basis of man-days produced which can also be defined as productivity of labour with respect to cost. Man-days were standardized as labour output constants (LOCs) for building works in IS-7272 part I (2010) which globally applies to all parts of the country. Also, these constants were developed based on the survey conducted on building constructions up to 10m height four decades ago (IS 7272, 2010). This standard is still referred by various construction organizations for arriving at the unit rates of particular building construction activities. On the other hand, Departments of States such as Telangana State (TS) were following their own LOCs.

An illustration of brickwork construction activity is taken to study the varying LOCs in Standard Schedule of Rates (SSR) of national and state construction public organisations and compared with IS 7272. SSR contains various construction activities with respective standard rates required to prepare the bill of quantities for any project to be carried out by the contractor. Rate for each activity includes labour, material, plant, overhead and profit. For labour cost, labour output value for a particular item is multiplied by respective skill rates. This shows that determination of LOCs is very important for making project cost estimations in the construction projects.

In construction industry, labour productivity is the most important aspect that influences the performance of any construction firm (Investopedia, 2017). Therefore, LOCs play a significant role in creating the benchmark for various construction activities, particularly labour-intensive activities (i.e., masonry construction activities). MLP problems are usually associated with the performance of workers involved with various masonry tasks on construction site. The performance of labour is primly influenced by factors such as time, cost, and quality of the construction projects (Ulubeyli et.al., 2014). A precise assessment of factors influencing MLP will enable in properly allocating available resources, provide workers who enjoy support and help in the improvement of construction labour productivity. Assessment of labour issues on construction site considering the influence of crucial MLP factors will assist construction engineers, supervisors and managers in making timely decisions in construction projects. This chapter explains the variation of LOCs for a masonry activity (i.e., brickwork) as from different organizational standards and analysis of significant factors influencing the MLP in building construction projects in India.

2.2 Comparison of labour output constants in India

Various types of workers were employed for particular activities to be carried out in a construction project. Workers were categorized based on their skills required for a particular construction activity. Each construction activity also includes various semi-skilled works and operational works associated with construction equipment such as miller, vibrator etc. LOCs for various construction activities involves both human skills and machinery operations to estimate and manage labour productivity. Finding out these parameters is a periodical process which is to be carried out individually for different construction activities to arrive at respective LOCs. Major building construction activities such as excavation, brickwork, plastering, concreting have different LOCs assigned with various skills/jobs including men and machinery, namely mason, mazdoor/beldar, bhisti, mixer, mixer operator, vibrator etc.

Apart from IS 7272, various state and national level construction organizations in India were following their own LOCs. For the purpose of comparing the variations in labour productivity parameters, brickwork item is chosen from Telangana State Standard Data (TSSD) and Delhi Schedule of Rates (DSR) 2016 by Central Public Works Department (CPWD). LOCs for one cubic meter of brick wall construction activity of varying thickness from TSSD, DSR and IS 7272 is given in Table 2.1. Both skilled and unskilled LOCs are given in Table 2.1. Skilled labour includes the sum of man days of major work contributors such as mason, 1st class and 2nd class mason whereas, unskilled labour is the sum of man days of all workers involved in contributory work such as mazdoor, beldar, bhisti, coolie and mate.

It is noted that for a given thickness of wall construction, TSSD adopted the same LOCs (skilled and unskilled) for both modular and non-modular bricks at above and below the plinth level of a building, whereas, DAR have varying constants for the respective item. IS 7272 had a common constant for each thickness of wall construction without further divisions based on type of brick or construction at varying heights in the building. For single brick wall (230mm) and more than one brick wall (300mm), both DAR and TSSD have the same labour productivity parameters (Skilled and Unskilled). IS 7272 has different LOCs for varying the thicknesses of wall. The value of LOCs for both skilled and unskilled of IS 7272 for single brick wall is greater than both the national and state level department standards i.e., DAR and TSSD, whereas for half brick wall, TSSD has the highest value.

Table 2.1 LOCs per one cum of brickwork from various standard manuals

Brick Work Items (per one cum)	IS 7272	DAR	TSSD
For Skilled Labour			
300mm thick wall	0.94		
Non-modular (<= plinth level)		0.72	0.80
Modular (<= plinth level)		0.66	0.80
Non-modular (>plinth level, <5 floors)		0.94	0.80
Modular (>plinth level, <5 floors)		0.88	0.80
230mm thick wall	1.09*		
Non-modular (<= plinth level)		0.72	0.80
Modular (<= plinth level)		0.66	0.80
Non-modular (>plinth level, <5 floors)		0.94	0.80
Modular (>plinth level, <5 floors)		0.88	0.80
115mm thick wall	1.04*		
Non-modular (<= plinth level)		0.90	1.20
Non-modular (>plinth level, <5 floors)		1.20	1.20
For Unskilled Labour			
300mm thick wall	2.00		
Non-modular (<= plinth level)		1.57	1.89
Modular (<= plinth level)		1.18	1.89
Non-modular (>plinth level, <5 floors)		2.00	1.89
Modular (>plinth level, <5 floors)		1.61	1.89
230mm thick wall	2.17*		
Non-modular (<= plinth level)		1.57	1.89
Modular (<= plinth level)		1.18	1.89
Non-modular (>plinth level, <5 floors)		2.00	1.89
Modular (>plinth level, <5 floors)		1.61	1.89
115mm thick wall	2.35*		
Non-modular (<= plinth level)		2.25	2.75
Non-modular (>plinth level, <5 floors)		2.70	2.75

*Converted value (actual value given in IS7272 is for one square metre of work)

Labour productivity in construction industry is considered as the main value-adding function. Varying LOCs are the clear indication of changes in construction labour productivity estimations among different regions in the country. Varying LOCs of similar construction items shows that labour productivity cannot be taken as an absolute value. Therefore, various significant factors influencing MLP in India need to be researched. Also, there is a need for continuous coordination among different construction organisations in India to ascertain the data responsible for productivity parameters.

2.3 Analysis of significant factors influencing MLP in building construction projects in India

Manpower resource being one of the major elements, it is most varying and uncontrollable in the construction productivity (Kazaz and Ulubeyli, 2007). Sheer performance of construction workers is the reason for underlying influences that considerably determine the productivity of any project. A developing country like India with sizeable manpower resource still faces labour issues such as low skill, low quality workmanship and work delays in the construction industry. Research on task level labour productivity issues in Indian construction industry is very limited and needs to be focussed. Alagbhari et al. (2019) adopted the Relative Importance Index (RII) method to provide researchers with useful knowledge of factors affecting labour productivity in Yemen. The present study employs the same technique in identification of factors affecting MLP in building construction projects in TS in India. The study was carried out from data collected through questionnaire and ranked using RII method. However, various people targeted for collecting the responses may have different perceptions/opinions, which may make it impossible to have absolute ranking of factors.

This part of the study finds factors affecting MLP and ranking them so as to observe major issues related to productivity of masonry labour in building construction projects in India. Since the aim is to rank significant MLP factors, low significant factors which were identified from the past studies were not included. All the identified factors were predefined and so their integrity was not tested.

2.3.1 Background

Several factors affecting labour productivity in construction industry have been identified in earlier studies (Thomas and Sudhakumar 2013; Soham and Rajiv 2013; Kaming et al. 1997; Alaghbari et al. 2019; Jarkas 2015; Jarkas et al. 2012; Kadir et al. 2005; Hickson and Ellis 2014; Jarkas et al. 2015; Gohary and Aziz 2013; Enshassi 2007; Gundecha 2012; Herbsman and Ellis 1990; Jarkas and Bitar 2011; Jarkas and Radosavljevic 2012; Kazaz et al. 2008; Khan et al. 2013; Makulsawatudom 2004; Olomolaive et al. 1987; Alwi 2003; Whitehead 1995). Factors surveyed globally and published in reputed international journals have been identified and considered for the present study. Thomas and Sudhakumar (2013) conducted a survey and analysed key factors affecting labour productivity in construction in Kerala, India and found that material availability was the most crucial factor affecting construction productivity. To bring about awareness and fill the gap in knowledge of factors affecting labour productivity in construction industry, Alagbhari et al. (2017), Jarkas (2015) and Jarkas et al. (2012) conducted questionnaire surveys in the Middle East in Yemen, Bahrain and Qatar respectively. A survey conducted by Kadir et al. (2005) collected information about factors affecting labour productivity for Malaysian residential building construction projects in which respondents were requested to specify importance of each item in a list of 50 project specific factors. In this study, material shortage was found to be the important and most frequent factor with highest severity index among all factors. The analysis of factor affecting labour productivity was carried out in Trinidad and Tobago, which contained ranking of forty-two predefined factors that were distributed into four categories, such as management, technological, human/labour and external factors (Hickson and Ellis 2014). The relative importance of indices was determined and these factors were ranked. Respondents were requested to give their score to all factors using an effect level ranging from 1 to 4 where 1 represents least effect and 4 represents most effect on labour productivity. In the same manner, a survey was conducted in Oman comprising thirty-three labour productivity factors identified and ranked in terms of their importance (Jarkas et al. 2015). Probabilistic sampling method was used in order to achieve a statistically representative sample of the population, and the data recorded were analysed by RII technique in Oman, Trinidad and Tobago (Hickson and Ellis 2014; Jarkas et al. 2015). Mahamid (2013) analysed thirty-one factors classified into five groups affecting labour productivity in building construction in Palestine from the contractor's perspective, through a structured questionnaire survey. Naoum and Hackman, (1996) conducted a questionnaire survey to find significant differences in opinions between office level and site level on factors that affect construction productivity. Another survey was conducted with construction personnel by Hanna and Heale (1994) to gauge the opinion on the construction field, with regard to precise data regarding factors that mainly affect construction productivity. From this analysis, a set of complete factors were recognized and categorized into six groups, such as contract work environment, planning, site level management, working conditions, working hours, and motivation. In this research, labour skill, communication, timeliness and crew supplies were found major factors affecting the construction productivity.

From relevant research carried out in the past, factors that are repeatedly found were constantly associated with poor productivity issues. It is noted from various studies that factors affecting labour productivity were interdependent and couldn't be controlled completely. Therefore, construction firms need to direct their projects towards better management and provide a healthy environment to the work force. Many of the construction companies in India are still oblivious to poor labour performance. Research in this area must be carried out to obtain relevant data deficiencies and remedy the situation.

2.3.2 Method of study

The method adopted in the present study was based on literature review and the main tool of collecting data from construction personnel was a structured questionnaire survey. Survey method was best suited for collecting data on factors that require identification by rating. The purpose of the survey was to analyse the perceptions of construction personnel on the severity of the factors affecting MLP in building projects. A detailed questionnaire was prepared to evaluate the forty-four factors affecting labour productivity which were adopted from past studies mentioned in literature review (Appendix I). Initially a pilot study was conducted with eighteen construction managers and thirty-eight predefined factors shortlisted for the survey. The survey format was divided into two sections. One section contains the general information of respondent and the other section includes thirty-eight factors adversely affecting MLP. These factors were then categorized into five groups: work force, management team, working condition, material and equipment, and unforeseen and unfamiliar factors. Each of these groups with various factors affecting MLP in building construction projects are listed in Table 2.2.

A total of 330 respondents working in various construction projects were contacted in TS in India and invited to take part in the survey through electronic mails. The respondents were selected such that they were expected to possess relevant experience of at least one complete project or minimum of 5 years in construction projects in India. Sample size of the data was determined by probabilistic sampling method (Hogg and Tanis 2009). Sample size is given by:

$$n = \frac{m}{1 + (\frac{m-1}{N})}$$

n =sample size required,

N =total size of population,

m =unlimited population,

$$m = \frac{z^2 p(1-p)}{\varepsilon^2}$$

p = 0.5 (population proportion) (Sincich et al. 2001),

ε = 5% sampling error,

z = 1.96 (statistical value of 95% confidence level taken);

Table 2.2 Factors affecting MLP in building construction in India

S.No	Categories	Nos	Description of Factors
1	Work force	10	Lack of skill and experience of workers (El-Gohary and Aziz 2014), lack of empowerment (Gopal & Murali 2016), high workforce absenteeism / turnover (Loganathan and Kalidindi 2016), physical performance and fatigue (Zhang et al. 2015), low labour morale/ commitment (Karim et al. 2013), poor relation among workers (Gopal & Murali 2016), low amount of pay (Tahir et al. 2015), little or no financial rewards (El-Gohary and Aziz 2014), lack of labour recognition program (Rahman et al. 2019) and payment delay (Hafez et al. 2014).
2	Management team	10	Bad leadership skill (El-Gohary and Aziz 2014), poor relation between workers and superintendent (Tahir et al. 2015), lack of labour surveillance (Gopal & Murali 2016), lack of periodic meeting with labour (Jarkas et al. 2012), poor or no supervision method (Jarkas 2015), incompetent supervisors (Makulsawatudom et al. 2004), incomplete / revise drawings (Makulsawatudom et al. 2004), inspection delay (Gopal & Murali 2016), variations/change orders during execution (Tahir et al. 2015) and method of construction (Alinaitwe et al. 2007)
3	Working condition	10	Working 7days per week (Tahir et al. 2015), frequency of working overtime (Mei 2006), poor work planning (Gopal & Murali 2016), unrealistic scheduling (Hickson and Ellis 2014), labour interface and congestion (Olomolaiye et al. 1987), design complexity (Jarkas and Bitar 2012), accidents (Van 2018), unsafe working conditions (Abrey and Smallwood 2014), inadequate safety plan (Enshassi 2007), working at heights (Robles et al. 2014)
4	Material and equipment	4	Material shortages (Kadir et al. 2005), unsuitable material locations (Tahir et al. 2015), equipment and tools shortages (Mahamid et al. 2013), poor condition of tools and equipment (Mahamid et al. 2013).

5	Unforeseen &unfamiliar factors	4	Rework (Olomolaiye et al. 1987), use of information and communication technologies (Hickson and Ellis 2014), weather conditions (El-Gohary and Aziz 2014) and stringent inspection (Gupta and Kansal 2014)

The size of unlimited population and required sample size was calculated using above formulae and it was found to be 384 and 178 population respectively. Sixty-seven percent i.e., 120 responses were collected in total (Appendix I). Respondents include consultants from educational institutes (11.67%), clients from various government organizations (11.67%), contracting firms (31.66%) and private construction builders (45%) in TS (Figure 2.1). Though the respondents are presently working in TS, much of their past experience was also in different parts of India. Therefore, the results of the survey received from the respondents were adequate to identify the influence of MLP factors in building construction projects in India.

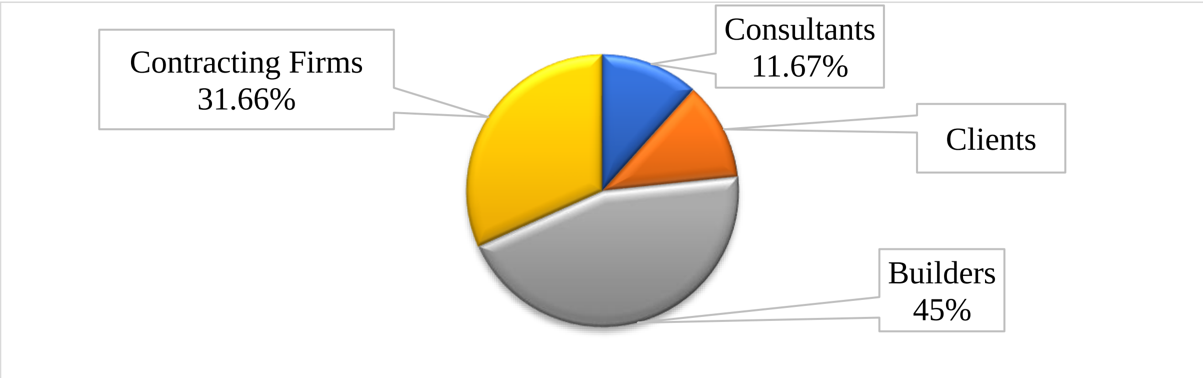

Figure 2.1 Percent of various respondents in the questionnaire survey

Respondents were asked to rate MLP factors listed in Table 2.2, taking various parameters into account, such as time, cost, and quality based on their own experiences. For this study, Likert scale was used to evaluate the individual´s performance or opinion of the given queries. Respondents gave their opinion on factors affecting MLP in building construction projects on a scale from “1,” very low; “2,” low; “3,” moderate; “4,” high to “5,” very high. RII technique was used for ranking of factors from the survey given by various respondents. RII can be calculated using the following equation

$$\mathbf{RII} = \frac{\sum_{i=1}^{n}(w_i x_i)}{\mathbf{AN}}$$

Where, ‘w’ is the weight assigned by respondent (1 to 5), x’ is frequency of each weightage, A is the highest weight and N is the no of respondents participated in the survey.

The higher the RII value, the more important was the influence of factors. Those respondents who handed in an incomplete questionnaire or did not use Likert scale judiciously would not be considered (Johnson and LeBreton 2004). RII technique proved to be suitable for respondent satisfaction ratings and hence adopted for the study. Data analysis was carried out and ranked using spread sheet software.

2.3.3 RII of MLP Factors

Forty-four factors that affect MLP in building construction project sites in India were examined. A total of 38 pre-defined factors were selected and divided into five categories as shown in Table 2.2. Using RII method, the influence of each factor in building construction projects was determined. Factors were ranked based on RII values and denoted by 'R' in which highest value indicated the highest rank among the various MLP factors considered in the study.

RII of factors of overall MLP factors were shown in Table 2.3. Factors such as poor relation among the workers, between workers and supervisors, accidents and unsafe work conditions with RII value equal to the threshold value (i.e., RII=0.8) were also equally significant to improve the MLP on construction site. The categories such as material and equipment factors, unforeseen and unfamiliar factors did not meet the threshold limit of RII taken for the study. RII of factors from above categories such as poor condition of equipment and tools, shortages of materials, weather condition, stringent inspection and rework is greater than or equal to 0.75. Even though these categories did not meet the tolerance of 0.8, three out of four factors in each category were considerably significant.

Ranking of MLP categories with the percentage of their average RII is shown in the above Table 2.3. Average percentage of RII for the Work force category indicated the highest among the five categories with a score of 78.40. This highlighted that the factors under workforce category is important in affecting the MLP in building construction project sites. This result corroborated with the findings of Soham and Rajiv, 2013. The usual prediction is that more efficient workers with good skill and experience show better productivity. Both the management team and working condition holds the next highest with recorded RII score of 74.70. At masonry level productivity, it is clearly observed that material and equipment show low significance when relatively compared to other factors. But the same category is primarily important when productivity was observed at industry or company level (Thomas and Sudhakumar 2013). Management team needs to plan and coordinate the projects with good leadership. Proper attention is required to provide better working conditions to achieve maximum MLP

Table 2.3 Relative Important Indices of MLP factors

S. No	MLP Factors	w_i 1	2	3	4	5	$\sum \frac{w_i}{x_i}$	RII	RII Avg
A	**Work Force**	x_i							**78.4**
1	Lack of skill and experience	0	1	12	10	21	183	0.83	
2	Physical Performance and Fatigue	1	0	9	19	15	179	0.81	
3	Poor relation among workers	0	3	11	14	16	175	0.80	
4	High workforce absenteeism	1	1	13	14	15	173	0.79	
5	Payment delay	1	4	6	19	14	173	0.79	
6	Lack of empowerment	0	0	14	20	10	172	0.78	
7	Low labour morale	0	4	13	12	15	170	0.77	
8	Little or no financial rewards	0	6	6	20	12	170	0.77	
9	Low amount of pay	2	4	12	11	15	165	0.75	
10	Lack of labour recognition problem	0	9	9	11	15	164	0.75	
B	**Management Team**								**74.7**
11	Poor or no supervision method	0	4	4	20	16	180	0.82	
12	Poor relation between labour and superintend	0	3	8	18	15	177	0.80	
13	Bad leadership skill	0	5	4	24	11	173	0.79	
14	Incompetent supervisors	0	2	8	27	7	171	0.78	
15	Lack of labour surveillance	1	2	10	22	9	168	0.76	
16	Change order during execution	0	7	8	22	7	161	0.73	
17	Method of construction	2	5	11	16	10	159	0.72	
18	Incomplete drawings	2	4	7	30	1	156	0.71	
19	Inspection delay	2	4	13	18	7	156	0.71	
20	Lack of periodic meeting	2	8	17	11	6	143	0.65	
C	**Working Condition**								**74.7**
21	Poor work planning	0	0	6	26	12	182	0.83	
22	Unrealistic scheduling	0	4	4	20	16	180	0.82	
23	Accidents	1	1	9	19	14	176	0.80	
24	Unsafe working conditions	1	3	5	21	14	176	0.80	
25	Working 7days per week	5	4	6	7	22	169	0.77	
26	Inadequate safety plan	1	5	10	19	9	162	0.74	
27	Frequency of working overtime	2	4	11	18	9	160	0.73	

28	Design complexity	0	5	17	19	3	152	0.69	
29	Working at heights	4	3	15	18	4	147	0.67	
30	Labour interface and congestion	2	8	19	14	1	136	0.62	
D	**Material and Equipment**								**73.3**
31	Poor condition of equipment	2	2	11	15	14	169	0.77	
32	Material shortages	4	2	8	15	15	167	0.76	
33	Equipment and tools shortages	0	7	6	23	8	164	0.75	
34	Unsuitable material storage	4	8	7	23	2	143	0.65	
E	**Unforeseen and Unfamiliar**								**74.3**
35	Weather conditions	0	0	16	16	12	172	0.78	
36	Stringent inspection	2	2	10	18	12	168	0.76	
37	Rework	0	2	14	22	6	164	0.75	
38	Use of information and communication technologies	2	8	11	17	6	149	0.68	

2.3.4 Summary

This study ranked in relative terms with the factors that affect MLP in building construction sites in India. There is a short fall of MLP in building construction projects and requires proper assessment measures in India. The focus towards the shortcomings and assessment of their effect could support building construction firms in solving MLP issues. Finding out the major factors affecting the construction labour productivity contributes to Indian construction industry positively and that formed the basis of the present study.

Data collected from the respondents with the help of questionnaire survey method was further simplified on ranking them using RII method. Ranking the responses using RII method designated top five prominent MLP factors namely, lack of skill and experience of worker, poor work planning, poor or no supervision method, unrealistic scheduling, physical performance and fatigue which are responsible for adverse effects in the building construction projects in India.

Three out of five factors such as poor work planning, poor or no supervision method and unrealistic scheduling are related to construction management. The other two factors such as expertise and efficiency of workers are related to instinctive physical performance on the construction project sites. These two factors can be taken as good predictors in productivity assessment or valuation from management level and reduce poor performance of workers. This presents good opportunity in research on construction workers i.e., human related factors which help in assessing their skill and performance on site.

2.4 Development of research area

The first part of this preliminary study is focussed on varying LOCs adopted for similar activities such as brickwork among the different central and state building works department standards in India including IS code. These constants were formed considering many construction labour productivity factors using work measurement techniques. Variations in these constants show that there is a need for coordination in collection of reliable data required for certain labour related measurements, which apparently is not possible in densely populated countries like India. From the variations and no periodical revisions from the ages, these LOCs were questionable for real time field construction labour productivity assessments.

A scientific method with major labour productivity governing factor will hold good for realistic assessment on project sites. The physical performance of labour and fatigue being among the top-rated influencing factors, these can be utilized in developing a scientific method for the assessment of labour performance. Therefore, present research area is focussed on developing a scientific approach which can be carried out in real time field for assessing labour productivity. The outcome of this research is expected to become a universal methodology that can be applied globally in the construction industry. For the purpose of case study, the present research area is specifically focused on masonry labour construction. An investigation on masonry workers in real time building construction projects was carried out in India.

Chapter-3

3. Literature Review

3.1 General

This chapter presents numerous aspects collated from various fields of study, such as human factors and construction labour productivity. While exploring relevant research topics, it was clear that research in this area is comparatively new and there is not much material available, there are nevertheless ample research papers to help the researcher frame objectives of the study. The topics with regard to the objectives of the present study are explained in the following sections.

3.2 Importance of human physical strength on labour productivity

Workforce related activities such as masonry works in building construction projects involves physically demanding tasks often performed in harsh conditions (Abdelhamid & Everett, 1999, 2002; Imbeau et al., 1995; Koningsveld & Molen, 1997). Usually, activities on construction sites comprise pushing, pulling, powerful exertions, carrying, heavy lifting, loadings, repetitive actions, vibrations, and uncomfortable work postures (Damlunda et al. 1986; Hartmann and Fleischer 2005; Schneider and Susi 1994).

Researchers in the past determined that there exists is a reciprocal relationship between physical strength of workers and their productivity (Abdelhamid & Everett, 1999, 2002; P. Astrand et al., 2003; Bouchard & Trudeau, 2008; Brouha, 1967; Edwards, 1972; Garet et al., 2005; Nechaev, 2001; Oglesby et al., 1989; Ramsey et al., 1983). These authors specifically suggest that physically demanding tasks can negatively affect labour productivity and quality of work due to decrease in capacity of workers to do muscular work because of increased fatigue. Decrease in performance of worker due to fatigue is broadly accepted (Abdelhamid & Everett, 1999). In case of physically demanding work, measuring the energy expenditure of worker can help to assess task intensity and establish a threshold of worker physical strength" (Bouchard & Trudeau, 2008).

3.2.1 Human factors in construction labour productivity

The concept of human factors is the scientific discipline involved in understanding the elements of a human mechanism that applies theoretical concepts, principles, information and techniques to evaluate overall human performance (IEA, 2011). Researchers effectively utilized principles of human factors in most activities to improve workers' performance. Hess, Hecker, Weinstein, and Lunger (2004) introduced human factors to reduce the risk of low-back disorder risk among masonry workers. Molen et al., (2009) dealt with musculoskeletal ailments in shoulder and low-back for skilled construction workers such as carpenters and pavers. Nevertheless, human factors is a vast area of research that covers numerous topics such as material handling techniques and analysis of working postures. Further, human factors are associated with many other disciplines such as physiology, biomechanics, anthropometry, psychology and industrial engineering.

The present study, however, emphases a specific aspect: the measure and analysis of worker physical ability. Therefore, a subject closely related to human factors is considered i.e., work physiology which includes age, body mass index, and assessment of human body muscular strength with regard to manual work (Astrand et al., 2003). Comprehensive knowledge of work physiology of characteristics of the human body is a prerequisite for designing the work performance. Human factors and work physiology represent the basis of present-day work science (Strasser, 2002). Finally, human factors is an area that can aid in improving worker productivity, safety and well-being.

3.2.2 Fatigue, stress and strain in construction labour

Fatigue is an instant of weakness or continuous tiredness which can be mental, physical or sometimes both. It can affect humans, mostly adults, when they have continuous work load. Defining physical fatigue in humans, not surprisingly, set the complex interaction of human body activities, functional phenomena, and behavioural indicators that has challenged researchers over ages (Aaronson et al., 1999). As cited by Astrand et al. (2003), it was even intended to abandon the conception of human fatigue altogether (Petajan, 1996). Regardless of the issues, the theory of physical fatigue is related to muscle strength failure (Berger et a.,1991), or condition of instable homeostasis (Christensen, 1960), which results from excess physical activity (Aaronson et al., 1999).

Work physiology has distinguished between general and muscular fatigue since many years (Astrand et al., 2003; International Labour Organization - ILO, 1983; Lenz et al., 1996). General fatigue in humans, is generally concerned with mental enervation that is described by reluctance to work. Still, many issues in humans can cause general fatigue (Figure 3.1). Instead, fatigue with regard to human muscular exertion is more specific and stated as any workout that can cause decrease in maximum capacity to produce force (Vollestad, 1997). However, it is essential to mention that this concept has its own limitations even after universally acknowledged in academia. For example, physical activity such as monotonous tasks of labour are induced by general fatigue and psychological influences such as motivation and attitude are induced by muscular fatigue. Likewise, this concept gives a critical limitation. Categorizing types of fatigue can be useful from a theoretical point of view but in real life cases, specifically on construction sites two types of human fatigue are generally concurrent and accepted as evidence of physical exhaustion.

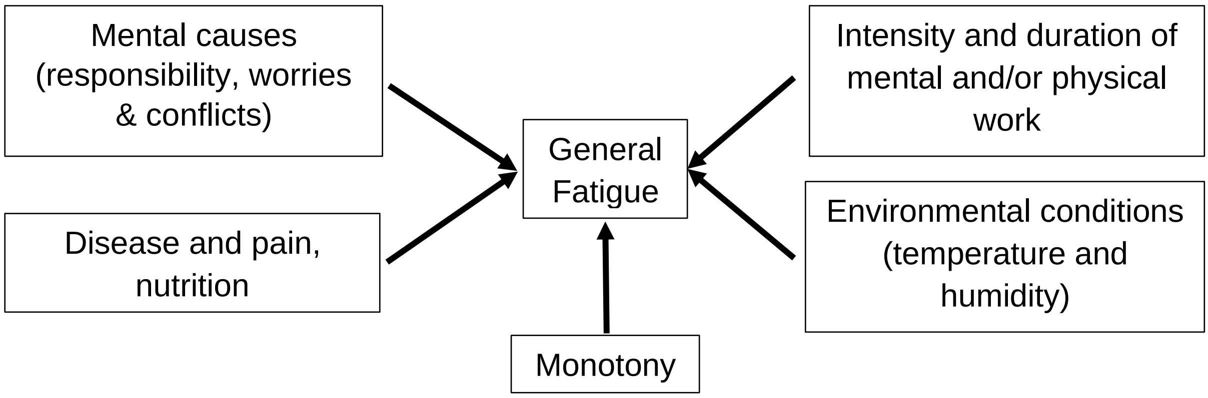

Figure 3.1 Causes for general fatigue in humans. Adopted from ILO (1983)

The concept of human fatigue is correlated with the concepts of physical stress and strain. In general, physical stress and strain concepts are perceived as synonyms. However, these concepts are studied as two different elements of the system (Figure 3.2) which demonstrates the event of fatigue happening (ILO, 1983).

Stress happens when a worker is performing a physical task, where several parameters can distress the worker's condition. These parameters arise from several types of tasks such as muscular and/or mental and environmental and/or social conditions under which this task is executed. Thus, stress is characterized by the sum of any external force or event that is noticed or detected, knowingly or unknowingly, by the human body which has an influence on the body and/or mind. The whole influence of these stress factors depends on intensity and duration.

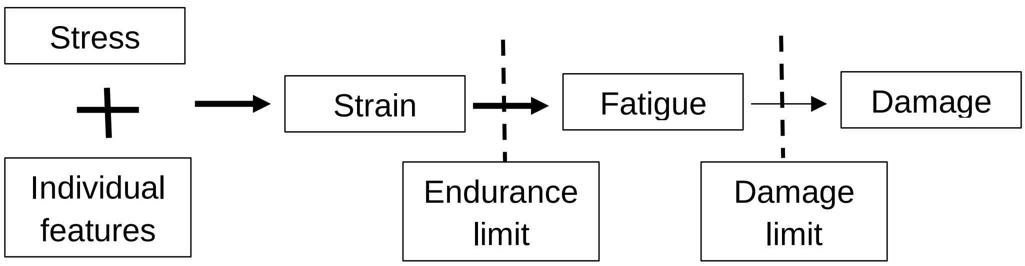

Figure 3.2 Stress, individual features, strain, fatigue and damage Adopted from ILO (1983).

Each one of the stress factors can have a range of influences in different people. This variation is generally due to individual physical features of workers such as experience, skills, muscle strength as well as psychological conditions such as motivation, attentiveness, and self-discipline (Aaronson et.al., 1999)

Strain represents relative changes in body size which is the sum of human body physical reactions performed to counterpoise the stress factors. Generally, certain stress factors are constantly present in the human body and therefore, human body is continuously subjected to a certain level of physical strain. However, it does not involve any physical fatigue as this occurs only after the endurance level of subject is surpassed (i.e., when available resources demand surpassed). Moreover, physical body is damaged (hurts) once the damage level is surpassed. Physical body damage is a failure of physiological reactions. It can be either temporary like exhaustion and subsequent incapability to perform further activity, which can be restored after resting for a period of time or permanent physical damage such as bone fractures, muscle ligament tear etc which need medical treatment to recover.

3.3 Age and Body Mass Index (BMI) on construction labour productivity

Safari et al., 2013 studied the effect of age and BMI on work ability index of industry workers and found the age is the most important factor when compared to BMI. Ability of labour in carrying out work, taking into consideration work severity and physical and mental conditions (Ilmarinen and Rantanen, 1999). Lund et al., (2001) and Berg et al., (2008) stated that underweight as well as obesity compared to normal weight decreases the work ability. Therefore, both these factors can be taken as measurement parameters in assessing the MLP.

Many reasons influence productivity with regard to age of construction labour and these include: experience, cognitive working, education, physical capabilities, physical stamina, health condition, motivation, compatibility with given task, loyalty and personality. In humans, average strength of body muscles decreases approximately 10% per decade for the age group between 20 and 60, (Mazzeo, 2000). Zwart *et al.* (1995) explained that aerobic capability of 20s will be the highest and thereby decreases 1% for every year. Flexibility of workers declines with increase in age, making it tough to take up certain working postures (Bosek *et al.*, 2005).

The process of aging in humans leads to distinct body muscle mass and physical strength loss (Keller and Engelhardt, 2013). The functional changes of human body occur due to aging process which can negatively influence the physical fitness. Muscle mass is one of the most notable changes among the functional changes of human body. As the aging process advances, physical fitness of human body will be reduced causing difficulties in performing daily activities (Tuna et.al., 2009). Van and Stoeldraijer (2010) found that labour between the age of 30 and 45 has higher productivity while the younger and older labour has comparatively low productivity. Workers below 25 were found to have the lowest productivity. There was a clear bell shape relationship between age and productivity of labour (Van and Stoeldraijer, 2010). Bukit et al., 2018 explains that neither age nor experience individually has significant effect on labour productivity. However, a combination of both age and experience gives interesting results in that labour with more experience perform well even though that they are younger in age.

Rating of labour productivity based on age factor does not give valid conclusions due to the following reasons: construction managers imagine that workers have equal capabilities in performing work within the same age group while overall work capability decreases with age; opinion ratings from the respondents can be biased. For example, evaluation of older age workers will be overstated due to the worker's loyalty and past achievement. Discriminatory behaviour of construction managers on older or younger workers also affects productivity (Levy, 2003; Salthouse and Maurer, 1996).

Assessing the influence of worker's age on labour productivity is sometimes based on work output. Researches based on this concept established that older workers have lower productivity. U.S. department of labour (1957) studied several industries and found that labour productivity increases until the age of 35 and subsequently decreases.

BMI is the metric used for defining anthropometric height/weight characteristics of humans and for classifying humans into groups. Generally, BMI is that which represents an index of an individual's body fatness (Nuttall, 2015). BMI has been useful in population-based studies by virtue of its wide acceptance in defining specific categories of body mass. BMI is calculated by dividing the body mass to the square of the height of a person. BMI is usually expressed in kg/m2. BMI is not a constant human parameter; it may increase or decrease with respect to age. However, it depends only on change in weight of an adult person. The most commonly used classification of BMI for adults aged 20 and above as per World Health Organisation (WHO) is as shown below (Table 3.1).

Table 3.1 BMI Classification as per WHO

BMI (kg/m^2)	Categorization
<18.5	Under Weight
18.5-24.9	Normal Weight
25-29.9	Over Weight
30-34.9	Class I Obesity
35-39.9	Class II Obesity
>=40	Class III Obesity

Even if one utilized the BMI or simply the ratio of body weight to height, population distribution is not Gaussian. In other words, BMI distribution is always skewed to the right but not symmetrical, specifically on a higher ratio of body weight to height. The distribution of BMIs in adult men and women is presented in Figure 3.3 (Flegal 1998).

As BMI improves with aging, physical strength, stamina, balance and aerobic endurance get worse in older people. However, more activeness in elderly people is beneficial with regard to BMI (Tuna et al. 2009). The connection between BMI and human performance was non-linear, with worse performance mainly noticed in overweight people, and also some signs of poor performance in underweight people (Hardy et al. 2013).

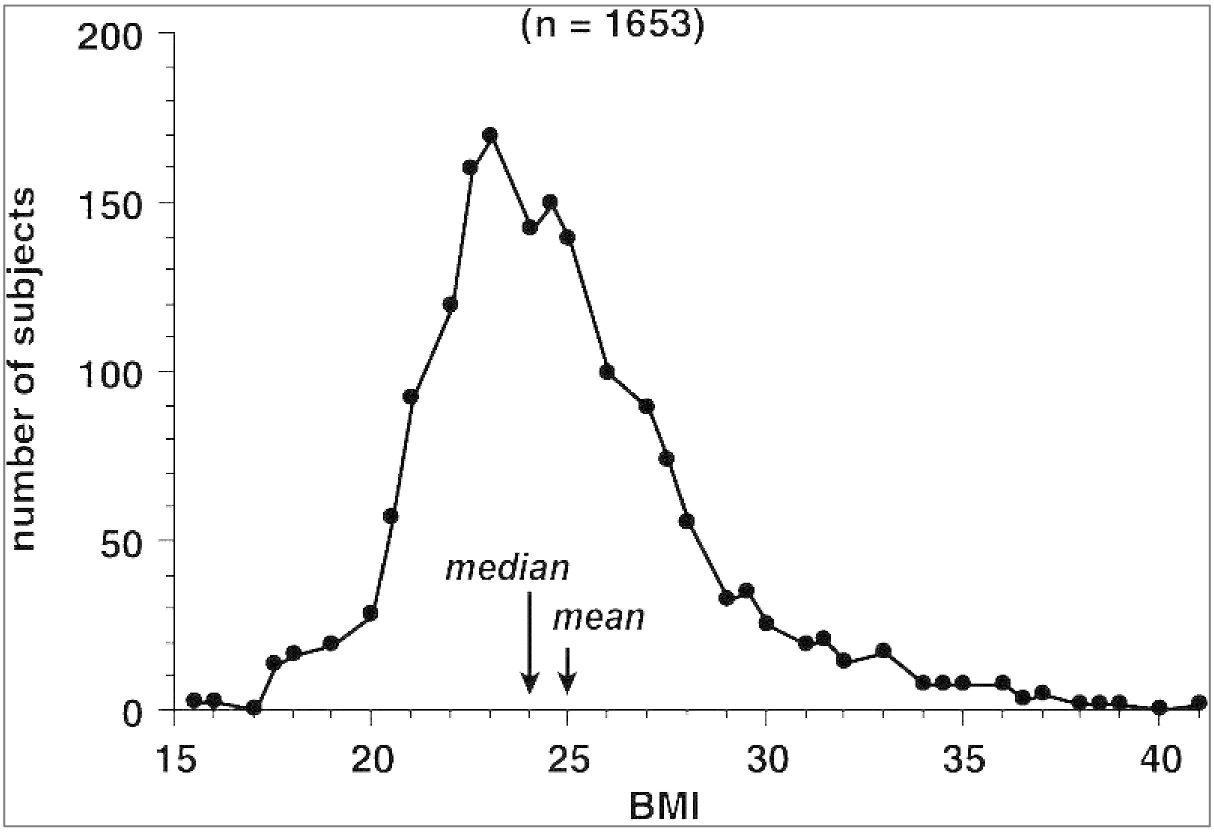

Figure 3.3 Distribution of BMI in adult American men and women (Nuttall, 2015)

3.4 Human muscular strength measurement

Human body muscles are made of contractile tissue and are mainly responsible for letting humans perform certain required works. Muscular strength tends to produce force and cause activity. Therefore, human muscles were able to perform several types of work. In general, muscular strength measurement was categorized in two types of works: dynamic (Isotonic strength) and static (Isometric strength). Muscular strength has been described as the maximum force (in N) achieved from maximum voluntary contraction under a given set of conditions (Sale, 1991).

A variety of methods were established in application to test the muscular strength of humans. Generally, various kinds of dynamometers were used in measuring the maximum force of human muscles (Jaric et al., 2002; Murphy et al., 1994; Pfeifer and Banzer, 1999; Pryor, 1994; Ugarkovic, 2002). Muscular strength is recorded in various contraction regimes, such as applied isometric strength testing (most frequently used), but also the isotonic strength testing which involves both eccentric and concentric contraction regimes. The isotonic strength testing for assessing muscles is usually stipulated by standard isokinetic equipment that lays down well-organized mechanical conditions for muscle contractions. Besides maximum force, some strength tests include 'rate of force development' that denotes the power of muscles to apply the average force in shortest possible time (Abernethy, 1995; Wilson and Murphy, 1996; Murphy et al., 1994; Pryor, 1994; Viljanen et al.,, 1991; Paasuke et al., 2001; Sleivert et al., 1995; Wisloff et al., 1998).

Usually, muscle strength tests have been performed under certain conditions so that the observed force resulted mainly from the action of a single muscle group. Yet, certain tests from the contraction of given muscle groups of a specific kinetic chain were also considered as human body muscle strength tests. Primarily, the theory of human body muscle strength tests was limited to those based on contraction of a single muscle group i.e., isometric strength tests. The present study proposes to assess muscle strength classifications that could provide the strongest possible relationship with productivity of masonry construction labour.

3.5 Isotonic strength

Isotonic strength test involves muscle contractions that depicts dynamic work of a worker. In this case you apply the same force on load with very smooth movement. There are two contractions in which concentric contractions shorten the muscle and eccentric contractions result in lengthening the muscle. An example of isotonic and isometric muscle contractions of hand bicep muscle is shown in Figure 3.4.

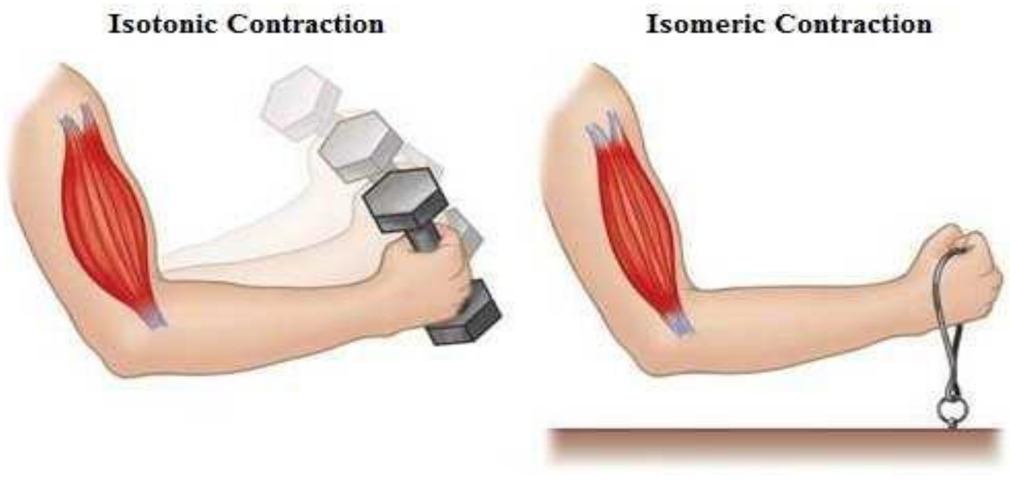

Figure 3.4 Isotonic and isomeric contractions of bicep muscle (Dorland's Medical Dictionary 2007).

These muscle contractions boost metabolic requirements, which are substantiated by rise in the blood flow. The metabolism of human body engages several processes to raise the blood flow such as increase in heart rate, open vessels in muscles and decrease blood flow to indirectly involved body organs. In addition, there will be a raise in rate of respiration with deeper breathing to collect sufficient oxygen to withstand energy metabolism.

3.6 Isometric strength

Isomeric strength test involves muscle contractions that depict the static work of a worker. The word "isometric" means same length. In this case, there will be a muscle contraction, but with no movement (I.e., it happens all the time). Isometric contractions occur due to the elastic qualities of muscle fibres. Ultimately, there is no shortening of muscles as the force is applied in static position. Therefore, this lack of muscle movement along with mechanical compression experienced by cells to generate the required force, impede blood flow.

Thus, the applied static force gets more fatigue than applied dynamic force with regard to same energy output. This is mainly due to the fact that the body muscles can't get sufficient oxygen from the blood. Indeed, there won't be any change in both heart rate and pulmonary ventilation during isomeric contractions. Table 3.2 shows the effects of isotonic and isometric strength tests on heart rate, pulmonary ventilation and blood pressure.

Table 3.2 Effects of isotonic and isometric muscle contractions on heart rate, pulmonary ventilation, and blood pressure.

	Heart rate	Pulmonary ventilation	Blood pressure
Isotonic strength testing	Increase	Increase	Increase
Isometric strength testing	No change	No change	Increase

3.6.1 Hand Grip Strength (HGS)

Hand grip is a measure of the hand and forearm muscles strength which plays an important role in the performance of various activities such as using tools, etc. Force applied by hand to pull the objects is defined as grip strength. The forceful bending and tightening of all finger joints with a great force that a person applied under normal bio kinetic conditions is the power of the grip (Richards et al., (1996); Bohannon, (1997)). HGS is a physical parameter and is influenced by various factors such as age, BMI, etc. Both the right and left HGS are positively interrelated to BMI (Chatterjee and Chowdhuri, 1991). HGS is found to have a positive correlation with body size and physical task, which determines human physical strength. HGS has been used to evaluate the physical strength of the worker to determine his capability to carry out the work. A study on HGS of female construction workers was conducted in India to find the required physical strength to perform various activities (Koley et al., 2009). It was observed that HGS of workers influences work skills. Chilima and Ismail (2001) reported that people with unusual BMI had lower HGS.

The measurement of HGS is most generally carried out using handheld dynamometer. Robson (1998) referred to this method of measurement as biomechanical measurement. These measurements help sports trainers to sense the bioenergetics and efficiency of movements involved in sports. Therefore, while training, they target attain maximum output with minimum energy expenditure, thus avoiding physical fatigue and stress. Handheld dynamometry is used for measuring the grip strength that measures the muscular force of hand and forearm muscles. These hand-held dynamometers are categorized in to three types of compressions: spring-loaded, air, and hydraulic compression devices. According to Waldo (1991), HGS should be measured in kilograms or pounds since grip is a function of force. The measurement of a hydraulic dynamometer gives most accurate results (Waldo, 1991).

There are several variables that need to be controlled when measuring HGS such as time of testing, human posture, anthropometric trials and dynamometer tunings. Goh et al., (2001) performed a study on human performance measurement with handgrip strength in which testing was conducted at different timings throughout the day and determined that HGS changes with time. The study also revealed that HGS increased gradually in day time, but declined at night. Similar results were found by Cappaert (1999) leading to the conclusion that HGS showed better results in day time. He further stated that time differences throughout the day in HGS reflected the differences in muscular strength.

Numerous studies in the past have showed that HGS shows greater values with minimal elbow flexion (Kuzala and Vargo, 1992; Momiyama et al., 2006; Su et al., 1994). Therefore, positioning of elbow and body posture during HGS testing was found to play a vital role in the test results. The standardization of anthropometric measures such as BMI, hand and finger length and perimeter also influence HGS test results (Visnapuu and Jurimae, 2007).

HGS is considered to be a good predictor of overall human body strength, but very little research has been done in correlating HGS and overall human body strength. Direct correlation between HGS and overall human body strength is found in old females and it was revealed that HGS had correlation with overall human body strength in older people (Smith et al., 2006). Fry et al., (2006) also established a correlation between HGS and performance of male population in Junior Weightlifting. Numerous studies also correlated HGS to several human physical variables such as fatigue, overall physical performance and nutritional condition.

