IDENTIFICATION OF THE BARRIERS OF INFORMATION AND COMMUNICATION TECHNOLOGY IMPLEMENTATIONS IN RELATION TO PRODUCTIVITY OF BUILDING CONSTRUCTION SECTOR IN SRI LANKA

BY

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DECLARATION

I certify that this Dissertation does not incorporate without acknowledgement any material previously submitted for the Degree or Diploma in any University, and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text

Date:..... .....

K.D.P. Reginold

The undersigned, have supervised the dissertation entitled **IDENTIFICATION OF THE BARRIERS OF INFORMATION AND COMMUNICATION TECHNOLOGY IMPLEMENTATIONS IN RELATION TO PRODUCTIVITY OF BUILDING CONSTRUCTION SECTOR IN SRI LANKA** presented by K.D.P. Reginold, a candidate for the degree of Masters in Information Systems Management, and hereby certify that, in my opinion, it is worthy of submission for examination.

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Abstract

The building construction industry is one of major contributors in Sri Lanka economy. Growth rate of the industry has recorded 9% in previous years. Constraints faced by the industry in preceding years have substantially gone up. Major hindering factor is the productivity problem that time and cost over runs. Thereby Information and Communication Technology (ICT) can play a vital role in building construction productivity concerned. Purpose of this study is to identify the ICT implementation barriers and ICT value added activities from the contractors' perspectives. Research study was based on the previous researches in same context. An industry-wide questionnaire survey was carried out to gather the views of professionals attached to large scale building construction companies during November – December 2010. Ten critical barriers were identified under four main areas along with eleven influencing factors belong to the three key areas. Survey was limited to the large scale contracts due to the problem of high productivity concern and problem in the knowledge extraction from the lower grades.

Research model was adopted from Sri Lanka construction context which has been conducted over productivity. Preliminary studies revealed that ICT collaboration is marginal in construction sector which affect to the productivity. High productivity is always demanded by the economy growth of the country. Research comprised of extensive literature survey in locally and internally conducted researches. Study shows most of the identified barriers are critical except two and all value added activities are equally important.

Keywords: Building construction industry, Information and Communication technology, Barriers, Value Added Activities, Productivity, Sri Lanka

List of Abbreviations

BOI	-	Board of Investments in Sri Lanka
CCI	-	Chamber of Construction Industry in Sri Lanka
CIMP	-	Construction Industry Master Plan
ECTP	-	European Construction Technology Platform
ICPM	-	Internet-based Construction Management
ICTAD	-	Institute for Construction Training and Development
IESL	-	Institute of Engineers' Sri Lanka
NCCA	-	National Construction Contractors' Association

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CHAPTER 1
INTRODUCTION

2.1 Introduction

This introduction chapter will provide the reader general orientation of the research area. It also reveals the background of the study and then followed by the problem motivation. The problem discussion ends with emerging of research requirement as influenced by the previous research literature.

1.2 Background of the Building Construction Industry

History of building construction in Sri Lanka runs up to construction of stupas. According to Ranaweera and Abeyruwan (2006), stupas in Sri Lanka are monumental structures built to honour Lord Buddha. The oldest stupa in Sri Lanka is Thuparama built by King Devanampiyatissa (250-210 BC) and Jethawana is still the largest brick structure in the world. The earliest studies of the construction industry commenced in1940s in Sri Lanka.

2.2.1 Overview of the Building Construction Industry in Sri Lanka

The construction industry boom in Sri Lanka commenced in late 1970s with the accelerated Mahaweli Project. With donor assistance mega irrigation schemes such as Victoria, Randenigala, Madhuru Oya, Rantambe, Kotmale etc. were completed. The construction

industry has characteristic that distinguish it from other industry. These are the physical nature of the product, the structure of the industry and the organization of the building and construction process. In the last fifty years, there has been a series of major studies concerned with the problems and issues of construction industry. Within the international arena, studies have been executed by several United Nations agencies such as the International Bank for Reconstruction and Development, World Bank, International Labour Office, United Nations Industrial Development Office, United Nations Centre for Human Settlements etc.

Development of construction industry in Sri Lanka is facilitated by Institute for Construction Training and Development (ICTAD). It is responsible for registering contractors, providing training, introducing standard documents, facilitating research and consultancy to address industry issues. Other institutions like Institute of Engineers Sri Lanka (IESL), National Construction Contractors Association (NCCA), and Chamber of Construction Industry (CCI) provide supportive roles for this development. Investments into Sri Lanka, including domestic development projects as well as foreign investments are handled by Board of Investment (BOI). The stability of foreign capital is also protected by law.