3.6.2 Upper Body Muscle Strength (UBMS)

Execution of construction tasks by workers requires bending and twisting of body parts such as back, neck, shoulder and knees. When workers assume a fixed posture for long while performing a task, they suffer from fatigue and lose strength. In case of masonry work, a worker performing a specific construction task uses mostly his upper body for movements. Therefore, UBMS test in various specified postures provide the strength of the worker. These postures require investigation based on observing most repeated motions. Yuan et.al, (2007) describe an integrated approach for ergonomic interventions for construction workers, which involves upper body muscles such as low back and shoulder during wall installation. A hand grip isometric trainer device quantifies UBMS. In this test, muscles in the upper body apply pull/push force through the hand grip.

3.7 Heart Rate (HR)

Assessing physical strength through HR has been successfully employed and verified in numerous laboratory experiments and in-situ studies. There are many limitations reported by researchers in using HR to estimate physical strength (Abdelhamid & Everett, 2002; Aminoff et al., 1998; Astrand, et al., 2003; Bussmann et al., 2000).

Either the use of small muscle (arms) or large muscle (legs) influences the HR with equal amount of workload (Aminoff et al., 1998; Bussmann et al., 2000). It is proven that HR is higher with arm muscles than with leg muscles for the same amount of work load (Astrand et al., 2003). This may be the main limitation when utilizing HR for construction activities where both arms and legs are involved.

Table 3.3 Work severity classification against average HR responses for prolonged physical work load (Astrand et al., 2003)

Average HR (beats/min)	**Work Severity**	**Energy Expenditure**
<90	Light work	Not fatiguing
90-110	Moderate work	Not fatiguing
110-130	Heavy work	Fatiguing
130-150	Very heavy work	Fatiguing
150-170	Extremely heavy work	Fatiguing

However, as most of the construction activities involve dynamic work with continuous shift amongst muscle contractions and relaxations with short-term work efforts, it shows that utilizing observed HR to assess the capability of workers is acceptable even in several work postures engaging arms or small upper body muscle groups (Astrand et al., 2003). Several standards have been classified with regard to physical work load capabilities in terms of average HR as shown below (Table 3.3). However, for a standard workload, HR should not exceed 110 beats/min in one shift (eight hour) for industrial workers (Brouha, 1967).

3.8 Relationship between physical strength and task productivity

Loss of labour productivity in construction on account of worker's physical strain, fatigue and ability is widely accepted (Oglesby et al., 1989; Abdelhamid and Everett, 2002; Umberto et al., 2013; Yung et al., 2017)). Numerous approaches and techniques have been developed to measure the physical strength of industrial workers using various human parameters such as age, BMI (Body Mass Index), heart rate, relative heart rate, breath rate, hand grip strength etc. (Umberto et al., 2013; Yuan et al., 2007), (Koley et al., 2009)). Low physical strength in humans is one of the factors that affects work performance (Astrand et al., 2003). A study on Hand Grip Strength (HGS) of female construction workers was conducted in India to find the required physical strength to perform various activities and based on this, the productivity of these female workers was evaluated (Koley et al., 2009). Chilima and Ismail (2001) reported that people with unusual BMI had lower HGS. Yuan et al., (2007) describe an integrated approach for ergonomic interventions for construction workers, which involve upper body muscles such as low back and shoulder during wall installation. Therefore, physical demands depend mainly upon human physical strength.

According to numerous studies in the field of human factors, there exists a correlation between physical strength and work productivity. Specially, researchers supported the theory that labour-intensive work (i.e., masonry work) is detrimental for construction labour productivity. However, these studies did not clearly validate the concept. Even though the studies were successful in estimating the physical work capabilities, they did not present any relationship between physical strength of labour and productivity. Human fatigue is widely accepted as being responsible for decrease in performance, but no scientific approach is established on how to quantify this decrease (Abdelhamid & Everett, 1999). Indeed, the classifications of work severity based on HR decides the level of severity in work (light, moderate, and heavy) in relation to human physical parameters (i.e., HR) without providing further information on performance of labour.

If there exists a relationship between human physical strength and performance, then it also implies that improvements in the construction labour productivity can be achieved through the assessment of physical abilities of the construction workforce. In particular, worker physical abilities need to be assessed in project sites to effectively manage labour productivity. Generally, the study of human factors measures physical strength abilities on employing one or more human parameters (i.e., Age, BMI, HGS, UBMS and HR). Even though these approaches are successful, earlier studies measuring worker physical demands in construction used certain measuring devices that are difficult to apply on construction sites. Further, there is a need to find an effective approach in collecting physical strength data of workers, that can be employed as standard construction process which also signifies another purpose of the present study.

3.9 Construction labour productivity

Productivity can be defined in many ways. As per the established statistics, productivity is generally specified as ratio of constant value to input efforts (man-hours). In case of the owner of a property or plant or equipment, it is the cost incurred per unit of output achieved by the service. For the contractor, it is the amount of expenditure that may be lower (or higher) than the payment received from the owner (Oglesby et al., 1989). There is no universal agreement with regard to the typical definition as well as standard measurement methods in the construction industry (Crawford & Vogl, 2006; Thomas & Mathews, 1986). This is primarily due to:

- The distinctiveness and non- recurring processes of construction activities (Oglesby et al., 1989; Sweis, 2001); and,
- The reality that firms apply their own definitions and measures irrespective of standardization (Thomas & Mathews, 1986).

Furthermore, in academia, productivity is described in various ways subjected to the extent of the study (Liu & Song, 2005). Fundamentally, all these definitions look to determine how efficiently management, labour, equipment and tools are employed with regard to labour-intensive activities to build the plant, structure, or a fixed facility in an economical way (Oglesby et al., 1989). Hence, productivity in construction is described as the possible output of a construction process restricted upon its inputs (Crawford & Vogl, 2006). Mostly, productivity is stated as the ratio between output achieved upon given input or input over output produced. Consequently, the productivity measurement infers the estimation of a specific intput to achieve specific output (Figure 3.5).

Figure 3.5 Construction management process (Drewin, 1995)

The choice of defining input or output is meticulously associated with the scope of the measure and data availability. In addition, from the characteristics of the construction, measurement of productivity is done at three levels: task level, project level and industry level (Chapman & Butry, 2008):

- Task level construction productivity emphases a single activity such as brickwork, plastering, structural steel erection or concrete placing. Task level productivity is utilized widely within the construction sector. The majority of task level productivity involves measurement of single factor related to workforce.
- Various construction tasks are linked to overall project. Apparently, various tasks imply various inputs and/or outputs. Thus, there is a need to utilize alternate methods to relate the task level individual productivity.
- Construction industry incorporates productivity data from various construction projects. This is the highest level of productivity. One such example is the labour output constants determined by Bureau of Indian Standards (IS 7272, 2010)

3.10 Labour productivity assessment approach

Numerous productivity estimation methods have been presented since the time Frederick W. Taylor initiated hypothesizing concerning scientific management. At present, there are a vast number of productivity estimation methods established within the construction industry or academia. Two main purposes which induced the improvement of productivity estimation methods are:

- Necessity of measuring productivity is to account, for manage, and assess a construction firm's performance;
- The necessity of productivity growth to improve the construction firm's performance.

In this manner, productivity estimation methods were primarily categorized into two major types: productivity measuring techniques and Productivity Improving techniques. Generally, productivity measurement techniques look at establishing definite productivity performance to develop benchmark for construction firms either for themselves or against other firms. On the contrary, productivity improvement techniques aim to achieve successful management of implementing the construction activities by improving the efficiency of equipment and performance of workforce. Work study is an example of productivity improvement techniques. Work study is a systematic study of work processes in order to find and standardize low-cost method, establishing standard times, and providing training support in an ideal manner (Thomas et al., 1990).

Although these two approaches differ in their scope, an apparent overlapping exists between them. Continuous assessment and evaluation with the industry were crucial factors for development (Park et al., 2005). Consequently, productivity measurement techniques also focus on productivity growth and also aim to improve productivity with methods that are different from productivity improvement techniques. On the other hand, productivity improvement techniques need to measure productivity to achieve and assess development and employ measuring techniques that are different to a large extent from the ones employed by productivity measurement techniques. Park (2006) stated that: "Even if the workstudy is a valuable tool to assess how successfully work is done, its main intent is to improve productivity by finding and decreasing non-productive work instead of measuring and assessing construction productivity". Nonetheless, Thomas (1981) states that workstudy assesses effective utilization of time. In this manner, workstudy is considered to be an indirect way of measuring actual productivity.

3.11 Labour productivity data collection - video studies

Video studies were very helpful in inspecting construction operations and processes that have been playing a vital role in construction labour productivity. They can capture the entire information without the expense of people recording the observations at the site location. In this method, a video camera is used to capture the real time construction work process on the field. This data collection method has been effectively employed in construction productivity experiments (Abudayyeh, 1997). Furthermore, their significance is increasing due to technological developments in digital video technology. Video techniques offer several advantages (Abudayyeh, 1997), such as:

- Construction process information is permanently recorded which can later be utilized to study several aspects by variety of individuals.
- Construction operations or processes that take hours to complete can be studied in few minutes.

It consumes a lot of time to carry out detailed video analysis. Detailed analysis is required to gain the maximum possible benefits. It may be required to observe the recordings for at least three to five times, since it is hard to identify all the hindrances, useless motions, un productive time, repeated efforts, and various other inefficiencies by observing video recording only a few times. Thus, it also helps to study the activities of each worker independently.

In addition, video studies allow for permanently documenting the observed activities. Therefore, the gathered data is more detailed and reliable (i.e., even the minor mistakes done by the observer can be taken care of through video studies) and the recordings can be studied several times (Oglesby et al., 1989).

3.12 Summary

From the literature it is evident that utilization of human factors in construction will help in determining the performance of labour on site. In general, physical efficiency of humans is characterized by age and BMI. The process of aging in humans leads to significant changes in the body muscle mass and therefore loss of physical strength occurs (Keller and Engelhardt, 2013). Physical fitness of human body in older people is reduced causing difficulties in performing tasks (Tuna et al., 2009). The physical fitness of human body can apparently be assessed using isometric strength tests. These tests involve a maximum controlled contraction performed at a specified body joint angle of humans in stationary position. HGS test is an isometric strength test carried out by hand grip, involving hand and forearm muscles (Koley et al., 2009). The frequency of upper extremity muscles activity is high in humans while they perform continuous tasks (Gruevski et al., 2017). Therefore, a parameter which can measure upper body strength may be useful in assessing the workers' physical ability. Physical strength changes with change in body mass which is represented in BMI. Index of an individual's body fatness is represented by BMI (Nuttall, 2015). Based on the anthropometric height/weight characteristics, BMI is used to categorize humans. BMI is the metric calculated by dividing the body mass to the square of the height of a person and usually represented in kg/m2. Therefore, to focus on effective application of human factors, the present study selected four human parameters: age, BMI, HGS and UBMS for measuring labour performance on site. Human parameters such as heart rate, oxygen intake and energy expenditure were not considered. This is because some parameters require continuous tracking of their physical movements and also it should be carried out under controlled conditions which cannot make a field study.

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Chapter - 04

4. Objectives

4.1 Research gap

After a thorough search on the past studies, it is observed that even though there is plenty of research on productivity growth and significant factors responsible for variation of labour productivity, there is limited focus on assessment of labour productivity based on the worker's individual performance. No two workers will have the same efficiency in carrying out various labour-intensive tasks on the construction field. There is uncertainty in labour productivity which was mainly due to its dependence on several factors. Then the most debated issue is how to manage the workforce with varied labour performance. Is regular training and development of construction labour sufficient or does it require more realistic estimation or is it sufficient enough to depend on previous data. Much depends on the goal of the management. The problem to be addressed in this research is the estimation of labour productivity, specifically in masonry construction with regard to human physical capabilities, and how these capabilities (i.e., human parameters) predict the task level labour productivity in masonry construction activities.

Workers have varying physical capabilities and that needs to be taken into account when assessing the problem facing productivity as a whole. Therefore, when assessing the problem of MLP, looking at labour efficiency alone is not sufficient. There are many other critical factors that need to be taken into consideration, such as the factors affecting the industry, the assessment model they follow and the methods used for generation of standards to effectively study the problem.

Based on thorough search towards establishing the correlation between labour productivity and human physical efficiency, the hope is to shed new light on how management can estimate labour performance to enhance labour productivity and therefore boost competitiveness in the global economy. The fact that the Indian economy is growing even more with emerging construction projects involving diversified work forces, which affects reliability in estimating labour output standards, is an essential concern to solve effectively. Therefore, the issue of estimating labour productivity is highly important and needs to be addressed to maintain economic activities in construction industry in India.

Labour productivity is broadly debated issue in the Indian construction industry. The reliability of labour productivity standards based on data from various central and state government construction department manuals and also Indian standards were questionable on real time construction field. These standards were developed considering the essential factors affecting labour productivity in the construction industry and are commonly followed for arriving at the tender estimates in construction projects. From the preliminary study of these standards, it is observed that there is a considerable variation of labour productivity constants specifically on masonry construction activities (clearly described in chapter 2).

Firstly, there is a necessity to gauge the opinions of construction personnel on significant factors affecting MLP in India to raise the level of understanding of primary issues related to MLP in India, so that the efforts and attention can be focussed towards improving productivity. Another important issue in construction productivity is related to the techniques adopted by the industry for measuring construction labour productivity. Presently, there are no commonly implemented methods and engineers will, if necessity arises, utilise various work measurement methods such as work sampling and time and motion studies that were developed for the purpose of arriving company or project level productivity standards. Although the Indian standard (IS 7272 Part I) has published labour productivity data for various building construction activities, it is prudent for researchers to assess the productivity in workers due to varying human abilities and examine in detail the relationship between labour productivity and human physical parameters.

Presently, there are no approaches proposed for assessing the productivity variation of masonry labour in building construction projects based on human physical parameters. For example, there is no published data on the possible ranges of various levels of labour performances for masonry trades. A search of many national and international sources also failed to reveal a method that of assessing masonry labour performances with regard to human physical parameters. It is therefore timely for researchers to deliver proposals for measuring both labour productivity performance ranges as well as individual labour efficiencies. Researchers can also continue to make thorough analysis and standard methods for measuring productivity of other construction workers such as architectural works and building services. This present research programme cannot take forward the study of labour productivity measurement for all the major construction trades due to the limited time frame and other constraints, but it will be limited to detailed study of overall masonry construction productivity and that of building works.

4.2 Research objectives

The objectives of the research are as follows:

1. To examine the labour productivity data of a selected masonry activity from construction sites in India based on individual physical capabilities.
2. To identify various human parameters such as age, BMI and human body muscle strength tests that can be utilized as standard predictors in assessing labour productivity on construction sites for various masonry construction activities.

3. To identify a new parameter related to the human body muscle strength apart from the existing human physical parameters in the literature.
4. To investigate the researcher’s perspective in the construction industry to evaluate selected human physical parameters suitability for estimating the task level construction labour productivity
5. To identify physiological strength detecting devices that can be used in collecting human parameters on construction sites.
6. To develop a unified indexing parameter as a function of various human physical parameters to represent the performance of a masonry worker.
7. To analyse the relationship between physical abilities of labour against their productivity and develop a standardized model for estimating MLP.

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Chapter - 05

5. Field Investigation

5.1 General

This chapter presents the field survey. Various stages involved in the survey from data collection to organization is presented in a flow chart (Figure 5.1). Information regarding collection of data and various devices and methods used to study the masonry labour are also provided.

From the preliminary study, it is clear that labour productivity parameters were not constant among various organizations in India. The variation in labour productivity may arise due to various methods of work measurement or due to the data of previous construction projects. Analysis of questionnaire survey shows that work force related factors were highly influential on MLP in construction. Physical performance and fatigue of workers (i.e., human factors) which ranked 2nd among the work force related factors is selected as a relative predictor for estimating MLP in the present research programme. Therefore, the present research method has adopted the scheme of human parameters related to the physical strength to predict the labour productivity for masonry activities in construction projects. Introducing the study of human factors in association with construction labour productivity is not new and has been practiced for many years with different scope and objectives.

5.2 Field data collection

The method of field investigation is explained in Figure 5.1. The study involves collection of human parameter data such as age, BMI, HGS and UBMS. Several ongoing construction projects were visited and observed for carrying out field investigation. These projects were located in and around Warangal and Hyderabad in TS, India. Construction projects include multi storeyed structures such as residential, educational, hospital buildings. Initially, for the purpose of case study, two residential building apartments and one educational institute were selected and the required studies were conducted to gather information related to human parameters and labour productivity of brick masonry workers. Survey was conducted on forty-five brick layers in which the data of thirty-eight workers was successfully recorded for the research study. After developing the research model, another forty-four brick layers and sixteen tile laying masons data was gathered for the purpose of validation. Heart rate information of tile laying masons was recorded for comparison with the work of Abdelhamid and Everett, (2002).

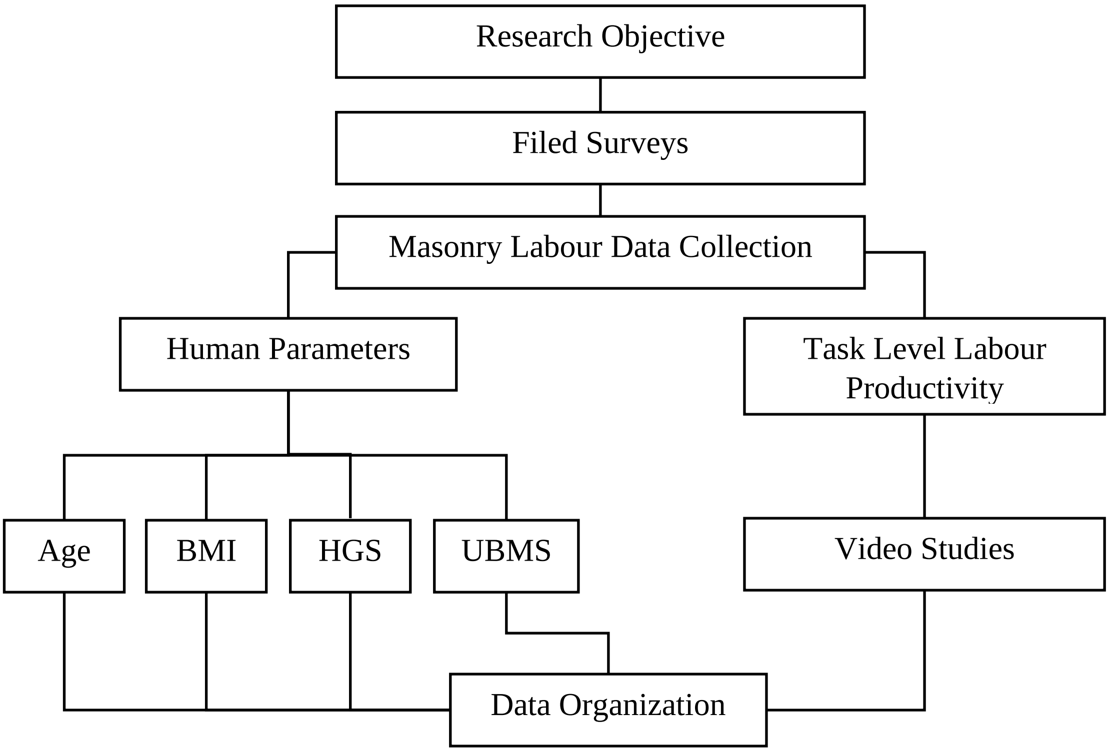

Figure 5.1 Field investigation

In the experimental study, all the workers were informed regarding the procedure and their consent to participate in the study was taken, and the study was conducted under the supervision of the respective site personnel. The subjects of the study were regular employees in the project. The age group of workers varied between 18 and 52 years. Experiment was conducted over a period of 3 to 4 months (September to December, 2016). Data was recorded on specific days that did not suffer any severe climatic disturbances. Care was taken to ensure that all the workers were in good health during the time of field trials.

A Brick wall construction activity using AAC (Autoclaved aerated concrete) blocks was chosen for the study. Video studies were used to record the performance of these workers. A total of 2644 minutes were recorded successfully on site during the days when the activities were in full progress, and there were no disturbances, such as bad climatic conditions, non-availability of resources, etc.

5.3 Human physical parameters data collection methods

The human physical parameter data collection was carried out on construction site while the workers were engaged in selected masonry construction activity i e., Brickwork. Four human parameters for the respective workers i.e., Age, BMI, HGS and UBMS were recorded for the study. Standard labour data collection sheets were prepared and used for recording the observations on field (Table 5.1).

The personal details of workers such as name and age on site was collected through an interview. Age of workers was taken as genuine on producing proof of government issued identity card. Weight and height of the workers were measured using an auto calibrated electronic weighing machine (5-180kg range) and stature meter (2m length), from which BMI was calculated. The method of measuring height and weight of the subjects was clearly explained in the following:

5.3.1 Measurement of height

Height of a person is one of the most widely used indicators for the assessment of physical body characteristic and provides an index of linear skeletal growth. A height measurement device called stature meter can be used to measure the height of a person. Stature meter selected for the study can measure up to 78 inches or 2 meters. This measurement device is ideal for measuring the height at both sitting or standing position. It comes along with the screws so that it can be attached to the wall. The least value that the stature meter can measure is 0.1 centimetre.

Since few decades ago, height measurements were carried out in places where there is no perfect level of the ground or vertical wall. Therefore, height of the subject was measured by either a stadiometer or anthropometry rod. Stadiometer is a large and heavy device which occupies a large amount of space whereas, anthropometry rod is comparatively small but a thorough training is compulsory to maintain the rod in perpendicular position and precisely measure the height of the subject. Presently most of the places have concrete buildings with flat floor and vertical walls and so the portable wall mount was readily available for measuring a person's height.

In the present experimental study, as the measurement is conducted on the construction site, stature meter is fixed to a finished wall by nailing it to the wall through the holes in vertical limb of the stature meter. The measurement tape is pulled out after ensuring that the horizontal limb lies evenly on the floor. A line is drawn on either side of the measurement tape to ensure if the tape is being pulled down without any deviation while height measurement is carried out. By holding the device in 90-degree vertical plane, two lines are drawn on both sides of the measurement tape plane such that these lines indicate that the tape is pulled down without any deviation. This deviation has to be checked and rectified before the worker's height is measured. The worker should be barefoot and the hair should be flat. His feet should be kept together while buttocks and shoulder touch the surface of the wall. Ear tragus and lower orbital line should be along horizontal plane and this is called Frankfrut plane. The horizontal limb of the device should be steadily arranged on the worker's head. Investigator eyes should be level with the reading pane. The height of the worker is measured to the nearest 0.01m for this study. In case the worker height is taller than the investigator, a chair or stool was used to make sure that investigator's eye is on the same level as the reading pane in the stature meter. If the worker was shorter, the investigator bends down to take the measurement. The device used for worker's height measurement is shown in Figure 5.2

Table 5.1 Worker information sheet for recording the human parameters data

<table>
<tr><td colspan="7">Data Recording Sheet</td></tr>
<tr><td colspan="4">Worker Information</td><td colspan="3">Project Information</td></tr>
<tr><td colspan="4">Worker Name:</td><td colspan="3">Name:</td></tr>
<tr><td colspan="4">Worker Code:</td><td colspan="3">Location:</td></tr>
<tr><td rowspan="2">Days:</td><td>1</td><td>2</td><td>3</td><td colspan="3" rowspan="2">Date:</td></tr>
<tr><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td>Age (years)</td><td colspan="2">Weight (kgs)</td><td>Height (m)</td><td colspan="3">BMI (kg/m^2)</td></tr>
<tr><td></td><td colspan="2"></td><td></td><td colspan="3"></td></tr>
<tr><td colspan="7"></td></tr>
<tr><td colspan="7">Hand Grip Strength (lbs)</td></tr>
<tr><td>Hand</td><td colspan="3">Right Hand</td><td colspan="3">Left Hand</td></tr>
<tr><td>Time</td><td>1</td><td>2</td><td>3</td><td>1</td><td>2</td><td>3</td></tr>
<tr><td>Before Work (BW)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>During Work (BW)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>After Work (BW)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="7"></td></tr>
<tr><td colspan="7">Upper Body Muscle Strength (lbs)</td></tr>
<tr><td>Pose</td><td colspan="2">Chest Pose</td><td colspan="2">Head Pose</td><td colspan="2">Wall Climb Pose</td></tr>
<tr><td>Time</td><td>Pull</td><td>Push</td><td>Pull</td><td>Push</td><td>Pull</td><td>Push</td></tr>
<tr><td>Before Work (BW)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>During Work (BW)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>After Work (BW)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="7">Notes:

Investigator</td></tr>
</table>

Figure 5.2 Stature meter (2 meter) (Kang, 2011)

5.3.2 Weight measurement

Weight is also an important parameter used for assessment of physical body in all age groups. Advanced battery operated and sensor based digital weighing machines provide accurate measurement of weight. With these devices, weight measurement has become easier. However, accuracy of these devices is an essential requirement for true weight measurement of the subjects. It is essential that accuracy of devices needs to be checked using standard certified weights or by weighing subjects of varying weights five times and comparing the values with the standard weighing machine. The device "HealthSense PS 126 Ultra-Lite Personal Scale" which can weigh from 5-180kg is used for the present experiment. Digital weighing devices minimize errors. Every day, during the experiment, the device needs to be checked for accuracy before the weight measurement. Leave the first measurement as trial as the device gets auto-calibrated. The device used for worker's weight measurement is shown in Figure 5.3.

Figure 5.3 Weighing device (5-180kg) (Yorkin et al., 2013)

5.3.3 HGS measurement

A pilot experiment was conducted by Greesh and Sanjay (2018) to find out whether masonry labour had work-related evidence of repetitive use of the wrist, mechanical stress on the hand and palm and long period of strong gripping. It is found that masonry workers repetitively expended their dominant hand and wrist when working with hand tools such as trowel/spatula for entire day. HGS also aids as an alternative measure for human body muscle function and also physical health (Karatrantou 2018). A digital hand grip dynamometer has been developed with high accuracy and sensitivity to measure grip strength. The device comprises a hydraulic system for the measurement of maximum voluntary contraction of palm and is suitable for determining the amount of grip force exerted (Zwarts et al., 2008; Boyas, 2011). This instrument is deemed to be the "gold standard" for the measurement of HGS which was endorsed by the American Society of Hand Therapists (ASHT) as an extensively used reliable measurement device (Smith et al., 1989; Schechtman et al., 2005; Bohannon and Schaubert, 2005; Bohannon et al., 2006; Couto, 1995).Therefore, for the current study experiment, this device was used to measure the HGS of construction workers.

The purpose of hand grip dynamometer test is to assess the maximum isometric strength which involves hand and forearm muscles. The dynamometer can be altered for various hand sizes and needs to be calibrated for reliable results. The device used in the present study is “Electronic Handgrip Dynamometer” (Figure 5.4). The device is light weight and easy to carry. It captures the maximum HGS in either kilograms or pounds that can measure isometric strength of the hand grip up to 90kg / 200lb. Popular digital dynamometers for measuring HGS have been proposed since isometric hand grip test alone can’t be a valid measure of the total body strength of subjects. There are other similar tests which can be utilized to assess the strength of other muscle groups. However, the hand grip dynamometer provides a reliable and simple measurement that can be used as a predictor of human physical strength.

Figure 5.4 Digital hand dynamometer (200lbs) (Shechtman et al., 2005)

The usage of hand dynamometer is simple and easy to train workers on site. The position of the hand and arm influences the results. The position selected for the study; the arm in hanging position by the side with the arm extended and swung to the head level then outside while in the squeezing action. The HGS of both left and right hands was measured while in standing position with shoulder adducted and neutrally rotated and elbow in full extension (Koley et al., 2009). The workers were asked to put maximum grip force on the hand dynamometer with both the hands (Figure 5.5). Each worker did three test trails for each hand and the experiment was conducted three times in a day (before work, during work and after work) for three working days. Average of the observation (2hands x 3trails x 3times/day x 3 days) trails was used for further analysis. Thirty seconds rest is given between each trail and each hand received 1 min rest during the experiment (Gasior et al., 2018). The hand dynamometer display faced towards investigator.

Figure 5.5 Measuring the HGS of construction workers in standing position

5.3.4 UBMS measurement

Construction labour, while performing masonry activities such as brick wall construction undergo heavy strain on low back and shoulder (yuan et al., 2007). The strength of muscles in the upper body can used to predict the overall performance of the worker. Therefore, an isometric strength test called UBMS similar to HGS is introduced in the present experiment as one of the predictors to estimate the performance of the masonry workers. In this test, a hand grip digital trainer device with 200lb resistance capacity is used for UBMS measurement (Figure 5.6). The hand grip digital isometric trainer provides three types of muscle contractions with both pull and push forces, namely, static, progressive and mobile contractions. Of these three contractions, static contraction is best suited for untrained individuals, and so was chosen for the experiment.

Figure 5.6 Hand grip digital isometric trainer (200lbs) (IGRIP SPORTS, 2019)

These isometric tests involve muscle contractions without movement of the body. The range of motion is directly focussed on the muscle, eliminating the need for multiple trails. There are nine poses with various upper body muscle contractions (Table 5.2). Similar to the real time posture analysis done by Ray and Teizer (2012) on construction workers, UBMS test in the present study was conducted by taking three different postures i.e., chest pose, wall climb pose and head pose while in standing position. These three poses involved almost all the prime upper body muscle contractions such as shoulder, back, upper back, deltoid, traps, pectorial, biceps, lats and abdominal.

Table 5.2 Different upper body muscle contractions and their respective poses

Pose	**Muscles Involved**	
	Push Force	**Pull Force**
Chest Pose	Pectorial, bicep, deltoid and abdominal	Shoulder and upper back
Wall Climb Pose	Lats and abdominal	Lats and abdominal
Head pose	Shoulders and back	Traps and upper back
Mid Arm Pose	Outer chest, full arm, triceps and abdominal	Triceps, traps and upper back
Fly Pose	Outer chest, triceps, abdominal and forearms	Outer chest, triceps and shoulder
Decline Pose	Biceps, abdominal and lower chest	Lats
Back Pose	Deltoid and lower chest	Front deltoid and triceps
Bicep Pose	Biceps and triceps	Biceps and triceps
Reverse Fly Pose	NIL	Deltoids and triceps

Three poses in which the UBMS test was conducted in the present experiment are shown in Figure 5.7. Workers were asked to exert maximum force to pull and push by holding the hand grip isometric trainer for six seconds (The device contains alarm settings for six to twenty seconds hold) as shown in Figure 5.8. Average peak force is achieved with device by holding it for six seconds and so repeated trials are avoided. Each worker performed all three poses and the experiment was conducted three times a day (before work, during work and after work) for three working days. Average of observation (3 poses x 2 forces x 3times/day x 3 days) was recorded in pounds the further analysis. Sufficient rest was given between each test pose to allow the worker to regain the full energy for the next pose. Investigator records the value obtained from the device after each successful trail conducted on individual worker.

Figure 5.7 Chest, wall climb and head poses for UBMS measurement

Figure 5.8 Measuring the UBMS of construction workers on site (wall climb and head pose)

5.4 Labour productivity measurement studies

Both task level construction productivity and human performance are reliant on one another. The most commonly used method for measuring labour productivity is the continuous recording of construction work done per hour on the field. This method of measurement was conducted by filming the selected activity process with regard to masonry workers on field. These recordings can be stored and later utilized for further individual analysis of measuring each worker's productivity. Care is taken to find a suitable video camera position. Position of the camera is fixed in such a way that it is above the level of the work process that needs to be captured. A tripod is used to adjust the camera height. This can avoid significant obstructions in the foreground and also present loss of information from workers who cannot be seen in the video frame. For greater height requirement, small scaffolds were utilized on site. Zooming capabilities of the camera were utilized to zero in on the specific area of interest to be captured. Sometimes it may be difficult to keep track of one particular group of workers in a congested area where several crews are gathered. So, the colour of the workers' clothes or any other distinctive feature or mark is noted for easy identification. To frame the recording in its proper context, sometimes a panoramic view of the entire work location is captured in which area of interest is selected later by zooming the recorded video.

However, in order to obtain maximum benefits possible, a detailed video analysis is indispensable. Recordings needs to be observed at least three to five times, as it is difficult to identify all the hurdles, wasted motions, lost time, duplicated efforts and a variety of other inefficiencies looking at a recording only a couple of times. Each and every worker needed a separate study to record his productive working time on the field.

In the present study, masonry workers on site were observed by tracking their real time field performance of brickwork activity using video cameras. Time consumed in brickwork activity by a group of workers at one location was recorded using a video camera. A total of 2644 minutes of observation were successfully analysed on site when the selected activity was in full progress without any disturbances. Some of the working photos of workers are shown in Figure 5.9. In order to calculate MLP, the total time spent and quantity installed is noted in a standard format prepared for MLP data observation as shown in Table 5.3.

Table 5.3 Masonry labour time data and the work quantity recording sheet

S.No	Mason Code	Time recorded (hr)	Quantity executed (cft)	Productivity (cft/hr)

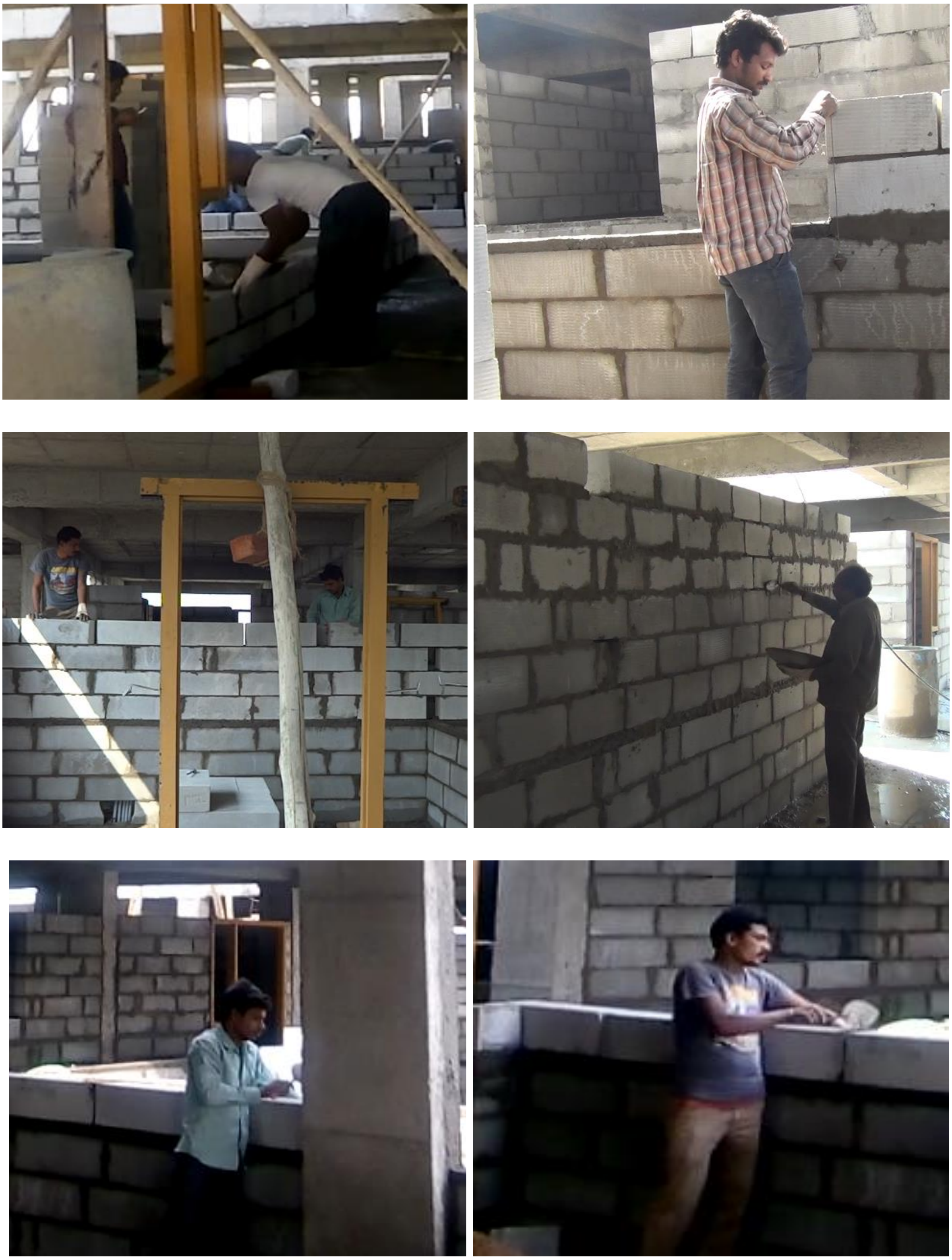

Figure 5.9 Construction site photos of brick masonry workers

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Chapter - 06

6. Parametric Analysis

6.1 Introduction

Essentially, statistical analysis is a scientific methodology to analyse parameters in order to assist to elaborate the interpretation, understanding and usage. Therefore, statistical analysis supports the collected parameters data into information i.e., data is clearly interpreted, understood and useful to form the research model. Generally, analysis with statistical tests is the logical collection and analysis of numerical data, to examine or determine relationships among singularities in order to illuminate, predict and control their formation.

There are extensive and rational tests available in statistics. The choice of opting for a statistical test depend mainly on the design of research, type of variables and the distribution of parameters in the study. In particular, if the data is normally distributed, parametric tests were considerable. The data obtained in the present study is assumed to have random independent variables with no outliers. Therefore, parametric tests were adopted. Table 6.1 specifies general statistical tests that were adopted and carried out using Microsoft excel functions in the present study.

Table 6.1 Various statistical tests adopted in the study and their purposes

Statistical Test	Purpose
Correlation	To show that whether and how the pairs of brick masonry labour parameters were effectively related
F-test (equality of variance)	Variations in brick masonry labour parameters was tested for the hypothesis of equality
ANOVA (Analysis of variance)	To determine the significant variation of means of isometric strength tests conducted to brick masons at three periods of time in a day.
Simple Linear Regression	To check the variation in any of two parameters and also prediction possibility of MLP with any one of the parameters, based on R^2 of regression analysis
Multiple Linear Regression	To check the prediction possibility of MLP based on the R^2 value of two or more parameters.

6.2 Data collection

Data regarding physical parameters and labour productivity of brick masonry workers was collected by the investigator on standard data sheets. All the data was entered and recorded in excel sheets for further analysis. In case of HGS test two forces (i.e., left and right hands) were considered whereas, for UBMS, six different forces (i.e., 3 poses x two forces (push and pull)) were conducted. For HGS, an average of three trails of test in a day (i.e., d1, d2, d3) in each period of time in a day i.e., before work (bw), during work (dw) and after work (aw) was recorded (Table 6.2 to 6.4). For UBMS, average of three days trial ((d1+d2+d3)/3) for two grip forces (i.e., push and pull) in each period of time in a day (bw, dw, aw) was recorded (Table 6.5 to 6.8). Age and BMI collected from the site were recorded. Labour productivity data was analysed directly from the video tape recordings from the field. Time lapse for the respective worker was taken in such a way that the activity cycles were completely observed. Unnecessary breaks between the activity cycles were not taken into consideration i.e., only working time was recorded in excel sheets for the analysis. Table 6.9 shows the productivity data of brick masons observed from the field investigation. Labour parameter data was organized in Table 6.10 and various statistical parameters for each parameter such as mean (μ), standard deviation (σ), standard error (S_x) and percentage of sample confidence intervals at 95% confidence level (p) was calculated as:

$$\mu = \frac{\sum fx}{n} ; \sigma = \sqrt{\frac{\sum (x-\mu)^2}{n}} ; S_x = \frac{\sigma}{\sqrt{n}} ; p = (\text{T.INV.2T } (0.05,37)) \times (S_x)$$

Where, T.INV.2T (0.05,37) is the function to calculate the inverse of the two-tailed data T distribution at 0.05 significance level, n-1 degrees of freedom.

For grouped data, standard normal distribution is determined when μ=0 and σ=1.

The formula for standard normal distribution is:

$$f(x,\mu,\sigma) = \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

Normal distribution data for all the labour parameters are calculated in Table 6.11. respective curves were presented in Figure 6.1. All the labour parameters data is found normally distributed in the study.

Table 6.2 HGS data of the brick masons in pounds (Right Hand)

S. No	Mason Code	bw (lbs)			dw (lbs)			aw (lbs)		
		d1	d2	d3	d1	d2	d3	d1	d2	d3
1	C1M1	83.8	84.6	82.4	72.4	81.4	77.0	73.0	79.0	78.0
2	C1M2	74.1	70.2	69.4	70.8	67.2	64.8	68.0	64.4	63.6
3	C1M3	64.4	93.6	92.4	90.8	91.2	89.6	92.0	92.8	90.8
4	C1M4	60.4	59.8	58.6	58.8	54.2	63.8	54.6	52.0	51.4
5	C1M5	68.8	64.4	63.4	72.8	68.8	70.8	68.8	69.2	65.4
6	C1M6	83.0	81.8	79.6	82.4	81.2	80.6	79.4	77.6	75.2
7	C2M1	84.2	85.0	84.8	81.0	81.8	80.4	83.6	80.8	81.0
8	C2M2	91.8	90.2	90.0	89.6	88.2	88.2	90.0	89.1	88.0
9	C2M3	81.2	84.6	83.4	86.6	86.2	85.2	91.2	90.4	91.4
10	C2M4	86.8	85.2	84.6	83.4	83.8	84.0	82.0	81.6	80.8
11	C2M5	81.8	83.8	80.4	87.6	88.4	88.0	86.4	86.8	84.6
12	C2M6	101.8	96.8	94.0	93.6	92.6	91.8	94.8	93.2	93.6
13	C3M1	91.8	94.8	94.0	91.2	92.6	93.4	89.6	90.2	91.4
14	C3M2	89.2	86.2	85.4	88.2	87.4	87.8	84.8	84.2	83.2
15	C3M3	93.4	92.2	90.8	93.2	91.0	89.2	90.4	88.2	85.4
16	C3M4	53.2	48.6	46.8	47.6	46.8	45.2	44.8	46.2	41.4
17	C3M5	73.4	71.8	70.4	76.2	72.0	73.2	68.8	70.4	68.6
18	C4M1	91.2	90.4	91.4	91.2	92.4	95.4	90.0	89.4	90.4
19	C4M2	81.8	83.8	80.4	87.6	88.4	88.0	86.4	86.8	84.6
20	C4M3	91.8	90.2	90.0	89.6	88.2	88.2	90.0	89.1	88.0
21	C4M4	73.4	73.8	70.6	81.0	80.0	81.8	79.0	74.0	80.0
22	C4M5	82.8	77.8	76.8	78.8	76.6	74.4	75.4	72.8	73.6
23	C4M6	53.2	48.6	46.8	47.6	46.8	45.2	44.8	46.2	41.4
24	C4M7	96.2	94.4	92.6	94.4	90.2	91.2	91.0	89.9	88.0
25	C4M8	91.2	90.4	91.4	91.2	92.4	95.4	90.0	89.4	90.4
26	C4M9	91.0	91.6	93.4	88.6	86.0	86.4	83.2	84.8	86.0
27	C4M10	68.8	64.4	63.4	72.8	68.8	70.8	68.8	69.2	65.4
28	C5M1	83.8	84.6	82.4	72.4	81.4	77.0	73.0	79.0	78.0
29	C5M2	82.8	77.8	76.8	78.8	76.6	74.4	75.4	72.8	73.6
30	C5M3	76.4	76.8	73.6	80.0	81.0	81.8	74.0	77.0	79.0
31	C5M4	58.0	56.4	55.4	57.4	55.8	51.8	53.0	52.8	52.2
32	C5M5	91.8	90.2	90.0	89.6	88.2	88.2	90.0	89.1	88.0
33	C5M6	82.8	77.8	76.8	78.8	76.6	74.4	75.4	72.8	73.6
34	C5M7	72.8	70.8	69.6	71.2	68.8	69.2	68.0	68.4	68.2
35	C6M1	89.2	86.2	85.4	88.2	87.4	87.8	84.8	84.2	83.2
36	C6M2	73.4	71.8	70.4	76.2	72.0	73.2	68.8	70.4	68.6
37	C6M3	58.0	56.4	55.4	57.4	55.8	51.8	53.0	52.8	52.2
38	C6M4	52.2	51.8	50.2	50.2	48.6	46.4	49.4	49.2	46.2

Table 6.3 HGS data of the brick masons in pounds (Left Hand)

S. No	Mason Code	bw (lbs)			dw (lbs)			aw (lbs)		
		1	2	3	1	2	3	1	2	3
1	C1M1	71.4	72.0	70.2	68.4	68.0	69.1	67.0	68.4	66.2
2	C1M2	66.8	64.6	63.4	62.2	62.8	64.0	62.2	59.2	58.4
3	C1M3	73.4	73.8	70.6	81.0	80.0	81.8	79.0	74.0	80.0
4	C1M4	58.0	56.4	55.4	57.4	55.8	51.8	53.0	52.8	52.2
5	C1M5	64.8	63.6	63.2	63.6	62.4	61.0	62.6	61.4	61.0
6	C1M6	80.8	78.6	74.8	79.2	78.4	78.2	75.8	74.2	74.0
7	C2M1	82.8	77.8	76.8	78.8	76.6	74.4	75.4	72.8	73.6
8	C2M2	96.2	94.4	92.6	94.4	90.2	91.2	91.0	89.9	88.0
9	C2M3	91.0	91.6	93.4	88.6	86.0	86.4	83.2	84.8	86.0
10	C2M4	76.4	76.8	73.6	80.0	81.0	81.8	74.0	77.0	79.0
11	C2M5	91.2	90.4	91.4	91.2	92.4	95.4	90.0	89.4	90.4
12	C2M6	81.2	84.6	80.0	78.4	80.4	80.0	77.4	78.2	76.6
13	C3M1	103.4	101.8	99.6	101.4	98.8	97.8	99.2	98.0	96.4
14	C3M2	75.4	74.0	73.2	73.8	72.0	70.8	72.8	71.4	70.2
15	C3M3	87.6	84.6	83.8	86.0	86.2	84.8	84.6	80.2	77.6
16	C3M4	52.2	51.8	50.2	50.2	48.6	46.4	49.4	49.2	46.2
17	C3M5	72.8	70.8	69.6	71.2	68.8	69.2	68.0	68.4	68.2
18	C4M1	82.8	77.8	76.8	78.8	76.6	74.4	75.4	72.8	73.6
19	C4M2	89.2	86.2	85.4	88.2	87.4	87.8	84.8	84.2	83.2
20	C4M3	91.0	91.6	93.4	88.6	86.0	86.4	83.2	84.8	86.0
21	C4M4	76.4	76.8	73.6	80.0	81.0	81.8	74.0	77.0	79.0
22	C4M5	83.8	84.6	82.4	72.4	81.4	77.0	73.0	79.0	78.0
23	C4M6	58.0	56.4	55.4	57.4	55.8	51.8	53.0	52.8	52.2
24	C4M7	101.8	96.8	94.0	93.6	92.6	91.8	94.8	93.2	93.6
25	C4M8	76.4	76.8	73.6	80.0	81.0	81.8	74.0	77.0	79.0
26	C4M9	81.8	83.8	80.4	87.6	88.4	88.0	86.4	86.8	84.6
27	C4M10	72.8	70.8	69.6	71.2	68.8	69.2	68.0	68.4	68.2
28	C5M1	80.2	77.6	77.4	78.2	76.8	76.0	76.2	75.6	74.8
29	C5M2	82.8	77.8	76.8	78.8	76.6	74.4	75.4	72.8	73.6
30	C5M3	82.8	77.8	76.8	78.8	76.6	74.4	75.4	72.8	73.6
31	C5M4	53.2	48.6	46.8	47.6	46.8	45.2	44.8	46.2	41.4
32	C5M5	81.8	83.8	80.4	87.6	88.4	88.0	86.4	86.8	84.6
33	C5M6	83.8	84.6	82.4	72.4	81.4	77.0	73.0	79.0	78.0
34	C5M7	82.8	77.8	76.8	78.8	76.6	74.4	75.4	72.8	73.6
35	C6M1	91.2	90.4	91.4	91.2	92.4	95.4	90.0	89.4	90.4
36	C6M2	82.8	77.8	76.8	78.8	76.6	74.4	75.4	72.8	73.6
37	C6M3	52.2	51.8	50.2	50.2	48.6	46.4	49.4	49.2	46.2
38	C6M4	68.8	64.4	63.4	72.8	68.8	70.8	68.8	69.2	65.4

Table 6.4 HGS of the brick masons in pounds (average of both hands)

S. No	Mason Code	Right Hand (RH) (lbs)				Left Hand (LH) (lbs)				HGS Avg. (RH, LH)
		bw	dw	aw	avg.	bw	dw	aw	avg.	
1	C1M1	83.6	76.9	76.7	79.1	71.2	68.5	67.2	69.0	**74.1**
2	C1M2	71.2	67.6	65.3	68.0	64.9	63.0	59.9	62.6	**65.3**
3	C1M3	83.5	90.5	91.9	88.6	72.6	80.9	77.7	77.1	**82.9**
4	C1M4	59.6	58.9	52.7	57.1	56.6	55.0	52.7	54.8	**56.0**
5	C1M5	65.5	70.8	67.8	68.0	63.9	62.3	61.7	62.6	**65.3**
6	C1M6	81.5	81.4	77.4	80.1	78.1	78.6	74.7	77.1	**78.6**
7	C2M1	84.7	81.1	81.8	82.5	79.1	76.6	73.9	76.5	**79.5**
8	C2M2	90.7	88.7	89.0	89.5	94.4	91.9	89.6	92.0	**90.8**
9	C2M3	83.1	86.0	91.0	86.7	92.0	87.0	84.7	87.9	**87.3**
10	C2M4	85.5	83.7	81.5	83.6	75.6	80.9	76.7	77.7	**80.7**
11	C2M5	82.0	88.0	85.9	85.3	91.0	93.0	89.9	91.3	**88.3**
12	C2M6	97.5	92.7	93.9	94.7	81.9	79.6	77.4	79.6	**87.2**
13	C3M1	93.5	92.4	90.4	92.1	101.6	99.3	97.9	99.6	**95.9**
14	C3M2	86.9	87.8	84.1	86.3	74.2	72.2	71.5	72.6	**79.5**
15	C3M3	92.1	91.1	88.0	90.4	85.3	85.7	80.8	83.9	**87.2**
16	C3M4	49.5	46.5	44.1	46.7	51.4	48.4	48.3	49.4	**48.1**
17	C3M5	71.9	73.8	69.3	71.7	71.1	69.7	68.2	69.7	**70.7**
18	C4M1	91.0	93.0	89.9	91.3	79.1	76.6	73.9	76.5	**83.9**
19	C4M2	82.0	88.0	85.9	85.3	86.9	87.8	84.1	86.3	**85.8**
20	C4M3	90.7	88.7	89.0	89.5	92.0	87.0	84.7	87.9	**88.7**
21	C4M4	72.6	80.9	77.7	77.1	75.6	80.9	76.7	77.7	**77.4**
22	C4M5	79.1	76.6	73.9	76.5	83.6	76.9	76.7	79.1	**77.8**
23	C4M6	49.5	46.5	44.1	46.7	56.6	55.0	52.7	54.8	**50.8**
24	C4M7	94.4	91.9	89.6	92.0	97.5	92.7	93.9	94.7	**93.4**
25	C4M8	91.0	93.0	89.9	91.3	75.6	80.9	76.7	77.7	**84.5**
26	C4M9	92.0	87.0	84.7	87.9	82.0	88.0	85.9	85.3	**86.6**
27	C4M10	65.5	70.8	67.8	68.0	71.1	69.7	68.2	69.7	**68.9**
28	C5M1	83.6	76.9	76.7	79.1	78.4	77.0	75.5	77.0	**78.1**
29	C5M2	79.1	76.6	73.9	76.5	79.1	76.6	73.9	76.5	**76.5**
30	C5M3	75.6	80.9	76.7	77.7	79.1	76.6	73.9	76.5	**77.1**
31	C5M4	56.6	55.0	52.7	54.8	49.5	46.5	44.1	46.7	**50.8**
32	C5M5	90.7	88.7	89.0	89.5	82.0	88.0	85.9	85.3	**87.4**
33	C5M6	79.1	76.6	73.9	76.5	83.6	76.9	76.7	79.1	**77.8**
34	C5M7	71.1	69.7	68.2	69.7	79.1	76.6	73.9	76.5	**73.1**
35	C6M1	86.9	87.8	84.1	86.3	91.0	93.0	89.9	91.3	**88.8**
36	C6M2	71.9	73.8	69.3	71.7	79.1	76.6	73.9	76.5	**74.1**
37	C6M3	56.6	55.0	52.7	54.8	51.4	48.4	48.3	49.4	**52.1**
38	C6M4	51.4	48.4	48.3	49.4	65.5	70.8	67.8	68.0	**58.7**

Table 6.5 UBMS data of the brick masons in pounds (Chest Pose)

S. No	Mason Code	bw (lbs)			dw (lbs)			aw (lbs)		
		push	pull	avg.	push	pull	avg.	push	pull	avg.
1	C1M1	24	17	20.5	28	21	24.5	26	19	22.5
2	C1M2	33	28	30.5	29	24	26.5	31	22	26.5
3	C1M3	38	32	35.0	33	28	30.5	34	31	32.5
4	C1M4	16	14	15.0	15	12	13.5	14	13	13.5
5	C1M5	18	28	23.0	22	25	23.5	22	24	23.0
6	C1M6	35	30	32.5	43	32	37.5	42	33	37.5
7	C2M1	40	36	38.0	39	33	36.0	40	36	38.0
8	C2M2	35	38	36.5	31	37	34.0	29	34	31.5
9	C2M3	27	34	30.5	28	34	31.0	26	30	28.0
10	C2M4	19	31	25.0	23	33	28.0	22	34	28.0
11	C2M5	28	34	31.0	24	33	28.5	20	27	23.5
12	C2M6	35	30	32.5	33	29	31.0	31	29	30.0
13	C3M1	37	42	39.5	34	40	37.0	35	38	36.5
14	C3M2	28	24	26.0	27	25	26.0	25	23	24.0
15	C3M3	39	44	41.5	37	41	39.0	36	40	38.0
16	C3M4	22	16	19.0	21	18	19.5	19	17	18.0
17	C3M5	29	33	31.0	28	35	31.5	25	31	28.0
18	C4M1	38	32	35.0	33	28	30.5	34	30	32.0
19	C4M2	19	31	25.0	23	34	28.5	22	34	28.0
20	C4M3	35	38	36.5	31	37	34.0	29	34	31.5
21	C4M4	27	31	29.0	26	33	29.5	20	27	23.5
22	C4M5	35	30	32.5	43	32	37.5	42	33	37.5
23	C4M6	38	32	35.0	34	28	31.0	34	31	32.5
24	C4M7	18	28	23.0	22	25	23.5	21	24	22.5
25	C4M8	35	30	32.5	41	32	36.5	42	33	37.5
26	C4M9	29	33	31.0	28	35	31.5	25	31	28.0
27	C4M10	19	31	25.0	23	33	28.0	22	34	28.0
28	C5M1	18	28	23.0	21	25	23.0	22	24	23.0
29	C5M2	27	34	30.5	28	34	31.0	26	31	28.5
30	C5M3	35	30	32.5	33	29	31.0	30	29	29.5
31	C5M4	23	17	20.0	28	21	24.5	26	19	22.5
32	C5M5	21	16	18.5	21	19	20.0	19	17	18.0
33	C5M6	33	28	30.5	29	24	26.5	31	22	26.5
34	C5M7	30	24	27.0	29	25	27.0	25	24	24.5
35	C6M1	39	36	37.5	39	33	36.0	40	36	38.0
36	C6M2	39	44	41.5	38	41	39.5	36	40	38.0
37	C6M3	35	30	32.5	34	29	31.5	31	29	30.0
38	C6M4	16	14	15.0	16	12	14.0	15	13	14.0

Table 6.6 UBMS data of the brick masons in pounds (Wall climb Pose)

S. No	Mason Code	bw (lbs)			dw (lbs)			aw (lbs)		
		push	pull	avg.	push	pull	avg.	push	pull	avg.
1	C1M1	10	16	13.0	8	15	11.5	9	13	11.0
2	C1M2	10	12	11.0	9	14	11.5	7	10	8.5
3	C1M3	11	18	14.5	14	17	15.5	14	15	14.5
4	C1M4	15	9	12.0	10	6	8.0	10	7	8.5
5	C1M5	12	14	13.0	11	16	13.5	12	14	13.0
6	C1M6	10	13	11.5	8	14	11.0	7	12	9.5
7	C2M1	20	23	21.5	18	21	19.5	17	22	19.5
8	C2M2	14	16	15.0	12	16	14.0	12	14	13.0
9	C2M3	24	26	25.0	22	28	25.0	18	26	22.0
10	C2M4	22	29	25.5	21	30	25.5	19	27	23.0
11	C2M5	13	17	15.0	11	16	13.5	10	13	11.5
12	C2M6	16	18	17.0	15	17	16.0	15	16	15.5
13	C3M1	10	16	13.0	9	14	11.5	9	13	11.0
14	C3M2	14	16	15.0	13	17	15.0	11	14	12.5
15	C3M3	16	20	18.0	15	22	18.5	14	18	16.0
16	C3M4	10	8	9.0	9	7	8.0	11	9	10.0
17	C3M5	12	14	13.0	10	13	11.5	11	13	12.0
18	C4M1	14	16	15.0	12	16	14.0	12	14	13.0
19	C4M2	13	17	15.0	11	16	13.5	10	13	11.5
20	C4M3	11	16	13.5	8	14	11.0	9	13	11.0
21	C4M4	12	14	13.0	10	16	13.0	11	14	12.5
22	C4M5	12	16	14.0	10	14	12.0	11	13	12.0
23	C4M6	12	15	13.5	11	16	13.5	12	14	13.0
24	C4M7	10	13	11.5	9	14	11.5	8	10	9.0
25	C4M8	13	17	15.0	10	16	13.0	10	14	12.0
26	C4M9	12	18	15.0	14	17	15.5	14	15	14.5
27	C4M10	15	9	12.0	10	7	8.5	10	7	8.5
28	C5M1	20	23	21.5	19	21	20.0	17	21	19.0
29	C5M2	22	29	25.5	20	28	24.0	18	27	22.5
30	C5M3	10	18	14.0	8	14	11.0	7	12	9.5
31	C5M4	16	20	18.0	15	22	18.5	16	18	17.0
32	C5M5	10	16	13.0	11	14	12.5	9	13	11.0
33	C5M6	22	28	25.0	21	30	25.5	19	27	23.0
34	C5M7	14	16	15.0	11	15	13.0	11	14	12.5
35	C6M1	10	8	9.0	9	7	8.0	10	9	9.5
36	C6M2	12	16	14.0	11	17	14.0	12	14	13.0
37	C6M3	16	19	17.5	13	17	15.0	12	16	14.0
38	C6M4	24	26	25.0	21	28	24.5	18	26	22.0

Table 6.7 UBMS data of the brick masons in pounds (Head Pose)

S. No	Mason Code	bw (lbs)			dw (lbs)			aw (lbs)		
		push	pull	avg.	push	pull	avg.	push	pull	avg.
1	C1M1	14	21	18	12	19	16	10	14	12
2	C1M2	16	22	19	13	17	15	11	17	14
3	C1M3	22	28	25	18	24	21	19	22	21
4	C1M4	8	12	10	7	10	9	7	8	8
5	C1M5	12	15	14	10	13	12	9	12	11
6	C1M6	23	18	21	21	16	19	20	17	19
7	C2M1	22	26	24	21	24	23	20	22	21
8	C2M2	19	23	21	21	24	23	22	24	23
9	C2M3	21	25	23	20	22	21	19	23	21
10	C2M4	22	34	28	19	27	23	23	31	27
11	C2M5	12	18	15	10	14	12	7	12	10
12	C2M6	20	25	23	19	23	21	18	22	20
13	C3M1	16	19	18	17	20	19	18	19	19
14	C3M2	20	23	22	18	25	22	19	22	21
15	C3M3	25	33	29	24	30	27	23	31	27
16	C3M4	8	13	11	7	12	10	6	8	7
17	C3M5	16	15	16	17	14	16	15	12	14
18	C4M1	11	16	14	10	14	12	9	12	11
19	C4M2	22	25	24	20	23	22	19	23	21
20	C4M3	22	27	25	18	24	21	19	23	21
21	C4M4	14	22	18	12	20	16	10	16	13
22	C4M5	21	25	23	19	23	21	18	24	21
23	C4M6	25	31	28	24	29	27	23	28	26
24	C4M7	20	26	23	19	24	22	18	23	21
25	C4M8	15	22	19	14	17	16	12	17	15
26	C4M9	14	18	16	12	16	14	11	14	13
27	C4M10	19	23	21	17	25	21	16	22	19
28	C5M1	22	18	20	20	16	18	19	17	18
29	C5M2	22	28	25	20	26	23	19	24	22
30	C5M3	20	25	23	19	22	21	18	23	21
31	C5M4	17	15	16	18	14	16	15	12	14
32	C5M5	9	13	11	8	12	10	7	9	8
33	C5M6	11	14	13	8	12	10	7	11	9
34	C5M7	18	24	21	20	24	22	21	23	22
35	C6M1	8	14	11	7	13	10	7	9	8
36	C6M2	22	30	28	19	28	23	23	26	27
37	C6M3	12	16	14	10	14	12	10	13	12
38	C6M4	18	20	19	16	19	18	15	18	17

Table 6.8 UBMS of the brick masons in pounds (average of three poses)

S. No	Mason Code	Chest Pose (CP) (lbs)	Wall Climb Pose (WP) (lbs)	Head Pose (HP) (lbs)	UBMS Avg. (3 poses)
		avg. (bw,dw,aw)	avg. (bw,dw,aw)	avg. (bw,dw,aw)	
1	C1M1	22.5	11.8	15.0	16.4
2	C1M2	27.8	10.3	16.0	18.0
3	C1M3	32.7	14.8	22.2	23.2
4	C1M4	14.0	9.5	8.7	10.7
5	C1M5	23.2	13.2	11.8	16.1
6	C1M6	35.8	10.7	19.2	21.9
7	C2M1	37.3	20.2	22.5	26.7
8	C2M2	34.0	14.0	22.2	23.4
9	C2M3	29.8	24.0	21.7	25.2
10	C2M4	27.0	24.7	26.0	25.9
11	C2M5	27.7	13.3	12.2	17.7
12	C2M6	31.2	16.2	21.2	22.9
13	C3M1	37.7	11.8	18.2	22.6
14	C3M2	25.3	14.2	21.2	20.2
15	C3M3	39.5	17.5	27.7	28.2
16	C3M4	18.8	9.0	9.0	12.3
17	C3M5	30.2	12.2	14.8	19.1
18	C4M1	32.5	14.0	12.0	19.5
19	C4M2	27.2	13.3	22.0	20.8
20	C4M3	34.0	11.8	22.2	22.7
21	C4M4	27.3	12.8	15.7	18.6
22	C4M5	35.8	12.7	21.7	23.4
23	C4M6	32.8	13.3	26.7	24.3
24	C4M7	23.0	10.7	21.7	18.5
25	C4M8	35.5	13.3	16.2	21.7
26	C4M9	30.2	15.0	14.2	19.8
27	C4M10	27.0	9.7	20.3	19.0
28	C5M1	23.0	20.2	18.7	20.6
29	C5M2	30.0	24.0	23.2	25.7
30	C5M3	31.0	11.5	21.2	21.2
31	C5M4	22.3	17.8	15.2	18.4
32	C5M5	18.8	12.2	9.7	13.6
33	C5M6	27.8	24.5	10.5	20.9
34	C5M7	26.2	13.5	21.7	20.5
35	C6M1	37.2	8.8	9.7	18.6
36	C6M2	39.7	13.7	26.0	26.5
37	C6M3	31.3	15.5	12.5	19.8
38	C6M4	14.3	23.8	17.7	18.6

Table 6.9 MLP of brick masonry activity observed on the construction field.

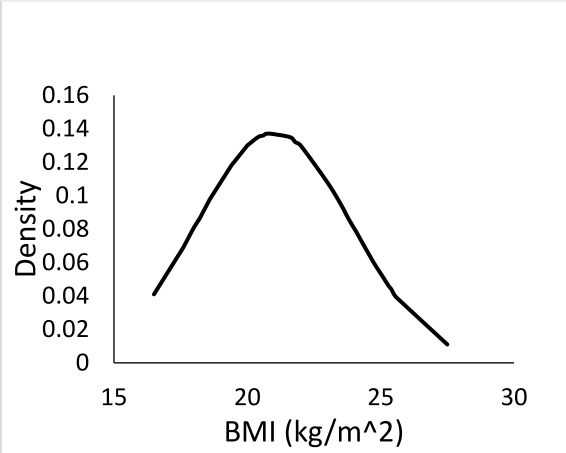
S. No	Mason Code	Time (mins)	Quantity (cum)	MLP (cum/min)	MLP (cft/hr)
1	C1M1	68	0.437	0.32	**13.6**
2	C1M2	57	0.313	0.38	**11.6**
3	C1M3	40	0.273	0.31	**14.5**
4	C1M4	39	0.260	0.31	**14.1**
5	C1M5	36	0.283	0.27	**7.1**
6	C1M6	43	0.281	0.32	**13.8**
7	C2M1	66	0.333	0.41	**11.3**
8	C2M2	41	0.195	0.44	**16.8**
9	C2M3	86	0.486	0.37	**15.4**
10	C2M4	63	0.280	0.47	**9.4**
11	C2M5	83	0.359	0.48	**9.2**
12	C2M6	89	0.378	0.49	**10.4**
13	C3M1	116	0.559	0.43	**10.2**
14	C3M2	90	0.377	0.50	**12.4**
15	C3M3	75	0.355	0.44	**16.2**
16	C3M4	100	0.551	0.38	**6.8**
17	C3M5	77	0.413	0.39	**7.6**
18	C4M1	42	0.179	0.49	**12.5**
19	C4M2	115	0.520	0.46	**13.1**
20	C4M3	83	0.475	0.36	**12.1**
21	C4M4	89	0.380	0.49	**9.0**
22	C4M5	50	0.234	0.45	**9.9**
23	C4M6	73	0.439	0.35	**12.7**
24	C4M7	63	0.267	0.49	**9.0**
25	C4M8	77	0.582	0.28	**16.0**
26	C4M9	78	0.415	0.39	**11.3**
27	C4M10	76	0.487	0.33	**7.8**
28	C5M1	58	0.299	0.40	**10.9**
29	C5M2	58	0.406	0.30	**14.8**
30	C5M3	89	0.416	0.45	**9.9**
31	C5M4	87	0.358	0.51	**8.7**
32	C5M5	82	0.486	0.37	**12.6**
33	C5M6	46	0.281	0.32	**8.7**
34	C5M7	52	0.179	0.49	**7.3**
35	C6M1	79	0.378	0.49	**10.1**
36	C6M2	68	0.413	0.39	**12.9**
37	C6M3	54	0.281	0.32	**11.0**
38	C6M4	56	0.333	0.41	**12.5**

Table 6.10 Brick Masonry labour data gathered from the field investigation

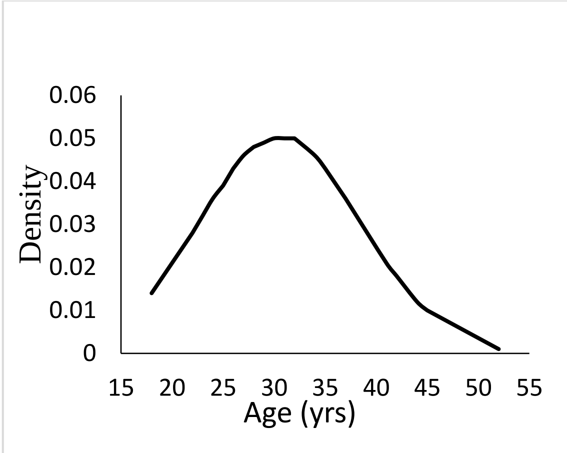
S. No	Mason Code	BMI (kg/sqm)	Age (years)	HGS (lbs)	UBMS (lbs)	MLP (cft/hr)
1	C1M1	27.5	52	74.1	16.4	13.6
2	C1M2	25.1	37	65.3	18.0	11.6
3	C1M3	23.5	26	82.9	23.2	14.5
4	C1M4	25.6	30	56.0	10.7	14.1
5	C1M5	25.3	45	65.3	16.1	7.1
6	C1M6	18.4	23	78.6	21.9	13.8
7	C2M1	23.0	32	79.5	26.7	11.3
8	C2M2	19.4	31	90.8	23.4	16.8
9	C2M3	18.6	35	87.3	25.2	15.4
10	C2M4	17.6	24	80.7	25.9	9.4
11	C2M5	18.0	25	88.3	17.7	9.2
12	C2M6	25.4	37	87.2	22.9	10.4
13	C3M1	24.1	35	95.9	22.6	10.2
14	C3M2	25.5	25	79.5	20.2	12.4
15	C3M3	20.9	23	87.2	28.2	16.2
16	C3M4	17.6	45	48.1	12.3	6.8
17	C3M5	16.5	18	70.7	19.1	7.6
18	C4M1	20.7	29	83.9	19.5	12.5
19	C4M2	19.5	27	85.8	20.8	13.1
20	C4M3	18.3	25	88.7	22.7	12.1
21	C4M4	24.1	26	77.4	18.6	9.0
22	C4M5	18.2	35	77.8	23.4	9.9
23	C4M6	19.5	31	50.8	24.3	12.7
24	C4M7	18.4	26	93.4	18.5	9.0
25	C4M8	18.6	23	84.5	21.7	16.0
26	C4M9	21.6	28	86.6	19.8	11.3
27	C4M10	23.8	22	68.9	19.0	7.8
28	C5M1	20.6	29	78.1	20.6	10.9
29	C5M2	20.0	32	76.5	25.7	14.8
30	C5M3	21.8	41	77.1	21.2	9.9
31	C5M4	20.4	44	50.8	18.4	8.7
32	C5M5	18.3	26	87.4	13.6	12.6
33	C5M6	24.7	42	77.8	20.9	8.7
34	C5M7	17.8	34	73.1	20.5	7.3
35	C6M1	19.2	22	88.8	18.6	10.1
36	C6M2	18.3	20	74.1	26.5	12.9
37	C6M3	22.0	28	52.1	19.8	11.0
38	C6M4	20.0	31	58.7	18.6	12.5
μ		21.0	30.6	76.6	20.6	11.4
σ		2.91	7.77	12.56	3.81	2.66
S_x		0.47	1.26	2.04	0.62	0.43
p		0.95	2.55	4.13	1.26	0.87

Table 6.11 Calculation of normal distribution data for respective parameter

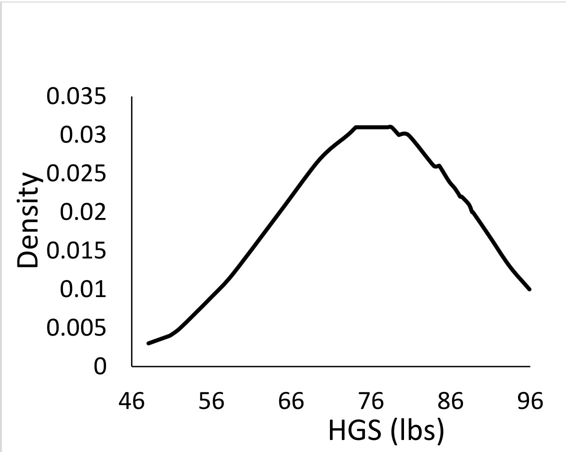
S. No	Mason Code	BMI	Age	HGS	UBMS	MLP
1	C1M1	0.011	0.001	0.031	0.057	0.106
2	C1M2	0.051	0.037	0.021	0.083	0.147
3	C1M3	0.095	0.043	0.026	0.083	0.076
4	C1M4	0.039	0.051	0.008	0.004	0.090
5	C1M5	0.046	0.009	0.021	0.052	0.042
6	C1M6	0.092	0.032	0.031	0.099	0.100
7	C2M1	0.108	0.050	0.031	0.029	0.148
8	C2M2	0.118	0.051	0.017	0.080	0.020
9	C2M3	0.098	0.044	0.022	0.050	0.049
10	C2M4	0.069	0.036	0.030	0.040	0.112
11	C2M5	0.081	0.040	0.021	0.078	0.106
12	C2M6	0.044	0.037	0.022	0.087	0.138
13	C3M1	0.078	0.044	0.010	0.091	0.134
14	C3M2	0.041	0.040	0.031	0.104	0.138
15	C3M3	0.137	0.032	0.022	0.014	0.030
16	C3M4	0.069	0.009	0.002	0.010	0.035
17	C3M5	0.041	0.014	0.028	0.097	0.055
18	C4M1	0.137	0.050	0.027	0.101	0.136
19	C4M2	0.120	0.046	0.024	0.105	0.121
20	C4M3	0.089	0.040	0.020	0.090	0.143
21	C4M4	0.078	0.043	0.032	0.091	0.100
22	C4M5	0.086	0.044	0.032	0.080	0.127
23	C4M6	0.120	0.051	0.004	0.065	0.132
24	C4M7	0.092	0.043	0.013	0.090	0.100
25	C4M8	0.098	0.032	0.026	0.101	0.035
26	C4M9	0.135	0.048	0.023	0.103	0.148
27	C4M10	0.086	0.028	0.026	0.096	0.061
28	C5M1	0.136	0.050	0.031	0.105	0.145
29	C5M2	0.130	0.050	0.032	0.043	0.067
30	C5M3	0.132	0.021	0.032	0.104	0.127
31	C5M4	0.135	0.012	0.004	0.089	0.090
32	C5M5	0.089	0.043	0.022	0.019	0.134
33	C5M6	0.061	0.018	0.032	0.105	0.090
34	C5M7	0.075	0.047	0.030	0.105	0.047
35	C6M1	0.113	0.028	0.020	0.091	0.132
36	C6M2	0.089	0.020	0.031	0.031	0.127
37	C6M3	0.130	0.048	0.005	0.103	0.146
38	C6M4	0.130	0.051	0.012	0.091	0.136



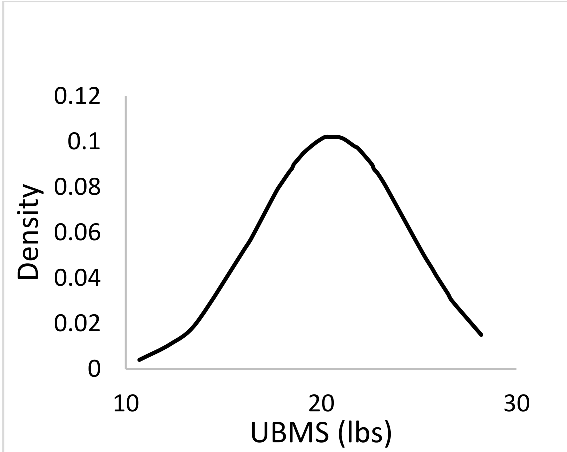
a) BMI normal distribution curve



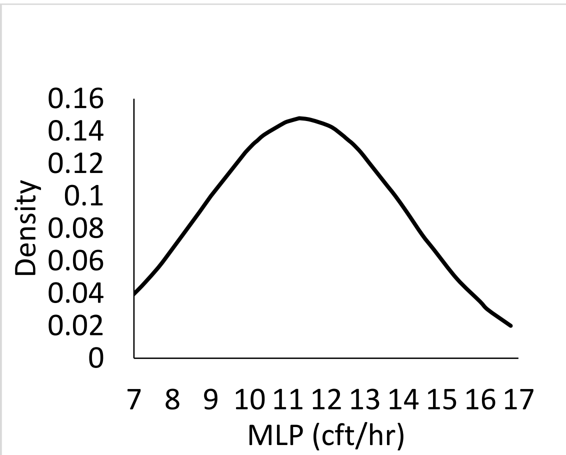
b) Age normal distribution curve



c) HGS normal distribution curve



d) UBMS normal distribution curve



d) MLP normal distribution curve

Figure 6.1 Normal distribution curves of various labour parameters in the study

6.3 Parametric correlation

Correlation among the various physical parameters of workers was analysed using correlation coefficient, which is a statistical measurement that states a suggestion of how meaningfully two variables are associated. As a consequence, correlation coefficient results in a value between -1 and 1. Values nearer to either side of the farthest signify a sound relationship, while the value nearer to 0 signifies a weak or even no relationship. This measurement is also known as Pearson's correlation coefficient or simply "r". Correlation can be classified in three different ways; positive, negative and no relation. Positive correlation is when one variable increases, so does the other and negative correlation is when one variable increases, the other decreases. No relationship, when movement in one variable cannot be predicted with other. Correlation coefficient between two variables can be calculated as:

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

Where:

N = number of pairs of scores

$\sum xy$ = sum of the products of the paired scores

$\sum x$ = sum of x scores

$\sum y$ = sum of y scores

$\sum x^2$ = sum of squared x scores

$\sum y^2$ = sum of squared y scores

Therefore, correlation coefficients for all pairs of physical parameters of brick masonry labour data are shown in Table 6.12. Based on Mukala (2012), no sound relation is found between any pair of parameters. This is due to the fact that each individual human physical parameter represents certain characteristics of every mason and therefore no significant correlation will exist

Table 6.12 Correlation coefficient among physical parameters of labour

Pair	Correlation coefficient (r)	Negative/positive	Sound relation
Age, BMI	0.432*	Positive	Lower
HGS, BMI	0.111	Negative	Negligible
UBMS, BMI	0.201	Negative	Negligible
HGS, Age	0.342*	Negative	Lower
UBMS, Age	0.269	Negative	Negligible
HGS, UBMS	0.382*	Positive	Lower

*P < 0.05

6.4 Parametric variation

Variation within the various physical parameters of labour and with regard to MLP was analysed using F-test, which explains the possibility of a value in a sample, assumed that null hypothesis is true. The F-test is a statistical measurement that evaluates the variances of two samples in order to test the hypothesis that the samples have been collected from people with different variances. The basic intent of this test is to verify the differences between sample variance. This test compares two variances (S_1 & S_2) by dividing them (S_1^2/S_2^2) and the outcome is always a positive number (since variance is always a positive number.

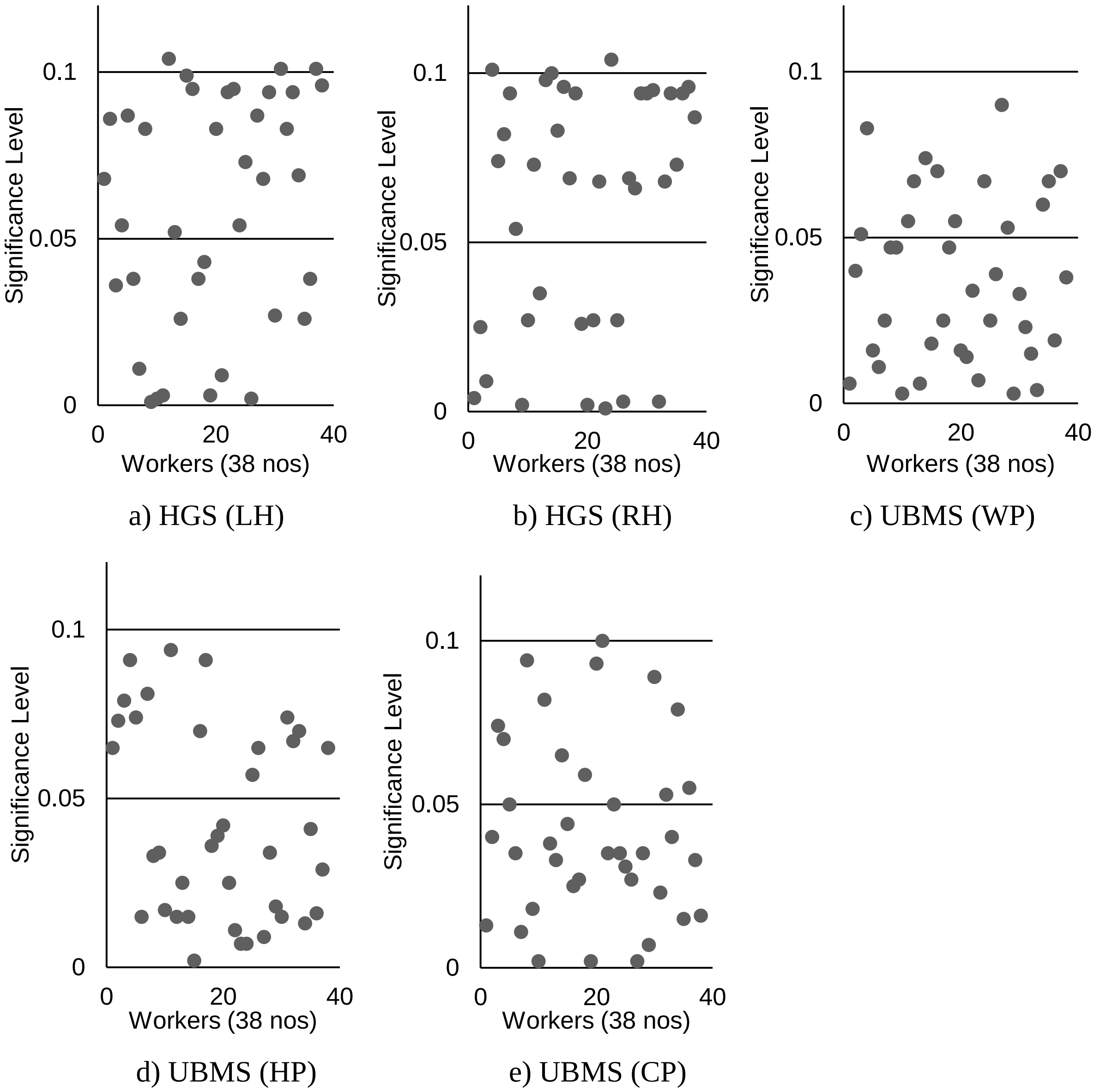
It is always anticipated that the variances are equal and therefore, null hypothesis is that when the variances are always equal. The higher variance is always placed in the numerator to force the test into a right-tailed test which is easier to calculate. F critical is calculated from the probability distribution table (95% confidence level) and null hypothesis is rejected when F is greater than F critical (Fc). Therefore, the variances of two parameters are unequal. The results of F-test (Appendix II) for all the parametric pairs is shown in Table 6.13. Since at 95% CL, F>Fc, null hypothesis is rejected for all the parametric pairs except for BMI-MLP (F<Fc). This clearly shows that alternate hypothesis is accepted for all the parameters to develop a statistically significant relationship.

Table 6.13 F-test results two-sample for variances

Pair	S_1^2	S_2^2	F	Fc (95%CL)	P (F<=f) one-tail
Age - BMI	61.97	8.69	7.13	1.73	1.50E-08
HGS - BMI	161.91	8.69	18.63	1.73	4.54E-15
UBMS - BMI	15.03	8.69	1.73	1.73	0.050
HGS - Age	161.91	61.97	2.61	1.73	0.002
UBMS - Age	15.03	61.97	4.12	1.73	1.90E-05
HGS - UBMS	161.91	15.03	10.78	1.73	3.17E-11
BMI - MLP	8.69	7.26	1.20	1.73	0.293
Age - MLP	61.97	7.26	8.54	1.73	1.09E-09
HGS - MLP	161.91	7.26	22.31	1.73	2.17E-16
UBMS - MLP	15.03	7.26	2.07	1.73	0.015

6.5 Variations in work periods of isometric strength tests

There were three work periods conducted in the study for collecting two isometric strength test parameters (HGS and UBMS). A statistical method called Analysis of variance (ANOVA) can decide whether the means of three or more groups are different. There are two main types: one-way and two-way ANOVA tests. Two-way ANOVA tests can be with or without replication. One-way ANOVA is used when testing is required for groups to check if there is any difference between them. Two-way ANOVA test without replication is used in the case of one group and testing double to that same group. Therefore, for present study, so as to test the variations in isometric strength, test parameters were conducted at three different time periods in a day, and one-way ANOVA test was carried out. P value from ANOVA test results are tabulated in Table 6.14 and presented in Figure 6.2. The detailed analysis of ANOVA was carried out using Microsoft excel with Data Analysis tool and shown in Appendix II. From Figure 6.2, it clearly displays that almost 50% of the data is having less than 5% error. However, error for the remaining data was under 10%. Therefore, the tests conducted at different work periods in a day have considerable variation but are not very strong. These tests may also give good metrics even if they are conducted only once in a day.



a) HGS (LH) b) HGS (RH) c) UBMS (WP)

d) UBMS (HP) e) UBMS (CP)

Figure 6.2 Variations of P value of isomeric strength tests carried out by ANOVA at three different time periods of work in a day

Table 6.14 P-values resulted from ANOVA of isometric strength tests conducted at three different periods of work for all brick masons.

S. No	Mason Code	HGS		UBMS		
		RH	LH	CP	WP	HP
1	C1M1	0.068	0.004	0.013	0.006	0.065
2	C1M2	0.086	0.025	0.040	0.040	0.073
3	C1M3	0.036	0.009	0.074	0.051	0.079
4	C1M4	0.054	0.101	0.070	0.083	0.091
5	C1M5	0.087	0.074	0.050	0.016	0.074
6	C1M6	0.038	0.082	0.035	0.011	0.015
7	C2M1	0.011	0.094	0.011	0.025	0.081
8	C2M2	0.083	0.054	0.094	0.047	0.033
9	C2M3	0.001	0.002	0.018	0.047	0.034
10	C2M4	0.002	0.027	0.002	0.003	0.017
11	C2M5	0.003	0.073	0.082	0.055	0.094
12	C2M6	0.104	0.035	0.038	0.067	0.015
13	C3M1	0.052	0.098	0.033	0.006	0.025
14	C3M2	0.026	0.100	0.065	0.074	0.015
15	C3M3	0.099	0.083	0.044	0.018	0.002
16	C3M4	0.095	0.096	0.025	0.070	0.070
17	C3M5	0.038	0.069	0.027	0.025	0.091
18	C4M1	0.043	0.094	0.059	0.047	0.036
19	C4M2	0.003	0.026	0.002	0.055	0.039
20	C4M3	0.083	0.002	0.093	0.016	0.042
21	C4M4	0.009	0.027	0.100	0.014	0.025
22	C4M5	0.094	0.068	0.035	0.034	0.011
23	C4M6	0.095	0.001	0.050	0.007	0.007
24	C4M7	0.054	0.104	0.035	0.067	0.007
25	C4M8	0.073	0.027	0.031	0.025	0.057
26	C4M9	0.002	0.003	0.027	0.039	0.065
27	C4M10	0.087	0.069	0.002	0.090	0.009
28	C5M1	0.068	0.066	0.035	0.053	0.034
29	C5M2	0.094	0.094	0.007	0.003	0.018
30	C5M3	0.027	0.094	0.089	0.033	0.015
31	C5M4	0.101	0.095	0.023	0.023	0.074
32	C5M5	0.083	0.003	0.053	0.015	0.067
33	C5M6	0.094	0.068	0.040	0.004	0.070
34	C5M7	0.069	0.094	0.079	0.060	0.013
35	C6M1	0.026	0.073	0.015	0.067	0.041
36	C6M2	0.038	0.094	0.055	0.019	0.016
37	C6M3	0.101	0.096	0.033	0.070	0.029
38	C6M4	0.096	0.087	0.016	0.038	0.065

6.6 Regression analysis among human physical parameters

Simple linear regression analysis is a statistical approach that summarizes and examines relationships between two quantitative variables. Therefore, various human physical parameters collected from the field were analysed using simple linear regression analysis. By mathematical principle, the two parameters involved in this analysis are assigned x and y. The equation that explains how y is correlated to x is established as the regression model. This regression model also holds an error represented by E which is used to interpret the unpredictability in y which cannot be described by the model. The simple linear regression equation is represented as:

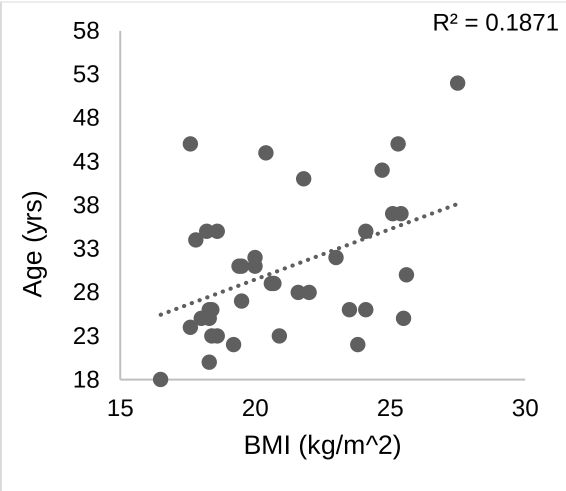
$$E(y) = (\beta 0 + \beta 1\ x).$$

This equation is presented as a straight line where β0, β1 is the y intercept of the regression line and slope respectively. E(y) is the expected value of y for a given value of x. A regression line can determine a positive, negative or no linear relationship. If the regression line is flat, there is no relationship between the two variables. If the regression line slope is ascending, a positive linear relationship exists. If the regression line slope is descending, a negative linear relationship exists. Relationships between pairs of various physical parameters of brick masons is shown in Figure 6.3

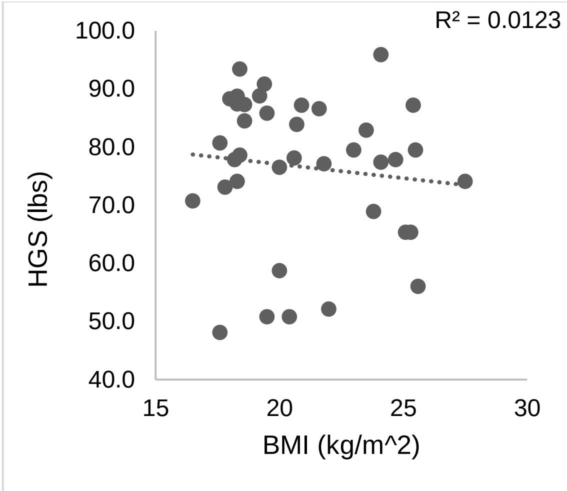
The purpose of regression analysis is not to interpret cause and effect relations between parameters. However, this analysis indicates to what extent the parametric pairs are related to each other and it can be observed from R^2 value of the model. R^2 signifies the percentage of the variance in the dependent variable that the independent variables describe together collectively and it also measures the relationship strength among model and the dependent variable on a range of 0 – 100% scale. R^2 is the percentage of the dependent variable variation that a linear model explains.

$$R^2 = \frac{\text{variance explained by the model}}{\text{total variance}}$$

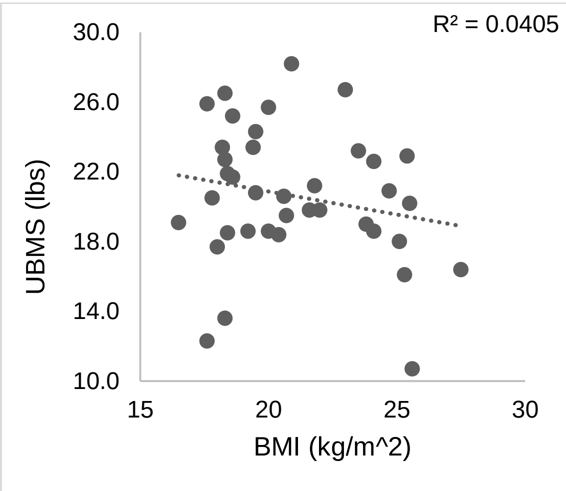
Generally, the larger the $R^2$is, the better the regression model fits the data. Therefore, detailed regression analysis for various parametric pairs in the study is conducted using Microsoft excel data analysis tool, which figures in the Appendix II. From Figure 6.3 It is clear that R^2 values of all regression analysis showed very low values i.e., not more than 20% and no significant relationship exists between any two parameters.