The value added of the building construction sector is estimated to have grown by 9.1% in real terms during the first half of the year 2007 (Central Bank Data, 2008). The growth in this sector came from both government and private sector involvements in construction activities, particularly in condominium projects and private housing projects. But there is an increase in the cost of constructions in terms of wages, materials etc. force some downsize risks. As per the CCI annual report (2007) says, that building construction represents over 82% of the entire construction industry. But productivity remains as dominant issue of construction sector in Sri Lanka. Being a developing country which faces unemployment problems,

inflation, resource scarcity seek to utilize resources in such a way to achieve economic targets. CCI further emphasizes that out of the total work force of 6.2 million people 6.6 % are employed in construction sector. As such conducting study over the construction sector is very important. Sri Lanka construction industry work force consist of 51% unskilled workers, 33% masons, 10% carpenters, 1-2% other skilled workers approximately 80% work force is casually employed (CCI annual report, 2007). Therefore improvement in building construction productivity is very much important at this stage.

1.3 Productivity in Building Construction Industry in Sri Lanka

The construction industry has gained the reputation of being one of the most challenging and demanding industry in Sri Lanka and it is still having many opportunities for productivity improvement. Increased productivity can have a large impact on the overall construction process and will result significant cost and time saving. Improving the productivity is the major concern for any profit oriented organization, as representing the effective and efficient conversion of resources into marketable product and determining profitability. Consequently considerable effort has been directed to understand the productivity concept with different approaches taken by researchers resulting in a wide variety of definition of productivity. Profitability describes the financial result of business operation. Productivity and price recovery are the main factors affecting profitability.

Devis (2007) stated that at the broadest level, productivity refers to an industry ability to convert inputs into outputs. Productivity is a relative concept. Measures that relate output to only one class of inputs are known as partial productivity. For example, labour productivity is measured dividing total output by the amount of labour used in production. It was observed

by the researchers like Tague and Jergeas (2002), industry output has grown in line with the broader economy. At the broadest level productivity refers to an industry ability to convert inputs into output. Productivity is a relevant concept with comparison either being made across time or between different production units.

1.4 Future Challenges in Building Construction Industry in Sri Lanka

Globalization and rapid technological change will drive the knowledge economy. Specially ICT is considered as a key factor and the driving force. Businesses know the importance of managing knowledge in order to get the competitive advantage. At the annual general meeting (AGM) of Engineers guild, Sri Lanka in 2007, Engineer Lankathilake had covered the topic 'Current situation of construction industry in Sri Lanka with special reference to challenges and future perspectives' with emphasis on information and communication technologies. Same idea has been discussed by Molnar, Andersson and Ekholm (2007) that development of many technological advances in the construction industry and it was witnessed in 1990s the technological shift in the construction sector with IT driven solutions.

Challenges and future perspectives are important in the context of construction industry because success of the industry is wholly dependent upon how industry is facing the challenges and conquer such instances with the use of modern technologies. As Turban et al. (2008) describe the advantages of using modern technological aspects in order to overcome the challenges faced by every industry.

1.5 Motivation and Getting Intention for Research Area

Viewing the world through digitized form, it was noticed that some ventures are gradually moving to the digitized activities while some are rather behind the scene. In fact, world is

moving fast towards the digital world and thereby those ventures in front of the scene are definitely getting the competitive advantage of any business that they operate. Step by step, it is creating a digital world under the digital economy (Turbun et al., 2008). No business can survive further without integrating the ICT innovations emerging from day by day.

I began my carrier in construction field though it was switched to the information systems field at latter stage. I have convinced through my IS experience how any business activity can be influenced, motivated and accelerated through ICT utilization. I had a little thought at beginning, why construction field is behind the ICT innovations so far. It was gradually matured and finally I was compelled to discuss with field experts including senior engineers, consultants and even with university intellectuals. All the time almost everyone emphasized that there is an impact of ICT on the construction productivity concerned because every expert in the field straightly talked about the construction productivity. What ICT can do is to improve the productivity through its tools and applications which are widely giving the effective cost-benefits for their investments. This aspect is wholly concerned about the Sri Lankan construction industry. It was impressed to study the barriers in ICT implementation while identifying the ICT value added activities which can influence the construction productivity concern. It was a dream at this stage until relevant studies were taken into consideration through literature survey. The idea was heavily enforced by the subsequent literature surveys which were enabling me to justify the research study. Department of building economics, University of Moratuwa gave me some literature pertaining previous similar studies. Through various literature surveys it was enable me to grasp and formulate important variables. Molnar et al. (2004) stated that construction industry concerned, except architectural design, engineering analysis and similar technically focused activities for which information and communication technologies are indispensable. They further stressed that

perspective of work and results of work, concerned impact of the productivity that process on time, reducing the cost with improved quality.