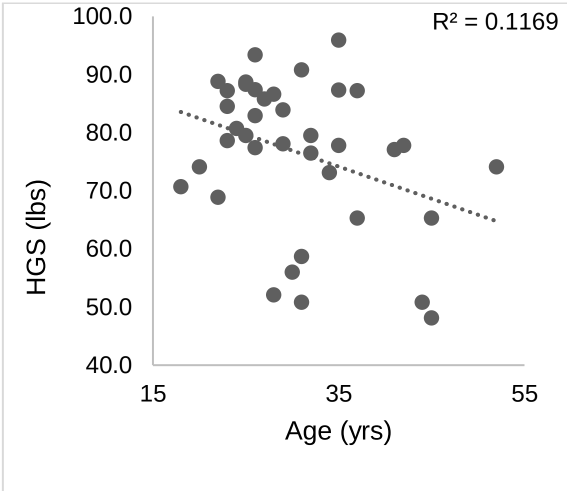
a) BMI vs Age



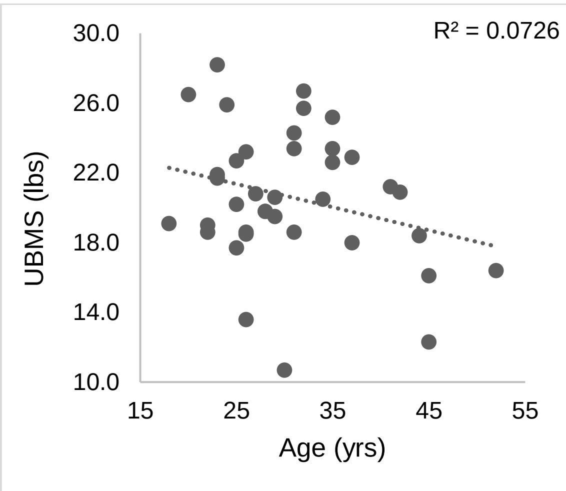
b) BMI vs HGS



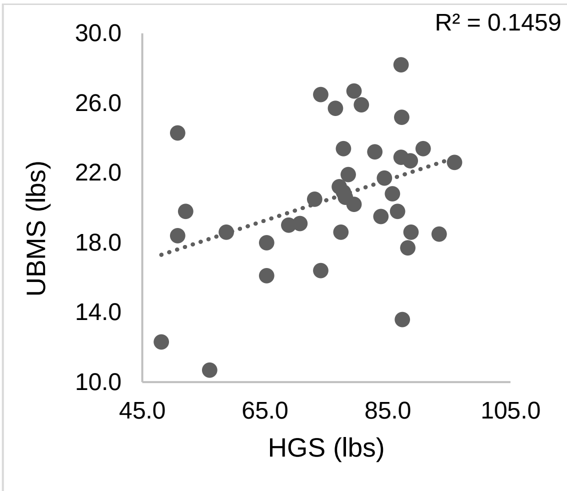
c) BMI vs UBMS



d) Age vs HGS



e) Age vs UBMS

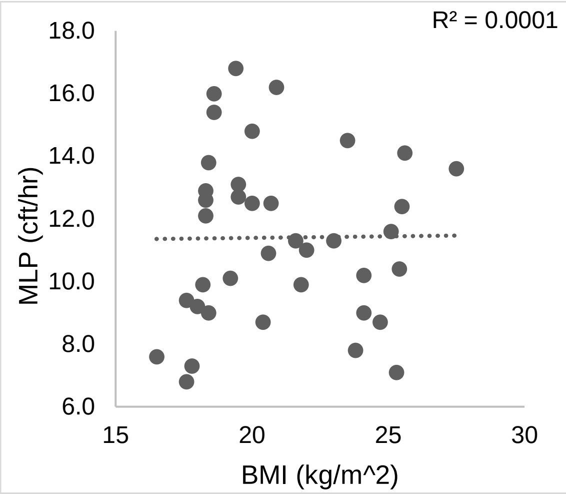


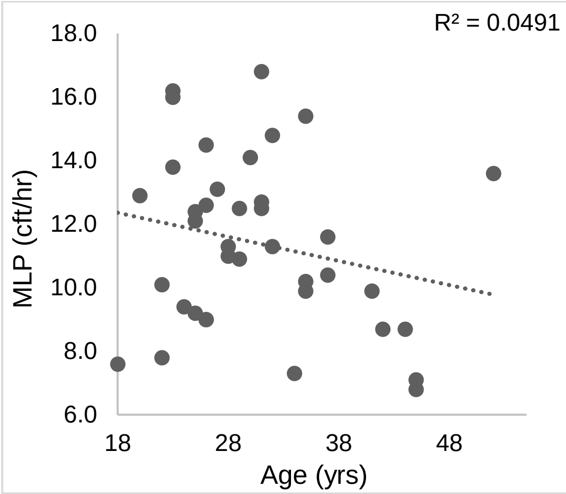
f) UBMS vs HGS

Figure 6.3 Graphs showing the simple linear regression relationship among the various physical parameters of brick masons

6.7 Influence of human physical parameters on MLP

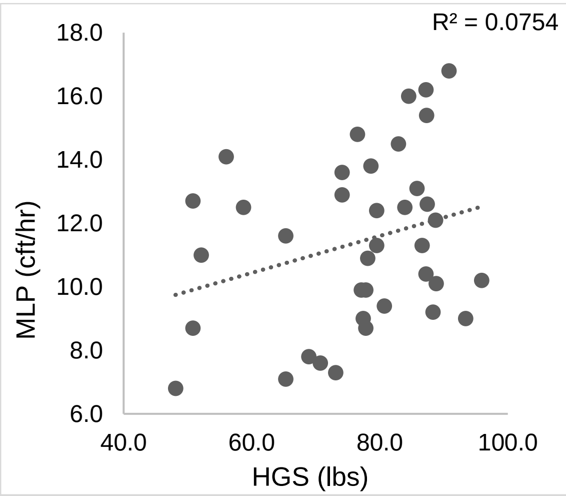
In the present investigation, productivity of masonry labour is defined as the ratio of the quantity installed to physical ability. This is to say that physical ability of workers is taken as the input. The measurement of physical ability is characterized by various parameters such as Age, BMI, HGS and UBMS. It is a known fact that the labour productivity depends upon several factors. However, the present study focussed only on human abilities. The physical abilities are quantified and are given in Table 6.10.

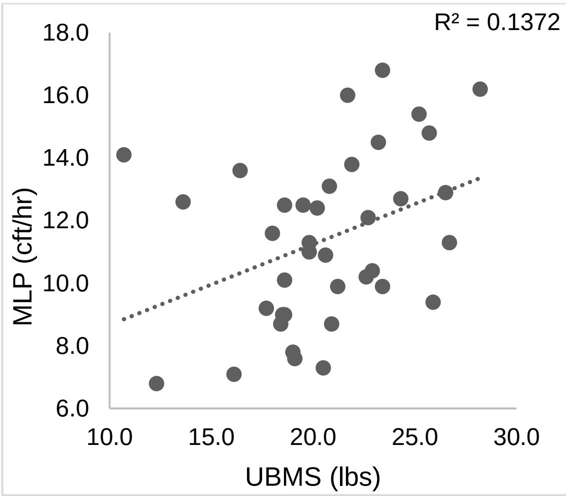




a) BMI vs MLP

b) Age vs MLP





c) HGS vs MLP

d) UBMS vs MLP

Figure 6.4 Graphs showing simple linear regression relationship between the physical parameters of labour and their productivity

Now, to study the influence of physical ability, for example age, on the output. The points are plotted as shown in Figure 6.4. The plot gives a simple trend showing the influence of the parameters viz. Age, BMI, HGS and UBMS. If a single linear regression model is attempted between the masonry labour physical parameters and their productivity, it can be seen that BMI does not show any prediction on MLP. This is mainly due to the fact that the trend curve of BMI is hump and therefore cannot have a linear prediction. The effect of age showed decrease in MLP for older people, which is consistent with established research (Skirrbekk, 2008). The parameter HGS is identified as a very good indicator to represent physical ability, where productivity depends on overall body strength (Tietjen-Smith et.al., 2006; Koley et.al., 2009) as in case of masonry workers. When comparing three parameters BMI, age and HGS, using regression coefficient (R^2 values), HGS and age indicate the trends but show a very weak linear relation with MLP.

In this study, a new human physical parameter UBMS similar to HGS was introduced. However, UBMS involves various upper body muscle strength that are required for better performance of masonry labour. From Figure 6.4, the plot between MLP and UBMS shows a trend and it is that MLP increased with UBMS. The simple linear relation between UBMS and MLP has given a correlation coefficient (R^2) of 13.72% which is better than HGS (R^2 =7.54%). This shows that the new parameter UBMS is at least equal to or sometimes even better than other established parameters such as BMI, Age and HGS. It is clear from the above study that four parameters influence MLP but a dependable simple linear regression model cannot be established. This can be seen from the R^2 values plot versus various physical parameters of labour (Figure 6.4).

It is now proposed to investigate whether a multi regression model can be obtained to predict MLP. Since there are four parameters under consideration, if a combination of two parameters is taken, there exist six combinations, namely; Age-BMI, HGS-BMI, Age-HGS, BMI-UBMS, Age-UBMS and HGS-UBMS. Multiple linear regression analysis has been conducted between MLP and the above mentioned six pairs of parameters. The R^2 values of these regression analysis are shown in Table 6.15 and the plots in Figure 6.5. This shows that a combination of pair of weak and weak parameters gives lower R^2 value and strong and strong parameter gives higher R^2 value, i.e., Age-BMI has R^2 value of 6.31% and HGS-UBMS has R^2 value of 15.79%. Thus, there is improvement in obtaining the relation between MLP and human physical parameters by considering them in pairs. However, even the HGS-UBMS has R^2 value of 15.79% which is still a weak relationship but better than simple linear regression analysis.

Table 6.15 R^2 values of regression analysis between dependant variable (MLP) and independent variables (human physical parameters)

S. No	Parametric Combinations	R^2 %	S. No	Parametric Combinations	R^2 %
1	BMI	0.01	9	BMI, UBMS	14.48**
2	Age	4.91	10	Age, UBMS	15.32**
3	HGS	7.54	11	BMI, Age, HGS	10.58
4	UBMS	13.72	12	Age, HGS, UBMS	16.63**
5	BMI, Age	6.31	13	BMI, Age, UBMS	17.58**
6	Age, HGS	9.39	14	BMI, HGS, UBMS	16.65**
7	HGS, UBMS	15.79*	15	Age, BMI, HGS, UBMS	18.64
8	BMI, HGS	7.72			

*P < 0.05, **P < 0.1

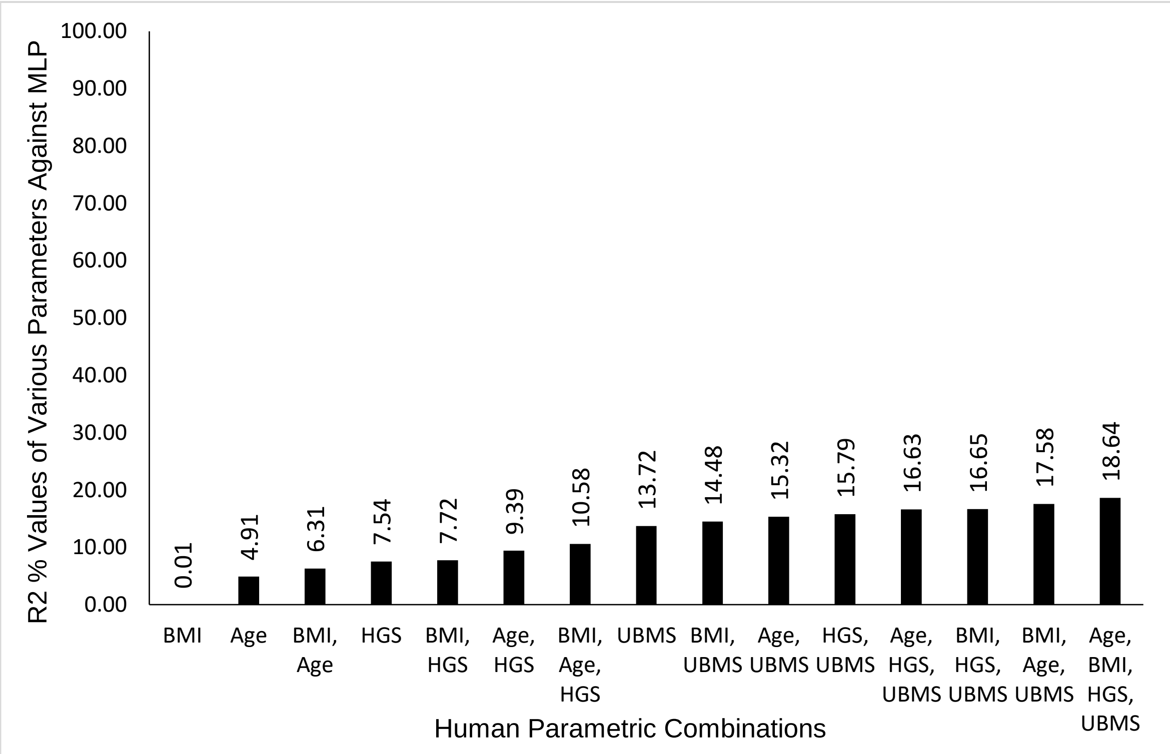


Figure 6.5 R^2% values of regression analysis of parametric combinations of masonry labour against productivity

Hence, it is now proposed to examine if a multiple regression relation with three or all the four parameters will give a better trend and relation. The experiment is conducted with a combination of three parameters. This has resulted in four possible three parametric combinations of multiple linear regression analysis namely; Age-BMI-HGS, Age-HGS-UBMS, BMI-HGS-UBMS and BMI-Age-UBMS. Detailed analysis of multiple regression analysis is carried out using Microsoft excel data analysis tool and results are shown in the Appendix II. The R^2 values of these parametric combinations are shown in Table 6.12 and are plotted in Figure 6.5. It can be understood that the best possible trend and multiple linear relation can be obtained when any of the parametric combination involves UBMS parameter. Thus, it establishes that the parameter UBMS will improve the significance of predicting the MLP model with regard to human physical parameters. This is mainly because isometric grip strength using UBMS involves various upper body muscles in assessing the human strength. This corroborates the isometric grip strength using HGS which involves only hand and forearm muscles as a measure of overall body strength (Koley et.al., 2009).

Now all four parameters are combined in multiple linear regression for establishing the relation between MLP and human physical parameters. The R^2 value of regression analysis with all four parameters was found to be 18.64%, as shown in Figure 6.5 and Table 6.12. It is the highest of all R^2 value with all four parameters but is still only about 20%, while the multilinear regression is also a weak model. This shows that the parameters individually influence MLP but neither a simple linear nor a multilinear regression with various combinations of human physical parameters is able to give a reliable and valid regression model for predicting the MLP. Hence, it is necessary to investigate further if a new parameter is possible by combining all the four parameters.

To summarize, all the labour parameters that were collected were noticed to have normally distributed data. Various statistical tests such as correlation, F-test, ANOVA, simple and multilinear regression analysis were conducted to check the possibility of developing a prediction model for assessing the MLP from human physical parameters. Parametric variation of BMI with MLP is almost equal to 1 (i.e F=1.2). However, F-test is less than F critical. Therefore, alternate hypothesis is required. Individually all the labour data collected hold good statistical value but failed to form a significant relationship. This shows that there is need to unify all the variables by developing a statistical weightage. Combination of all four parameters to predict MLP showed the highest significance which conveys that the more statistically independent, the variables are, more precise the model. Therefore, a new scientific method needs to be developed to form a statistically significant MLP prediction model. This investigation is explained in the following chapter.

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Chapter - 07

7. Relationship Between Human Physical Parameters and MLP

7.1 Introduction

Human ability represented by the physical parameters such as Age, BMI, HGS and UBMS has an impact on the productivity of masonry labour. As discussed in the previous chapter, an attempt to obtain a simple and multi linear regression relation gave low R^2 values which prompted the researcher to explore a better parameter to predict the MLP. It is established in the literature corresponding to MLP that middle-aged masonry labour gives best productivity (Skirbekk, 2004). As the age increases, MLP is likely to reduce. Similarly, earlier research and WHO recommendations show that obese and weak people, represented by BMI, are likely to have lower MLP. Thus, an increase in the numerical value of age or BMI, cannot really give a proportionate increase in MLP. Further to this, it is also established in literature that the human ability represented by HGS will have proportionate influence i.e., the increase in HGS of a worker will result in increase in MLP. Similar to HGS, UBMS also has the same influence on MLP. As understood from statistical analysis in the previous chapter, the absolute value of a worker with respect to single parameter should not be taken. Then, the question is how MLP is to be reflected through human physical abilities. A keen observation of the data presented in Table 6.10 shows that the human physical parameters should be denoted in the form of categories. Therefore, the productivity of workers with respect to various categories of human physical parameter is given as:

$$\hat{P}_{hp,ca} = \frac{\sum P_{hp,ca}}{n_{ca}} \quad \text{......} (6.1)$$

Where $\hat{P}_{hp,ca}$ represents average productivity of workers for the respective category in which "hp" stands for respective parameter and "ca" stands for category. $P_{hp,ca}$ represents the individual productivity of worker and "n_{ca}" is the no of workers in the respective parametric category. The typical trends of various human physical parameters with respect to the labour productivity are shown in Figure 7.1.

Thus, there cannot be an absolute number for Age, BMI, HGS and UBMS for a worker but may fall into their defined categories and hence, this provides a broad hint about classifying parameters as lower, middle and higher range categories. It is needless to

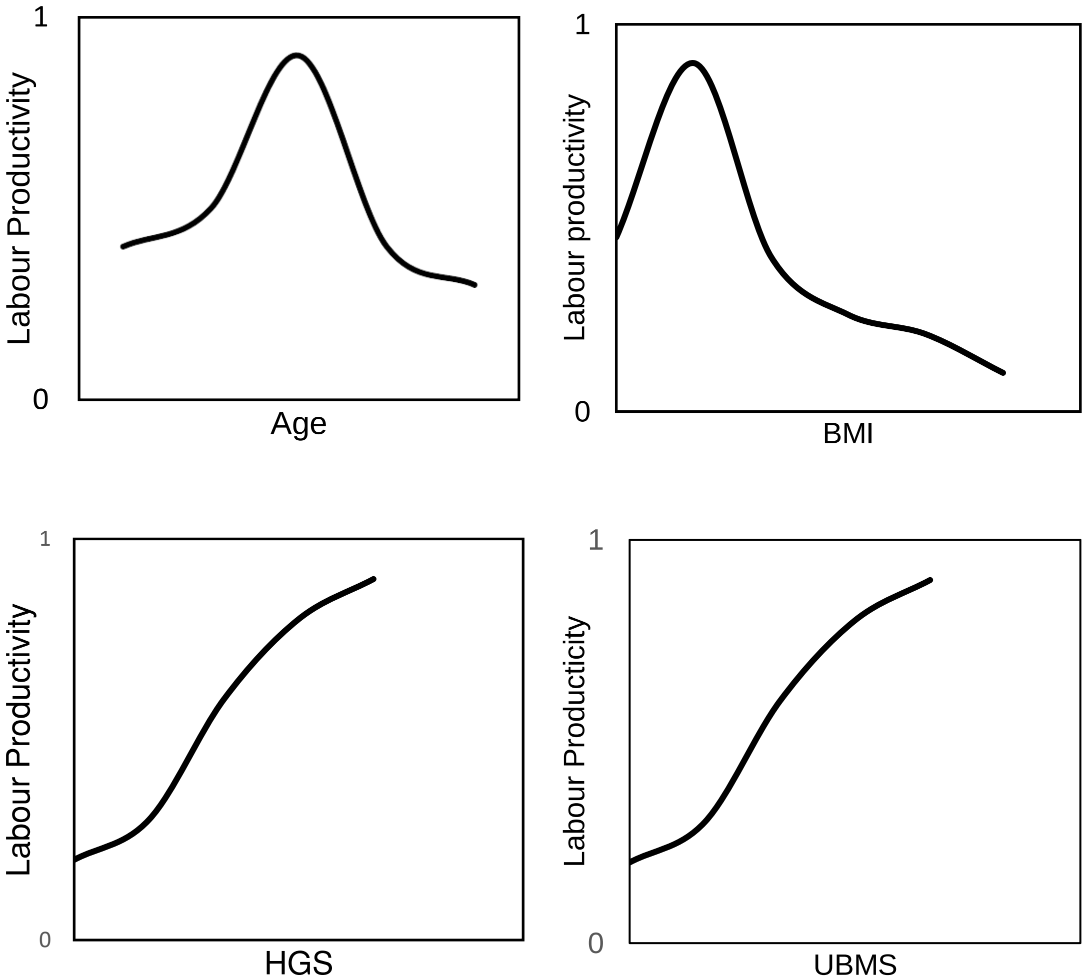


Figure 7.1 Typical trend of labour productivity with various human parameters

say such categorization has already been made in case of Age and BMI parameters and now the isometric strength test parameters (HGS and UBMS) also need to be classified in similar way. Therefore, categorization for masonry workers is done and the same is described in the following section.

7.2 Masonry labour categorization

Productivity of an individual worker is extracted from the video observations recorded on construction site. Each video observation contains a group of workers performing the given tasks. Human parameter data was also collected on the site itself. The personal details of workers such as name, age etc., on site was collected through an interview as stated earlier. Weight and height of the workers were measured using an auto calibrated electronic weighing machine (5-180kg range) and stature meter (2m length), from which BMI was calculated. From the normal distribution curves (Figure 6.1), the parameters age, BMI, HGS, UBMS and MLP were slotted into three ranges *(Rn)* i.e., lower range, middle range and upper range. The probability and standard deviation of the respective labour parameter are shown in Table 6.10.

The ratio of probability to the standard deviation obtained is 0.33 for all human physical parameters and MLP. Hence, ranges are as given below:

$$\left.\begin{array}{rl} & \bar{\bar{x}}\pm(p/\sigma)\sigma = \bar{x}\pm 0.33\sigma \\ \text{lower Than} & \bar{x} - 0.33\sigma = \textit{Lower Range (LR)} \\ \text{greater Than} & \bar{\bar{x}}+0.33\sigma = \textit{Upper Range (UR)} \\ \text{between "}\bar{x}\text{-0.33}\sigma\text{" \& "}\bar{\bar{x}}\text{+0.33}\sigma\text{"} & = \textit{Mid Range (MR)} \end{array}\right\} \quad \ldots\ldots\ldots\ldots\ldots (6.2)$$

Where, $\bar{x}$ is the average and "σ" is the standard deviation. Human parameters of masonry labour were categorized using equation (6.2) and shown in Table 7.1. However, in case of BMI, the ranges given by WHO was adopted. Masons falling into a category are collated from Table 6.10 corresponding to each human physical parameter and is shown in Table 7.1

Table 7.1 Various categories of physical parameters of construction masonry labour

hp	***Rn***	**($P_{hp,ca}$)**	**Masons falling in the category**	**Nos**
Age *(a)*	LR	$\hat{p}_{a,(<28)}$	C3M5, C6M2, C4M10, C6M1, C1M6, C3M3, C4M8, C2M4, C2M5, C3M2, C4M3, C1M3, C4M4, C4M7, C5M5, C4M2	16
	MR	$\hat{p}_{a,(28-33)}$	C4M9, C6M3, C4M1, C5M1, C1M4, C2M2, C4M6, C6M4, C2M1, C5M2	10
	UR	$\hat{p}_{a,(>33)}$	C5M7, C2M3, C3M1, C4M5, C1M2, C2M6, C5M3, C5M6, C5M4, C1M5, C3M4, C1M1	12
BMI *(b)*	LR	$\hat{p}_{b,(<18.5)}$	C3M5, C2M4, C3M4, C5M7, C2M5, C4M5, C4M3, C5M5, C6M2, C1M6, C4M7	11
	MR	$\hat{p}_{b,(18.5-24.9)}$	C2M3, C4M8, C6M1, C2M2, C4M2, C4M6, C5M2, C6M4, C5M4, C5M1, C4M1, C3M3, C4M9, C5M3, C6M3, C2M1, C1M3, C4M10, C3M1, C4M4, C5M6	21
	UR	$\hat{p}_{b,(>24.9)}$	C1M2, C1M5, C2M6, C3M2, C1M4, C1M1	6
HGS *(h)*	LR	$\hat{p}_{h,(<72.5)}$	C3M4, C4M6, C5M4, C6M3, C1M4, C6M4, C1M2, C1M5, C4M10, C3M5	10
	MR	$\hat{p}_{h,(72.5-80.7)}$	C5M7, C1M1, C6M2, C5M2, C5M3, C4M4, C4M5, C5M6, C5M1, C1M6, C2M1, C3M2, C2M4	13
	UR	$\hat{p}_{h,(>80.7)}$	C1M3, C4M1, C4M8, C4M2, C4M9, C2M6, C3M3, C2M3, C5M5, C2M5, C4M3, C6M1, C2M2, C4M7, C3M1	15
UBMS *(u)*	LR	$\hat{p}_{u,(<19.4)}$	C1M4, C3M4, C5M5, C1M5, C1M1, C2M5, C1M2, C5M4, C4M7, C4M4, C6M1, C4M10, C3M5	13
	MR	$\hat{p}_{u,(19.4-21.8)}$	C4M1, C4M9, C6M3, C6M4, C3M2, C5M7, C5M1, C4M2, C5M6, C5M3, C4M8	11
	UR	$\hat{p}_{u,(>21.8)}$	C1M6, C3M1, C4M3, C2M6, C1M3, C2M2, C4M5, C4M6, C2M3, C5M2, C2M4, C6M2, C2M1, C3M3	14

7.3 Human parameter performance

Categorization of masonry labour is shown in Table 7.1 and is given again in 1st column of Table 7.2. Productivity of a mason is drawn from Table 6.10 for the respective human category as mentioned in the 4th column of Table 7.1 and given in 3rd column of Table 7.2. Average value of MLP of workers is given in 4th column. Parametric categories (ca_n) are assigned in 5th column of Table 7.2, based on the average value of MLP. The highest average value of MLP is assigned as ca_1; subsequently ca_2 and ca_3 were assigned.

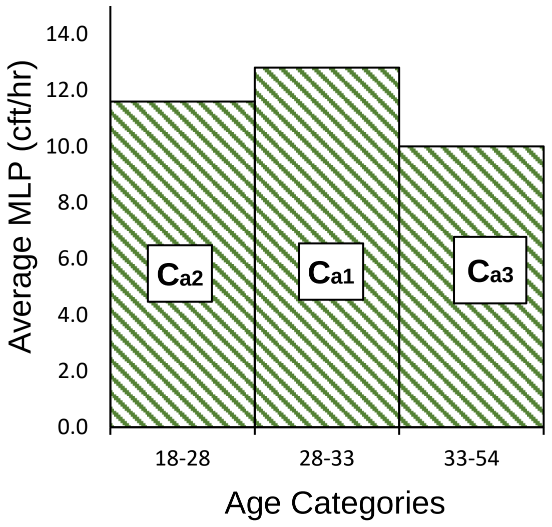
Table 7.2 Categorization of physical parameters with respect to their average MLP

Sn	$P_{hp,ca}$	Productivities of Masons (cft/hr)	Average	ca_n
1	$\hat{p}_{a,(<28)}$	7.6, 12.9, 7.8, 10.1, 13.8, 16.2, 16, 9.4, 9.2, 12.4, 12.1, 14.5, 9, 9, 12.6, 13.1	11.6	ca_2
2	$\hat{p}_{a,(28-33)}$	11.3, 11, 12.5, 10.9, 14.1, 16.8, 12.7, 12.5, 11.3, 14.8	12.8	ca_1
3	$\hat{p}_{a,(>33)}$	7.3, 15.4, 10.2, 9.9, 11.6, 10.4, 9.9, 8.7, 8.7, 7.1, 6.8, 13.6	10.0	ca_3
4	$\hat{p}_{b,(<18.5)}$	7.6, 9.4, 6.8, 7.3, 9.2, 9.9, 12.1, 12.6, 12.9, 13.8, 9	10.1	ca_3
5	$\hat{p}_{b,(18.5-24.9)}$	15.4, 16, 10.1, 16.8, 13.1, 12.7, 14.8, 12.5, 8.7, 10.9, 12.5, 16.2, 11.3, 9.9, 11, 11.3, 14.5, 7.8, 10.2, 9, 8.7	12.1	ca_1
6	$\hat{p}_{b,(>24.9)}$	11.6, 7.1, 10.4, 12.4, 14.1, 13.6	11.5	ca_2
7	$\hat{p}_{h,(<72.5)}$	6.8, 12.7, 8.7, 11, 14.1, 12.5, 11.6, 7.1, 7.8, 7.6	10.0	ca_3
8	$\hat{p}_{h,(72.5-80.7)}$	7.3, 13.6, 12.9, 14.8, 9.9, 9, 9.9, 8.7, 10.9, 13.8, 11.3, 12.4, 9.4	11.1	ca_2
9	$\hat{p}_{h,(>80.7)}$	14.5, 12.5, 16, 13.1, 11.3, 10.4, 16.2, 15.4, 12.6, 9.2, 12.1, 10.1, 16.8, 9, 10.2	12.6	ca_1
10	$\hat{p}_{u,(<19.4)}$	14.1, 6.8, 12.6, 7.1, 13.6, 9.2, 11.6, 8.7, 9, 9, 10.1, 7.8, 7.6	9.8	ca_3
11	$\hat{p}_{u,(19.4-21.8)}$	12.5, 11.3, 11, 12.5, 12.4, 7.3, 10.9, 13.1, 8.7, 9.9, 16	11.4	ca_2
12	$\hat{p}_{u,(>21.8)}$	13.8, 10.2, 12.1, 10.4, 14.5, 16.8, 9.9, 12.7, 15.4, 14.8, 9.4, 12.9, 11.3, 16.2	12.9	ca_1

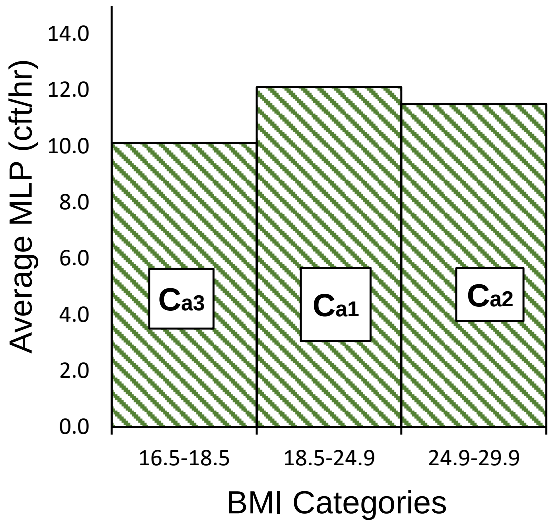
Serial numbers (Sn) 1,2,3 belong to parameter Age. The highest average value of MLP which is 12.8 cft/hr is given category ca_1 which belongs to middle age labour. The next highest average MLP (11.6cft/hr) i.e., younger age labour is given category ca_2 and the labour with lowest average MLP is given category ca_3. The same methodology is followed for classifying BMI, HGS and UBMS. The human physical parameters which were now classified into three are plotted against MLP in Figure 7.2.

Age had a reasonable effect on MLP. From Figure 7.2, graph (a), it is observed that middle age workers show higher MLP whereas older workers showed lower MLP. Also, younger workers showed considerably higher MLP compared to older workers. Therefore, middle age workers can be taken as highly productive on the construction field and hence placed under category ca_1, subsequent categories being class ca_2 and class ca_3.

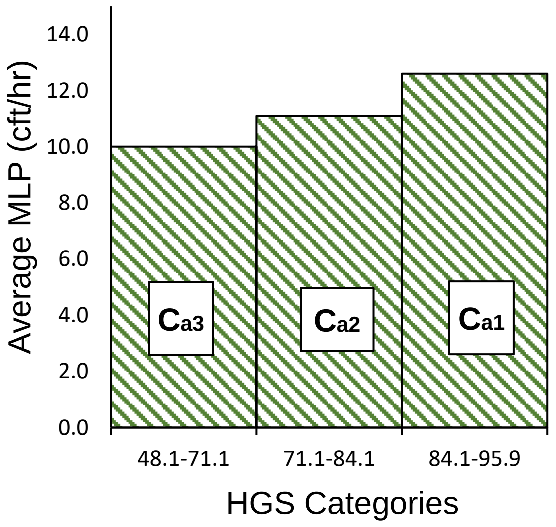
MLP of workers against BMI categories as per WHO were plotted as shown in Figure 7.2 (b). Maximum MLP showed up under normal weight category. Both overweight and underweight categories showed low MLP in which underweight category showed the least MLP. Normal weight category workers fall under category ca_1, whereas overweight and underweight workers fall under category ca_2 and category ca_3 respectively.



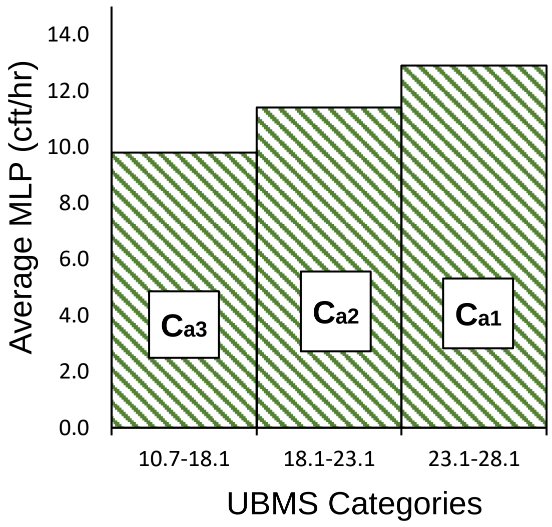
(a) Age vs MLP



(b) BMI vs MLP



(c) HGS vs MLP



(d) UBMS vs MLP

Figure 7.2 Trends of MLP with regard to human physical parameter categories

The measurement of HGS and UBMS has a good prognostic value. MLP variations are shown in Figure 7.2 (c) & Figure 7.2 (d). It is observed that MLP of workers is linearly increasing with increase in muscular strength. Based on the average MLP of workers in particular categories of both isometric strength tests, the workers in upper category are treated as best performers and hence figured under category ca_1 while subsequent categories were labelled ca_2 and ca_3.

7.4 Human Parameter Index (HPI)

Now, the parameters have to be combined into a unified parameter using parametric categorization. Every worker is categorized as ca_1, ca_2 or ca_3 corresponding to the respective range of human physical parameter. For example, parameter age is having three categories (ca_1, ca_2, ca_3). A mason depending upon his productivity will fall into either ca_1 or ca_2 or ca_3. Similarly, the same mason corresponding to other parameters, for example BMI, may figure in any one of the categories ca_1 or ca_2 or ca_3.

The possibility is that a mason who is likely to give highest productivity is ideally expected to fall in category ca_1 in all physical parameters. Similarly, a mason who is likely to have lowest productivity is ideally expected to fall in category ca_3 in all parameters. But, in reality, a construction worker may have different abilities corresponding to the human physical parameters. These abilities are further classified based on the MLP and are given in the relevant performance class weightage. Thus, the sum of the weightages of respective performance classes corresponding to human parametric category (ca_n) of a worker will be the index of that worker. Hence, a parameter called Human Parameter Index (HPI) is defined as

$$\text{HPI} = \sum_{i=1}^{k} \text{W}^{i}{}_{c_n} \varphi^{i} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6.3)$$

$$= \text{W}^{1}{}_{c_n}\varphi^{1} + \text{W}^{2}{}_{c_n}\varphi^{2} + \text{W}^{3}{}_{c_n}\varphi^{3} \ldots\ldots\ldots\ldots\ldots\ldots + \text{W}^{k}{}_{c_n}\varphi^{k}$$

Where $\text{W}^{i}{}_{c_n}$ represents the productivity weightage based on human physical parameter and φ^{i} is relative importance of respective parameter of an individual worker in which $i=1,2,3\ldots k$ represents various parameters and $c_n = c_1, c_2, \ldots\ldots c_n$ represents different performance classes in the respective parameter.

In the present study φ^{i} is taken as 1. Hence, equation (6.3) can be written as

$$\text{HPI} = \sum_{i=1}^{k} \text{W}^{i}{}_{c_n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6.4)$$

$$= \text{W}^{1}{}_{c_n} + \text{W}^{2}{}_{c_n} + \text{W}^{3}{}_{c_n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots + \text{W}^{k}{}_{c_n}$$

Further, in the present study, human physical parameter is classified in to three performance classes and are called c_1, c_2 & c_3. Now, for weightages $\text{W}^{i}{}_{c_n}$, i^{th} parameter is to be assigned in order to represent a worker with an index value. The weightage depends on the performance class. The highest performance class needs to have the highest value i.e., c_1 will have the highest and c_3 will have the lowest value. These weightages are worked out from the MLP as illustrated in Table 7.3

7.5 Productivity weightage

The weightages are assigned based on the analysis of the entire labour productivity data. It is already explained that MLP is normally distributed as shown in Figure 6.1 and the values of mean and standard deviation are given in Table 6.10. From equation (6.2), MLP is also categorized into three ranges in which middle range falls between the values of 10.5 cft/hr and 12.3 cft/hr and these values are termed as lower and upper limits respectively. Thus, middle range is classified as c_2. The upper range will have values between 12.3 cft/hr and maximum productivity value of 16.8cft/hr (upper limit) and is classified as c_1. Similarly, the lower range will have lower and upper limits as 6.8cft/hr and 10.5 cft/hr respectively. The above values are shown in 1st and 2nd columns of Table 7.3.

Now, the limits were normalized by dividing the highest productivity obtained i.e., 16.8 cft/hr and these normalized values are given in 3rd column of Table 7.3. These normalized values indicate the performance i.e., the productivity class c_1 will have performance level of 0.73 to 1.00 and similarly with the rest of the classes. In order to represent the class with a unique number, the average of normalized values of each class is taken and is given in 4th column of Table 7.3. These values are taken as the weighted averages (value of the respective performance class) and named as productivity weightage. Thus, the performance classes c_1, c_2 & c_3 will have weightages of 0.87, 0.68 & 0.52 respectively.

Productivity depends on ability. Human ability of workers is represented by human parameters viz., Age, BMI, HGS and UBMS. Each parameter is divided into three performance classes c_1, c_2 & c_3 as explained earlier. If a worker belongs to performance class c_1 of a parameter, then the worker will have productivity weightage of 0.87 as given in 4th column of Table 7.3. Similarly, if the worker belongs to performance classes c_2 and c_3 of a parameter, then the worker will have productivity weightage of 0.68 and 0.52 respectively.

Thus, any worker will fall into one of the performance classes corresponding to a parameter, which is given by $W^{i}_{c_n}$. In the present work, $W^{i}_{c_n}$ values for c_1, c_2 & c_3 were generalized as 1.00, 0.75 & 0.50 respectively as given in 4th column of Table 7.3. Thus, the performance classes c_1, c_2 & c_3 will have productivity weightages ($W^{i}_{c_n}$) of 1.00, 0.75 and 0.50 respectively in the present study.

Table 7.3 Calculation of productivity weightages with respect to MLP

1	2		3		4	
Performance Class (c_n)	**MLP categories** *(eq. 6.2)*		**Normalization** *(b/16.8)*		**Productivity Weightage** ($W^{i}_{c_n}$) = *average (LL, UL) from col '3'*	
	Lower Limit	*Upper Limit*	*Lower Limit*	*Upper Limit*	*Obtained*	*Proposed*
c_3	6.8	10.5	0.40	0.63	0.52	0.50
c_2	10.5	12.3	0.63	0.73	0.68	0.75
c_1	12.3	16.8	0.73	1.00	0.87	1.00

7.6 Relationship between HPI and MLP

HPI is a non-dimensional parameter representing human abilities of a worker with a single number. This index number will have to reflect the productivity capacity of a masonry worker. As HPI increases, the productivity of a masonry worker will increase and a relation between HPI and MLP can be proposed. But, HPI is a non-dimensional and MLP is a dimensional parameter. MLP can be made into non-dimensional by taking the performance levels and human physical parameters into consideration to form an indexed value, hereafter called Productivity Index (PI). Then the relation between HPI and PI can be a good fit. Hence the productivity of an individual worker recorded in the data is divided with the standard productivity and this is called normalized MLP. Further normalized MLP is multiplied with the HPI of a worker. Therefore, PI is defined as the product of physical ability or HPI and the normalized MLP.

$$\text{PI} = \text{Norm(MLP)} \times \text{HPI}$$

$$\text{PI} = \frac{\text{MLP}}{\text{MLP}_{\text{std}}} \times \text{HPI} \quad \ldots\ldots (6.5)$$

Here, in the present study, standard MLP is taken as average MLP. Therefore, PI in the present study is given as:

$$\text{PI} = \frac{\text{MLP}}{\text{MLP}_{\text{avg}}} \times \text{HPI} \quad \ldots\ldots (6.6)$$

Table 7.4 Calculation of Performance weightages, HPI and PI of workers

S. No	Mason Code	Weighted Averages ($W^{i}_{c_n}$)								HPI	PI
		Age		BMI		HGS		UBMS		($\sum_{i=1}^{4} W^{i}_{c_n}$)	($\frac{MLP}{MLP\ avg}$ x HPI)
1	C1M1	c_3	0.50	c_2	0.75	c_2	0.75	c_3	0.50	2.50	2.98
2	C1M2	c_3	0.50	c_2	0.75	c_3	0.50	c_3	0.50	2.25	2.29
3	C1M3	c_2	0.75	c_1	1.00	c_1	1.00	c_1	1.00	3.75	4.77
4	C1M4	c_1	1.00	c_2	0.75	c_3	0.50	c_3	0.50	2.75	3.40
5	C1M5	c_3	0.50	c_2	0.75	c_3	0.50	c_3	0.50	2.25	1.40
6	C1M6	c_2	0.75	c_3	0.50	c_2	0.75	c_1	1.00	3.00	3.63
7	C2M1	c_1	1.00	c_1	1.00	c_2	0.75	c_1	1.00	3.75	3.72
8	C2M2	c_1	1.00	c_1	1.00	c_1	1.00	c_1	1.00	4.00	5.89
9	C2M3	c_3	0.50	c_1	1.00	c_1	1.00	c_1	1.00	3.50	4.73
10	C2M4	c_2	0.75	c_3	0.50	c_2	0.75	c_1	1.00	3.00	2.47
11	C2M5	c_2	0.75	c_3	0.50	c_1	1.00	c_3	0.50	2.75	2.22
12	C2M6	c_3	0.50	c_2	0.75	c_1	1.00	c_1	1.00	3.25	2.96
13	C3M1	c_3	0.50	c_1	1.00	c_1	1.00	c_1	1.00	3.50	3.13
14	C3M2	c_2	0.75	c_2	0.75	c_2	0.75	c_2	0.75	3.00	3.26
15	C3M3	c_2	0.75	c_1	1.00	c_1	1.00	c_1	1.00	3.75	5.33
16	C3M4	c_3	0.50	c_3	0.50	c_3	0.50	c_3	0.50	2.00	1.19
17	C3M5	c_2	0.75	c_3	0.50	c_3	0.50	c_3	0.50	2.25	1.50
18	C4M1	c_1	1.00	c_1	1.00	c_1	1.00	c_2	0.75	3.75	4.11
19	C4M2	c_2	0.75	c_1	1.00	c_1	1.00	c_2	0.75	3.50	4.02
20	C4M3	c_2	0.75	c_3	0.50	c_1	1.00	c_1	1.00	3.25	3.45
21	C4M4	c_2	0.75	c_1	1.00	c_2	0.75	c_3	0.50	3.00	2.37
22	C4M5	c_3	0.50	c_3	0.50	c_2	0.75	c_1	1.00	2.75	2.39
23	C4M6	c_1	1.00	c_1	1.00	c_3	0.50	c_1	1.00	3.50	3.90
24	C4M7	c_2	0.75	c_3	0.50	c_1	1.00	c_3	0.50	2.75	2.17
25	C4M8	c_2	0.75	c_1	1.00	c_1	1.00	c_2	0.75	3.50	4.91
26	C4M9	c_1	1.00	c_1	1.00	c_1	1.00	c_2	0.75	3.75	3.72
27	C4M10	c_2	0.75	c_1	1.00	c_3	0.50	c_3	0.50	2.75	1.88
28	C5M1	c_1	1.00	c_1	1.00	c_2	0.75	c_2	0.75	3.50	3.35
29	C5M2	c_1	1.00	c_1	1.00	c_2	0.75	c_1	1.00	3.75	4.87
30	C5M3	c_3	0.50	c_1	1.00	c_2	0.75	c_2	0.75	3.00	2.61
31	C5M4	c_3	0.50	c_1	1.00	c_3	0.50	c_3	0.50	2.50	1.91
32	C5M5	c_2	0.75	c_3	0.50	c_1	1.00	c_3	0.50	2.75	3.04
33	C5M6	c_3	0.50	c_1	1.00	c_2	0.75	c_2	0.75	3.00	2.29
34	C5M7	c_3	0.50	c_3	0.50	c_2	0.75	c_2	0.75	2.50	1.60
35	C6M1	c_2	0.75	c_1	1.00	c_1	1.00	c_3	0.50	3.25	2.88
36	C6M2	c_2	0.75	c_3	0.50	c_2	0.75	c_1	1.00	3.00	3.39
37	C6M3	c_1	1.00	c_1	1.00	c_3	0.50	c_2	0.75	3.25	3.14
38	C6M4	c_1	1.00	c_1	1.00	c_3	0.50	c_3	0.50	3.00	3.29

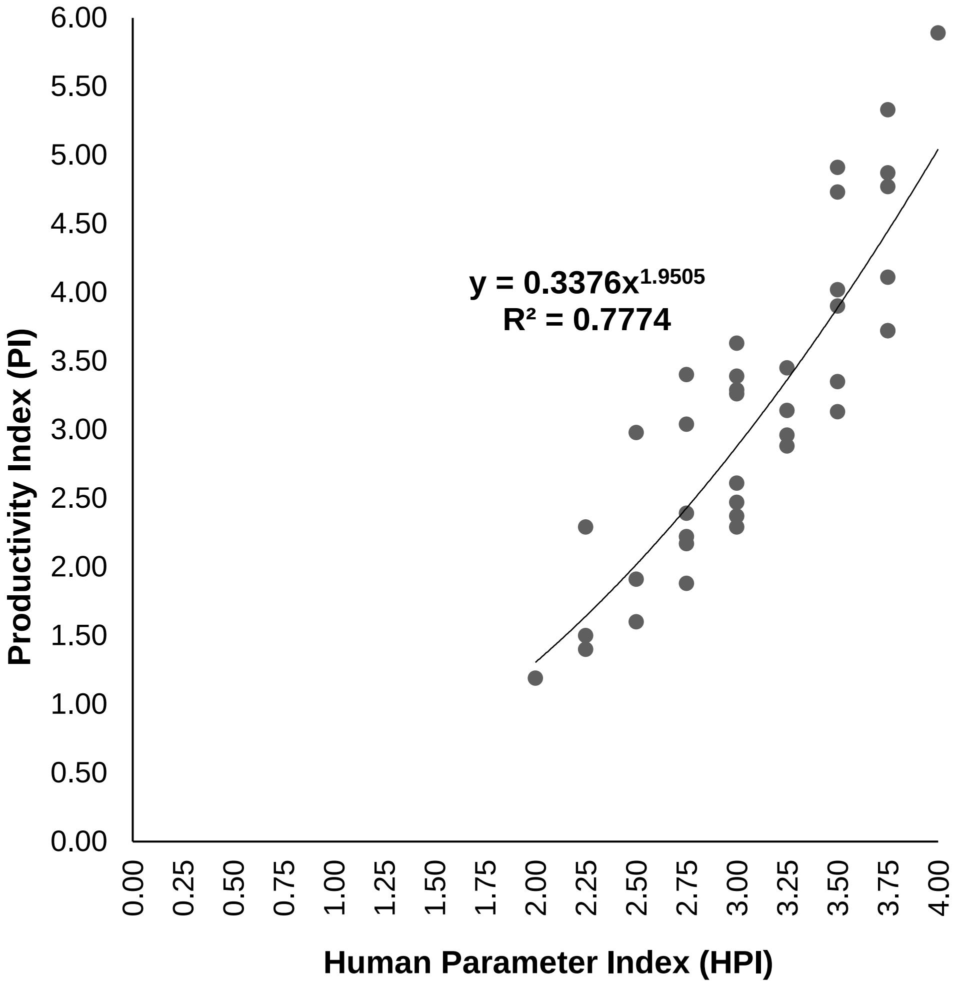


Figure 7.3 Relationship showing PI with respect to HPI

The HPI and PI of workers are calculated from equation (6.4) and (6.6) respectively and are shown in Table 7.4. The present study clearly shows that the labour productivity is influenced by physical strength (Figure 7.2). It should come as no surprise that workers having lower physical strength will show low productivity and may not perform equally compared to workers having higher physical strength. Therefore, the influence of human physical parameters on MLP will have a significant relationship. This relationship is explained with regression analysis between HPI and PI of workers as shown in Figure 7.3. PI and HPI of thirty-eight workers are plotted in Figure 7.3. With R^2-value (0.78), the plot shown in Figure 7.3 clearly indicates that PI is significantly influenced by HPI. Therefore, PI increases with increase in HPI of workers. The regression curve is fitted and the equation obtained from the trendline is:

$$y = 0.3376x^{1.9505}$$

Where y is the PI of an individual worker and x is the HPI.

$$PI = 0.3376\,(HPI)^{1.9505} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6.7)$$

Since PI is the normalized labour productivity multiplied by HPI, therefore, MLP of a worker is

$$\text{NORM (MLP) x HPI} = 0.3376 \text{ x } (\text{HPI}^{1.9505}) \text{ ………….. (6.8)}$$

Now, by dividing HPI on both sides for the above equation (6.8), productivity of a masonry worker is given as:

$$\frac{\text{NORM (MLP) x HPI}}{\text{HPI}} = \frac{0.3376 \text{ x } (\text{HPI}^{1.9505})}{\text{HPI}}$$

$$\text{NORM (MLP)} = 0.3376 \text{ x } (\text{HPI}^{0.9505})$$

Since, in the present study, normalized MLP is taken as ratio of MLP to average MLP

$$\frac{\text{MLP}}{\text{MLP}_{\text{avg}}} = 0.3376 \text{ x } (\text{HPI}^{0.9505})$$

$$\text{MLP} = 0.3376 \text{ x } (\text{HPI}^{0.9505}) \text{ x } \text{MLP}_{\text{avg}} \text{……………….. (6.9)}$$

The above model can be utilized in estimating the MLP on construction project sites. Companies can adopt their targeted labour productivity in place of MLP_{avg} in the above model. Thus, the model would aid in estimating manpower efficiency. The research model further helps the construction industry in categorizing the performance levels of masonry workers based on standard labour productivity.

7.7 Discussion

The relationship between PI of a masonry construction worker and HPI is obtained as given in equation (6.7). This relationship shows that PI is a second order function of HPI that depends on the number of parameters under consideration. If the number of parameters were 4, the maximum and minimum values of HPI are 4 and 2 as taken in the present work. Thus, if the number of parameters were ‘n’, the maximum and minimum values of HPI are ‘n’ and ‘n/2’. Now, the constant in equation (6.9) i.e., 0.3376 will have to be obtained if the no of parameters were other than 4. However, this model is not limited to the number of parameters to be considered. The relevant constant however needs to be obtained.

The predicted values of MLP will be nearly equal to standard MLP for medium range values of HPI. Further, in case of standard MLP, the proposed model predicts higher MLP i.e., higher values of HPI and lower MLP for lower values of HPI. Normally, a labour crew consists of workers with varying physical abilities. Hence this model can also be adopted to assess the crew productivity even though it is developed for a single worker i.e., the average HPI of the crew can be taken to predict the crew productivity. Hence, in an organization, the HPI of individual workers may be assessed and the members can be grouped into best performing crew. The grouping of workers is done based on HPI so to obtain the best output for the entire masonry construction activities in a project. The relationship between MLP and HPI as given in the equation (6.9) can also be utilized to estimate the MLP of the entire labour resource in a company by taking the average HPI of all the labourers. Further this model can also be used for creating and managing the labour productivity benchmarking for masonry construction activities.

Thus, the proposed relationship model is useful in predicting the individual labour productivity and a crew productivity to compare the company's productivity targets with available workers or to create and manage the productivity benchmarking of labour involving masonry related construction activities. An independent study is conducted to verify and validate the relationship model between MLP and HPI as given in equation (6.9), which is presented in the following chapter.

Chapter - 08

8. Validation

8.1 Introduction

The relationship between MLP and HPI as given in equation (6.9) is obtained for masonry labour involving AAC block wall construction activity. The validity of the model is checked by conducting an independent survey. In a way it is proposed to apply the relationship model for a real time field construction activity and examine its level of prediction. Hence, various construction sites were selected in and around the Hyderabad and Warangal cities in Telangana State, India. Validation of the model is carried out for similar and other masonry construction activity. The newly developed parameter HPI is verified with the established HR parameter of the past.

8.2 Validation with masons of AAC block wall construction

The data of forty-four masons involved in AAC block wall construction from thirteen construction sites were collected. The data compiled includes the required human physical parameters information in order to calculate the HPI of a construction masonry worker. Parameters such as Age, BMI, HGS and UBMS were collected. Simultaneously the quantity of installed work was also recorded on site for the respective masonry worker. The above observations were taken for a day for a construction site. The masons were given a code (S#M#), where, 'S' indicates the site number and 'M' indicates mason number. The values of Age, BMI, HGS, UBMS and the corresponding weightages are given in Table 8.1. The values of observed MLP and the calculated HPI are given in the last two columns of Table 8.1. In order to compare the observed MLP value with the value predicted from equation (6.9), the standard values of a construction organization are required. Hence, the standards from the manuals such as TSSD, DSR and IS 7272 were taken.

The masonry labour component for ACC block wall construction in DSR is 0.72md/cum whereas, data is not available in both TSSD and IS 7272. Therefore, masonry labour component of TS SSR and IS 7272 for red brick wall construction activity is taken. The standard labour component values of TSSD and IS 7272 were 0.8md/cum and 0.25md/sft of a single brick wall. The labour productivity values from three standard manuals such as DSR, TSSD and IS 7272 were converted to 49cft/d, 44cft/d and 32cft/d respectively to compare them with the field observations. By substituting these standard MLP values for DSR, TSSD, IS 7272 and the HPI of a mason in equation (6.9), the predicted MLP values were calculated and given in Table 8.2

Table 8.1 Brick Masons data collected from various sites in Hyderabad and Warangal

Sn	**Mason Code**	**BMI**		**Age**		**HGS**		**UBMS** (lbs)		**MLP** (cft/d)	**HPI**
		kg/m^2	$W^{i}{}_{c_n}$	years	$W^{i}{}_{c_n}$	lbs	$W^{i}{}_{c_n}$	lbs	$W^{i}{}_{c_n}$		
1	S1M1	23	1.00	32	1.00	76.6	0.75	21.5	0.75	59	3.50
2	S1M2	15.9	0.50	45	0.50	79.2	0.75	23.7	1.00	40	2.75
3	S1M3	20	1.00	27	0.75	79.5	0.75	24.6	1.00	56	3.50
4	S1M4	21.8	1.00	22	0.75	79.6	0.75	19.8	0.75	51	3.25
5	S2M1	20.4	1.00	42	0.50	93.4	1.00	23.8	1.00	53	3.50
6	S2M2	18.3	0.50	35	0.50	84.5	1.00	19.1	0.50	34	2.50
7	S2M3	24.7	1.00	40	0.50	86.6	1.00	24.7	1.00	61	3.50
8	S2M4	17.8	0.50	24	0.75	68.9	0.50	20.7	0.75	32	2.50
9	S2M5	27.1	0.75	36	0.50	78.1	0.75	24.3	1.00	51	3.00
10	S3M1	18.8	1.00	31	1.00	76.5	0.75	18.5	0.50	51	3.25
11	S3M2	17.2	0.50	35	0.50	77.1	0.75	21.7	0.75	36	2.50
12	S3M3	16	0.50	29	1.00	50.8	0.50	25.2	1.00	46	3.00
13	S4M1	25.4	0.75	32	1.00	79.6	0.75	25.9	1.00	53	3.50
14	S4M2	24.1	1.00	41	0.50	81.3	1.00	17.7	0.50	48	3.00
15	S5M1	25.5	0.75	44	0.50	82.2	1.00	22.9	1.00	53	3.25
16	S5M2	20.9	1.00	26	0.75	81.3	1.00	22.6	1.00	62	3.75
17	S5M3	17.6	0.50	42	0.50	82.2	1.00	20.2	0.75	40	2.75
18	S6M1	16.5	0.50	36	0.50	79.5	0.75	28.2	1.00	41	2.75
19	S6M2	20.7	1.00	43	0.50	79.6	0.75	12.3	0.50	39	2.75
20	S6M3	19.5	1.00	28	1.00	81.3	1.00	25.9	1.00	63	4.00
21	S6M4	18.3	0.50	24	0.75	65.3	0.50	17.7	0.50	24	2.25
22	S7M1	24.1	1.00	43	0.50	68.9	0.50	22.9	1.00	51	3.00
23	S7M2	25.6	0.75	28	1.00	78.1	0.75	21.9	1.00	53	3.50
24	S8M1	17	0.50	24	0.75	76.5	0.75	21.5	0.75	39	2.75
25	S8M2	27.1	0.75	24	0.75	77.1	0.75	23.7	1.00	51	3.25
26	S8M3	18.8	1.00	43	0.50	50.8	0.50	24.6	1.00	48	3.00
27	S8M4	17.2	0.50	33	1.00	87.4	1.00	19.8	0.75	53	3.25
28	S8M5	17.2	0.50	39	0.50	77.8	0.75	23.8	1.00	36	2.75
29	S9M1	21.9	1.00	23	0.75	73.1	0.75	19.1	0.50	51	3.00
30	S9M2	22.8	1.00	32	1.00	88.8	1.00	24.7	1.00	63	4.00
31	S9M3	19.5	1.00	31	1.00	74.1	0.75	20.7	0.75	59	3.50
32	S10M1	23.1	1.00	35	0.50	52.1	0.50	19	0.50	35	2.50
33	S10M2	18.7	1.00	24	0.75	82.2	1.00	25.2	1.00	62	3.75
34	S10M3	19.5	1.00	25	0.75	79.2	0.75	25.9	1.00	59	3.50
35	S10M4	17	0.50	37	0.50	81.3	1.00	17.7	0.50	36	2.50
36	S11M1	27.1	0.75	35	0.50	82.2	1.00	22.9	1.00	53	3.25
37	S11M2	18.8	1.00	25	0.75	81.3	1.00	22.6	1.00	61	3.75
38	S11M3	17.2	0.50	23	0.75	82.2	1.00	19	0.50	43	2.75
39	S12M1	21.9	1.00	40	0.50	79.5	0.75	20.6	0.75	51	3.00
40	S12M2	22.8	1.00	24	0.75	79.6	0.75	25.7	1.00	56	3.50
41	S12M3	19.5	1.00	36	0.50	81.3	1.00	21.2	0.75	55	3.25
42	S13M1	23.1	1.00	43	0.50	82.2	1.00	18.4	0.50	48	3.00
43	S13M2	18.7	1.00	28	1.00	79.2	0.75	13.6	0.50	51	3.25
44	S13M3	19.5	1.00	24	0.75	82.2	1.00	20.9	0.75	61	3.50

Table 8.2 Calculation of predicted values for validation of brick work masons

Sn	Mason Code	HPI	MLP (cft/d)	Predicted Values (cft/d)		
				TS SSR	DAR	IS 7272
1	S1M1	3.50	59	49	55	36
2	S1M2	2.75	40	39	43	29
3	S1M3	3.50	56	49	55	36
4	S1M4	3.25	51	46	51	34
5	S2M1	3.50	53	49	55	36
6	S2M2	2.50	34	36	40	26
7	S2M3	3.50	61	49	55	36
8	S2M4	2.50	32	36	40	26
9	S2M5	3.00	51	42	47	31
10	S3M1	3.25	51	46	51	34
11	S3M2	2.50	36	36	40	26
12	S3M3	3.00	46	42	47	31
13	S4M1	3.50	53	49	55	36
14	S4M2	3.00	48	42	47	31
15	S5M1	3.25	53	46	51	34
16	S5M2	3.75	62	52	58	38
17	S5M3	2.75	40	39	43	29
18	S6M1	2.75	41	39	43	29
19	S6M2	2.75	39	39	43	29
20	S6M3	4.00	63	56	62	41
21	S6M4	2.25	24	32	36	24
22	S7M1	3.00	51	42	47	31
23	S7M2	3.50	53	49	55	36
24	S8M1	2.75	39	39	43	29
25	S8M2	3.25	51	46	51	34
26	S8M3	3.00	48	42	47	31
27	S8M4	3.25	53	46	51	34
28	S8M5	2.75	36	39	43	29
29	S9M1	3.00	51	42	47	31
30	S9M2	4.00	63	56	62	41
31	S9M3	3.50	59	49	55	36
32	S10M1	2.50	35	36	40	26
33	S10M2	3.75	62	52	58	38
34	S10M3	3.50	59	49	55	36
35	S10M4	2.50	36	36	40	26
36	S11M1	3.25	53	46	51	34
37	S11M2	3.75	61	52	58	38
38	S11M3	2.75	43	39	43	29
39	S12M1	3.00	51	42	47	31
40	S12M2	3.50	56	49	55	36
41	S12M3	3.25	55	46	51	34
42	S13M1	3.00	48	42	47	31
43	S13M2	3.25	51	46	51	34
44	S13M3	3.50	61	49	55	36

The observed MLP data is compared with predicted MLP. The points are plotted between observed values and predicted values for DSR, TSSD and IS 7272 in Figure 8.1 to 8.3.

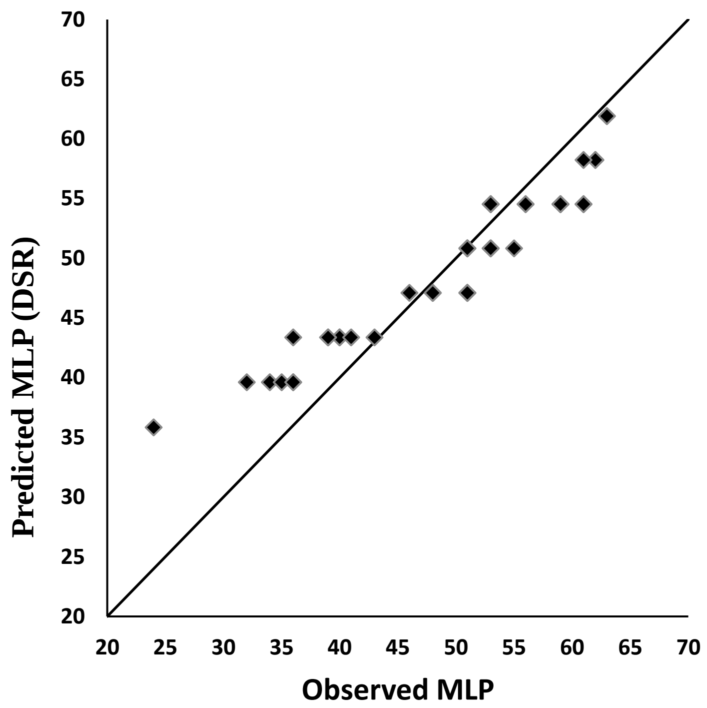


Figure 8.1 Plot for observed MLP vs predicted MLP (DSR) of brick masons

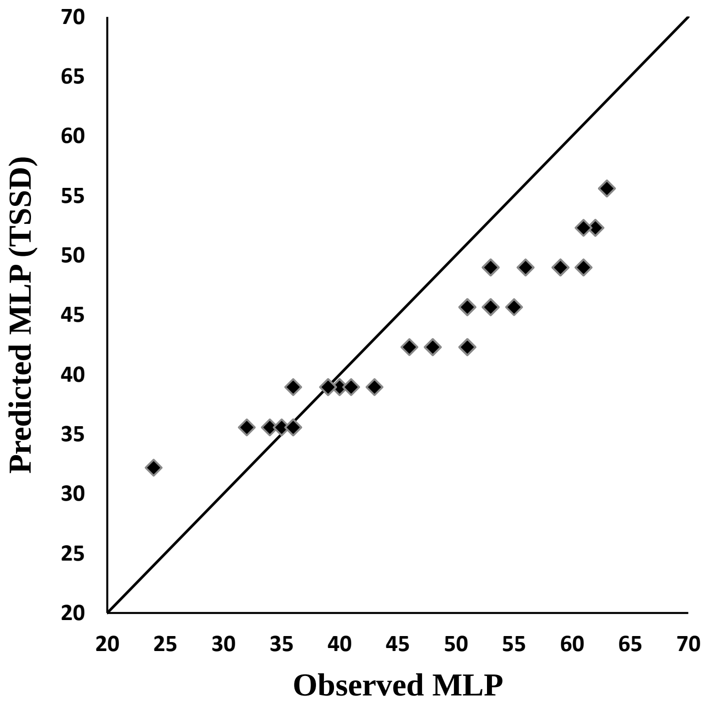


Figure 8.2 Plot for observed MLP vs predicted MLP (TSSD) of brick masons

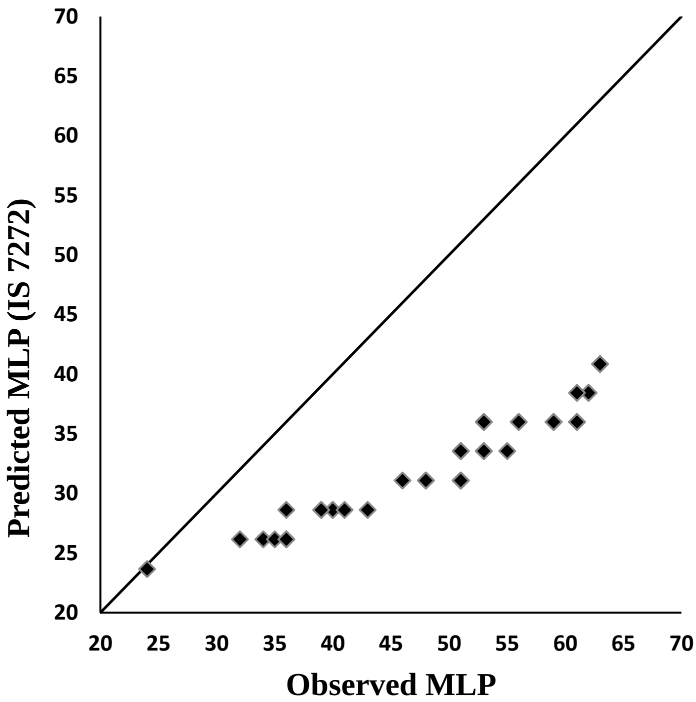


Figure 8.3 Plot for observed MLP vs predicted MLP (IS 7272) of brick masons

Line of equality is also drawn in the plot. It can be observed that all the points are lying closer to equality when compared with DAR standard value (Figure 8.1). The points were slightly away from equality line and towards observed values when compared with TSSD standard value whereas, in case of IS 7272, points were far away from the equality line and towards the observed values. TSSD value has a slightly lower MLP while IS 7272 was largely varying with MLP due to the change in material and unit of measurement respectively. Hence, equation (6.9) can be validated only with a similar item of work in both observed and predicted values even though type of construction activity is similar in both cases

Thus, in the relationship model pertaining to masonry activity, it is proposed to verify if the standard data of any other masonry construction activity like plastering, concreting, flooring in equation (6.9) can be used. Hence, another masonry activity, tile flooring with vitrified tiles is taken and explained in the following section.

8.3 Validation with masons of vitrified tile laying

The data of sixteen masons involving in tile flooring with vitrified tiles of size 600mm x 600mm size from seven construction sites were collected. The collected data includes the required human physical parameters information in order to calculate the HPI of a construction masonry worker. Parameters such as Age, BMI, HGS and UBMS was collected. Simultaneously, the quantity of flooring work was also recorded on site. The above observations were taken for a day for a construction site. The masons were given a code as mentioned in the above section.

The values of Age, BMI, HGS, UBMS and the corresponding weightages are given in Table 8.3. The values of observed MLP and the calculated HPI are given in the last two columns of Table 8.3.

Table 8.3 Tile mason's physical parameters and MLP data for validation analysis

Sn	**Mason Code**	**BMI**		**Age**		**HGS**		**UBMS** (lbs)		**MLP**	**HPI**
		kg/m^2	$W^i{}_{c_n}$	years	$W^i{}_{c_n}$	lbs	$W^i{}_{c_n}$	lbs	$W^i{}_{c_n}$	(sft/d)	
1	S14M1	23	1.00	32	1.00	76.6	0.75	21.5	0.75	40	3.25
2	S14M2	15.9	0.50	45	0.50	79.2	0.75	23.7	1.00	28	2.50
3	S14M3	20	1.00	27	0.75	79.5	0.75	24.6	1.00	34	2.75
4	S14M4	21.8	1.00	22	0.75	79.6	0.75	19.8	0.75	28	2.50
5	S15M1	20.4	1.00	42	0.50	93.4	1.00	23.8	1.00	32	2.75
6	S15M2	18.3	0.50	35	0.50	84.5	1.00	19.1	0.50	23	2.00
7	S16M3	24.7	1.00	40	0.50	86.6	1.00	24.7	1.00	31	2.75
8	S16M4	17.8	0.50	24	0.75	68.9	0.50	20.7	0.75	27	2.50
9	S17M1	27.1	0.75	36	0.50	78.1	0.75	24.3	1.00	26	2.25
10	S17M2	18.8	1.00	31	1.00	76.5	0.75	18.5	0.50	37	3.00
11	S18M3	17.2	0.50	35	0.50	77.1	0.75	21.7	0.75	34	2.75
12	S18M4	16	0.50	29	1.00	50.8	0.50	25.2	1.00	37	3.25
13	S19M1	25.4	0.75	32	1.00	79.6	0.75	25.9	1.00	34	2.75
14	S19M2	24.1	1.00	41	0.50	81.3	1.00	17.7	0.50	38	3.00
15	S20M3	25.5	0.75	44	0.50	82.2	1.00	22.9	1.00	28	2.50
16	S20M4	20.9	1.00	26	0.75	81.3	1.00	22.6	1.00	34	2.75

In order to compare the observed MLP value with the value predicted from the equation (6.9), standard values were taken in the above section. The masonry labour component for vitrified tile floor laying in DSR and TSSD is 0.25md/sqm and 0.32md/sqm respectively. Since vitrified tile work item is not available, labour component of IS 7272 for terrazzo tile laying activity was taken. The standard labour component IS 7272 is 0.22md/sqm. The labour productivity values from three standard manuals such as DSR, TSSD and IS 7272 were converted to 43sft/d, 34sft/d and 49sft/d respectively to compare them with the field observations. By substituting standard MLP values for DSR, TSSD, IS 7272 and the HPI of a mason in equation (6.9), the predicted MLP values were calculated and are given in Table 8.4

Table 8.4 Calculation of predicted values for validation of tile laying masons

Sn	Mason Code	HPI	MLP (sft/d)	Predicted Values (sft/d)		
				TS SSR	CPWD	IS 7272
1	S14M1	3.25	40	35	45	51
2	S14M2	2.50	28	27	35	39
3	S14M3	2.75	34	30	38	43
4	S14M4	2.50	28	27	35	39
5	S15M1	2.75	32	30	38	43
6	S15M2	2.00	23	22	28	32
7	S16M3	2.75	31	30	38	43
8	S16M4	2.50	27	27	35	39
9	S17M1	2.25	26	25	31	36
10	S17M2	3.00	37	32	41	47
11	S18M3	2.75	34	30	38	43
12	S18M4	3.25	37	35	45	51
13	S19M1	2.75	34	30	38	43
14	S19M2	3.00	38	32	41	47
15	S20M3	2.50	28	27	35	39
16	S20M4	2.75	34	30	38	43

The observed MLP data is compared with the predicted MLP. The points are plotted between observed values and predicted values for DSR, TSSD and IS 7272 in Figure 8.4 to 8.6.

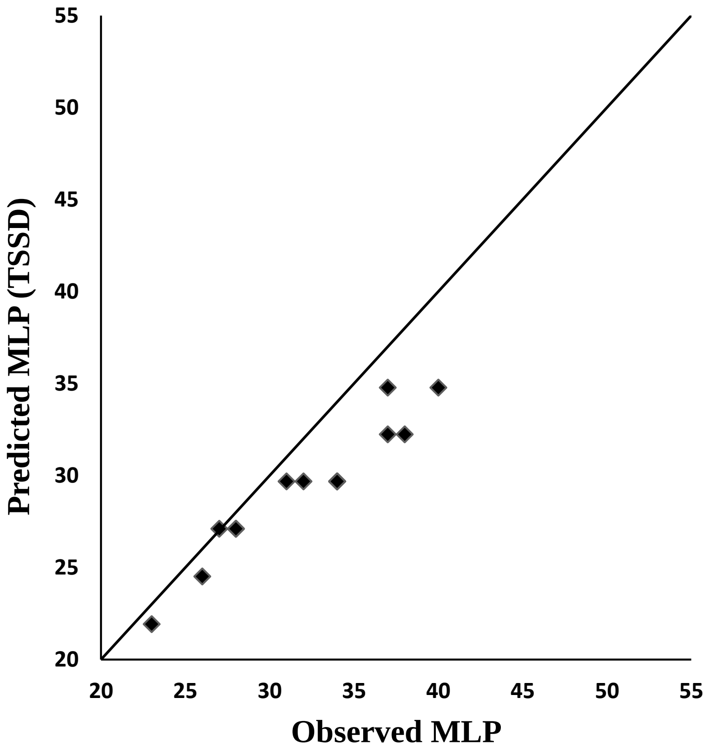


Figure 8.4 Plot for observed MLP vs predicted MLP (TSSD) of tile masons

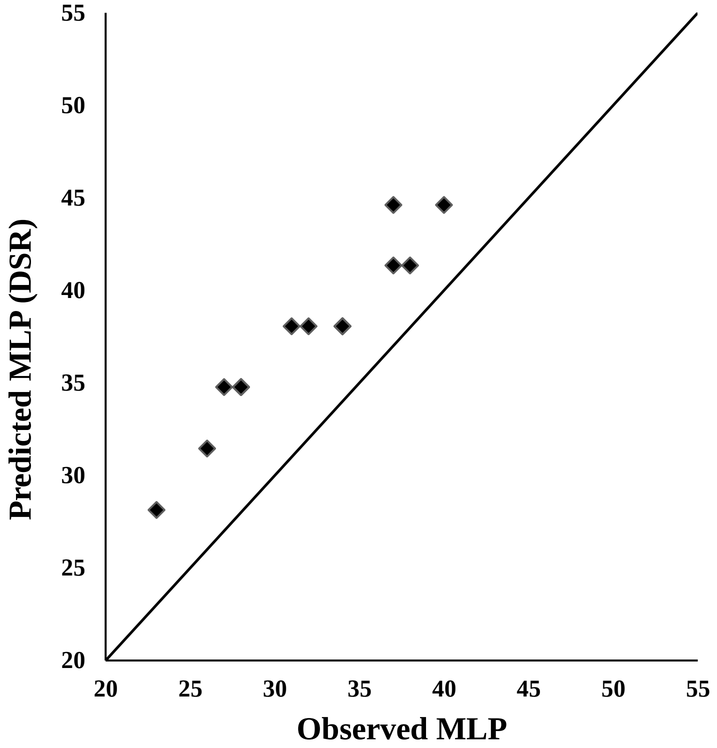


Figure 8.5 Plot for observed MLP vs predicted MLP (DSR) of tile masons

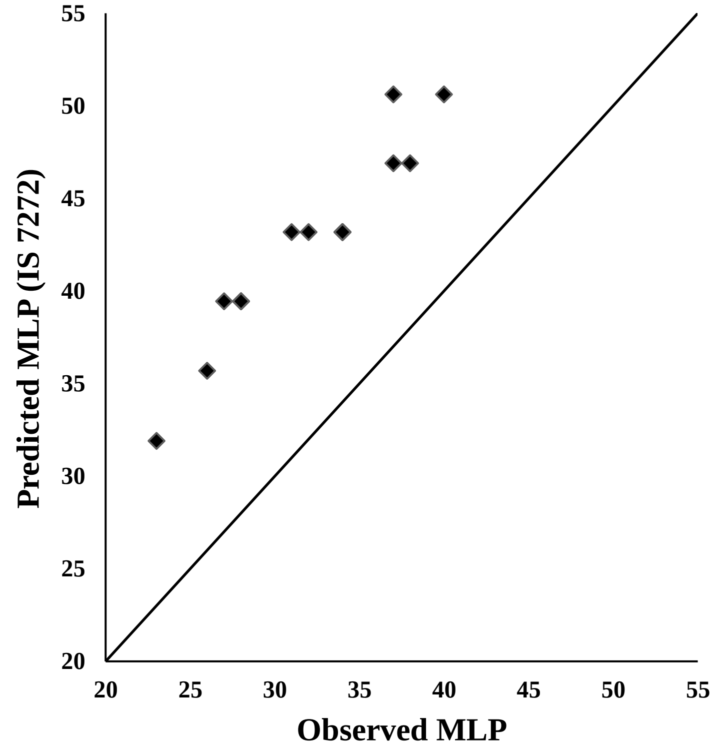


Figure 8.6 Plot for observed MLP vs predicted MLP (IS 7272) of tile masons

From the line of equality plot, it can be observed that all the points are lying closer to line of equality when compared with TSSD and DSR standard value (Figure 8.4). The points were much away from equality line and towards predicted values when compared with IS 7272. The prediction with IS 7272 is largely varying with MLP which is due to the change in material. Hence, equation (6.9) can validate only similar nature of work in both observed and predicted values even though construction activity may be similar.

Thus, the relationship model pertaining to masonry activity is verified with other masonry construction activity i.e., vitrified tile flooring. Hence, the proposed model can be applied to any masonry activity to predict the respective MLP. Hence, the newly developed parameter in the study i.e., HPI is proved in predicting the labour productivity. Now, parameter HPI is tested with the established parameter Heart Rate (HR) in the following section.

8.4 Validation with HR data

A new parameter Heart Rate (HR) was also tracked from the same tile laying masons who were mentioned in the above section. The HR data was tracked while they were involved in work in order to validate the HPI data with the work developed by Abdelhamid and Everett (2002). A chest worn HR tracking device was installed on to each worker for about one hour. This device was connected to a smart phone through Bluetooth Connectivity and live HR was tracked every second. The tracked data was then transferred to computer for analysis. The HR data of 3600 values for each tile laying mason was recorded (Appendix). HPI and average of 3600 HR values for each tile laying mason was shown in the Table 8.6. The data was then compared with the classification of work severity as shown in Table 3.3, which is again shown here in Table 8.5. Classification of work severity and fatigue condition with regard to respective HPI of tile laying masons were tabulated (Table 8.5).

It is observed that most of workers having less than or equal to HPI value of 2.5 were experiencing fatigue. A plot was drawn between HPI and average HR data (Figure 8.7). It is observed that as HPI increases the average HR of the workers decreased. Thus, workers with high HPI value were shown to have low fatigue levels, which shows that HPI determines physical ability of the worker. Hence, the parameter HPI corroborates with the established HR parameter.

Table 8.5 Average HR classification to work severity and energy expenditure (Astrand et al., 2003; Abdelhamid and Everett,2002)

Average HR (beats/min)	Work Severity	Energy Expenditure
<90	Light work	Not fatiguing
90-110	Moderate work	Not fatiguing
110-130	Heavy work	Fatiguing
130-150	Very heavy work	Fatiguing
150-170	Extremely heavy work	Fatiguing

Table 8.6 Tile laying mason's work severity classification based on average HR data

Sn	Mason code	HPI	Average HR	Work Severity	Energy Expenditure
1	S14M1	3.25	86	Light work	Non-Fatiguing
2	S14M2	2.50	113	Heavy work	Fatiguing
3	S14M3	2.75	110	Moderate work	Non-Fatiguing
4	S14M4	2.50	114	Heavy work	Fatiguing
5	S15M1	2.75	116	Heavy work	Fatiguing
6	S15M2	2.00	134	Very heavy work	Fatiguing
7	S16M3	2.75	117	Heavy work	Fatiguing
8	S16M4	2.50	93	Moderate work	Non-Fatiguing
9	S17M1	2.25	131	Very heavy work	Fatiguing
10	S17M2	3.00	118	Heavy work	Fatiguing
11	S18M3	2.75	107	Moderate work	Non-Fatiguing
12	S18M4	3.25	88	Light work	Non-Fatiguing
13	S19M1	2.75	105	Moderate work	Non-Fatiguing
14	S19M2	3.00	97	Moderate work	Non-Fatiguing
15	S20M3	2.50	122	Heavy work	Fatiguing
16	S20M4	2.75	104	Moderate work	Non-Fatiguing

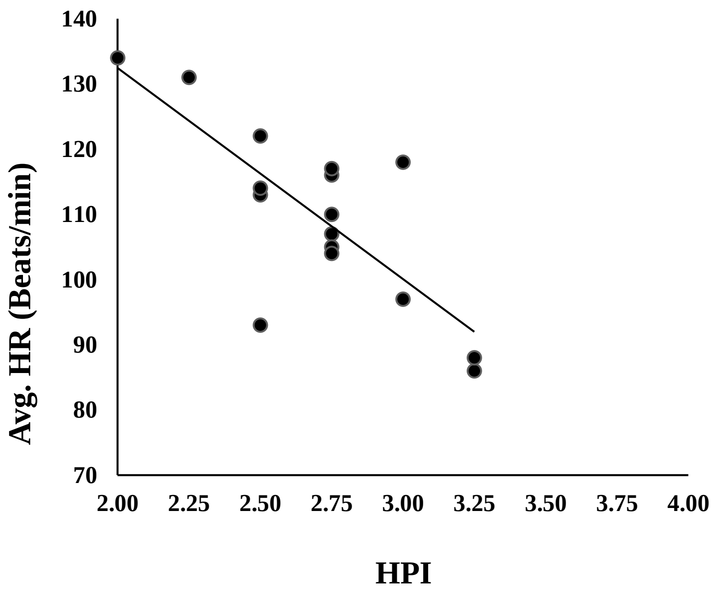


Figure 8.7 Plot for HPI vs average HR data of tile masons

Chapter - 09

9. Conclusions

9.1 Summary

Construction is a labour-intensive industry and labour productivity is a dominating aspect of it. Labour productivity is a direct measure to assess the productivity of any construction firm. In the present research, a preliminary study was conducted on the values representing labour productivity from various standard manuals in India which was found varying. To identify the relative importance of various factors responsible for variation of labour productivity for labour-intensive activities, expert opinions were analysed by heuristic approach. Further, a systematic investigation is carried out to develop a model for estimating MLP. Various conclusions arrived during the study are explained in the following.

The preliminary study relatively ranked the factors that affect MLP in building construction sites in India. There is a short fall of MLP in building construction projects and requires proper assessment measures in India. The focus on the shortcomings and assessment of their effect could support building construction firms in solving issues related to MLP. Finding out the major factors affecting the labour productivity contributes to Indian construction industry positively and that formed the basis of the present study.

1. From RII method of analysing expert opinions, prominent MLP factors were found, such as: lack of skill and experience of worker, poor work planning, poor or no supervision method, unrealistic scheduling, physical performance and fatigue.
2. It is obtained that three out of five factors such as poor work planning, poor or no supervision method and unrealistic scheduling were related to construction management while the other two factors such as expertise and efficiency of workers were related to instinctive physical performance in the construction project sites.
3. It is determined that the factors related to instinctive physical performance can be borne as good predictors of productivity assessment or valuation from management level to reduce poor performance of workers.
4. Preliminary study implied in research towards construction masonry workers i.e., human related factors which help in assessment of their skill and performance on site.

9.2 Conclusions

The influence of human physical parameters on MLP is examined in carrying out AAC block wall construction activity. Parameters, namely Age, BMI, HGS and UBMS together were found as good indicators in assessing MLP. The findings revealed that the subjects (masons) can be categorized with respect to physical parameters based on their level of performance such as lower(ca_3), middle(ca_2) and upper(ca_1) categories. Parameters when considered in category showed promising trends in MLP.

1. A newly implemented human physical parameter UBMS is found more influencing in predicting MLP when compared to other established parameters.
2. A quantitative parameter by unifying all human physical parameters was determined to identify the individual performance level of a worker.
3. This unified parameter was termed as Human Parameter Index (HPI) and defined as sum of the performance weightages of labour with regard to their human physical abilities. Hence, the equation for HPI is given as

$$\text{HPI} = \sum_{i=1}^{k} \text{W}^{i}{}_{c_n} \varphi^{i}$$

4. Statistical analysis bought out a significant relationship between human physical parameters and productivity of construction masonry labour.
5. The relationship model pertaining to the masonry activity is validated for the purpose of any masonry construction activity to predict the labour productivity.
6. The newly developed unified parameter in the study i.e., HPI is corroborated with classification of Heart Rate (HR) in determining the physical ability of labour by Abdelhamid and Everett (2002).

The study contributes to the knowledge about utilization of human physical parameters related to physical strength in qualitative assessment of MLP in construction industry. It is concluded that the productivity of construction labour on site can be assessed from their performance categorization.

9.3 Specific contribution of work

1. Established a new human physical parameter called UBMS to assess the physical performance of construction labour
2. Developed a unified indexed parameter HPI to assess the physical ability of masonry labour with regard to work productivity.
3. Developed a quantifiable model to estimate MLP using human physical parameters

9.4 Limitations of the study

1. The present study was limited to four parameters to assess worker physical ability.
2. Relative importance of human parameters was taken as equal for all human physical parameters in the study.

3. Parametric and Performance categories were limited to three levels which can be further increased.

9.5 Future scope of work

The applications in future could be towards optimization of work schedule based on worker performance; optimization of suitable workforce selection for labour intensive activities; and development of effective MLP assessments. This research accounted for human parameters that would assist in assessing MLP and furnish a new method that serves construction firms to estimate MLP and manage the required workforce capabilities.

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Publications related to Research Work

International Journals

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- Karthik, D. and Rao, C.B.K., 2019. The Analysis of Essential Factors Responsible for Loss of Labour Productivity in Building Construction Projects in India. Engineering Journal, 23(2), pp.55-70. https://doi.org/10.4186/ej.2019.23.2.55
- Karthik, D. and Rao, C.B.K., 2019. Identifying the significant factors affecting the masonry labour productivity in building construction projects in India. *International Journal of Construction Management* (Accepted); DOI: 10.1080/15623599.2019.1631978

Conference Papers

- "A Study on Construction Labour Productivity Parameters in India", Journal of Construction Engineering, Technology and Management, STM Journals, Vol 6, Issue 1, 2016
- "Assessment of Human Physical Performance from Isometric Strength Tests", Global Conference on Physical Education and Sports Sciences, 2018, Journal of Physical Education and Sports Sciences.

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APPENDIX I

A.Questionnaire

Factors affecting the masonry labour productivity in building construction projects in India

The following questionnaire survey is being conducted as part of my research work on identifying the significant factors affecting the masonry labour productivity in building construction projects in India. In the following questionnaire, likert scale was used to evaluate the performance of the masonry workers on site due to the effect of respective factor. Based on your experience, give your opinion rating on the factors organized under specified groups on a scale from "1," very low; "2," low; "3," moderate; "4," high to "5," very high. The information received will be kept confidential and will not be disclosed

From
Dasari Karthik
Research Scholar
Department of Civil Engineering
National Institute of Technology Warangal

* Required

Personal Information

1. **Full Name ***

2. **Email ID ***

3. **Mobile No ***

Experience Details

4. **Designation ***
Mark only one oval.
- Manager
- Engineer
- Supervisor
- Consultant/Professor

5. **Organization**
Mark only one oval.
- Government
- Private Contractors
- Private Builders
- Educational Institutions

6. **Others (Please Specify)**

7. **Work Experience** *
   Mark only one oval.

   - < 5 Years
   - 5-10 Years
   - 11-20 Years
   - 21-30 Years
   - >30 years

Work force

8. **Lack of skill and experience of workers** *
   Mark only one oval.

1	2	3	4	5

9. **Lack of empowerment** *
   Mark only one oval.

1	2	3	4	5

10. **High workforce absenteeism/turnover** *
    Mark only one oval.

1	2	3	4	5

11. **Physical performance and fatigue** *
    Mark only one oval.

1	2	3	4	5

12. **Low labour morale/commitment** *
    Mark only one oval.

1	2	3	4	5

13. **Poo relation among workers** *
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

14. **Low amount of pay** *
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

15. **Little or no financial rewards** *
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

16. **Lack of labour recognition program** *
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

17. **Payment delay** *
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

Management team

18. **Bad leadership skill** *
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

19. **Poor relation between workers and superintendent** *
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

20. **Lack of labour surveillance** *
Mark only one oval.

1	2	3	4	5
◯	◯	◯	◯	◯

21. **Lack of periodic meeting with labour** *
Mark only one oval.

1	2	3	4	5
◯	◯	◯	◯	◯

22. **Poor or no supervision method** *
Mark only one oval.

1	2	3	4	5
◯	◯	◯	◯	◯

23. **Incompetent supervisors** *
Mark only one oval.

1	2	3	4	5
◯	◯	◯	◯	◯

24. **Incomplete/revise drawings** *
Mark only one oval.

1	2	3	4	5
◯	◯	◯	◯	◯

25. **Inspection delay** *
Mark only one oval.

1	2	3	4	5
◯	◯	◯	◯	◯

26. **Variations/change orders during execution** *
Mark only one oval.

1	2	3	4	5
◯	◯	◯	◯	◯

27. **Method of construction** *
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

Working condition

28. **Working 7days per week** *
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

29. **Frequency of working overtime** *
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

30. **Poor work planning** *
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

31. **Unrealistic scheduling** *
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

32. **Labour interface and congestion** *
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

33. **Design complexity** *
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

34. **Accidents** *
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

35. **Unsafe working conditions** *
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

36. **Inadequate safety plan** *
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

37. **Working at heights** *
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

Material and equipment

38. **Material shortages** *
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

39. **Unsuitable material locations** *
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

40. **Equipment and tools shortages** *
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

41. **Poor condition of tools and equipment ***
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

Unforeseen and unfamiliar factors

42. **Rework ***
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

43. **Use of information and communication technologies ***
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

44. **Weather conditions ***
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

45. **Stringent inspection ***
Mark only one oval.