1.6 Information and Communication Technology in construction Productivity

In contemporary world, no business can compete with other rivals in same industry or survive without information systems or information and communication technology. In present market environment, the ability of construction companies to use information and communication technologies (ICT) and to manage business processes electronically will lead to gain critical importance in the business. While using ICT, productivity can be increased in construction industry. ICT benefits are cost benefits of IT investments, identify good practices and communicate potential business benefits of productivity enhancing technologies (e business w@tch workshop, 2005). Sundaraj (2006) stated that the construction industry is one of the productive sectors that constantly contribute to the economy. Also the demand for construction is highly sensitive to development in other sectors of the economy. The powers of ICT have not been fully tapped to benefit the construction industry all over the world. The use of ICT will also allow the industry to traverse the digital world. It will provide opportunity for outsourcing and off shoring. Also it forms of virtual partnership without a need to be physically close. Focusing on the development of ICT in construction can provide an opportunity to expand the construction markets. Also if construction functions are delivered efficiently cost effectively and on time it will be a benefit to any country. According to Sundaraj (2006), a construction process demands heavy exchange of data and information between project participants on a daily basis. Construction industry is one of the most information intensive industries and requires close

coordination among large number of specialized to achieve cost, time and quality goals of a construction project. As mentioned above in section 1.3 cost, time and quality are the critical factors over productivity concerned for any business or industry. This phenomenon is common for all countries irrespective of business or industry. It should be clearly mentioned that some businesses have already in the process of getting competitive advantage of ICT collaboration for their successes under the digital economy concept as revealed by Turbun et al. (2008). Information systems pertaining to construction industry can be outlined as in follow.

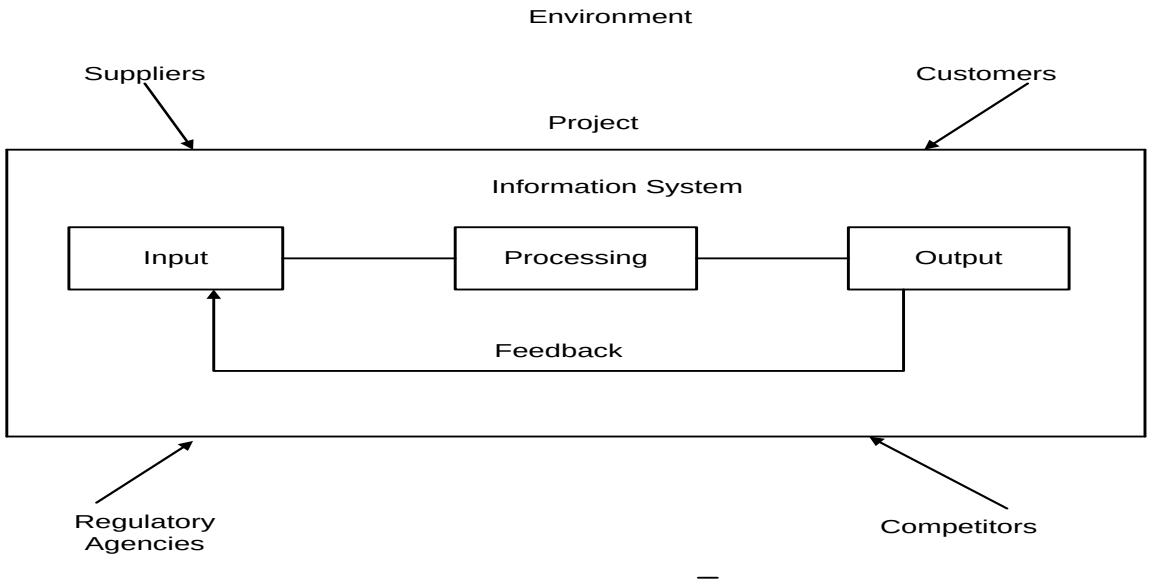

Figure 1.1 – Outline of the information system process pertaining to construction industry
Source – Laudon and Laudon (2006)

The construction project chain is a lengthy process. The main project participants are client, consultant and contractor. They require access of the project information at one time or another.