1	2	3	4	5
⬭	⬭	⬭	⬭	⬭

B. MLP Factors

Category	Factors	Code
Work Force	Lack of skill and experience of worker	**WF1**
	Lack of empowerment	**WF2**
	High workforce absenteeism/turnover	**WF3**
	Physical performance and fatigue	**WF4**
	Low labour morale/commitment	**WF5**
	Poor relation among workers	**WF6**
	Low amount of pay	**WF7**
	Little or no financial rewards	**WF8**
	Lack of labour recognition problem	**WF9**
	Payment delay	**WF10**
Management Team	Bad leadership skill	**MT1**
	Poor relation between labour and superintendent	**MT2**
	Lack of labour surveillance	**MT3**
	Lack of periodic meeting with labour	**MT4**
	Poor or no supervision method	**MT5**
	Incompetent supervisors	**MT6**
	Incomplete drawings	**MT7**
	Inspection delay	**MT8**
	Variations/change order during execution	**MT9**
	Method of construction	**MT10**
Work Condition	Working 7days per week	**WC1**
	Frequency of working overtime	**WC2**
	Poor work planning	**WC3**
	Unrealistic scheduling	**WC4**
	Labour interface and congestion	**WC5**
	Design complexity	**WC6**
	Accidents	**WC7**
	Unsafe working conditions	**WC8**
	Inadequate safety plan	**WC9**
	Working at heights	**WC10**
Material and Equipment	Material shortages	**ME1**
	Unsuitable material locations	**ME2**
	Equipment and tools shortages	**ME3**
	Poor condition of tools and equipment	**ME4**
Unforseen and unfamiliar factors	Rework	**UU1**
	Use of information and communication technologies	**UU2**
	Weather conditions	**UU3**
	Stringent inspection	**UU4**

C.Responses from questionnaire survey

Respondants	Designation	Organization	Work Experience	WF1	WF2	WF3	WF4	WF5	WF6	WF7	WF8	WF9	WF10
1	Consultant/Professor	Educational Institutions	21-30	4	4	5	4	3	4	3	3	4	3
2	Consultant/Professor	Educational Institutions	21-30	3	3	5	4	4	5	5	5	3	5
3	Consultant/Professor	Educational Institutions	>30	2	5	4	3	4	5	3	4	4	4
4	Consultant/Professor	Educational Institutions	11-20	5	3	5	4	3	4	5	4	5	5
5	Consultant/Professor	Educational Institutions	21-30	3	5	1	3	5	2	1	3	2	3
6	Consultant/Professor	Educational Institutions	21-30	5	4	5	5	5	3	5	5	5	5
7	Consultant/Professor	Educational Institutions	11-20	3	3	4	5	3	2	4	4	5	5
8	Consultant/Professor	Educational Institutions	11-20	3	5	3	3	4	3	4	3	4	2
9	Consultant/Professor	Educational Institutions	>30	3	3	4	3	3	3	2	2	2	4
10	Consultant/Professor	Educational Institutions	>30	3	3	3	4	4	2	3	5	3	2
11	Consultant/Professor	Educational Institutions	>30	4	3	5	3	4	5	4	5	4	4
12	Consultant/Professor	Educational Institutions	21-30	3	4	4	4	3	5	5	5	3	3
13	Consultant/Professor	Educational Institutions	>30	5	5	3	4	5	5	3	2	5	4
14	Consultant/Professor	Educational Institutions	11-20	5	4	3	4	2	3	4	4	3	4
15	Engineer	Government	5-10	5	4	5	5	5	4	5	5	5	5
16	Engineer	Government	11-20	5	5	5	5	5	4	5	5	5	5
17	Engineer	Government	5-10	4	3	5	4	4	5	3	4	3	5
18	Engineer	Government	5-10	5	3	4	5	5	4	3	4	5	4
19	Engineer	Government	11-20	3	4	3	3	5	3	4	4	5	3
20	Engineer	Government	5-10	4	4	2	5	5	4	5	5	2	5
21	Engineer	Government	5-10	4	4	3	5	4	5	3	3	4	4
22	Engineer	Government	11-20	4	4	3	5	4	5	4	3	3	4
23	Engineer	Government	5-10	5	4	4	5	3	4	3	4	4	4
24	Engineer	Government	11-20	5	4	4	4	3	3	2	2	2	4
25	Engineer	Government	11-20	4	3	4	3	4	4	5	4	4	2
26	Engineer	Government	5-10	4	4	3	4	4	5	4	4	4	4
27	Engineer	Government	11-20	3	5	5	1	2	3	2	4	5	1
28	Engineer	Government	5-10	5	3	5	4	3	4	5	4	2	5
29	Engineer	Private Builders	5-10	3	5	5	3	5	5	1	3	5	3
30	Manager	Private Builders	>30	5	4	5	5	5	3	5	5	5	5
31	Engineer	Private Builders	11-20	3	3	4	5	3	5	4	4	4	5
32	Engineer	Private Builders	11-20	5	3	4	5	5	4	3	4	5	4
33	Engineer	Private Builders	11-20	5	5	5	5	5	4	5	5	5	5
34	Manager	Private Builders	>30	5	5	3	4	5	5	3	2	3	4
35	Manager	Private Builders	>30	5	4	3	4	2	3	4	4	2	4
36	Supervisor	Private Builders	11-20	5	4	5	5	5	4	5	5	5	5
37	Supervisor	Private Builders	11-20	5	3	5	4	3	5	5	4	2	5
38	Supervisor	Private Builders	11-20	5	4	4	5	3	5	3	4	3	4
39	Engineer	Private Builders	11-20	5	4	4	4	3	3	2	2	2	4
40	Engineer	Private Builders	5-10	4	3	4	3	4	4	5	4	4	2
41	Manager	Private Builders	>30	4	4	3	4	4	4	4	4	4	4
42	Manager	Private Builders	>30	3	4	4	4	3	5	5	5	5	3
43	Supervisor	Private Builders	5-10	5	5	3	4	5	5	3	2	3	4
44	Engineer	Private Builders	21-30	5	4	3	4	2	3	4	4	2	4
45	Engineer	Private Builders	21-30	4	4	5	4	3	4	3	3	4	3
46	Manager	Private Builders	>30	3	3	5	4	4	5	5	5	3	5
47	Engineer	Private Builders	11-20	2	5	4	3	4	5	3	4	4	4
48	Engineer	Private Builders	11-20	5	3	5	4	3	4	5	4	5	5
49	Supervisor	Private Builders	5-10	3	5	1	3	5	2	1	3	2	3
50	Engineer	Private Builders	21-30	5	4	5	5	5	3	5	5	5	5
51	Supervisor	Private Builders	5-10	3	3	4	5	3	2	4	4	5	5
52	Engineer	Private Builders	>30	3	5	3	3	4	3	4	3	4	2
53	Engineer	Private Builders	>30	3	3	4	3	3	3	2	2	2	4
54	Supervisor	Private Builders	5-10	3	3	3	4	4	2	3	5	3	2
55	Manager	Private Builders	>30	4	3	5	3	4	5	4	5	4	4
56	Engineer	Private Builders	11-20	3	4	4	4	3	5	5	5	3	3
57	Engineer	Private Builders	11-20	5	5	3	4	5	5	3	2	5	4
58	Supervisor	Private Builders	11-20	5	4	3	4	2	3	4	4	3	4
59	Manager	Private Builders	5-10	5	4	5	5	5	4	5	5	5	5
60	Engineer	Private Builders	>30	5	5	5	5	5	4	5	5	5	5
61	Engineer	Private Builders	>30	4	3	5	4	4	5	3	4	3	5
62	Supervisor	Private Builders	5-10	5	3	4	5	5	4	3	4	5	4
63	Supervisor	Private Builders	5-10	3	4	3	3	5	3	4	4	5	3
64	Manager	Private Builders	>30	4	4	2	5	5	4	5	5	2	5
65	Supervisor	Private Builders	5-10	4	4	3	5	4	5	3	3	4	4

66	Engineer	Private Builders	>30	4	4	3	5	4	5	4	3	3	4
67	Engineer	Private Builders	11-20	5	4	4	5	3	4	3	4	4	4
68	Engineer	Private Builders	11-20	5	4	4	4	3	3	2	2	2	4
69	Manager	Private Builders	>30	4	3	4	3	4	4	5	4	4	2
70	Manager	Private Builders	>30	4	4	3	4	4	5	4	4	4	4
71	Engineer	Private Builders	21-30	3	5	5	1	2	3	2	4	5	1
72	Engineer	Private Builders	21-30	5	3	5	4	3	4	5	4	2	5
73	Engineer	Private Builders	11-20	3	5	5	3	5	5	1	3	5	3
74	Manager	Private Builders	>30	5	4	5	5	5	3	5	5	5	5
75	Supervisor	Private Builders	5-10	3	3	4	5	3	5	4	4	4	5
76	Supervisor	Private Builders	5-10	5	3	4	5	5	4	3	4	5	4
77	Supervisor	Private Builders	5-10	5	5	5	5	5	4	5	5	5	5
78	Supervisor	Private Builders	5-10	5	5	3	4	5	5	3	2	3	4
79	Manager	Private Builders	>30	5	4	3	4	2	3	4	4	2	4
80	Supervisor	Private Builders	5-10	5	4	5	5	5	4	5	5	5	5
81	Supervisor	Private Builders	5-10	5	3	5	4	3	5	5	4	2	5
82	Manager	Private Builders	>30	5	4	4	5	3	5	3	4	3	4
83	Engineer	Private Companies	11-20	5	4	4	4	3	3	2	2	2	4
84	Engineer	Private Companies	11-20	4	3	4	3	4	4	5	4	4	2
85	Engineer	Private Companies	11-20	4	4	3	4	4	4	4	4	4	4
86	Engineer	Private Companies	21-30	3	4	4	4	3	5	5	5	5	3
87	Engineer	Private Companies	21-30	5	5	3	4	5	5	3	2	3	4
88	Engineer	Private Companies	21-30	5	4	3	4	2	3	4	4	2	4
89	Engineer	Private Companies	21-30	4	4	5	4	3	4	3	3	4	3
90	Engineer	Private Companies	21-30	3	3	5	4	4	5	5	5	3	5
91	Engineer	Private Companies	21-30	2	5	4	3	4	5	3	4	4	4
92	Manager	Private Companies	>30	5	3	5	4	3	4	5	4	5	5
93	Manager	Private Companies	>30	3	5	1	3	5	2	1	3	2	3
94	Engineer	Private Companies	21-30	5	4	5	5	5	3	5	5	5	5
95	Manager	Private Companies	21-30	3	3	4	5	3	2	4	4	5	5
96	Engineer	Private Companies	11-20	3	5	3	3	4	3	4	3	4	2
97	Engineer	Private Companies	11-20	3	3	4	3	3	3	2	2	2	4
98	Engineer	Private Companies	11-20	3	3	3	4	4	4	3	5	3	2
99	Engineer	Private Companies	11-20	4	3	5	3	4	5	4	3	4	4
100	Manager	Private Companies	21-30	3	4	4	4	3	5	5	5	3	3
101	Manager	Private Companies	21-30	5	5	3	4	5	5	3	2	5	4
102	Engineer	Private Companies	21-30	5	4	3	4	2	3	4	4	3	4
103	Engineer	Private Companies	21-30	5	4	5	5	5	4	5	5	5	5
104	Manager	Private Companies	21-30	5	5	5	5	3	4	5	5	5	5
105	Engineer	Private Companies	21-30	4	3	5	4	4	5	3	4	3	5
106	Engineer	Private Companies	11-20	5	3	4	5	5	4	3	4	5	4
107	Engineer	Private Companies	11-20	3	4	3	3	5	3	4	4	5	3
108	Engineer	Private Companies	11-20	4	4	2	5	5	4	5	5	2	5
109	Engineer	Private Companies	11-20	4	4	3	5	4	5	3	3	4	4
110	Engineer	Private Companies	11-20	4	4	3	5	4	5	4	3	3	4
111	Engineer	Private Companies	21-30	5	4	4	5	3	4	3	4	4	4
112	Engineer	Private Companies	21-30	5	4	4	4	3	3	2	2	2	4
113	Manager	Private Companies	21-30	4	3	4	3	4	4	5	4	4	2
114	Engineer	Private Companies	21-30	4	4	3	4	4	5	4	4	4	4
115	Engineer	Private Companies	21-30	5	5	5	1	2	3	2	4	5	1
116	Engineer	Private Companies	21-30	5	3	5	4	3	4	5	4	2	5
117	Engineer	Private Companies	21-30	5	5	5	3	5	5	1	3	5	3
118	Manager	Private Companies	21-30	5	4	5	5	5	3	5	5	5	5
119	Engineer	Private Companies	11-20	3	3	4	5	3	5	4	4	4	5
120	Engineer	Private Companies	11-20	5	3	4	5	5	4	3	4	5	4
			Total Responses	120	120	120	120	120	120	120	120	120	120
			Count ("1")	0	0	3	3	0	0	6	0	0	3
			Count ("2")	3	0	3	0	10	8	11	15	23	11
			Count ("3")	33	40	34	26	36	30	33	19	24	17
			Count ("4")	28	53	38	49	34	39	30	54	31	50
			Count ("5")	56	27	42	42	40	43	40	32	42	39

Respondants	Designation	Organization	Work Experience	MT1	MT2	MT3	MT4	MT5	MT6	MT7	MT8	MT9	MT10
1	Consultant/Professor	Educational Institutions	21-30	4	4	3	3	3	4	5	3	4	3
2	Consultant/Professor	Educational Institutions	21-30	5	5	4	3	4	5	4	4	4	4
3	Consultant/Professor	Educational Institutions	>30	4	2	4	3	5	4	2	2	2	3
4	Consultant/Professor	Educational Institutions	11-20	5	3	5	4	5	4	4	3	3	2
5	Consultant/Professor	Educational Institutions	21-30	2	4	4	3	5	2	1	1	3	3
6	Consultant/Professor	Educational Institutions	21-30	4	5	5	3	4	4	2	2	2	4
7	Consultant/Professor	Educational Institutions	11-20	5	5	4	3	4	3	3	3	4	4
8	Consultant/Professor	Educational Institutions	11-20	5	5	4	4	4	4	4	2	4	4
9	Consultant/Professor	Educational Institutions	>30	2	5	4	2	3	3	3	4	4	3
10	Consultant/Professor	Educational Institutions	>30	4	5	1	2	5	3	4	3	3	2
11	Consultant/Professor	Educational Institutions	>30	4	4	4	4	4	3	4	3	3	3
12	Consultant/Professor	Educational Institutions	21-30	4	3	4	3	2	3	4	4	5	1
13	Consultant/Professor	Educational Institutions	>30	4	5	4	2	4	4	4	5	5	5
14	Consultant/Professor	Educational Institutions	11-20	4	4	3	2	5	4	3	3	2	5
15	Engineer	Government	5-10	5	5	4	3	5	5	4	4	4	5
16	Engineer	Government	11-20	5	5	5	5	4	4	4	4	4	5
17	Engineer	Government	5-10	3	3	4	4	3	3	4	4	5	3
18	Engineer	Government	5-10	4	4	4	5	5	5	4	4	4	4
19	Engineer	Government	11-20	4	4	5	3	4	4	3	3	5	4
20	Engineer	Government	5-10	3	4	5	3	4	4	4	4	2	4
21	Engineer	Government	5-10	4	4	4	5	4	4	4	4	4	4
22	Engineer	Government	11-20	4	4	3	4	3	4	4	4	4	4
23	Engineer	Government	5-10	4	4	3	4	4	4	4	5	4	3
24	Engineer	Government	11-20	2	3	3	3	5	5	4	5	4	4
25	Engineer	Government	11-20	3	2	2	1	2	4	4	4	4	3
26	Engineer	Government	5-10	4	4	4	4	4	4	4	4	4	4
27	Engineer	Government	11-20	4	4	3	5	4	4	2	3	3	2
28	Engineer	Government	5-10	5	3	5	4	5	4	4	3	3	2
29	Engineer	Private Builders	5-10	2	4	4	3	5	2	1	1	3	3
30	Manager	Private Builders	>30	4	5	5	3	4	4	2	2	2	4
31	Engineer	Private Builders	11-20	5	5	4	3	4	3	3	3	4	4
32	Engineer	Private Builders	11-20	4	4	4	5	5	5	4	4	4	4
33	Engineer	Private Builders	11-20	5	5	5	5	4	4	4	4	4	5
34	Manager	Private Builders	>30	4	5	4	2	4	4	4	5	5	5
35	Manager	Private Builders	>30	4	4	3	2	5	4	3	3	2	5
36	Supervisor	Private Builders	11-20	5	5	4	3	5	5	4	4	4	5
37	Supervisor	Private Builders	11-20	5	3	5	4	5	4	4	3	3	2
38	Supervisor	Private Builders	11-20	4	4	3	4	4	4	4	5	4	3
39	Engineer	Private Builders	11-20	2	3	3	3	5	5	4	5	4	4
40	Engineer	Private Builders	5-10	3	2	2	1	2	4	4	4	4	3
41	Manager	Private Builders	>30	4	4	4	4	4	4	4	4	4	4
42	Manager	Private Builders	>30	4	3	4	3	2	3	4	4	5	1
43	Supervisor	Private Builders	5-10	4	5	4	2	4	4	4	5	5	5
44	Engineer	Private Builders	21-30	4	4	3	2	5	4	3	3	2	5
45	Engineer	Private Builders	21-30	4	4	3	3	3	4	5	3	4	3
46	Manager	Private Builders	>30	5	5	4	3	4	5	4	4	4	4
47	Engineer	Private Builders	11-20	4	2	4	3	5	4	2	2	2	3
48	Engineer	Private Builders	11-20	5	3	5	4	5	4	4	3	3	2
49	Supervisor	Private Builders	5-10	2	4	4	3	5	2	1	1	3	3
50	Engineer	Private Builders	21-30	4	5	5	3	4	4	2	2	2	4
51	Supervisor	Private Builders	5-10	5	5	4	3	4	3	3	3	4	4
52	Engineer	Private Builders	>30	5	5	4	4	4	4	4	2	4	4
53	Engineer	Private Builders	>30	2	5	4	2	3	3	3	4	4	3
54	Supervisor	Private Builders	5-10	4	5	1	2	5	3	4	3	3	2
55	Manager	Private Builders	>30	4	4	4	4	4	3	4	3	3	3
56	Engineer	Private Builders	11-20	4	3	4	3	2	3	4	4	5	1
57	Engineer	Private Builders	11-20	4	5	4	2	4	4	4	5	5	5
58	Supervisor	Private Builders	11-20	4	4	3	2	5	4	3	3	2	5
59	Manager	Private Builders	5-10	5	5	4	3	5	5	4	4	4	5
60	Engineer	Private Builders	>30	5	5	5	5	4	4	4	4	4	5
61	Engineer	Private Builders	>30	3	3	4	4	3	3	4	4	5	3
62	Supervisor	Private Builders	5-10	4	4	4	5	5	5	4	4	4	4
63	Supervisor	Private Builders	5-10	4	4	5	3	4	4	3	3	5	4
64	Manager	Private Builders	>30	3	4	5	3	4	4	4	4	2	4
65	Supervisor	Private Builders	5-10	4	4	4	5	4	4	4	4	4	4

66	Engineer	Private Builders	>30	4	4	3	4	3	4	4	4	4	4
67	Engineer	Private Builders	11-20	4	4	3	4	4	4	4	5	4	3
68	Engineer	Private Builders	11-20	2	3	3	3	5	5	4	5	4	4
69	Manager	Private Builders	>30	3	2	2	1	2	4	4	4	4	3
70	Manager	Private Builders	>30	4	4	4	4	4	4	4	4	4	4
71	Engineer	Private Builders	21-30	4	4	3	5	4	4	2	3	3	2
72	Engineer	Private Builders	21-30	5	3	5	4	5	4	4	3	3	2
73	Engineer	Private Builders	11-20	2	4	4	3	5	2	1	1	3	3
74	Manager	Private Builders	>30	4	5	5	3	4	4	2	2	2	4
75	Supervisor	Private Builders	5-10	5	5	4	3	4	3	3	3	4	4
76	Supervisor	Private Builders	5-10	4	4	4	5	5	5	4	4	4	4
77	Supervisor	Private Builders	5-10	5	5	5	5	4	4	4	4	4	5
78	Supervisor	Private Builders	5-10	4	5	4	2	4	4	4	5	5	5
79	Manager	Private Builders	>30	4	4	3	2	5	4	3	3	2	5
80	Supervisor	Private Builders	5-10	5	5	4	3	5	5	4	4	4	5
81	Supervisor	Private Builders	5-10	5	3	5	4	5	4	4	3	3	2
82	Manager	Private Builders	>30	4	4	3	4	4	4	4	5	4	3
83	Engineer	Private Companies	11-20	2	3	3	3	5	5	4	5	4	4
84	Engineer	Private Companies	11-20	3	2	2	1	2	4	4	4	4	3
85	Engineer	Private Companies	11-20	4	4	4	4	4	4	4	4	4	4
86	Engineer	Private Companies	21-30	4	3	4	3	2	3	4	4	5	1
87	Engineer	Private Companies	21-30	4	5	4	2	4	4	4	5	5	5
88	Engineer	Private Companies	21-30	4	4	3	2	5	4	3	3	2	5
89	Engineer	Private Companies	21-30	4	4	3	3	3	4	5	3	4	3
90	Engineer	Private Companies	21-30	5	5	4	3	4	5	4	4	4	4
91	Engineer	Private Companies	21-30	4	2	4	3	5	4	2	2	2	3
92	Manager	Private Companies	>30	5	3	5	4	5	4	4	3	3	2
93	Manager	Private Companies	>30	2	4	4	3	5	2	1	1	3	3
94	Engineer	Private Companies	21-30	4	5	5	3	4	4	2	2	2	4
95	Manager	Private Companies	21-30	5	5	4	3	4	3	3	3	4	4
96	Engineer	Private Companies	11-20	5	5	4	4	4	4	4	2	4	4
97	Engineer	Private Companies	11-20	2	5	4	2	3	3	5	4	4	3
98	Engineer	Private Companies	11-20	4	5	1	2	5	3	4	5	3	2
99	Engineer	Private Companies	11-20	4	2	4	2	4	3	4	5	3	3
100	Manager	Private Companies	21-30	4	3	4	5	2	5	4	4	5	1
101	Manager	Private Companies	21-30	4	5	4	4	4	4	4	5	5	5
102	Engineer	Private Companies	21-30	4	4	3	3	5	4	3	3	2	5
103	Engineer	Private Companies	21-30	5	5	4	1	5	5	4	4	4	5
104	Manager	Private Companies	21-30	5	5	3	5	4	4	4	4	4	5
105	Engineer	Private Companies	21-30	3	3	4	3	3	3	4	4	5	3
106	Engineer	Private Companies	11-20	4	4	4	4	5	5	4	4	4	4
107	Engineer	Private Companies	11-20	4	4	5	2	4	4	3	3	5	4
108	Engineer	Private Companies	11-20	3	4	5	3	4	4	4	4	2	4
109	Engineer	Private Companies	11-20	4	4	4	5	4	4	4	4	4	4
110	Engineer	Private Companies	11-20	4	4	3	4	3	4	4	4	4	4
111	Engineer	Private Companies	21-30	4	4	3	4	4	4	4	5	4	3
112	Engineer	Private Companies	21-30	2	3	3	3	5	5	4	5	4	4
113	Manager	Private Companies	21-30	3	2	2	1	2	4	4	4	4	3
114	Engineer	Private Companies	21-30	4	4	4	4	4	4	4	4	4	4
115	Engineer	Private Companies	21-30	4	4	3	5	4	4	2	3	3	2
116	Engineer	Private Companies	21-30	5	3	5	4	5	4	4	3	3	2
117	Engineer	Private Companies	21-30	2	4	4	3	5	2	1	1	3	3
118	Manager	Private Companies	21-30	4	5	5	3	4	4	2	2	2	4
119	Engineer	Private Companies	11-20	5	5	4	3	4	3	3	3	4	4
120	Engineer	Private Companies	11-20	4	4	4	5	5	5	4	4	4	4
			Total Responses	120	120	120	120	120	120	120	120	120	120
			Count ("1")	0	0	3	6	0	0	6	6	0	5
			Count ("2")	14	9	5	20	10	6	12	12	19	14
			Count ("3")	11	21	27	47	12	22	18	34	23	31
			Count ("4")	65	49	61	30	55	72	80	49	60	46
			Count ("5")	30	41	24	17	43	20	4	19	18	24

Respondants	Designation	Organization	Work Experience	WC1	WC2	WC3	WC4	WC5	WC6	WC7	WC8	WC9	WC10
1	Consultant/Professor	Educational Institutions	21-30	3	4	4	3	5	5	5	4	2	4
2	Consultant/Professor	Educational Institutions	21-30	5	4	5	4	3	2	4	5	4	3
3	Consultant/Professor	Educational Institutions	>30	5	5	4	5	3	2	3	4	4	3
4	Consultant/Professor	Educational Institutions	11-20	5	5	3	5	3	3	5	3	3	4
5	Consultant/Professor	Educational Institutions	21-30	1	1	3	5	2	3	5	2	2	1
6	Consultant/Professor	Educational Institutions	21-30	5	5	5	4	4	4	4	4	4	4
7	Consultant/Professor	Educational Institutions	11-20	5	5	4	4	3	4	3	4	4	5
8	Consultant/Professor	Educational Institutions	11-20	5	3	4	4	3	3	5	5	5	3
9	Consultant/Professor	Educational Institutions	>30	4	3	4	3	3	3	3	3	4	4
10	Consultant/Professor	Educational Institutions	>30	5	4	3	5	2	2	2	2	3	2
11	Consultant/Professor	Educational Institutions	>30	5	3	5	4	3	4	3	4	3	1
12	Consultant/Professor	Educational Institutions	21-30	3	4	5	2	4	4	4	4	5	2
13	Consultant/Professor	Educational Institutions	>30	5	2	4	4	2	3	4	5	4	3
14	Consultant/Professor	Educational Institutions	11-20	2	3	4	5	3	4	3	4	3	4
15	Engineer	Government	5-10	5	4	4	5	3	3	4	4	4	5
16	Engineer	Government	11-20	4	3	4	4	3	4	4	4	4	4
17	Engineer	Government	5-10	2	4	4	3	4	4	4	5	3	3
18	Engineer	Government	5-10	5	4	5	5	4	3	5	5	5	4
19	Engineer	Government	11-20	3	3	5	4	4	3	5	3	3	1
20	Engineer	Government	5-10	5	5	4	4	3	2	3	4	4	4
21	Engineer	Government	5-10	5	4	5	4	4	4	5	5	5	3
22	Engineer	Government	11-20	5	4	4	3	3	4	5	5	5	4
23	Engineer	Government	5-10	4	4	4	4	4	4	5	5	5	4
24	Engineer	Government	11-20	4	4	5	5	2	5	4	4	4	3
25	Engineer	Government	11-20	1	3	4	2	1	3	4	4	2	3
26	Engineer	Government	5-10	3	4	4	4	4	4	4	5	4	3
27	Engineer	Government	11-20	1	2	4	4	4	2	1	1	1	3
28	Engineer	Government	5-10	5	5	3	5	3	3	5	3	3	4
29	Engineer	Private Builders	5-10	1	1	3	5	2	3	5	2	2	1
30	Manager	Private Builders	>30	5	5	5	4	4	4	4	4	4	4
31	Engineer	Private Builders	11-20	5	5	4	4	3	4	3	4	4	5
32	Engineer	Private Builders	11-20	5	4	5	5	4	3	5	5	5	4
33	Engineer	Private Builders	11-20	4	3	4	4	3	4	4	4	4	4
34	Manager	Private Builders	>30	5	2	4	4	2	3	4	5	4	3
35	Manager	Private Builders	>30	2	3	4	5	3	4	3	4	3	4
36	Supervisor	Private Builders	11-20	5	4	4	5	3	3	4	4	4	5
37	Supervisor	Private Builders	11-20	5	5	3	5	3	3	5	3	3	4
38	Supervisor	Private Builders	11-20	4	4	4	4	4	4	5	5	5	4
39	Engineer	Private Builders	11-20	4	4	5	5	2	5	4	4	4	3
40	Engineer	Private Builders	5-10	1	3	4	2	1	3	4	4	2	3
41	Manager	Private Builders	>30	3	4	4	4	4	4	4	5	4	3
42	Manager	Private Builders	>30	3	4	5	2	4	4	4	4	5	2
43	Supervisor	Private Builders	5-10	5	2	4	4	2	3	4	5	4	3
44	Engineer	Private Builders	21-30	2	3	4	5	3	4	3	4	3	4
45	Engineer	Private Builders	21-30	3	4	4	3	5	5	5	4	2	4
46	Manager	Private Builders	>30	5	4	5	4	3	2	4	5	4	3
47	Engineer	Private Builders	11-20	5	5	4	5	3	2	3	4	4	3
48	Engineer	Private Builders	11-20	5	5	3	5	3	3	5	3	3	4
49	Supervisor	Private Builders	5-10	1	1	3	5	2	3	5	2	2	1
50	Engineer	Private Builders	21-30	5	5	5	4	4	4	4	4	4	4
51	Supervisor	Private Builders	5-10	5	5	4	4	3	4	3	4	4	5
52	Engineer	Private Builders	>30	5	3	4	4	3	3	5	5	5	3
53	Engineer	Private Builders	>30	4	3	4	3	3	3	3	3	4	4
54	Supervisor	Private Builders	5-10	5	4	3	5	2	2	2	2	3	2
55	Manager	Private Builders	>30	5	3	5	4	3	4	3	4	3	1
56	Engineer	Private Builders	11-20	3	4	5	2	4	4	4	4	5	2
57	Engineer	Private Builders	11-20	5	2	4	4	2	3	4	5	4	3
58	Supervisor	Private Builders	11-20	2	3	4	5	3	4	3	4	3	4
59	Manager	Private Builders	5-10	5	4	4	5	3	3	4	4	4	5
60	Engineer	Private Builders	>30	4	3	4	4	3	4	4	4	4	4
61	Engineer	Private Builders	>30	2	4	4	3	4	4	4	5	3	3
62	Supervisor	Private Builders	5-10	5	4	5	5	4	3	5	5	5	4
63	Supervisor	Private Builders	5-10	3	3	5	4	4	3	5	3	3	1
64	Manager	Private Builders	>30	5	5	4	4	3	2	3	4	4	4
65	Supervisor	Private Builders	5-10	5	4	5	4	4	4	5	5	5	3

66	Engineer	Private Builders	>30	5	4	4	3	3	4	5	5	5	4
67	Engineer	Private Builders	11-20	4	4	4	4	4	4	5	5	5	4
68	Engineer	Private Builders	11-20	4	4	5	5	2	5	4	4	4	3
69	Manager	Private Builders	>30	1	3	4	2	1	3	4	4	2	3
70	Manager	Private Builders	>30	3	4	4	4	4	4	4	5	4	3
71	Engineer	Private Builders	21-30	1	2	4	4	4	2	1	1	1	3
72	Engineer	Private Builders	21-30	5	5	3	5	3	3	5	3	3	4
73	Engineer	Private Builders	11-20	1	1	3	5	2	3	5	2	2	1
74	Manager	Private Builders	>30	5	5	5	4	4	4	4	4	4	4
75	Supervisor	Private Builders	5-10	5	5	4	4	3	4	3	4	4	5
76	Supervisor	Private Builders	5-10	5	4	5	5	4	3	5	5	5	4
77	Supervisor	Private Builders	5-10	4	3	4	4	3	4	4	4	4	4
78	Supervisor	Private Builders	5-10	5	2	4	4	2	3	4	5	4	3
79	Manager	Private Builders	>30	2	3	4	5	3	4	3	4	3	4
80	Supervisor	Private Builders	5-10	5	4	4	5	3	3	4	4	4	5
81	Supervisor	Private Builders	5-10	5	5	3	5	3	3	5	3	3	4
82	Manager	Private Builders	>30	4	4	4	4	4	4	5	5	5	4
83	Engineer	Private Companies	11-20	4	4	5	5	2	5	4	4	4	3
84	Engineer	Private Companies	11-20	1	3	4	2	1	3	4	4	2	3
85	Engineer	Private Companies	11-20	3	4	4	4	4	4	4	5	4	3
86	Engineer	Private Companies	21-30	3	4	5	2	4	4	4	4	5	2
87	Engineer	Private Companies	21-30	5	2	4	4	2	3	4	5	4	3
88	Engineer	Private Companies	21-30	2	3	4	5	3	4	3	4	3	4
89	Engineer	Private Companies	21-30	3	4	4	3	5	5	5	4	2	4
90	Engineer	Private Companies	21-30	5	4	5	4	3	2	4	5	4	3
91	Engineer	Private Companies	21-30	5	5	4	5	3	2	3	4	4	3
92	Manager	Private Companies	>30	5	5	3	5	3	3	5	3	3	4
93	Manager	Private Companies	>30	1	1	3	5	2	3	5	2	2	1
94	Engineer	Private Companies	21-30	5	5	5	4	4	4	4	4	4	4
95	Manager	Private Companies	21-30	5	5	4	4	3	4	3	4	4	5
96	Engineer	Private Companies	11-20	5	3	4	4	3	3	5	5	5	3
97	Engineer	Private Companies	11-20	4	3	4	3	3	3	3	3	4	4
98	Engineer	Private Companies	11-20	5	4	3	5	2	2	2	2	3	2
99	Engineer	Private Companies	11-20	5	3	5	4	3	4	3	4	3	1
100	Manager	Private Companies	21-30	3	4	5	2	4	4	4	4	5	2
101	Manager	Private Companies	21-30	5	2	4	4	2	3	4	5	4	3
102	Engineer	Private Companies	21-30	2	3	4	5	3	4	3	4	3	4
103	Engineer	Private Companies	21-30	5	4	4	5	3	3	4	4	4	5
104	Manager	Private Companies	21-30	4	3	4	4	3	4	4	4	4	4
105	Engineer	Private Companies	21-30	2	4	4	3	4	4	4	5	3	3
106	Engineer	Private Companies	11-20	5	4	5	5	4	3	5	5	5	4
107	Engineer	Private Companies	11-20	3	3	5	4	4	3	5	3	3	1
108	Engineer	Private Companies	11-20	5	5	4	4	3	2	3	4	4	4
109	Engineer	Private Companies	11-20	5	4	5	4	4	4	5	5	5	3
110	Engineer	Private Companies	11-20	5	4	4	3	3	4	5	5	5	4
111	Engineer	Private Companies	21-30	4	4	4	4	4	4	5	5	5	4
112	Engineer	Private Companies	21-30	4	4	5	5	2	5	4	4	4	3
113	Manager	Private Companies	21-30	1	3	4	2	1	3	4	4	2	3
114	Engineer	Private Companies	21-30	3	4	4	4	4	4	4	5	4	3
115	Engineer	Private Companies	21-30	1	2	4	4	4	2	1	1	1	3
116	Engineer	Private Companies	21-30	5	5	3	5	3	3	5	3	3	4
117	Engineer	Private Companies	21-30	1	1	3	5	2	3	5	2	2	1
118	Manager	Private Companies	21-30	5	5	5	4	4	4	4	4	4	4
119	Engineer	Private Companies	11-20	5	5	4	4	3	4	3	4	4	5
120	Engineer	Private Companies	11-20	5	4	5	5	4	3	5	5	5	4
			Total Responses	120	120	120	120	120	120	120	120	120	120
			Count ("1")	14	6	0	0	5	0	3	3	3	12
			Count ("2")	10	10	0	10	21	15	3	9	14	8
			Count ("3")	16	29	17	12	52	46	25	14	27	40
			Count ("4")	18	49	69	55	39	51	49	56	51	49
			Count ("5")	62	26	34	43	3	8	40	38	25	11

Respondants	Designation	Organization	Work Experience	ME1	ME2	ME3	ME4	UU1	UU2	UU3	UU4
1	Consultant/Professor	Educational Institutions	21-30	4	4	4	4	4	3	4	4
2	Consultant/Professor	Educational Institutions	21-30	4	4	4	4	3	3	5	3
3	Consultant/Professor	Educational Institutions	>30	4	4	4	5	3	4	3	3
4	Consultant/Professor	Educational Institutions	11-20	4	2	4	3	3	2	5	3
5	Consultant/Professor	Educational Institutions	21-30	1	1	2	2	2	2	3	2
6	Consultant/Professor	Educational Institutions	21-30	5	5	4	4	4	5	5	4
7	Consultant/Professor	Educational Institutions	11-20	4	4	4	5	4	2	4	5
8	Consultant/Professor	Educational Institutions	11-20	4	4	4	4	5	4	5	5
9	Consultant/Professor	Educational Institutions	>30	4	4	4	3	3	3	4	3
10	Consultant/Professor	Educational Institutions	>30	3	2	2	3	3	4	3	3
11	Consultant/Professor	Educational Institutions	>30	4	3	4	5	4	2	3	3
12	Consultant/Professor	Educational Institutions	21-30	3	4	2	5	3	1	4	1
13	Consultant/Professor	Educational Institutions	>30	5	4	5	5	5	4	3	5
14	Consultant/Professor	Educational Institutions	11-20	5	2	4	3	3	4	3	4
15	Engineer	Government	5-10	4	3	3	4	4	5	5	5
16	Engineer	Government	11-20	4	3	4	4	4	5	5	5
17	Engineer	Government	5-10	3	4	3	4	4	3	4	4
18	Engineer	Government	5-10	5	4	5	5	4	4	4	4
19	Engineer	Government	11-20	5	4	4	4	3	3	5	4
20	Engineer	Government	5-10	2	2	5	5	4	3	4	3
21	Engineer	Government	5-10	5	4	4	3	4	3	4	4
22	Engineer	Government	11-20	5	4	4	4	4	4	4	4
23	Engineer	Government	5-10	3	4	3	4	4	4	4	5
24	Engineer	Government	11-20	3	3	4	3	4	3	4	4
25	Engineer	Government	11-20	1	1	2	1	4	3	3	4
26	Engineer	Government	5-10	5	4	5	5	5	4	3	4
27	Engineer	Government	11-20	2	4	3	4	3	4	3	3
28	Engineer	Government	5-10	4	2	4	3	3	2	5	3
29	Engineer	Private Builders	5-10	1	1	2	2	2	2	3	2
30	Manager	Private Builders	>30	5	5	4	4	4	5	5	4
31	Engineer	Private Builders	11-20	4	4	4	5	4	2	4	5
32	Engineer	Private Builders	11-20	5	4	5	5	4	4	4	4
33	Engineer	Private Builders	11-20	4	3	4	4	4	5	5	5
34	Manager	Private Builders	>30	5	4	5	5	5	4	3	5
35	Manager	Private Builders	>30	5	2	4	3	3	4	3	4
36	Supervisor	Private Builders	11-20	4	3	3	4	4	5	5	5
37	Supervisor	Private Builders	11-20	4	2	4	3	3	2	5	3
38	Supervisor	Private Builders	11-20	3	4	3	4	4	4	4	5
39	Engineer	Private Builders	11-20	3	3	4	3	4	3	4	4
40	Engineer	Private Builders	5-10	1	1	2	1	4	3	3	4
41	Manager	Private Builders	>30	5	4	5	5	5	4	3	4
42	Manager	Private Builders	>30	3	4	2	5	3	1	4	1
43	Supervisor	Private Builders	5-10	5	4	5	5	5	4	3	5
44	Engineer	Private Builders	21-30	5	2	4	3	3	4	3	4
45	Engineer	Private Builders	21-30	4	4	4	4	4	3	4	4
46	Manager	Private Builders	>30	4	4	4	4	3	3	5	3
47	Engineer	Private Builders	11-20	4	4	4	5	3	4	3	3
48	Engineer	Private Builders	11-20	4	2	4	3	3	2	5	3
49	Supervisor	Private Builders	5-10	1	1	2	2	2	2	3	2
50	Engineer	Private Builders	21-30	5	5	4	4	4	5	5	4
51	Supervisor	Private Builders	5-10	4	4	4	5	4	2	4	5
52	Engineer	Private Builders	>30	4	4	4	4	5	4	5	5
53	Engineer	Private Builders	>30	4	4	4	3	3	3	4	3
54	Supervisor	Private Builders	5-10	3	2	2	3	3	4	3	3
55	Manager	Private Builders	>30	4	3	4	5	4	2	3	3
56	Engineer	Private Builders	11-20	3	4	2	5	3	1	4	1
57	Engineer	Private Builders	11-20	5	4	5	5	5	4	3	5
58	Supervisor	Private Builders	11-20	5	2	4	3	3	4	3	4
59	Manager	Private Builders	5-10	4	3	3	4	4	5	5	5
60	Engineer	Private Builders	>30	4	3	4	4	4	5	5	5
61	Engineer	Private Builders	>30	3	4	3	4	4	3	4	4
62	Supervisor	Private Builders	5-10	5	4	5	5	4	4	4	4
63	Supervisor	Private Builders	5-10	5	4	4	4	3	3	5	4
64	Manager	Private Builders	>30	2	2	5	5	4	3	4	3
65	Supervisor	Private Builders	5-10	5	4	4	3	4	3	4	4

66	Engineer	Private Builders	>30	5	4	4	4	4	4	4	4
67	Engineer	Private Builders	11-20	3	4	3	4	4	4	4	5
68	Engineer	Private Builders	11-20	3	3	4	3	4	3	4	4
69	Manager	Private Builders	>30	1	1	2	1	4	3	3	4
70	Manager	Private Builders	>30	5	4	5	5	5	4	3	4
71	Engineer	Private Builders	21-30	2	4	3	4	3	4	3	3
72	Engineer	Private Builders	21-30	4	2	4	3	3	2	5	3
73	Engineer	Private Builders	11-20	1	1	2	2	2	2	3	2
74	Manager	Private Builders	>30	5	5	4	4	4	5	5	4
75	Supervisor	Private Builders	5-10	4	4	4	5	4	2	4	5
76	Supervisor	Private Builders	5-10	5	4	5	5	4	4	4	4
77	Supervisor	Private Builders	5-10	4	3	4	4	4	5	5	5
78	Supervisor	Private Builders	5-10	5	4	5	5	5	4	3	5
79	Manager	Private Builders	>30	5	2	4	3	3	4	3	4
80	Supervisor	Private Builders	5-10	4	3	3	4	4	5	5	5
81	Supervisor	Private Builders	5-10	4	2	4	3	3	2	5	3
82	Manager	Private Builders	>30	3	4	3	4	4	4	4	5
83	Engineer	Private Companies	11-20	3	3	4	3	4	3	4	4
84	Engineer	Private Companies	11-20	1	1	2	1	4	3	3	4
85	Engineer	Private Companies	11-20	5	4	5	5	5	4	3	4
86	Engineer	Private Companies	21-30	3	4	2	5	3	1	4	1
87	Engineer	Private Companies	21-30	5	4	5	5	5	4	3	5
88	Engineer	Private Companies	21-30	5	2	4	3	3	4	3	4
89	Engineer	Private Companies	21-30	4	4	4	4	4	3	4	4
90	Engineer	Private Companies	21-30	4	4	4	4	3	3	5	3
91	Engineer	Private Companies	21-30	4	4	4	5	3	4	3	3
92	Manager	Private Companies	>30	4	2	4	3	3	2	5	3
93	Manager	Private Companies	>30	1	1	2	2	2	2	3	2
94	Engineer	Private Companies	21-30	5	5	4	4	4	5	5	4
95	Manager	Private Companies	21-30	4	4	4	5	4	2	4	5
96	Engineer	Private Companies	11-20	4	4	4	4	5	4	3	5
97	Engineer	Private Companies	11-20	4	4	4	3	3	5	4	3
98	Engineer	Private Companies	11-20	3	2	2	3	5	4	3	3
99	Engineer	Private Companies	11-20	4	3	4	5	4	2	3	3
100	Manager	Private Companies	21-30	3	4	2	5	3	1	4	1
101	Manager	Private Companies	21-30	5	2	5	5	5	4	3	5
102	Engineer	Private Companies	21-30	5	2	4	3	3	4	3	4
103	Engineer	Private Companies	21-30	4	3	3	4	4	5	5	5
104	Manager	Private Companies	21-30	4	3	4	4	4	5	5	5
105	Engineer	Private Companies	21-30	3	4	3	4	4	3	4	4
106	Engineer	Private Companies	11-20	5	4	5	5	4	4	4	4
107	Engineer	Private Companies	11-20	5	4	4	4	3	3	5	4
108	Engineer	Private Companies	11-20	2	2	5	5	4	3	4	3
109	Engineer	Private Companies	11-20	5	4	4	3	4	3	4	4
110	Engineer	Private Companies	11-20	5	4	4	4	4	4	4	4
111	Engineer	Private Companies	21-30	3	4	3	4	4	4	4	5
112	Engineer	Private Companies	21-30	3	3	4	3	4	3	4	4
113	Manager	Private Companies	21-30	1	1	2	1	4	3	3	4
114	Engineer	Private Companies	21-30	5	4	5	5	5	4	3	4
115	Engineer	Private Companies	21-30	2	4	3	4	3	4	3	3
116	Engineer	Private Companies	21-30	4	2	4	3	3	2	5	3
117	Engineer	Private Companies	21-30	1	1	2	2	2	2	3	2
118	Manager	Private Companies	21-30	5	5	4	4	4	5	5	4
119	Engineer	Private Companies	11-20	4	4	4	5	4	2	4	5
120	Engineer	Private Companies	11-20	5	4	5	5	4	4	4	4
			Total Responses	120	120	120	120	120	120	120	120
			Count ("1")	11	11	0	5	0	5	0	5
			Count ("2")	6	22	19	6	6	23	0	6
			Count ("3")	21	18	16	29	37	30	43	29
			Count ("4")	42	63	64	42	61	45	45	49
			Count ("5")	40	6	21	38	16	17	32	31

APPENDIX II

A. F-Test for all parametric pairs

01	Age	BMI
Mean	30.63157895	20.99473684
Variance	61.96870555	8.691863442
Observations	38	38
df	37	37
F	7.129507494	
P(F<=f) one-tail	1.49883E-08	
F Critical one-tail	1.729507032	

02	HGS	BMI
Mean	76.57105263	20.99473684
Variance	161.9134637	8.691863442
Observations	38	38
df	37	37
F	18.6281647	
P(F<=f) one-tail	4.54593E-15	
F Critical one-tail	1.729507032	

03	UBMS	BMI
Mean	20.61052632	20.99473684
Variance	15.02529161	8.691863442
Observations	38	38
df	37	37
F	1.72866172	
P(F<=f) one-tail	0.050149737	
F Critical one-tail	1.729507032	

04	HGS	Age
Mean	76.57105263	30.63157895
Variance	161.9134637	61.96870555
Observations	38	38
df	37	37
F	2.612826302	
P(F<=f) one-tail	0.002194923	
F Critical one-tail	1.729507032	

05	Age	UBMS
Mean	30.63157895	20.61052632
Variance	61.96870555	15.02529161
Observations	38	38
df	37	37
F	4.124293036	

P(F<=f) one-tail	1.89314E-05	
F Critical one-tail	1.729507032	

06	HGS	UBMS
Mean	76.57105263	20.61052632
Variance	161.9134637	15.02529161
Observations	38	38
df	37	37
F	10.77606132	
P(F<=f) one-tail	3.17276E-11	
F Critical one-tail	1.729507032	

07	BMI	MLP
Mean	20.99473684	11.4
Variance	8.691863442	7.256756757
Observations	38	38
df	37	37
F	1.197761443	
P(F<=f) one-tail	0.292956376	
F Critical one-tail	1.729507032	

08	Age	MLP
Mean	30.63157895	11.4
Variance	61.96870555	7.256756757
Observations	38	38
df	37	37
F	8.539449182	
P(F<=f) one-tail	1.08842E-09	
F Critical one-tail	1.729507032	

09	HGS	MLP
Mean	76.57105263	11.4
Variance	161.9134637	7.256756757
Observations	38	38
df	37	37
F	22.31209742	
P(F<=f) one-tail	2.16903E-16	
F Critical one-tail	1.729507032	

10	UBMS	MLP
Mean	20.61052632	11.4
Variance	15.02529161	7.256756757
Observations	38	38
df	37	37
F	2.070524356	
P(F<=f) one-tail	0.014807013	
F Critical one-tail	1.729507032	

B. ANOVA (HGS-RH)

S.No	1		Observations		
Mason	C1M1		Before Work	During Work	After Work
		Trail 1	83.8	72.4	73.0
		Trail 2	84.6	81.4	79.0
		Trail 3	82.4	77.0	78.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	250.8	83.6	1.24
During Work	3	230.8	76.93333333	20.25333333
After Work	3	230	76.66666667	10.33333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	92.59	2	46.29333333	4.363636364	0.06762181	5.143253
Within Groups	63.65	6	10.60888889			
Total	156.2	8				

S.No	2		Observations		
Mason	C1M2		Before Work	During Work	After Work
		Trail 1	74.1	70.8	68.0
		Trail 2	70.2	67.2	64.4
		Trail 3	69.4	64.8	63.6

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	213.7	71.23333333	6.323333333
During Work	3	202.8	67.6	9.12
After Work	3	196	65.33333333	5.493333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	53.15	2	26.57444444	3.807833148	0.08557306	3.463304
Within Groups	41.87	6	6.978888889			
Total	95.02	8				

S.No	3		Observations		
Mason	C1M3		Before Work	During Work	After Work
		Trail 1	95.4	90.8	92.0
		Trail 2	93.6	91.2	92.8
		Trail 3	92.4	89.6	90.8

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	281.4	93.8	2.28
During Work	3	271.6	90.53333333	0.693333333
After Work	3	275.6	91.86666667	1.013333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	16.19	2	8.093333333	6.090301003	0.03594421	3.463304
Within Groups	7.973	6	1.328888889			
Total	24.16	8				

S.No	4		Observations		
Mason	C1M4		Before Work	During Work	After Work
		Trail 1	60.4	58.8	54.6
		Trail 2	59.8	54.2	52.0
		Trail 3	58.6	63.8	51.4

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	178.8	59.6	0.84
During Work	3	176.8	58.93333333	23.05333333
After Work	3	158	52.66666667	2.893333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	87.79	2	43.89333333	4.915878547	0.05443352	3.463304
Within Groups	53.57	6	8.928888889			
Total	141.4	8				

S.No	5		Observations		
Mason	C1M5		Before Work	During Work	After Work
		Trail 1	68.8	72.8	68.8
		Trail 2	64.4	68.8	69.2
		Trail 3	63.4	70.8	65.4

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	196.6	65.53333333	8.253333333
During Work	3	212.4	70.8	4
After Work	3	203.4	67.8	4.36

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	41.88	2	20.93777778	3.780898876	0.08659682	3.463304
Within Groups	33.23	6	5.537777778			
Total	75.1	8				

S.No	6		Observations		
Mason	C1M6		Before Work	During Work	After Work
		Trail 1	83.0	82.4	79.4
		Trail 2	81.8	81.2	77.6
		Trail 3	79.6	80.6	75.2

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	244.4	81.46666667	2.973333333
During Work	3	244.2	81.4	0.84
After Work	3	232.2	77.4	4.44

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	32.54	2	16.27111111	5.914378029	0.03811453	3.463304
Within Groups	16.51	6	2.751111111			
Total	49.05	8				

S.No	7		Observations		
Mason	C2M1		Before Work	During Work	After Work
		Trail 1	84.2	81.0	83.6
		Trail 2	85.0	81.8	80.8
		Trail 3	84.8	80.4	81.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	254	84.66666667	0.173333333
During Work	3	243.2	81.06666667	0.493333333
After Work	3	245.4	81.8	2.44

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	21.72	2	10.85777778	10.48497854	0.01101065	3.463304
Within Groups	6.213	6	1.035555556			
Total	27.93	8				

S.No	8		Observations		
Mason	C2M2		Before Work	During Work	After Work
		Trail 1	91.8	89.6	90.0
		Trail 2	90.2	88.2	89.1
		Trail 3	90.0	88.2	88.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	272	90.66666667	0.973333333
During Work	3	266	88.66666667	0.653333333
After Work	3	267.1	89.03333333	1.003333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6.802	2	3.401111111	3.879594423	0.08292305	3.463304
Within Groups	5.26	6	0.876666667			
Total	12.06	8				

S.No	9		Observations		
Mason	C2M3		Before Work	During Work	After Work
		Trail 1	81.2	86.6	91.2
		Trail 2	84.6	86.2	90.4
		Trail 3	83.4	85.2	91.4

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	249.2	83.06666667	2.973333333
During Work	3	258	86	0.52
After Work	3	273	91	0.28

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	96.54	2	48.27111111	38.37809187	0.00038111	3.463304
Within Groups	7.547	6	1.257777778			
Total	104.1	8				

S.No	10		Observations		
Mason	C2M4		Before Work	During Work	After Work
		Trail 1	86.8	83.4	82.0
		Trail 2	85.2	83.8	81.6
		Trail 3	84.6	84.0	80.8

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	256.6	85.53333333	1.293333333
During Work	3	251.2	83.73333333	0.093333333
After Work	3	244.4	81.46666667	0.373333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	24.92	2	12.45777778	21.23484848	0.00189689	3.463304
Within Groups	3.52	6	0.586666667			
Total	28.44	8				

S.No	11		Observations		
Mason	C2M5		Before Work	During Work	After Work
		Trail 1	81.8	87.6	86.4
		Trail 2	83.8	88.4	86.8
		Trail 3	80.4	88.0	84.6

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	246	82	2.92
During Work	3	264	88	0.16
After Work	3	257.8	85.93333333	1.373333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	55.74	2	27.87111111	18.7754491	0.00261494	3.463304
Within Groups	8.907	6	1.484444444			
Total	64.65	8				

S.No	12		Observations		
Mason	C2M6		Before Work	During Work	After Work
		Trail 1	101.8	93.6	94.8
		Trail 2	96.8	92.6	93.2
		Trail 3	94.0	91.8	93.6