1. Role players of a construction project are:

   Client, Architect, Engineer, Quantity Surveyor, Sub Contractors etc

2. Documents of a construction project are:

   Drawings, Specifications, Bill of Quantities etc. (Sundaraj, 2006)

The construction industry is currently shifting from traditional paper based to digital based information. The use of ICT can impact change in organizational processes, working methods and even culture. Harvey and Bernstein (2004) defined construction productivity as '….contract expenditures in constant dollars (output) divided by man-hours worked (input)'. They have further emphasized that some benefits of ICT are reducing time for data processing and improving communication methods in order to make effective decision making and coordination among construction participants to enhance the construction productivity. This is possible because of internet based tools of ICT allow to share files, comment on changes and request for information etc.

2.6.1 Implementing ICT as an Innovation Process in Construction Industry

In fact, ICT implementation involves complex technical and social issues. Grifith et al. (1999) reveals that most of the ICT implementation barriers are due to technical issues rather than social issues. As per the recent studies conducted by Bjork (2002) and O'Brien (2000) reveal that ICT implementation is required to be managed and structured because it has been identified as critical facilitator of success for any business venture. In order to identify the concept behind the managing of ICT implementation factors and processors need to be identified. These factors can be divided into two categories: ICT implementation barriers and ICT value added activities which are significant in construction productivity (IT Con, 2005).

1.7 Problem Statement of the Study

Devis (2007) has identified cost and time overruns as the main problem behind the construction productivity and he has further emphasized that cost and time overruns directly affect to the quality of construction and mainly for firm's profitability. Findings of Devis (2007) are also

applicable to the Sri Lanka construction industry because world economic recession in recent past, low productivity in construction industry has become a national issue in every country. Construction industry in Sri Lanka has also experienced productivity problem (Lankathilake, 2007). Les (2006) describes, '…responsible authorities have not identified that construction industry operates in digital economy and also failed to recognize that ICT as a key driving force in achieving productivity goals'. Les's (2006) idea has been further enforced by the studies carried out by Gren (2008), Amor & Betts n.d. and Kazi (2005) stating the hindered factors as, traditional paper based works, adopting poor communication methods and not sharing expert knowledge etc. **In fact, such factors act as ICT implementation barriers in achieving construction productivity.**

In Sri Lanka building industry context, it has been identified the low level of usage of ICT which can badly affect to the construction productivity. Therefore it is worthwhile at this stage to identify the factors acting as barriers against the ICT implementations which can affect to the construction productivity. Several researches have identified that ICT as a crucial factor of enhancing construction productivity but there is a problem in implementing such aspects (Dimuth and Navaratne, 2006).

Experts in the field of construction have also identified some motivators which can enhance the efficiency of construction sector. **Accordingly, some ICT factors such as digitized construction management, use of ICT administration tools and expert knowledge sharing have been identified as value added activities** which can be adapted to enhance the construction productivity. As in the problem content it is required to evaluate such factors in order to identify the significant value added activities which can enhance the productivity.

1.8 Significance of the Study

As per the definition made by European Productivity Agency (1959) 'Productivity is a state of mind …an attitude that seeks the continuous improvement of what exists. It is a conviction that once can do better today than yesterday and that tomorrow will be better than today'. Previous research conducted by Becchetti et al. (2003) revealed some useful findings about the ICT investments and productivity. The study argues that ICT investment makes facility to modify the trade-off between scale and scope economies. It further suggests the measurement of return of ICT investment which enables to realize the productivity gains. It is assured to identify the potential ICT implementation barriers in accordance with some value added activities equipped with ICT in the context of building construction productivity.

Further to enhance the prevailing situation as evidence, Oladapo (2006) stated that most of project activities are mainly based on paper documents exchanging between engineers, consultants and contractors. These paper documents are architectural & engineering drawings, specifications, bill of quantities and material schedules. Mostly these documents involve loss of information. It was noticed as about two thirds of construction problems are blamed on inadequate communication and exchange of information and data.