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	292.6	97.53333333	15.61333333
During Work	3	278	92.66666667	0.813333333
After Work	3	281.6	93.86666667	0.693333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	38.57	2	19.28444444	3.379283489	0.10400352	3.463304
Within Groups	34.24	6	5.706666667			
Total	72.81	8				

S.No	13		Observations		
Mason	C3M1		Before Work	During Work	After Work
		Trail 1	91.8	91.2	89.6
		Trail 2	94.8	92.6	90.2
		Trail 3	94.0	93.4	91.4

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Before Work	3	280.6	93.53333333	2.413333333
During Work	3	277.2	92.4	1.24
After Work	3	271.2	90.4	0.84

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	15.1	2	7.551111111	5.041543027	0.0519213	3.463304
Within Groups	8.987	6	1.497777778			
Total	24.09	8				

S.No	14		Observations		
Mason	C3M2		Before Work	During Work	After Work
		Trail 1	89.2	88.2	84.8
		Trail 2	86.2	87.4	84.2
		Trail 3	85.4	87.8	83.2

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Before Work	3	260.8	86.93333333	4.013333333
During Work	3	263.4	87.8	0.16
After Work	3	252.2	84.06666667	0.653333333

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	22.91	2	11.45333333	7.11878453	0.02606026	3.463304
Within Groups	9.653	6	1.608888889			
Total	32.56	8				

S.No	15		Observations		
Mason	C3M3		Before Work	During Work	After Work
		Trail 1	93.4	93.2	90.4
		Trail 2	92.2	91.0	88.2
		Trail 3	90.8	89.2	85.4

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	276.4	92.13333333	1.693333333
During Work	3	273.4	91.13333333	4.013333333
After Work	3	264	88	6.28

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	27.9	2	13.95111111	3.491657397	0.09869542	3.463304
Within Groups	23.97	6	3.995555556			
Total	51.88	8				

S.No	16		Observations		
Mason	C3M4		Before Work	During Work	After Work
		Trail 1	53.2	47.6	44.8
		Trail 2	48.6	46.8	46.2
		Trail 3	46.8	45.2	41.4

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	148.6	49.53333333	10.89333333
During Work	3	139.6	46.53333333	1.493333333
After Work	3	132.4	44.13333333	6.093333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	43.92	2	21.96	3.564935065	0.09542726	3.463304
Within Groups	36.96	6	6.16			
Total	80.88	8				

S.No	17		Observations		
Mason	C3M5		Before Work	During Work	After Work
		Trail 1	73.4	76.2	68.8
		Trail 2	71.8	72.0	70.4
		Trail 3	70.4	73.2	68.6

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	215.6	71.86666667	2.253333333
During Work	3	221.4	73.8	4.68
After Work	3	207.8	69.26666667	0.973333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	31.05	2	15.52444444	5.890387858	0.03842392	3.463304
Within Groups	15.81	6	2.635555556			
Total	46.86	8				

S.No	18		Observations		
Mason	C4M1		Before Work	During Work	After Work
		Trail 1	91.2	91.2	90.0
		Trail 2	90.4	92.4	89.4
		Trail 3	91.4	95.4	88.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	273	91	0.28
During Work	3	279	93	4.68
After Work	3	267.4	89.13333333	1.053333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	22.44	2	11.21777778	5.596452328	0.04250167	3.463304
Within Groups	12.03	6	2.004444444			
Total	34.46	8				

S.No	19		Observations		
Mason	C4M2		Before Work	During Work	After Work
		Trail 1	81.8	87.6	86.4
		Trail 2	83.8	88.4	86.8
		Trail 3	80.4	88.0	84.6

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Before Work	3	246	82	2.92
During Work	3	264	88	0.16
After Work	3	257.8	85.93333333	1.373333333

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	55.74	2	27.87111111	18.7754491	0.00261494	3.463304
Within Groups	8.907	6	1.484444444			
Total	64.65	8				

S.No	20		Observations		
Mason	C4M3		Before Work	During Work	After Work
		Trail 1	91.8	89.6	90.0
		Trail 2	90.2	88.2	89.1
		Trail 3	90.0	88.2	88.0

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Before Work	3	272	90.66666667	0.973333333
During Work	3	266	88.66666667	0.653333333
After Work	3	267.1	89.03333333	1.003333333

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	6.802	2	3.401111111	3.879594423	0.08292305	3.463304
Within Groups	5.26	6	0.876666667			
Total	12.06	8				

S.No	21		Observations		
Mason	C4M4		Before Work	During Work	After Work
		Trail 1	73.4	81.0	79.0
		Trail 2	73.8	80.0	74.0
		Trail 3	70.6	81.8	80.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	217.8	72.6	3.04
During Work	3	242.8	80.93333333	0.813333333
After Work	3	233	77.66666667	10.33333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	105.8	2	52.89333333	11.18515038	0.00945936	3.463304
Within Groups	28.37	6	4.728888889			
Total	134.2	8				

S.No	22		Observations		
Mason	C4M5		Before Work	During Work	After Work
		Trail 1	82.8	78.8	75.4
		Trail 2	77.8	76.6	72.8
		Trail 3	76.8	74.4	73.6

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	237.4	79.13333333	10.33333333
During Work	3	229.8	76.6	4.84
After Work	3	221.8	73.93333333	1.773333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	40.57	2	20.28444444	3.590873328	0.09430503	3.463304
Within Groups	33.89	6	5.648888889			
Total	74.46	8				

S.No	23		Observations		
Mason	C4M6		Before Work	During Work	After Work
		Trail 1	53.2	47.6	44.8
		Trail 2	48.6	46.8	46.2
		Trail 3	46.8	45.2	41.4

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	148.6	49.53333333	10.89333333
During Work	3	139.6	46.53333333	1.493333333
After Work	3	132.4	44.13333333	6.093333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	43.92	2	21.96	3.564935065	0.09542726	3.463304
Within Groups	36.96	6	6.16			
Total	80.88	8				

S.No	24		Observations		
Mason	C4M7		Before Work	During Work	After Work
		Trail 1	96.2	94.4	91.0
		Trail 2	94.4	90.2	89.9
		Trail 3	92.6	91.2	88.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	283.2	94.4	3.24
During Work	3	275.8	91.93333333	4.813333333
After Work	3	268.9	89.63333333	2.303333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	34.1	2	17.04777778	4.938204055	0.05397554	3.463304
Within Groups	20.71	6	3.452222222			
Total	54.81	8				

S.No	25		Observations		
Mason	C4M8		Before Work	During Work	After Work
		Trail 1	91.2	91.2	90.0
		Trail 2	90.4	92.4	89.4
		Trail 3	91.4	95.4	90.4

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	273	91	0.28
During Work	3	279	93	4.68
After Work	3	269.8	89.93333333	0.253333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	14.54	2	7.271111111	4.184143223	0.07281801	3.463304
Within Groups	10.43	6	1.737777778			
Total	24.97	8				

S.No	26		Observations		
Mason	C4M9		Before Work	During Work	After Work
		Trail 1	91.0	88.6	83.2
		Trail 2	91.6	86.0	84.8
		Trail 3	93.4	86.4	86.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	276	92	1.56
During Work	3	261	87	1.96
After Work	3	254	84.66666667	1.973333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	84.22	2	42.11111111	22.99757282	0.00153662	3.463304
Within Groups	10.99	6	1.831111111			
Total	95.21	8				

S.No	27		Observations		
Mason	C4M10		Before Work	During Work	After Work
		Trail 1	68.8	72.8	68.8
		Trail 2	64.4	68.8	69.2
		Trail 3	63.4	70.8	65.4

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	196.6	65.53333333	8.253333333
During Work	3	212.4	70.8	4
After Work	3	203.4	67.8	4.36

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	41.88	2	20.93777778	3.780898876	0.08659682	3.463304
Within Groups	33.23	6	5.537777778			
Total	75.1	8				

S.No	28		Observations		
Mason	C5M1		Before Work	During Work	After Work
		Trail 1	83.8	72.4	73.0
		Trail 2	84.6	81.4	79.0
		Trail 3	82.4	77.0	78.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	250.8	83.6	1.24
During Work	3	230.8	76.93333333	20.25333333
After Work	3	230	76.66666667	10.33333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	92.59	2	46.29333333	4.363636364	0.06762181	3.463304
Within Groups	63.65	6	10.60888889			
Total	156.2	8				

S.No	29		Observations		
Mason	C5M2		Before Work	During Work	After Work
		Trail 1	82.8	78.8	75.4
		Trail 2	77.8	76.6	72.8
		Trail 3	76.8	74.4	73.6

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	237.4	79.13333333	10.33333333
During Work	3	229.8	76.6	4.84
After Work	3	221.8	73.93333333	1.773333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	40.57	2	20.28444444	3.590873328	0.09430503	3.463304
Within Groups	33.89	6	5.648888889			
Total	74.46	8				

S.No	30		Observations		
Mason	C5M3		Before Work	During Work	After Work
		Trail 1	76.4	80.0	74.0
		Trail 2	76.8	81.0	77.0
		Trail 3	73.6	81.8	79.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	226.8	75.6	3.04
During Work	3	242.8	80.93333333	0.813333333
After Work	3	230	76.66666667	6.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	47.79	2	23.89333333	7.036649215	0.0267053	3.463304
Within Groups	20.37	6	3.395555556			
Total	68.16	8				

S.No	31		Observations		
Mason	C5M4		Before Work	During Work	After Work
		Trail 1	58.0	57.4	53.0
		Trail 2	56.4	55.8	52.8
		Trail 3	55.4	51.8	52.2

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	169.8	56.6	1.72
During Work	3	165	55	8.32
After Work	3	158	52.66666667	0.173333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	23.48	2	11.73777778	3.447780679	0.10072401	3.463304
Within Groups	20.43	6	3.404444444			
Total	43.9	8				

S.No	32		Observations		
Mason	C5M5		Before Work	During Work	After Work
		Trail 1	91.8	89.6	90.0
		Trail 2	90.2	88.2	89.1
		Trail 3	90.0	88.2	88.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	272	90.66666667	0.973333333
During Work	3	266	88.66666667	0.653333333
After Work	3	267.1	89.03333333	1.003333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6.802	2	3.401111111	3.879594423	0.08292305	3.463304
Within Groups	5.26	6	0.876666667			
Total	12.06	8				

S.No	33		Observations		
Mason	C5M6		Before Work	During Work	After Work
		Trail 1	82.8	78.8	75.4
		Trail 2	77.8	76.6	72.8
		Trail 3	76.8	74.4	73.6

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	237.4	79.13333333	10.33333333
During Work	3	229.8	76.6	4.84
After Work	3	221.8	73.93333333	1.773333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	40.57	2	20.28444444	3.590873328	0.09430503	3.463304
Within Groups	33.89	6	5.648888889			
Total	74.46	8				

S.No	34		Observations		
Mason	C5M7		Before Work	During Work	After Work
		Trail 1	72.8	71.2	68.0
		Trail 2	70.8	68.8	68.4
		Trail 3	69.6	69.2	68.2

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	213.2	71.06666667	2.613333333
During Work	3	209.2	69.73333333	1.653333333
After Work	3	204.6	68.2	0.04

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	12.35	2	6.173333333	4.300309598	0.06939688	3.463304
Within Groups	8.613	6	1.435555556			
Total	20.96	8				

S.No	35		Observations		
Mason	C6M1		Before Work	During Work	After Work
		Trail 1	89.2	88.2	84.8
		Trail 2	86.2	87.4	84.2
		Trail 3	85.4	87.8	83.2

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	260.8	86.93333333	4.013333333
During Work	3	263.4	87.8	0.16
After Work	3	252.2	84.06666667	0.653333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	22.91	2	11.45333333	7.11878453	0.02606026	3.463304
Within Groups	9.653	6	1.608888889			
Total	32.56	8				

S.No	36		Observations		
Mason	C6M2		Before Work	During Work	After Work
		Trail 1	73.4	76.2	68.8
		Trail 2	71.8	72.0	70.4
		Trail 3	70.4	73.2	68.6

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	215.6	71.86666667	2.253333333
During Work	3	221.4	73.8	4.68
After Work	3	207.8	69.26666667	0.973333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	31.05	2	15.52444444	5.890387858	0.03842392	3.463304
Within Groups	15.81	6	2.635555556			
Total	46.86	8				

S.No	37		Observations		
Mason	C6M3		Before Work	During Work	After Work
		Trail 1	58.0	57.4	53.0
		Trail 2	56.4	55.8	52.8
		Trail 3	55.4	51.8	52.2

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	169.8	56.6	1.72
During Work	3	165	55	8.32
After Work	3	158	52.66666667	0.173333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	23.48	2	11.73777778	3.447780679	0.10072401	3.463304
Within Groups	20.43	6	3.404444444			
Total	43.9	8				

S.No	38		Observations		
Mason	C6M4		Before Work	During Work	After Work
		Trail 1	52.2	50.2	49.4
		Trail 2	51.8	48.6	49.2
		Trail 3	50.2	46.4	46.2

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	154.2	51.4	1.12
During Work	3	145.2	48.4	3.64
After Work	3	144.8	48.26666667	3.213333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	18.84	2	9.417777778	3.543478261	0.09636909	3.463304
Within Groups	15.95	6	2.657777778			
Total	34.78	8				

C. ANOVA (HGS_LH)

S.No	1		Observations		
Mason	C1M1		Before Work	During Work	After Work
		Trail 1	71.4	68.4	67.0
		Trail 2	72.0	68.0	68.4
		Trail 3	70.2	69.1	66.2

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	213.6	71.2	0.84
During Work	3	205.5	68.5	0.31
After Work	3	201.6	67.2	1.24

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	24.98	2	12.49	15.67782427	0.00414367	3.463304
Within Groups	4.78	6	0.796666667			
Total	29.76	8				

S.No	2		Observations		
Mason	C1M2		Before Work	During Work	After Work
		Trail 1	66.8	62.2	62.2
		Trail 2	64.6	62.8	59.2
		Trail 3	63.4	64.0	58.4

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	194.8	64.93333333	2.973333333
During Work	3	189	63	0.84
After Work	3	179.8	59.93333333	4.013333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	38.14	2	19.07111111	7.310051107	0.02463663	3.463304
Within Groups	15.65	6	2.608888889			
Total	53.8	8				

S.No	3		Observations		
Mason	C1M3		Before Work	During Work	After Work
		Trail 1	73.4	81.0	79.0
		Trail 2	73.8	80.0	74.0
		Trail 3	70.6	81.8	80.0

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Before Work	3	217.8	72.6	3.04
During Work	3	242.8	80.93333333	0.813333333
After Work	3	233	77.66666667	10.33333333

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	105.8	2	52.89333333	11.18515038	0.00945936	3.463304
Within Groups	28.37	6	4.728888889			
Total	134.2	8				

S.No	4		Observations		
Mason	C1M4		Before Work	During Work	After Work
		Trail 1	58.0	57.4	53.0
		Trail 2	56.4	55.8	52.8
		Trail 3	55.4	51.8	52.2

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Before Work	3	169.8	56.6	1.72
During Work	3	165	55	8.32
After Work	3	158	52.66666667	0.173333333

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	23.48	2	11.73777778	3.447780679	0.10072401	3.463304
Within Groups	20.43	6	3.404444444			
Total	43.9	8				

S.No	5		Observations		
Mason	C1M5		Before Work	During Work	After Work
		Trail 1	64.8	63.6	62.6
		Trail 2	63.6	62.4	61.4
		Trail 3	63.2	61.0	61.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
64.8	2	126.8	63.4	0.08
63.6	2	123.4	61.7	0.98
62.6	2	122.4	61.2	0.08

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5.32	2	2.66	7	0.07413248	5.462383
Within Groups	1.14	3	0.38			
Total	6.46	5				

S.No	6		Observations		
Mason	C1M6		Before Work	During Work	After Work
		Trail 1	80.8	79.2	75.8
		Trail 2	78.6	78.4	74.2
		Trail 3	74.8	78.2	74.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	234.2	78.06666667	9.213333333
During Work	3	235.8	78.6	0.28
After Work	3	224	74.66666667	0.973333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	27.32	2	13.65777778	3.914649682	0.08166824	3.463304
Within Groups	20.93	6	3.488888889			
Total	48.25	8				

S.No	7		Observations		
Mason	C2M1		Before Work	During Work	After Work
		Trail 1	82.8	78.8	75.4
		Trail 2	77.8	76.6	72.8
		Trail 3	76.8	74.4	73.6

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	237.4	79.13333333	10.33333333
During Work	3	229.8	76.6	4.84
After Work	3	221.8	73.93333333	1.773333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	40.57	2	20.28444444	3.590873328	0.09430503	3.463304
Within Groups	33.89	6	5.648888889			
Total	74.46	8				

S.No	8		Observations		
Mason	C2M2		Before Work	During Work	After Work
		Trail 1	96.2	94.4	91.0
		Trail 2	94.4	90.2	89.9
		Trail 3	92.6	91.2	88.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	283.2	94.4	3.24
During Work	3	275.8	91.93333333	4.813333333
After Work	3	268.9	89.63333333	2.303333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	34.1	2	17.04777778	4.938204055	0.05397554	3.463304
Within Groups	20.71	6	3.452222222			
Total	54.81	8				

S.No	9		Observations		
Mason	C2M3		Before Work	During Work	After Work
		Trail 1	91.0	88.6	83.2
		Trail 2	91.6	86.0	84.8
		Trail 3	93.4	86.4	86.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	276	92	1.56
During Work	3	261	87	1.96
After Work	3	254	84.66666667	1.973333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	84.22	2	42.11111111	22.99757282	0.00153662	3.463304
Within Groups	10.99	6	1.831111111			
Total	95.21	8				

S.No	10		Observations		
Mason	C2M4		Before Work	During Work	After Work
		Trail 1	76.4	80.0	74.0
		Trail 2	76.8	81.0	77.0
		Trail 3	73.6	81.8	79.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	226.8	75.6	3.04
During Work	3	242.8	80.93333333	0.813333333
After Work	3	230	76.66666667	6.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	47.79	2	23.89333333	7.036649215	0.0267053	3.463304
Within Groups	20.37	6	3.395555556			
Total	68.16	8				

S.No	11		Observations		
Mason	C2M5		Before Work	During Work	After Work
		Trail 1	91.2	91.2	90.0
		Trail 2	90.4	92.4	89.4
		Trail 3	91.4	95.4	90.4

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	273	91	0.28
During Work	3	279	93	4.68
After Work	3	269.8	89.93333333	0.253333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	14.54	2	7.271111111	4.184143223	0.07281801	3.463304
Within Groups	10.43	6	1.737777778			
Total	24.97	8				

S.No	12		Observations		
Mason	C2M6		Before Work	During Work	After Work
		Trail 1	81.2	78.4	77.4
		Trail 2	84.6	80.4	78.2
		Trail 3	80.0	80.0	76.6

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	245.8	81.93333333	5.693333333
During Work	3	238.8	79.6	1.12
After Work	3	232.2	77.4	0.64

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	30.84	2	15.41777778	6.205724508	0.03460906	3.463304
Within Groups	14.91	6	2.484444444			
Total	45.74	8				

S.No	13		Observations		
Mason	C3M1		Before Work	During Work	After Work
		Trail 1	103.4	101.4	99.2
		Trail 2	101.8	98.8	98.0
		Trail 3	99.6	97.8	96.4

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	304.8	101.6	3.64
During Work	3	298	99.33333333	3.453333333
After Work	3	293.6	97.86666667	1.973333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	21.23	2	10.61333333	3.511764706	0.09778397	3.463304
Within Groups	18.13	6	3.022222222			
Total	39.36	8				

S.No	14		Observations		
Mason	C3M2		Before Work	During Work	After Work
		Trail 1	75.4	73.8	72.8
		Trail 2	74.0	72.0	71.4
		Trail 3	73.2	70.8	70.2

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	222.6	74.2	1.24
During Work	3	216.6	72.2	2.28
After Work	3	214.4	71.46666667	1.693333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	12.01	2	6.004444444	3.455242967	0.1003751	3.463304
Within Groups	10.43	6	1.737777778			
Total	22.44	8				

S.No	15		Observations		
Mason	C3M3		Before Work	During Work	After Work
		Trail 1	87.6	86.0	84.6
		Trail 2	84.6	86.2	80.2
		Trail 3	83.8	84.8	77.6

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	256	85.33333333	4.013333333
During Work	3	257	85.66666667	0.573333333
After Work	3	242.4	80.8	12.52

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	44.35	2	22.17333333	3.888542479	0.08260032	3.463304
Within Groups	34.21	6	5.702222222			
Total	78.56	8				

S.No	16		Observations		
Mason	C3M4		Before Work	During Work	After Work
		Trail 1	52.2	50.2	49.4
		Trail 2	51.8	48.6	49.2
		Trail 3	50.2	46.4	46.2

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	154.2	51.4	1.12
During Work	3	145.2	48.4	3.64
After Work	3	144.8	48.26666667	3.213333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	18.84	2	9.417777778	3.543478261	0.09636909	3.463304
Within Groups	15.95	6	2.657777778			
Total	34.78	8				

S.No	17		Observations		
Mason	C3M5		Before Work	During Work	After Work
		Trail 1	72.8	71.2	68.0
		Trail 2	70.8	68.8	68.4
		Trail 3	69.6	69.2	68.2

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	213.2	71.06666667	2.613333333
During Work	3	209.2	69.73333333	1.653333333
After Work	3	204.6	68.2	0.04

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	12.35	2	6.173333333	4.300309598	0.06939688	3.463304
Within Groups	8.613	6	1.435555556			
Total	20.96	8				

S.No	18		Observations		
Mason	C4M1		Before Work	During Work	After Work
		Trail 1	82.8	78.8	75.4
		Trail 2	77.8	76.6	72.8
		Trail 3	76.8	74.4	73.6

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	237.4	79.13333333	10.33333333
During Work	3	229.8	76.6	4.84
After Work	3	221.8	73.93333333	1.773333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	40.57	2	20.28444444	3.590873328	0.09430503	3.463304
Within Groups	33.89	6	5.648888889			
Total	74.46	8				

S.No	19		Observations		
Mason	C4M2		Before Work	During Work	After Work
		Trail 1	89.2	88.2	84.8
		Trail 2	86.2	87.4	84.2
		Trail 3	85.4	87.8	83.2

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	260.8	86.93333333	4.013333333
During Work	3	263.4	87.8	0.16
After Work	3	252.2	84.06666667	0.653333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	22.91	2	11.45333333	7.11878453	0.02606026	3.463304
Within Groups	9.653	6	1.608888889			
Total	32.56	8				

S.No	20		Observations		
Mason	C4M3		Before Work	During Work	After Work
		Trail 1	91.0	88.6	83.2
		Trail 2	91.6	86.0	84.8
		Trail 3	93.4	86.4	86.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	276	92	1.56
During Work	3	261	87	1.96
After Work	3	254	84.66666667	1.973333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	84.22	2	42.11111111	22.99757282	0.00153662	3.463304
Within Groups	10.99	6	1.831111111			
Total	95.21	8				

S.No	21		Observations		
Mason	C4M4		Before Work	During Work	After Work
		Trail 1	76.4	80.0	74.0
		Trail 2	76.8	81.0	77.0
		Trail 3	73.6	81.8	79.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	226.8	75.6	3.04
During Work	3	242.8	80.93333333	0.813333333
After Work	3	230	76.66666667	6.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	47.79	2	23.89333333	7.036649215	0.0267053	3.463304
Within Groups	20.37	6	3.395555556			
Total	68.16	8				

S.No	22		Observations		
Mason	C4M5		Before Work	During Work	After Work
		Trail 1	83.8	72.4	73.0
		Trail 2	84.6	81.4	79.0
		Trail 3	82.4	77.0	78.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	250.8	83.6	1.24
During Work	3	230.8	76.93333333	20.25333333
After Work	3	230	76.66666667	10.33333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	92.59	2	46.29333333	4.363636364	0.06762181	3.463304
Within Groups	63.65	6	10.60888889			
Total	156.2	8				

S.No	23		Observations		
Mason	C4M6		Before Work	During Work	After Work
		Trail 1	58.0	47.6	44.8
		Trail 2	56.4	46.8	46.2
		Trail 3	55.4	45.2	41.4

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	169.8	56.6	1.72
During Work	3	139.6	46.53333333	1.493333333
After Work	3	132.4	44.13333333	6.093333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	262.5	2	131.2577778	42.31088825	0.00029024	3.463304
Within Groups	18.61	6	3.102222222			
Total	281.1	8				

S.No	24		Observations		
Mason	C4M7		Before Work	During Work	After Work
		Trail 1	101.8	93.6	94.8
		Trail 2	96.8	92.6	93.2
		Trail 3	94.0	91.8	93.6

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	292.6	97.53333333	15.61333333
During Work	3	278	92.66666667	0.813333333
After Work	3	281.6	93.86666667	0.693333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	38.57	2	19.28444444	3.379283489	0.10400352	3.463304
Within Groups	34.24	6	5.706666667			
Total	72.81	8				

S.No	25		Observations		
Mason	C4M8		Before Work	During Work	After Work
		Trail 1	76.4	80.0	74.0
		Trail 2	76.8	81.0	77.0
		Trail 3	73.6	81.8	79.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	226.8	75.6	3.04
During Work	3	242.8	80.93333333	0.813333333
After Work	3	230	76.66666667	6.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	47.79	2	23.89333333	7.036649215	0.0267053	3.463304
Within Groups	20.37	6	3.395555556			
Total	68.16	8				

S.No	26		Observations		
Mason	C4M9		Before Work	During Work	After Work
		Trail 1	81.8	87.6	86.4
		Trail 2	83.8	88.4	86.8
		Trail 3	80.4	88.0	84.6

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	246	82	2.92
During Work	3	264	88	0.16
After Work	3	257.8	85.93333333	1.373333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	55.74	2	27.87111111	18.7754491	0.00261494	3.463304
Within Groups	8.907	6	1.484444444			
Total	64.65	8				

S.No	27		Observations		
Mason	C4M10		Before Work	During Work	After Work
		Trail 1	72.8	71.2	68.0
		Trail 2	70.8	68.8	68.4
		Trail 3	69.6	69.2	68.2

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	213.2	71.06666667	2.613333333
During Work	3	209.2	69.73333333	1.653333333
After Work	3	204.6	68.2	0.04

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	12.35	2	6.173333333	4.300309598	0.06939688	3.463304
Within Groups	8.613	6	1.435555556			
Total	20.96	8				

S.No	28		Observations		
Mason	C5M1		Before Work	During Work	After Work
		Trail 1	80.2	78.2	76.2
		Trail 2	77.6	76.8	75.6
		Trail 3	77.4	76.0	74.8

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	235.2	78.4	2.44
During Work	3	231	77	1.24
After Work	3	226.6	75.53333333	0.493333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	12.33	2	6.164444444	4.431309904	0.06579118	3.463304
Within Groups	8.347	6	1.391111111			
Total	20.68	8				

S.No	29		Observations		
Mason	C5M2		Before Work	During Work	After Work
		Trail 1	82.8	78.8	75.4
		Trail 2	77.8	76.6	72.8
		Trail 3	76.8	74.4	73.6

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	237.4	79.13333333	10.33333333
During Work	3	229.8	76.6	4.84
After Work	3	221.8	73.93333333	1.773333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	40.57	2	20.28444444	3.590873328	0.09430503	3.463304
Within Groups	33.89	6	5.648888889			
Total	74.46	8				

S.No	30		Observations		
Mason	C5M3		Before Work	During Work	After Work
		Trail 1	82.8	78.8	75.4
		Trail 2	77.8	76.6	72.8
		Trail 3	76.8	74.4	73.6

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	237.4	79.13333333	10.33333333
During Work	3	229.8	76.6	4.84
After Work	3	221.8	73.93333333	1.773333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	40.57	2	20.28444444	3.590873328	0.09430503	3.463304
Within Groups	33.89	6	5.648888889			
Total	74.46	8				

S.No	31		Observations		
Mason	C5M4		Before Work	During Work	After Work
		Trail 1	53.2	47.6	44.8
		Trail 2	48.6	46.8	46.2
		Trail 3	46.8	45.2	41.4

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	148.6	49.53333333	10.89333333
During Work	3	139.6	46.53333333	1.493333333
After Work	3	132.4	44.13333333	6.093333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	43.92	2	21.96	3.564935065	0.09542726	3.463304
Within Groups	36.96	6	6.16			
Total	80.88	8				

S.No	32		Observations		
Mason	C5M5		Before Work	During Work	After Work
		Trail 1	81.8	87.6	86.4
		Trail 2	83.8	88.4	86.8
		Trail 3	80.4	88.0	84.6

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	246	82	2.92
During Work	3	264	88	0.16
After Work	3	257.8	85.93333333	1.373333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	55.74	2	27.87111111	18.7754491	0.00261494	3.463304
Within Groups	8.907	6	1.484444444			
Total	64.65	8				

S.No	33		Observations		
Mason	C5M6		Before Work	During Work	After Work
		Trail 1	83.8	72.4	73.0
		Trail 2	84.6	81.4	79.0
		Trail 3	82.4	77.0	78.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	250.8	83.6	1.24
During Work	3	230.8	76.93333333	20.25333333
After Work	3	230	76.66666667	10.33333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	92.59	2	46.29333333	4.363636364	0.06762181	3.463304
Within Groups	63.65	6	10.60888889			
Total	156.2	8				

S.No	34		Observations		
Mason	C5M7		Before Work	During Work	After Work
		Trail 1	82.8	78.8	75.4
		Trail 2	77.8	76.6	72.8
		Trail 3	76.8	74.4	73.6

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	237.4	79.13333333	10.33333333
During Work	3	229.8	76.6	4.84
After Work	3	221.8	73.93333333	1.773333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	40.57	2	20.28444444	3.590873328	0.09430503	3.463304
Within Groups	33.89	6	5.648888889			
Total	74.46	8				

S.No	35		Observations		
Mason	C6M1		Before Work	During Work	After Work
		Trail 1	91.2	91.2	90.0
		Trail 2	90.4	92.4	89.4
		Trail 3	91.4	95.4	90.4

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	273	91	0.28
During Work	3	279	93	4.68
After Work	3	269.8	89.93333333	0.253333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	14.54	2	7.271111111	4.184143223	0.07281801	3.463304
Within Groups	10.43	6	1.737777778			
Total	24.97	8				

S.No	36		Observations		
Mason	C6M2		Before Work	During Work	After Work
		Trail 1	82.8	78.8	75.4
		Trail 2	77.8	76.6	72.8
		Trail 3	76.8	74.4	73.6

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	237.4	79.13333333	10.33333333
During Work	3	229.8	76.6	4.84
After Work	3	221.8	73.93333333	1.773333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	40.57	2	20.28444444	3.590873328	0.09430503	3.463304
Within Groups	33.89	6	5.648888889			
Total	74.46	8				

S.No	37		Observations		
Mason	C6M3		Before Work	During Work	After Work
		Trail 1	52.2	50.2	49.4
		Trail 2	51.8	48.6	49.2
		Trail 3	50.2	46.4	46.2

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	154.2	51.4	1.12
During Work	3	145.2	48.4	3.64
After Work	3	144.8	48.26666667	3.213333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	18.84	2	9.417777778	3.543478261	0.09636909	3.463304
Within Groups	15.95	6	2.657777778			
Total	34.78	8				

S.No	38		Observations		
Mason	C6M4		Before Work	During Work	After Work
		Trail 1	68.8	72.8	68.8
		Trail 2	64.4	68.8	69.2
		Trail 3	63.4	70.8	65.4

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Before Work	3	196.6	65.53333333	8.253333333
During Work	3	212.4	70.8	4
After Work	3	203.4	67.8	4.36

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	41.88	2	20.93777778	3.780898876	0.08659682	3.463304
Within Groups	33.23	6	5.537777778			
Total	75.1	8				

D. ANOVA (UBMS_CP)

S.No	1		Observations	
Mason	C1M1		Push	Pull
		Before Work	24.0	17.0
		During Work	28.0	21.0
		After Work	26.0	19.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	78	26	4
Pull	3	57	19	4

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	73.5	1	73.5	18.375	0.01278048	4.544771
Within Groups	16	4	4			
Total	89.5	5				

S.No	2		Observations	
Mason	C1M2		Push	Pull
		Before Work	33.0	28.0
		During Work	29.0	24.0
		After Work	31.0	22.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	93	31	4
Pull	3	74	24.66666667	9.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	60.17	1	60.16666667	9.025	0.03977836	4.544771
Within Groups	26.67	4	6.666666667			
Total	86.83	5				

S.No	3		Observations	
Mason	C1M3		Push	Pull
		Before Work	38.0	32.0
		During Work	33.0	28.0
		After Work	34.0	31.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	105	35	7
Pull	3	91	30.33333333	4.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	32.67	1	32.66666667	5.764705882	0.07427733	4.544771
Within Groups	22.67	4	5.666666667			
Total	55.33	5				

S.No	4		Observations	
Mason	C1M4		Push	Pull
		Before Work	16.0	14.0
		During Work	15.0	12.0
		After Work	14.0	13.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	45	15	1
Pull	3	39	13	1

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6	1	6	6	0.070484	4.544771
Within Groups	4	4	1			
Total	10	5				

S.No	5		Observations	
Mason	C1M5		Push	Pull
		Before Work	18.0	28.0
		During Work	22.0	25.0
		After Work	22.0	24.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	62	20.66666667	5.333333333
Pull	3	77	25.66666667	4.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	37.5	1	37.5	7.75862069	0.04954275	4.544771
Within Groups	19.33	4	4.833333333			
Total	56.83	5				

S.No	6		Observations	
Mason	C1M6		Push	Pull
		Before Work	35.0	30.0
		During Work	43.0	32.0
		After Work	42.0	33.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	120	40	19
Pull	3	95	31.66666667	2.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	104.2	1	104.1666667	9.765625	0.03535546	4.544771
Within Groups	42.67	4	10.66666667			
Total	146.8	5				

S.No	7		Observations	
Mason	C2M1		Push	Pull
		Before Work	40.0	36.0
		During Work	39.0	33.0
		After Work	40.0	36.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	119	39.66666667	0.333333333
Pull	3	105	35	3

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	32.67	1	32.66666667	19.6	0.01144691	4.544771
Within Groups	6.667	4	1.666666667			
Total	39.33	5				

S.No	8		Observations	
Mason	C2M2		Push	Pull
		Before Work	35.0	38.0
		During Work	31.0	37.0
		After Work	29.0	34.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	95	31.66666667	9.333333333
Pull	3	109	36.33333333	4.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	32.67	1	32.66666667	4.780487805	0.09406601	4.544771
Within Groups	27.33	4	6.833333333			
Total	60	5				

S.No	9		Observations	
Mason	C2M3		Push	Pull
		Before Work	27.0	34.0
		During Work	28.0	34.0
		After Work	26.0	30.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	81	27	1
Pull	3	98	32.66666667	5.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	48.17	1	48.16666667	15.21052632	0.01754047	4.544771
Within Groups	12.67	4	3.166666667			
Total	60.83	5				

S.No	10		Observations	
Mason	C2M4		Push	Pull
		Before Work	19.0	31.0
		During Work	23.0	33.0
		After Work	22.0	34.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	64	21.33333333	4.333333333
Pull	3	98	32.66666667	2.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	192.7	1	192.6666667	57.8	0.00160618	4.544771
Within Groups	13.33	4	3.333333333			
Total	206	5				

S.No	11		Observations	
Mason	C2M5		Push	Pull
		Before Work	28.0	34.0
		During Work	24.0	33.0
		After Work	20.0	27.0

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Push	3	72	24	16
Pull	3	94	31.33333333	14.33333333

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	80.67	1	80.66666667	5.318681319	0.08237312	4.544771
Within Groups	60.67	4	15.16666667			
Total	141.3	5				

S.No	12		Observations	
Mason	C2M6		Push	Pull
		Before Work	35.0	30.0
		During Work	33.0	29.0
		After Work	31.0	29.0

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Push	3	99	33	4
Pull	3	88	29.33333333	0.333333333

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	20.17	1	20.16666667	9.307692308	0.0379966	4.544771
Within Groups	8.667	4	2.166666667			
Total	28.83	5				

S.No	13		Observations	
Mason	C3M1		Push	Pull
		Before Work	37.0	42.0
		During Work	34.0	40.0
		After Work	35.0	38.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	106	35.33333333	2.333333333
Pull	3	120	40	4

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	32.67	1	32.66666667	10.31578947	0.03253253	4.544771
Within Groups	12.67	4	3.166666667			
Total	45.33	5				

S.No	14		Observations	
Mason	C3M2		Push	Pull
		Before Work	28.0	24.0
		During Work	27.0	25.0
		After Work	25.0	23.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	80	26.66666667	2.333333333
Pull	3	72	24	1

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	10.67	1	10.66666667	6.4	0.06467689	4.544771
Within Groups	6.667	4	1.666666667			
Total	17.33	5				

S.No	15		Observations	
Mason	C3M3		Push	Pull
		Before Work	39.0	44.0
		During Work	37.0	41.0
		After Work	36.0	40.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	112	37.33333333	2.333333333
Pull	3	125	41.66666667	4.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	28.17	1	28.16666667	8.45	0.04381445	4.544771
Within Groups	13.33	4	3.333333333			
Total	41.5	5				

S.No	16		Observations	
Mason	C3M4		Push	Pull
		Before Work	22.0	16.0
		During Work	21.0	18.0
		After Work	19.0	17.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	62	20.66666667	2.333333333
Pull	3	51	17	1

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	20.17	1	20.16666667	12.1	0.02538645	4.544771
Within Groups	6.667	4	1.666666667			
Total	26.83	5				

S.No	17		Observations	
Mason	C3M5		Push	Pull
		Before Work	29.0	33.0
		During Work	28.0	35.0
		After Work	25.0	31.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	82	27.33333333	4.333333333
Pull	3	99	33	4

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	48.17	1	48.16666667	11.56	0.02727733	4.544771
Within Groups	16.67	4	4.166666667			
Total	64.83	5				

S.No	18		Observations	
Mason	C4M1		Push	Pull
		Before Work	38.0	32.0
		During Work	33.0	28.0
		After Work	34.0	30.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	105	35	7
Pull	3	90	30	4

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	37.5	1	37.5	6.818181818	0.05934731	4.544771
Within Groups	22	4	5.5			
Total	59.5	5				

S.No	19		Observations	
Mason	C4M2		Push	Pull
		Before Work	19.0	31.0
		During Work	23.0	34.0
		After Work	22.0	34.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	64	21.33333333	4.333333333
Pull	3	99	33	3

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	204.2	1	204.1666667	55.68181818	0.0017236	4.544771
Within Groups	14.67	4	3.666666667			
Total	218.8	5				

S.No	20		Observations	
Mason	C4M3		Push	Pull
		Before Work	35.0	38.0
		During Work	31.0	37.0
		After Work	29.0	34.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
35	2	60	30	2
38	2	71	35.5	4.5

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	30.25	1	30.25	9.307692308	0.09273529	8.526316
Within Groups	6.5	2	3.25			
Total	36.75	3				

S.No	21		Observations	
Mason	C4M4		Push	Pull
		Before Work	27.0	31.0
		During Work	26.0	33.0
		After Work	20.0	27.0

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Push	3	73	24.33333333	14.33333333
Pull	3	91	30.33333333	9.333333333

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	54	1	54	4.563380282	0.09951103	4.544771
Within Groups	47.33	4	11.83333333			
Total	101.3	5				

S.No	22		Observations	
Mason	C4M5		Push	Pull
		Before Work	35.0	30.0
		During Work	43.0	32.0
		After Work	42.0	33.0

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Push	3	120	40	19
Pull	3	95	31.66666667	2.333333333

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	104.2	1	104.1666667	9.765625	0.03535546	4.544771
Within Groups	42.67	4	10.66666667			
Total	146.8	5				

S.No	23		Observations	
Mason	C4M6		Push	Pull
		Before Work	38.0	32.0
		During Work	34.0	28.0
		After Work	34.0	31.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	106	35.33333333	5.333333333
Pull	3	91	30.33333333	4.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	37.5	1	37.5	7.75862069	0.04954275	4.544771
Within Groups	19.33	4	4.833333333			
Total	56.83	5				

S.No	24		Observations	
Mason	C4M7		Push	Pull
		Before Work	18.0	28.0
		During Work	22.0	25.0
		After Work	21.0	24.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	61	20.33333333	4.333333333
Pull	3	77	25.66666667	4.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	42.67	1	42.66666667	9.846153846	0.03491971	4.544771
Within Groups	17.33	4	4.333333333			
Total	60	5				

S.No	25		Observations	
Mason	C4M8		Push	Pull
		Before Work	35.0	30.0
		During Work	41.0	32.0
		After Work	42.0	33.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	118	39.33333333	14.33333333
Pull	3	95	31.66666667	2.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	88.17	1	88.16666667	10.58	0.03129604	4.544771
Within Groups	33.33	4	8.333333333			
Total	121.5	5				

S.No	26		Observations	
Mason	C4M9		Push	Pull
		Before Work	29.0	33.0
		During Work	28.0	35.0
		After Work	25.0	31.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	82	27.33333333	4.333333333
Pull	3	99	33	4

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	48.17	1	48.16666667	11.56	0.02727733	4.544771
Within Groups	16.67	4	4.166666667			
Total	64.83	5				

S.No	27		Observations	
Mason	C4M10		Push	Pull
		Before Work	19.0	31.0
		During Work	23.0	33.0
		After Work	22.0	34.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	64	21.33333333	4.333333333
Pull	3	98	32.66666667	2.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	192.7	1	192.6666667	57.8	0.00160618	4.544771
Within Groups	13.33	4	3.333333333			
Total	206	5				

S.No	28		Observations	
Mason	C5M1		Push	Pull
		Before Work	18.0	28.0
		During Work	21.0	25.0
		After Work	22.0	24.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	61	20.33333333	4.333333333
Pull	3	77	25.66666667	4.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	42.67	1	42.66666667	9.846153846	0.03491971	4.544771
Within Groups	17.33	4	4.333333333			
Total	60	5				

S.No	29		Observations	
Mason	C5M2		Push	Pull
		Before Work	27.0	34.0
		During Work	28.0	34.0
		After Work	26.0	31.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	81	27	1
Pull	3	99	33	3

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	54	1	54	27	0.00653338	4.544771
Within Groups	8	4	2			
Total	62	5				

S.No	30		Observations	
Mason	C5M3		Push	Pull
		Before Work	35.0	30.0
		During Work	33.0	29.0
		After Work	30.0	29.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	98	32.66666667	6.333333333
Pull	3	88	29.33333333	0.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	16.67	1	16.66666667	5	0.08900934	4.544771
Within Groups	13.33	4	3.333333333			
Total	30	5				

S.No	31		Observations	
Mason	C5M4		Push	Pull
		Before Work	23.0	17.0
		During Work	28.0	21.0
		After Work	26.0	19.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	77	25.66666667	6.333333333
Pull	3	57	19	4

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	66.67	1	66.66666667	12.90322581	0.02291875	4.544771
Within Groups	20.67	4	5.166666667			
Total	87.33	5				

S.No	32		Observations	
Mason	C5M5		Push	Pull
		Before Work	21.0	16.0
		During Work	21.0	19.0
		After Work	19.0	17.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	61	20.33333333	1.333333333
Pull	3	52	17.33333333	2.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	13.5	1	13.5	7.363636364	0.05333826	4.544771
Within Groups	7.333	4	1.833333333			
Total	20.83	5				

S.No	33		Observations	
Mason	C5M6		Push	Pull
		Before Work	33.0	28.0
		During Work	29.0	24.0
		After Work	31.0	22.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	93	31	4
Pull	3	74	24.66666667	9.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	60.17	1	60.16666667	9.025	0.03977836	4.544771
Within Groups	26.67	4	6.666666667			
Total	86.83	5				

S.No	34		Observations	
Mason	C5M7		Push	Pull
		Before Work	30.0	24.0
		During Work	29.0	25.0
		After Work	25.0	24.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	84	28	7
Pull	3	73	24.33333333	0.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	20.17	1	20.16666667	5.5	0.07892758	4.544771
Within Groups	14.67	4	3.666666667			
Total	34.83	5				

S.No	35		Observations	
Mason	C6M1		Push	Pull
		Before Work	39.0	36.0
		During Work	39.0	33.0
		After Work	40.0	36.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	118	39.33333333	0.333333333
Pull	3	105	35	3

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	28.17	1	28.16666667	16.9	0.01472059	4.544771
Within Groups	6.667	4	1.666666667			
Total	34.83	5				

S.No	36		Observations	
Mason	C6M2		Push	Pull
		Before Work	39.0	44.0
		During Work	38.0	41.0
		After Work	36.0	40.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	113	37.66666667	2.333333333
Pull	3	125	41.66666667	4.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	24	1	24	7.2	0.05504061	4.544771
Within Groups	13.33	4	3.333333333			
Total	37.33	5				

S.No	37		Observations	
Mason	C6M3		Push	Pull
		Before Work	35.0	30.0
		During Work	34.0	29.0
		After Work	31.0	29.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	100	33.33333333	4.333333333
Pull	3	88	29.33333333	0.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	24	1	24	10.28571429	0.03267792	4.544771
Within Groups	9.333	4	2.333333333			
Total	33.33	5				

S.No	38		Observations	
Mason	C6M4		Push	Pull
		Before Work	16.0	14.0
		During Work	16.0	12.0
		After Work	15.0	13.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	47	15.66666667	0.333333333
Pull	3	39	13	1

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	10.67	1	10.66666667	16	0.01613009	4.544771
Within Groups	2.667	4	0.666666667			
Total	13.33	5				

E. ANOVA (UBMS_WP)

S.No	1		Observations	
Mason	C1M1		Push	Pull
		Before Work	10.0	16.0
		During Work	8.0	15.0
		After Work	9.0	13.0

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Push	3	27	9	1
Pull	3	44	14.66666667	2.333333333

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	48.17	1	48.16666667	28.9	0.00578456	4.544771
Within Groups	6.667	4	1.666666667			
Total	54.83	5				

S.No	2		Observations	
Mason	C1M2		Push	Pull
		Before Work	33.0	28.0
		During Work	29.0	24.0
		After Work	31.0	22.0

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Push	3	93	31	4
Pull	3	74	24.66666667	9.333333333

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	60.17	1	60.16666667	9.025	0.03977836	4.544771
Within Groups	26.67	4	6.666666667			
Total	86.83	5				

S.No	3		Observations	
Mason	C1M3		Push	Pull
		Before Work	11.0	18.0
		During Work	14.0	17.0
		After Work	14.0	15.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	39	13	3
Pull	3	50	16.66666667	2.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	20.17	1	20.16666667	7.5625	0.05137443	4.544771
Within Groups	10.67	4	2.666666667			
Total	30.83	5				

S.No	4		Observations	
Mason	C1M4		Push	Pull
		Before Work	15.0	9.0
		During Work	10.0	6.0
		After Work	10.0	7.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	35	11.66666667	8.333333333
Pull	3	22	7.333333333	2.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	28.17	1	28.16666667	5.28125	0.08311286	4.544771
Within Groups	21.33	4	5.333333333			
Total	49.5	5				

S.No	5		Observations	
Mason	C1M5		Push	Pull
		Before Work	12.0	14.0
		During Work	11.0	16.0
		After Work	12.0	14.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	35	11.66666667	0.333333333
Pull	3	44	14.66666667	1.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	13.5	1	13.5	16.2	0.01579985	4.544771
Within Groups	3.333	4	0.833333333			
Total	16.83	5				

S.No	6		Observations	
Mason	C1M6		Push	Pull
		Before Work	10.0	13.0
		During Work	8.0	14.0
		After Work	7.0	12.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	25	8.333333333	2.333333333
Pull	3	39	13	1

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	32.67	1	32.66666667	19.6	0.01144691	4.544771
Within Groups	6.667	4	1.666666667			
Total	39.33	5				

S.No	7		Observations	
Mason	C2M1		Push	Pull
		Before Work	20.0	23.0
		During Work	18.0	21.0
		After Work	17.0	22.0

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Push	3	55	18.33333333	2.333333333
Pull	3	66	22	1

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	20.17	1	20.16666667	12.1	0.02538645	4.544771
Within Groups	6.667	4	1.666666667			
Total	26.83	5				

S.No	8		Observations	
Mason	C2M2		Push	Pull
		Before Work	14.0	16.0
		During Work	12.0	16.0
		After Work	12.0	14.0

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Push	3	38	12.66666667	1.333333333
Pull	3	46	15.33333333	1.333333333

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	10.67	1	10.66666667	8	0.04742066	4.544771
Within Groups	5.333	4	1.333333333			
Total	16	5				

S.No	9		Observations	
Mason	C2M3		Push	Pull
		Before Work	24.0	26.0
		During Work	22.0	28.0
		After Work	18.0	26.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	64	21.33333333	9.333333333
Pull	3	80	26.66666667	1.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	42.67	1	42.66666667	8	0.04742066	4.544771
Within Groups	21.33	4	5.333333333			
Total	64	5				

S.No	10		Observations	
Mason	C2M4		Push	Pull
		Before Work	22.0	29.0
		During Work	21.0	30.0
		After Work	19.0	27.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	62	20.66666667	2.333333333
Pull	3	86	28.66666667	2.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	96	1	96	41.14285714	0.00303581	4.544771
Within Groups	9.333	4	2.333333333			
Total	105.3	5				

S.No	11		Observations	
Mason	C2M5		Push	Pull
		Before Work	13.0	17.0
		During Work	11.0	16.0
		After Work	10.0	13.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	34	11.33333333	2.333333333
Pull	3	46	15.33333333	4.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	24	1	24	7.2	0.05504061	4.544771
Within Groups	13.33	4	3.333333333			
Total	37.33	5				

S.No	12		Observations	
Mason	C2M6		Push	Pull
		Before Work	16.0	18.0
		During Work	15.0	17.0
		After Work	15.0	16.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	46	15.33333333	0.333333333
Pull	3	51	17	1

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4.167	1	4.166666667	6.25	0.06676654	4.544771
Within Groups	2.667	4	0.666666667			
Total	6.833	5				

S.No	13		Observations	
Mason	C3M1		Push	Pull
		Before Work	10.0	16.0
		During Work	9.0	14.0
		After Work	9.0	13.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	28	9.333333333	0.333333333
Pull	3	43	14.33333333	2.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	37.5	1	37.5	28.125	0.00607361	4.544771
Within Groups	5.333	4	1.333333333			
Total	42.83	5				

S.No	14		Observations	
Mason	C3M2		Push	Pull
		Before Work	14.0	16.0
		During Work	13.0	17.0
		After Work	11.0	14.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	38	12.66666667	2.333333333
Pull	3	47	15.66666667	2.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	13.5	1	13.5	5.785714286	0.07392619	4.544771
Within Groups	9.333	4	2.333333333			
Total	22.83	5				

S.No	15		Observations	
Mason	C3M3		Push	Pull
		Before Work	16.0	20.0
		During Work	15.0	22.0
		After Work	14.0	18.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	45	15	1
Pull	3	60	20	4

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	37.5	1	37.5	15	0.01794791	4.544771
Within Groups	10	4	2.5			
Total	47.5	5				

S.No	16		Observations	
Mason	C3M4		Push	Pull
		Before Work	10.0	8.0
		During Work	9.0	7.0
		After Work	11.0	9.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	30	10	1
Pull	3	24	8	1

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6	1	6	6	0.070484	4.544771
Within Groups	4	4	1			
Total	10	5				

S.No	17		Observations	
Mason	C3M5		Push	Pull
		Before Work	12.0	14.0
		During Work	10.0	13.0
		After Work	11.0	13.0

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Push	3	33	11	1
Pull	3	40	13.33333333	0.333333333

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8.167	1	8.166666667	12.25	0.02489616	4.544771
Within Groups	2.667	4	0.666666667			
Total	10.83	5				

S.No	18		Observations	
Mason	C4M1		Push	Pull
		Before Work	14.0	16.0
		During Work	12.0	16.0
		After Work	12.0	14.0

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Push	3	38	12.66666667	1.333333333
Pull	3	46	15.33333333	1.333333333

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	10.67	1	10.66666667	8	0.04742066	4.544771
Within Groups	5.333	4	1.333333333			
Total	16	5				

S.No	19		Observations	
Mason	C4M2		Push	Pull
		Before Work	13.0	17.0
		During Work	11.0	16.0
		After Work	10.0	13.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	34	11.33333333	2.333333333
Pull	3	46	15.33333333	4.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	24	1	24	7.2	0.05504061	4.544771
Within Groups	13.33	4	3.333333333			
Total	37.33	5				

S.No	20		Observations	
Mason	C4M3		Push	Pull
		Before Work	11.0	16.0
		During Work	8.0	14.0
		After Work	9.0	13.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	28	9.333333333	2.333333333
Pull	3	43	14.33333333	2.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	37.5	1	37.5	16.07142857	0.01601097	4.544771
Within Groups	9.333	4	2.333333333			
Total	46.83	5				

S.No	21		Observations	
Mason	C4M4		Push	Pull
		Before Work	12.0	14.0
		During Work	10.0	16.0
		After Work	11.0	14.0

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Push	3	33	11	1
Pull	3	44	14.66666667	1.333333333

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	20.17	1	20.16666667	17.28571429	0.01417259	4.544771
Within Groups	4.667	4	1.166666667			
Total	24.83	5				

S.No	22		Observations	
Mason	C4M5		Push	Pull
		Before Work	12.0	16.0
		During Work	10.0	14.0
		After Work	11.0	13.0

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Push	3	33	11	1
Pull	3	43	14.33333333	2.333333333

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	16.67	1	16.66666667	10	0.03410942	4.544771
Within Groups	6.667	4	1.666666667			
Total	23.33	5				

S.No	23		Observations	
Mason	C4M6		Push	Pull
		Before Work	12.0	15.0
		During Work	11.0	16.0
		After Work	12.0	14.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	35	11.66666667	0.333333333
Pull	3	45	15	1

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	16.67	1	16.66666667	25	0.00749043	4.544771
Within Groups	2.667	4	0.666666667			
Total	19.33	5				

S.No	24		Observations	
Mason	C4M7		Push	Pull
		Before Work	10.0	13.0
		During Work	9.0	14.0
		After Work	8.0	10.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	27	9	1
Pull	3	37	12.33333333	4.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	16.67	1	16.66666667	6.25	0.06676654	4.544771
Within Groups	10.67	4	2.666666667			
Total	27.33	5				

S.No	25		Observations	
Mason	C4M8		Push	Pull
		Before Work	13.0	17.0
		During Work	10.0	16.0
		After Work	10.0	14.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	33	11	3
Pull	3	47	15.66666667	2.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	32.67	1	32.66666667	12.25	0.02489616	4.544771
Within Groups	10.67	4	2.666666667			
Total	43.33	5				

S.No	26		Observations	
Mason	C4M9		Push	Pull
		Before Work	12.0	18.0
		During Work	14.0	17.0
		After Work	14.0	15.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	40	13.33333333	1.333333333
Pull	3	50	16.66666667	2.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	16.67	1	16.66666667	9.090909091	0.03935185	4.544771
Within Groups	7.333	4	1.833333333			
Total	24	5				

S.No	27		Observations	
Mason	C4M10		Push	Pull
		Before Work	15.0	9.0
		During Work	10.0	7.0
		After Work	10.0	7.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	35	11.66666667	8.333333333
Pull	3	23	7.666666667	1.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	24	1	24	4.965517241	0.08977587	4.544771
Within Groups	19.33	4	4.833333333			
Total	43.33	5				

S.No	28		Observations	
Mason	C5M1		Push	Pull
		Before Work	20.0	23.0
		During Work	19.0	21.0
		After Work	17.0	21.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	56	18.66666667	2.333333333
Pull	3	65	21.66666667	1.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	13.5	1	13.5	7.363636364	0.05333826	4.544771
Within Groups	7.333	4	1.833333333			
Total	20.83	5				

S.No	29		Observations	
Mason	C5M2		Push	Pull
		Before Work	22.0	29.0
		During Work	20.0	28.0
		After Work	18.0	27.0

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Push	3	60	20	4
Pull	3	84	28	1

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	96	1	96	38.4	0.00344838	4.544771
Within Groups	10	4	2.5			
Total	106	5				

S.No	30		Observations	
Mason	C5M3		Push	Pull
		Before Work	10.0	18.0
		During Work	8.0	14.0
		After Work	7.0	12.0

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Push	3	25	8.333333333	2.333333333
Pull	3	44	14.66666667	9.333333333

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	60.17	1	60.16666667	10.31428571	0.03253977	4.544771
Within Groups	23.33	4	5.833333333			
Total	83.5	5				

S.No	31		Observations	
Mason	C5M4		Push	Pull
		Before Work	16.0	20.0
		During Work	15.0	22.0
		After Work	16.0	18.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	47	15.66666667	0.333333333
Pull	3	60	20	4

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	28.17	1	28.16666667	13	0.022646	4.544771
Within Groups	8.667	4	2.166666667			
Total	36.83	5				

S.No	32		Observations	
Mason	C5M5		Push	Pull
		Before Work	10.0	16.0
		During Work	11.0	14.0
		After Work	9.0	13.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	30	10	1
Pull	3	43	14.33333333	2.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	28.17	1	28.16666667	16.9	0.01472059	4.544771
Within Groups	6.667	4	1.666666667			
Total	34.83	5				

S.No	33		Observations	
Mason	C5M6		Push	Pull
		Before Work	22.0	28.0
		During Work	21.0	30.0
		After Work	19.0	27.0

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Push	3	62	20.66666667	2.333333333
Pull	3	85	28.33333333	2.333333333

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	88.17	1	88.16666667	37.78571429	0.00355229	4.544771
Within Groups	9.333	4	2.333333333			
Total	97.5	5				

S.No	34		Observations	
Mason	C5M7		Push	Pull
		Before Work	14.0	16.0
		During Work	11.0	15.0
		After Work	11.0	14.0

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Push	3	36	12	3
Pull	3	45	15	1

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	13.5	1	13.5	6.75	0.06016985	4.544771
Within Groups	8	4	2			
Total	21.5	5				

S.No	35		Observations	
Mason	C6M1		Push	Pull
		Before Work	10.0	8.0
		During Work	9.0	7.0
		After Work	10.0	9.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	29	9.666666667	0.333333333
Pull	3	24	8	1

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4.167	1	4.166666667	6.25	0.06676654	4.544771
Within Groups	2.667	4	0.666666667			
Total	6.833	5				

S.No	36		Observations	
Mason	C6M2		Push	Pull
		Before Work	12.0	16.0
		During Work	11.0	17.0
		After Work	12.0	14.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	2	23	11.5	0.5
Pull	2	33	16.5	0.5

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	25	1	25	50	0.01941932	8.526316
Within Groups	1	2	0.5			
Total	26	3				

S.No	37		Observations	
Mason	C6M3		Push	Pull
		Before Work	16.0	19.0
		During Work	13.0	17.0
		After Work	12.0	16.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	41	13.66666667	4.333333333
Pull	3	52	17.33333333	2.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	20.17	1	20.16666667	6.05	0.06971581	4.544771
Within Groups	13.33	4	3.333333333			
Total	33.5	5				

S.No	38		Observations	
Mason	C6M4		Push	Pull
		Before Work	24.0	26.0
		During Work	21.0	28.0
		After Work	18.0	26.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	63	21	9
Pull	3	80	26.66666667	1.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	48.17	1	48.16666667	9.322580645	0.03790612	4.544771
Within Groups	20.67	4	5.166666667			
Total	68.83	5				

F. ANOVA (UBMS_HP)

S.No	1		Observations	
Mason	C1M1		Push	Pull
		Before Work	14.0	21.0
		During Work	12.0	19.0
		After Work	10.0	14.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	36	12	4
Pull	3	54	18	13

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	54	1	54	6.352941176	0.06532168	4.544771
Within Groups	34	4	8.5			
Total	88	5				

S.No	2		Observations	
Mason	C1M2		Push	Pull
		Before Work	16.0	22.0
		During Work	13.0	17.0
		After Work	11.0	17.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	40	13.33333333	6.333333333
Pull	3	56	18.66666667	8.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	42.67	1	42.66666667	5.818181818	0.07338846	4.544771
Within Groups	29.33	4	7.333333333			
Total	72	5				

S.No	3		Observations	
Mason	C1M3		Push	Pull
		Before Work	22.0	28.0
		During Work	18.0	24.0
		After Work	19.0	22.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	59	19.66666667	4.333333333
Pull	3	74	24.66666667	9.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	37.5	1	37.5	5.487804878	0.07915239	4.544771
Within Groups	27.33	4	6.833333333			
Total	64.83	5				

S.No	4		Observations	
Mason	C1M4		Push	Pull
		Before Work	8.0	12.0
		During Work	7.0	10.0
		After Work	7.0	8.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	22	7.333333333	0.333333333
Pull	3	30	10	4

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	10.67	1	10.66666667	4.923076923	0.09073317	4.544771
Within Groups	8.667	4	2.166666667			
Total	19.33	5				

S.No	5		Observations	
Mason	C1M5		Push	Pull
		Before Work	12.0	15.0
		During Work	10.0	13.0
		After Work	9.0	12.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	31	10.33333333	2.333333333
Pull	3	40	13.33333333	2.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	13.5	1	13.5	5.785714286	0.07392619	4.544771
Within Groups	9.333	4	2.333333333			
Total	22.83	5				

S.No	6		Observations	
Mason	C1M6		Push	Pull
		Before Work	23.0	18.0
		During Work	21.0	16.0
		After Work	20.0	17.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	64	21.33333333	2.333333333
Pull	3	51	17	1

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	28.17	1	28.16666667	16.9	0.01472059	4.544771
Within Groups	6.667	4	1.666666667			
Total	34.83	5				

S.No	7		Observations	
Mason	C2M1		Push	Pull
		Before Work	22.0	26.0
		During Work	21.0	24.0
		After Work	20.0	22.0

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Push	3	63	21	1
Pull	3	72	24	4

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	13.5	1	13.5	5.4	0.08080014	4.544771
Within Groups	10	4	2.5			
Total	23.5	5				

S.No	8		Observations	
Mason	C2M2		Push	Pull
		Before Work	19.0	23.0
		During Work	21.0	24.0
		After Work	22.0	24.0

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Push	3	62	20.66666667	2.333333333
Pull	3	71	23.66666667	0.333333333

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	13.5	1	13.5	10.125	0.03347174	4.544771
Within Groups	5.333	4	1.333333333			
Total	18.83	5				

S.No	9		Observations	
Mason	C2M3		Push	Pull
		Before Work	21.0	25.0
		During Work	20.0	22.0
		After Work	19.0	23.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	60	20	1
Pull	3	70	23.33333333	2.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	16.67	1	16.66666667	10	0.03410942	4.544771
Within Groups	6.667	4	1.666666667			
Total	23.33	5				

S.No	10		Observations	
Mason	C2M4		Push	Pull
		Before Work	22.0	34.0
		During Work	19.0	27.0
		After Work	23.0	31.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	64	21.33333333	4.333333333
Pull	3	92	30.66666667	12.33333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	130.7	1	130.6666667	15.68	0.01668047	4.544771
Within Groups	33.33	4	8.333333333			
Total	164	5				

S.No	11		Observations	
Mason	C2M5		Push	Pull
		Before Work	12.0	18.0
		During Work	10.0	14.0
		After Work	7.0	12.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	29	9.666666667	6.333333333
Pull	3	44	14.66666667	9.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	37.5	1	37.5	4.787234043	0.09390415	4.544771
Within Groups	31.33	4	7.833333333			
Total	68.83	5				

S.No	12		Observations	
Mason	C2M6		Push	Pull
		Before Work	20.0	25.0
		During Work	19.0	23.0
		After Work	18.0	22.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	57	19	1
Pull	3	70	23.33333333	2.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	28.17	1	28.16666667	16.9	0.01472059	4.544771
Within Groups	6.667	4	1.666666667			
Total	34.83	5				

S.No	13		Observations	
Mason	C3M1		Push	Pull
		Before Work	16.0	19.0
		During Work	17.0	20.0
		After Work	18.0	19.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	51	17	1
Pull	3	58	19.33333333	0.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.167	1	8.166666667	12.25	0.02489616	4.544771
Within Groups	2.667	4	0.666666667			
Total	10.83	5				

S.No	14		Observations	
Mason	C3M2		Push	Pull
		Before Work	20.0	23.0
		During Work	18.0	25.0
		After Work	19.0	22.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	57	19	1
Pull	3	70	23.33333333	2.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	28.17	1	28.16666667	16.9	0.01472059	4.544771
Within Groups	6.667	4	1.666666667			
Total	34.83	5				

S.No	15		Observations	
Mason	C3M3		Push	Pull
		Before Work	25.0	33.0
		During Work	24.0	30.0
		After Work	23.0	31.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	72	24	1
Pull	3	94	31.33333333	2.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	80.67	1	80.66666667	48.4	0.00224331	4.544771
Within Groups	6.667	4	1.666666667			
Total	87.33	5				

S.No	16		Observations	
Mason	C3M4		Push	Pull
		Before Work	8.0	13.0
		During Work	7.0	12.0
		After Work	6.0	8.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	21	7	1
Pull	3	33	11	7

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	24	1	24	6	0.070484	4.544771
Within Groups	16	4	4			
Total	40	5				

S.No	17		Observations	
Mason	C3M5		Push	Pull
		Before Work	16.0	15.0
		During Work	17.0	14.0
		After Work	15.0	12.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	48	16	1
Pull	3	41	13.66666667	2.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.167	1	8.166666667	4.9	0.09126024	4.544771
Within Groups	6.667	4	1.666666667			
Total	14.83	5				

S.No	18		Observations	
Mason	C4M1		Push	Pull
		Before Work	11.0	16.0
		During Work	10.0	14.0
		After Work	9.0	12.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	30	10	1
Pull	3	42	14	4

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	24	1	24	9.6	0.03627782	4.544771
Within Groups	10	4	2.5			
Total	34	5				

S.No	19		Observations	
Mason	C4M2		Push	Pull
		Before Work	22.0	25.0
		During Work	20.0	23.0
		After Work	19.0	23.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	61	20.33333333	2.333333333
Pull	3	71	23.66666667	1.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	16.67	1	16.66666667	9.090909091	0.03935185	4.544771
Within Groups	7.333	4	1.833333333			
Total	24	5				

S.No	20		Observations	
Mason	C4M3		Push	Pull
		Before Work	22.0	27.0
		During Work	18.0	24.0
		After Work	19.0	23.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	59	19.66666667	4.333333333
Pull	3	74	24.66666667	4.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	37.5	1	37.5	8.653846154	0.04231566	4.544771
Within Groups	17.33	4	4.333333333			
Total	54.83	5				

S.No	21		Observations	
Mason	C4M4		Push	Pull
		Before Work	14.0	22.0
		During Work	12.0	20.0
		After Work	10.0	16.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	36	12	4
Pull	3	58	19.33333333	9.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	80.67	1	80.66666667	12.1	0.02538645	4.544771
Within Groups	26.67	4	6.666666667			
Total	107.3	5				

S.No	22		Observations	
Mason	C4M5		Push	Pull
		Before Work	21.0	25.0
		During Work	19.0	23.0
		After Work	18.0	24.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	58	19.33333333	2.333333333
Pull	3	72	24	1

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	32.67	1	32.66666667	19.6	0.01144691	4.544771
Within Groups	6.667	4	1.666666667			
Total	39.33	5				

S.No	23		Observations	
Mason	C4M6		Push	Pull
		Before Work	25.0	31.0
		During Work	24.0	29.0
		After Work	23.0	28.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	72	24	1
Pull	3	88	29.33333333	2.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	42.67	1	42.66666667	25.6	0.00718233	4.544771
Within Groups	6.667	4	1.666666667			
Total	49.33	5				

S.No	24		Observations	
Mason	C4M7		Push	Pull
		Before Work	20.0	26.0
		During Work	19.0	24.0
		After Work	18.0	23.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	57	19	1
Pull	3	73	24.33333333	2.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	42.67	1	42.66666667	25.6	0.00718233	4.544771
Within Groups	6.667	4	1.666666667			
Total	49.33	5				

S.No	25		Observations	
Mason	C4M8		Push	Pull
		Before Work	15.0	22.0
		During Work	14.0	17.0
		After Work	12.0	17.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	41	13.66666667	2.333333333
Pull	3	56	18.66666667	8.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	37.5	1	37.5	7.03125	0.05688369	4.544771
Within Groups	21.33	4	5.333333333			
Total	58.83	5				

S.No	26		Observations	
Mason	C4M9		Push	Pull
		Before Work	14.0	18.0
		During Work	12.0	16.0
		After Work	11.0	14.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	37	12.33333333	2.333333333
Pull	3	48	16	4

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	20.17	1	20.16666667	6.368421053	0.06510851	4.544771
Within Groups	12.67	4	3.166666667			
Total	32.83	5				

S.No	27		Observations	
Mason	C4M10		Push	Pull
		Before Work	19.0	23.0
		During Work	17.0	25.0
		After Work	16.0	22.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	52	17.33333333	2.333333333
Pull	3	70	23.33333333	2.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	54	1	54	23.14285714	0.00858092	4.544771
Within Groups	9.333	4	2.333333333			
Total	63.33	5				

S.No	28		Observations	
Mason	C5M1		Push	Pull
		Before Work	22.0	18.0
		During Work	20.0	16.0
		After Work	19.0	17.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	61	20.33333333	2.333333333
Pull	3	51	17	1

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	16.67	1	16.66666667	10	0.03410942	4.544771
Within Groups	6.667	4	1.666666667			
Total	23.33	5				

S.No	29		Observations	
Mason	C5M2		Push	Pull
		Before Work	22.0	28.0
		During Work	20.0	26.0
		After Work	19.0	24.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	61	20.33333333	2.333333333
Pull	3	78	26	4

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	48.17	1	48.16666667	15.21052632	0.01754047	4.544771
Within Groups	12.67	4	3.166666667			
Total	60.83	5				

S.No	30		Observations	
Mason	C5M3		Push	Pull
		Before Work	20.0	25.0
		During Work	19.0	22.0
		After Work	18.0	23.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	57	19	1
Pull	3	70	23.33333333	2.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	28.17	1	28.16666667	16.9	0.01472059	4.544771
Within Groups	6.667	4	1.666666667			
Total	34.83	5				

S.No	31		Observations	
Mason	C5M4		Push	Pull
		Before Work	17.0	15.0
		During Work	18.0	14.0
		After Work	15.0	12.0

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Push	3	50	16.66666667	2.333333333
Pull	3	41	13.66666667	2.333333333

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	13.5	1	13.5	5.785714286	0.07392619	4.544771
Within Groups	9.333	4	2.333333333			
Total	22.83	5				

S.No	32		Observations	
Mason	C5M5		Push	Pull
		Before Work	9.0	13.0
		During Work	8.0	12.0
		After Work	7.0	9.0

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Push	3	24	8	1
Pull	3	34	11.33333333	4.333333333

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	16.67	1	16.66666667	6.25	0.06676654	4.544771
Within Groups	10.67	4	2.666666667			
Total	27.33	5				

S.No	33		Observations	
Mason	C5M6		Push	Pull
		Before Work	11.0	14.0
		During Work	8.0	12.0
		After Work	7.0	11.0

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Push	3	26	8.666666667	4.333333333
Pull	3	37	12.33333333	2.333333333

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	20.17	1	20.16666667	6.05	0.06971581	4.544771
Within Groups	13.33	4	3.333333333			
Total	33.5	5				

S.No	34		Observations	
Mason	C5M7		Push	Pull
		Before Work	18.0	24.0
		During Work	20.0	24.0
		After Work	21.0	23.0

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Push	3	59	19.66666667	2.333333333
Pull	3	71	23.66666667	0.333333333

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	24	1	24	18	0.0132356	4.544771
Within Groups	5.333	4	1.333333333			
Total	29.33	5				

S.No	35		Observations	
Mason	C6M1		Push	Pull
		Before Work	8.0	14.0
		During Work	7.0	13.0
		After Work	7.0	9.0

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Push	3	22	7.333333333	0.333333333
Pull	3	36	12	7

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	32.67	1	32.66666667	8.909090909	0.04054553	4.544771
Within Groups	14.67	4	3.666666667			
Total	47.33	5				

S.No	36		Observations	
Mason	C6M2		Push	Pull
		Before Work	22.0	30.0
		During Work	19.0	28.0
		After Work	23.0	26.0

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Push	3	64	21.33333333	4.333333333
Pull	3	84	28	4

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	66.67	1	66.66666667	16	0.01613009	4.544771
Within Groups	16.67	4	4.166666667			
Total	83.33	5				

S.No	37		Observations	
Mason	C6M3		Push	Pull
		Before Work	12.0	16.0
		During Work	10.0	14.0
		After Work	10.0	13.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	32	10.66666667	1.333333333
Pull	3	43	14.33333333	2.333333333

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	20.17	1	20.16666667	11	0.02947132	4.544771
Within Groups	7.333	4	1.833333333			
Total	27.5	5				

S.No	38		Observations	
Mason	C6M4		Push	Pull
		Before Work	18.0	20.0
		During Work	16.0	19.0
		After Work	15.0	18.0

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Push	3	49	16.33333333	2.333333333
Pull	3	57	19	1

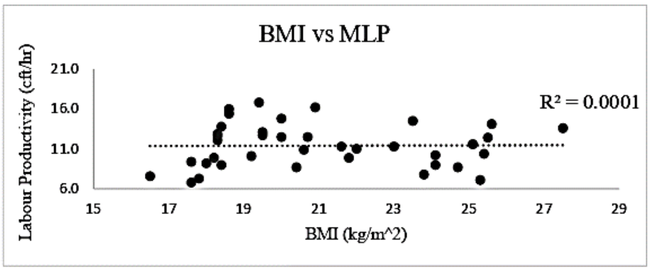
ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	10.67	1	10.66666667	6.4	0.06467689	4.544771
Within Groups	6.667	4	1.666666667			
Total	17.33	5				

G. Simple linear regression analysis of parameters

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.010753693
R Square	0.000115642
Adjusted R Square	-0.02765892
Standard Error	2.730837021
Observations	38



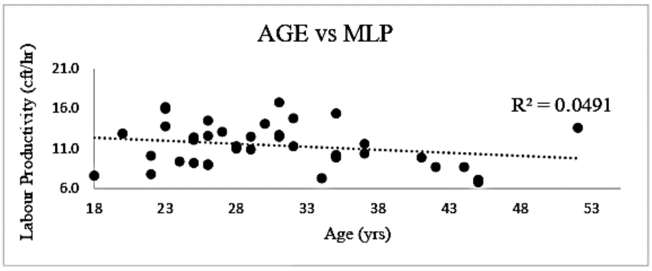
ANOVA

	df	SS	MS	F	Significance F
Regression	1	0.031049853	0.031049853	0.00416359	0.948908475
Residual	36	268.4689501	7.457470837		
Total	37	268.5			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	11.19370776	3.227592514	3.468129173	0.001375895	4.647846742	17.73956877	4.647846742	17.73956877
BMI	0.009825903	0.152278459	0.064525888	0.948908475	-0.299009126	0.318660931	-0.299009126	0.318660931

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.22163603
R Square	0.04912253
Adjusted R Square	0.022709267
Standard Error	2.663073625
Observations	38



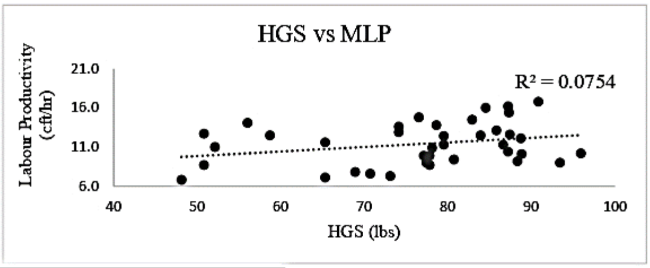
ANOVA

	df	SS	MS	F	Significance F
Regression	1	13.18939927	13.18939927	1.859767564	0.181118745
Residual	36	255.3106007	7.091961131		
Total	37	268.5			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	13.72324396	1.757513812	7.808327803	2.94435E-09	10.15884074	17.28764718	10.15884074	17.28764718
Age	-0.07584473	0.055615532	-1.36373295	0.181118745	-0.188638262	0.036948793	-0.188638262	0.036948793

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.274655853
R Square	0.075435838
Adjusted R Square	0.0497535
Standard Error	2.625967957
Observations	38



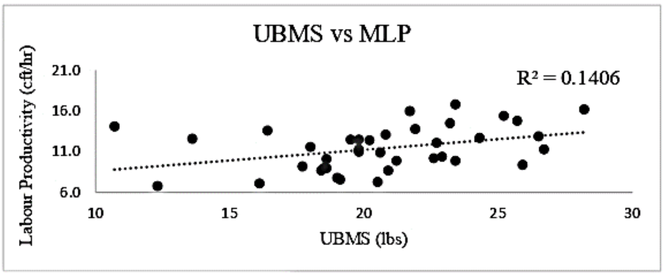
ANOVA

	df	SS	MS	F	Significance F
Regression	1	20.25452242	20.25452242	2.937265219	0.095156773
Residual	36	248.2454776	6.895707711		
Total	37	268.5			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	6.947711712	2.632530492	2.639176159	0.012204564	1.608692413	12.28673101	1.608692413	12.28673101
HGS	0.058145841	0.033927127	1.713845156	0.095156773	-0.01066156	0.126953243	-0.01066156	0.126953243

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.370360637
R Square	0.137167001
Adjusted R Square	0.113199418
Standard Error	2.536788544
Observations	38



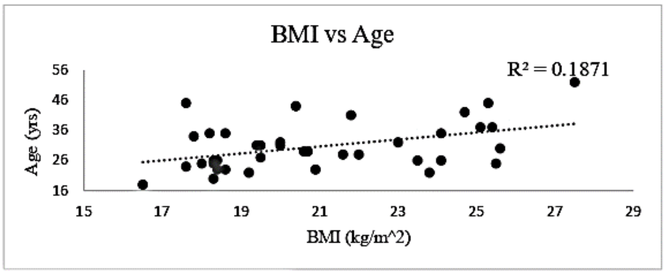
ANOVA

	df	SS	MS	F	Significance F
Regression	1	36.8293398	36.8293398	5.723021775	0.022087404
Residual	36	231.6706602	6.435296117		
Total	37	268.5			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	6.095142377	2.255348615	2.70252782	0.010432189	1.52108338	10.66920137	1.52108338	10.66920137
UBMS	0.25738584	0.107590011	2.392283799	0.022087404	0.039183184	0.475588495	0.039183184	0.475588495

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.432542003
R Square	0.187092584
Adjusted R Square	0.164511823
Standard Error	7.195423604
Observations	38



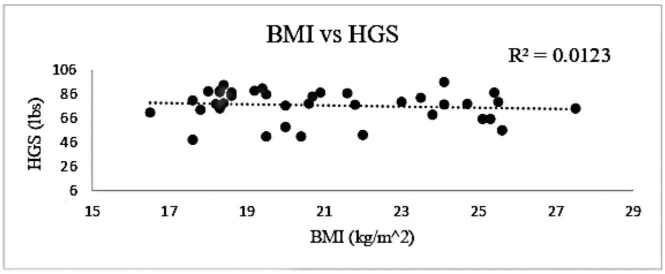
ANOVA

	df	SS	MS	F	Significance F
Regression	1	428.973755	428.973755	8.285486031	0.006684245
Residual	36	1863.86835	51.77412084		
Total	37	2292.842105			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	6.383994121	8.504313943	0.750677146	0.457725842	-10.86355397	23.63154221	-10.86355397	23.63154221
BMI	1.154936354	0.401235229	2.87845202	0.006684245	0.341193594	1.968679114	0.341193594	1.968679114

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.111024622
R Square	0.012326467
Adjusted R Square	-0.01510891
Standard Error	12.82028859
Observations	38

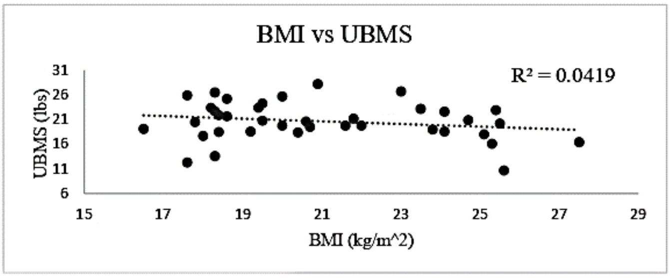


ANOVA

	df	SS	MS	F	Significance F
Regression	1	73.84537339	73.84537339	0.449290968	0.506949251
Residual	36	5916.952785	164.3597996		
Total	37	5990.798158			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	86.63144158	15.15237532	5.717350564	1.65872E-06	55.9010001	117.3618831	55.9010001	117.3618831
BMI	-0.47918624	0.714892091	-0.6702917	0.506949251	-1.929054598	0.970682123	-1.929054598	0.970682123

SUMMARY OUTPUT



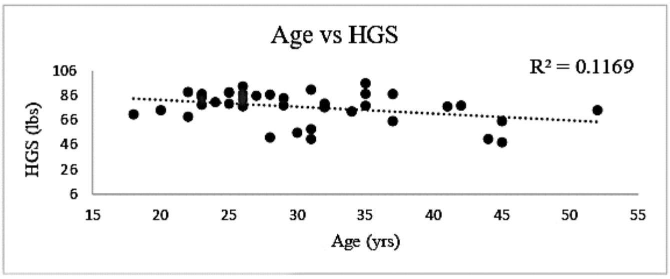
Regression Statistics	
Multiple R	0.201279814
R Square	0.040513563
Adjusted R Square	0.013861162
Standard Error	3.849288714
Observations	38

ANOVA

	df	SS	MS	F	Significance F
Regression	1	22.52293985	22.52293985	1.520071808	0.225599282
Residual	36	533.4128496	14.8170236		
Total	37	555.9357895			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	26.16657016	4.549497219	5.751530093	1.49303E-06	16.93976215	35.39337818	16.93976215	35.39337818
BMI	-0.26463984	0.214646187	-1.23291192	0.225599282	-0.699962486	0.170682801	-0.699962486	0.170682801

SUMMARY OUTPUT



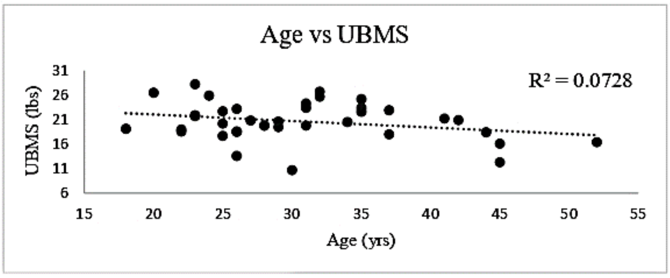
Regression Statistics	
Multiple R	0.341968488
R Square	0.116942447
Adjusted R Square	0.09241307
Standard Error	12.12231593
Observations	38

ANOVA

	df	SS	MS	F	Significance F
Regression	1	700.5785952	700.5785952	4.76744474	0.035602659
Residual	36	5290.219563	146.9505434		
Total	37	5990.798158			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	93.50314939	8.000206031	11.68759267	8.22854E-14	77.27797953	109.7283192	77.27797953	109.7283192
Age	-0.55276605	0.253162004	-2.1834479	0.035602659	-1.066202386	-0.0393297	-1.066202386	-0.039329705

SUMMARY OUTPUT



Regression Statistics	
Multiple R	0.269396648
R Square	0.072574554
Adjusted R Square	0.046812736
Standard Error	3.784430816
Observations	38

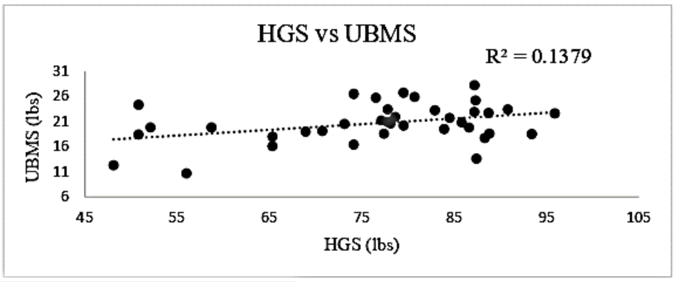
ANOVA

	df	SS	MS	F	Significance F
Regression	1	40.34679191	40.34679191	2.817136354	0.101924222
Residual	36	515.5889976	14.3219166		
Total	37	555.9357895			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	24.67390047	2.497561227	9.879197436	8.58703E-12	19.60861153	29.73918941	19.60861153	29.73918941
Age	-0.13265311	0.079033915	-1.67843271	0.101924222	-0.292941317	0.027635101	-0.292941317	0.027635101

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.381964249
R Square	0.145896687
Adjusted R Square	0.122171595
Standard Error	3.631752712
Observations	38



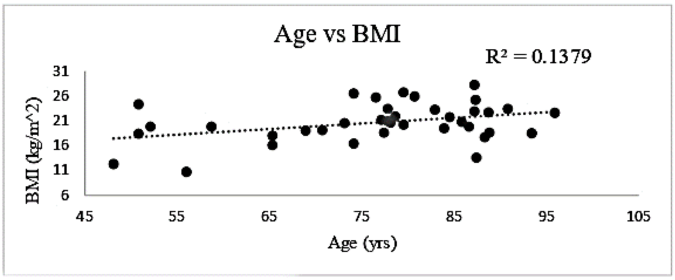
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	81.10919002	81.10919002	6.149467709	0.017959953
Residual	36	474.8265995	13.18962776		
Total	37	555.9357895			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	11.7009448	3.640828796	3.213813516	0.002762462	4.317001755	19.08488784	4.317001755	19.08488784
HGS	0.116357046	0.04692172	2.479812031	0.017959953	0.021195387	0.211518706	0.021195387	0.211518706

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.432542003
R Square	0.187092584
Adjusted R Square	0.164511823
Standard Error	2.69480039
Observations	38



ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	60.16877819	60.16877819	8.285486031	0.006684245
Residual	36	261.4301692	7.261949144		
Total	37	321.5989474			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	16.03260949	1.77845211	9.014923373	9.19664E-11	12.42574144	19.63947755	12.42574144	19.63947755
Age	0.161993848	0.056278113	2.87845202	0.006684245	0.047856545	0.276131152	0.047856545	0.276131152

H. Multi linear regression analysis of parameters

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.251210748
R Square	0.06310684
Adjusted R Square	0.009570088
Standard Error	2.680915694
Observations	38

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	16.94418648	8.47209324	1.178757347	0.319577501
Residual	35	251.5558135	7.187308958		
Total	37	268.5			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	11.80183847	3.193293236	3.695820459	0.000745141	5.319108558	18.28456839	5.319108558	18.28456839
BMI	0.119843591	0.165807933	0.722785627	0.47461407	-0.216764408	0.45645159	-0.216764408	0.45645159
Age	-0.095258659	0.062097704	-1.534012581	0.134017447	-0.221323699	0.030806382	-0.221323699	0.030806382

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.306441296
R Square	0.093906268
Adjusted R Square	0.042129483
Standard Error	2.636481243
Observations	38

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	25.21383292	12.60691646	1.813675152	0.17804497
Residual	35	243.2861671	6.951033345		
Total	37	268.5			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	9.265432409	3.809861441	2.431960467	0.020273017	1.531002491	16.99986233	1.531002491	16.99986233
Age	-0.049491324	0.058592645	-0.844667849	0.404033311	-0.168440718	0.06945807	-0.168440718	0.06945807
HGS	0.047675523	0.036248316	1.315247936	0.196978505	-0.025912471	0.121263517	-0.025912471	0.121263517

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.397413187
R Square	0.157937241
Adjusted R Square	0.109819369
Standard Error	2.541618443
Observations	38

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	42.40614919	21.2030746	3.282298958	0.049377382
Residual	35	226.0938508	6.459824309		
Total	37	268.5			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	4.420415053	2.890464677	1.529309487	0.135176375	-1.447540203	10.28837031	-1.447540203	10.28837031
HGS	0.033013788	0.03553144	0.929142974	0.359179182	-0.03911887	0.105146445	-0.03911887	0.105146445
UBMS	0.21599082	0.116638744	1.851793091	0.072506519	-0.020798419	0.452780058	-0.020798419	0.452780058

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.277774021
R Square	0.077158407
Adjusted R Square	0.024424602
Standard Error	2.660735493
Observations	38

ANOVA

	df	SS	MS	F	Significance F
Regression	2	20.71703226	10.35851613	1.463167819	0.245315678
Residual	35	247.7829677	7.079513364		
Total	37	268.5			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	6.071413011	4.343842938	1.397705464	0.170998332	-2.747056977	14.889883	-2.747056977	14.889883
BMI	0.038158955	0.149292395	0.255598785	0.79975684	-0.26492072	0.34123863	-0.26492072	0.34123863
HGS	0.059127433	0.034590166	1.709371161	0.096236081	-0.011094338	0.129349204	-0.011094338	0.129349204

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.380460622
R Square	0.144750285
Adjusted R Square	0.095878873
Standard Error	2.561442386
Observations	38

ANOVA

	df	SS	MS	F	Significance F
Regression	2	38.86545154	19.43272577	2.961860079	0.064807671
Residual	35	229.6345485	6.560987099		
Total	37	268.5			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	4.133404216	4.193655323	0.985632795	0.331078327	-4.380168704	12.64697714	-4.380168704	12.64697714
BMI	0.081231425	0.145816901	0.557078261	0.581019226	-0.21479262	0.377255471	-0.21479262	0.377255471
UBMS	0.269821513	0.110905442	2.432896969	0.020228414	0.044671496	0.494971529	0.044671496	0.494971529

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.391381495
R Square	0.153179475
Adjusted R Square	0.10478973
Standard Error	2.54878857
Observations	38

ANOVA

	df	SS	MS	F	Significance F
Regression	2	41.12868894	20.56434447	3.165535938	0.054494049
Residual	35	227.3713111	6.496323173		
Total	37	268.5			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	7.979518571	3.240402758	2.462508264	0.01886338	1.401151241	14.5578859	1.401151241	14.5578859
Age	-0.044965019	0.055272261	-0.813518711	0.421420808	-0.157173675	0.067243637	-0.157173675	0.067243637
UBMS	0.232785465	0.112248873	2.073833422	0.045516303	0.004908137	0.460662792	0.004908137	0.460662792

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.325297965
R Square	0.105818766
Adjusted R Square	0.026920422
Standard Error	2.657329826
Observations	38

ANOVA

	df	SS	MS	F	Significance F
Regression	3	28.4123386	9.470779533	1.341203885	0.277266289
Residual	34	240.0876614	7.061401806		
Total	37	268.5			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	7.590579868	4.575855668	1.658832887	0.106347961	-1.708677689	16.88983742	-1.708677689	16.88983742
BMI	0.110715338	0.164505222	0.673020203	0.505483549	-0.223599496	0.445030172	-0.223599496	0.445030172
Age	-0.068018903	0.065157157	-1.043920664	0.303887913	-0.200434177	0.064396372	-0.200434177	0.064396372
HGS	0.046603867	0.036569641	1.274386788	0.211167993	-0.027714584	0.120922318	-0.027714584	0.120922318

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.407738738
R Square	0.166250878
Adjusted R Square	0.092684779
Standard Error	2.56596295
Observations	38

ANOVA

	df	SS	MS	F	Significance F
Regression	3	44.63836081	14.8794536	2.259884384	0.09917026
Residual	34	223.8616392	6.584165859		
Total	37	268.5			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	6.125481485	4.134111354	1.481692427	0.14763157	-2.276043615	14.52700659	-2.276043615	14.52700659
Age	-0.033635894	0.057767779	-0.582260462	0.564232753	-0.151034145	0.083762358	-0.151034145	0.083762358
HGS	0.027189272	0.037240431	0.730100888	0.470329423	-0.04849239	0.102870933	-0.04849239	0.102870933
UBMS	0.204891802	0.119288816	1.717611167	0.094964346	-0.037532239	0.447315843	-0.037532239	0.447315843

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.419306655
R Square	0.175818071
Adjusted R Square	0.103096136
Standard Error	2.55119838
Observations	38

ANOVA

	df	SS	MS	F	Significance F
Regression	3	47.20715206	15.73571735	2.417675922	0.083255071
Residual	34	221.2928479	6.508613175		
Total	37	268.5			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	5.260338122	4.293862904	1.225082924	0.228963604	-3.465841187	13.98651743	-3.465841187	13.98651743
BMI	0.153213825	0.15854235	0.966390524	0.340672924	-0.168982996	0.475410646	-0.168982996	0.475410646
Age	-0.068372036	0.060394229	-1.132095507	0.265515648	-0.191107876	0.054363805	-0.191107876	0.054363805
UBMS	0.243434897	0.11289412	2.156311562	0.038221815	0.014006441	0.472863353	0.014006441	0.472863353

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.408055081
R Square	0.166508949
Adjusted R Square	0.092965621
Standard Error	2.565565797
Observations	38

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	44.70765278	14.90255093	2.2640932	0.098707554
Residual	34	223.7923472	6.582127859		
Total	37	268.5			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.292651576	4.63259399	0.494895858	0.623856764	-7.121912124	11.70721528	-7.121912124	11.70721528
BMI	0.086424766	0.146155627	0.59132014	0.558217163	-0.210599204	0.383448736	-0.210599204	0.383448736
HGS	0.033814255	0.035891757	0.942117562	0.352778835	-0.039126572	0.106755081	-0.039126572	0.106755081
UBMS	0.228217856	0.119539666	1.909139149	0.064713299	-0.014715974	0.471151685	-0.014715974	0.471151685

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.431704362
R Square	0.186368657
Adjusted R Square	0.087746676
Standard Error	2.572936159
Observations	38

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	50.03998428	12.50999607	1.889727367	0.135579181
Residual	33	218.4600157	6.620000476		
Total	37	268.5			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	3.737125831	4.916784758	0.760075133	0.452606045	-6.266147973	13.74039963	-6.266147973	13.74039963
BMI	0.144888708	0.160398904	0.903302357	0.372912329	-0.181445316	0.471222731	-0.181445316	0.471222731
HGS	0.024504513	0.037459731	0.654156131	0.517544432	-0.051707883	0.100716908	-0.051707883	0.100716908
UBMS	0.217716893	0.120452694	1.807488791	0.079809836	-0.027345954	0.462779741	-0.027345954	0.462779741
Age	-0.056889728	0.063387599	-0.897489879	0.375958997	-0.185852768	0.072073311	-0.185852768	0.072073311

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