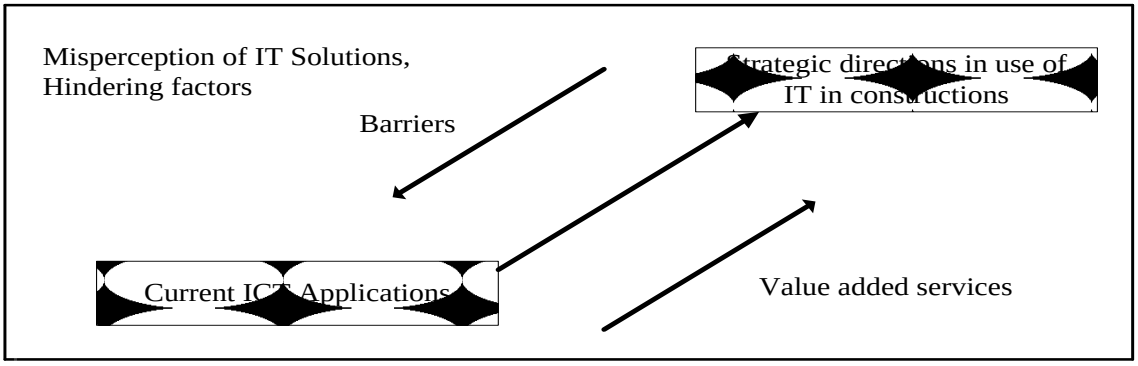

Figure 1.3 – ICT applications, barriers and value added services in construction

Source: ICT investment, productivity and efficiency, Beccheti et al. (2003)

Our main theme is to identify the ICT implementation factors affecting building construction productivity in Sri Lanka. As far as concerned about the productivity, any business pertaining to any industry should be intact with productivity concern because it directly affects to the profit of that business. Construction industry is also in same context since it is utilizing huge amount of resources both in physical and human. Thereby cost, time and quality as key factors play very important role. Utilization of above three aspects efficiently and effectively in industry matters is called the gain of productivity. One important phenomenon has been expressed by Pavlina (2005) regarding the productivity concerned. According to Pavlina (2005), productivity is measured the value over time. Presenting a research paper, Dimuth and Navaratne (2006) emphasized that Sri Lankan authorities have not given sufficient attention to improve construction productivity with use of information and communication technology. They are not aware of present situation of the construction productivity level and its trend. But in other countries they have targeted to achieve a specified productivity growth. Therefore it is important to review the present situation of Sri Lanka building construction

industry in ICT point of view. As revealed above, it is significant to conduct the study over ICT and productivity in building construction industry in Sri Lanka as following reasons.

- ICT will play an important role in terms of project cost, time and quality.
- Experts in the filed of construction have identified ICT as one of the future challenge that construction industry has to take up with the intention of achieving productivity goals.

1.9 Scope of the Study

In preceding paragraphs, it was discussed some important concepts behind the construction productivity and its relationship with information and communication technology. According to the previous studies it has been **proved** that there is a direct relationship between information and communication technology with construction productivity. It is a common phenomenon for any business that exists in the contemporary world under the digitized economy (Turbun et al. 2008). Study conducted by Bjork (2002) and O'Brien (2000) revealed that ICT implementation is required to be managed and structured because it has been identified as critical facilitator of success for any business venture in the productivity concerned.

In paragraph 1.6 – 1.6.1 described the relationship between ICT and construction productivity adopting the evidence from previous studies. Further analyses in this context are included in the chapter 2, under literature review. ***Accordingly, it has been identified through literature that there are some ICT implementation barriers and ICT value added activities affecting to the building construction productivity. It is a theoretically proven concept as facts reveled in the next chapter – literature review. The main theme of this***

study is to identify the both category of activities in Sri Lanka building construction industry context

Therefore it is required to identify what ICT activities are affecting building construction productivity and this research study is focused to identify both hindering and influencing factors separately. There is no intention to prove the relationship between ICT and construction productivity because such phenomenon has been studied previously by other researchers. Relevant facts are clearly indicated under the chapter 2 under literature review. **As theoretically proven by the literature survey according to the previous studies, ICT is a crucial facilitator of the building construction productivity. This research is based on that theoretically proven concept.** Therefore this study is directly focused on the objectives specified in following paragraphs. Results of the research study are specific to the Sri Lanka building construction industry because the study is equipped with measuring the perception of Sri Lanka building construction industry context.

1.10 General Objective of the Research

The general objective of this research study is to identify the factors that affect to the implementing of ICT activities in Sri Lanka building construction industry which impact on productivity. The relationship between said factors and productivity has been identified by the previous studies as literature reveals. It is further required to identify the factors separately. These factors are to be grouped into two categories. One category of activities is identified as hindering factors of ICT implementing while other category is enhancing the ICT activities. **Industry perception** over usage of above two categories is measured through the industry based data. The prime objective of the research study is to get the exact

perception of the industry people. They are the people who are doing the job with immunity to various difficulties and anticipated shortcomings. Monitoring and reading of the gravity of their perceptions regarding the research objective would be important and crucial.

1.10.1 Specific Objectives of the Research

It should be mentioned that no. of specific objectives can be fixed as per the revealed problem area. But it is worthwhile to specify the most important specific objectives required in accordance with the significance of the study. As per the literature review it has been identified (details reviews are in chapter 2) two significant factors that affect to the ***Sri Lanka building construction productivity concern through ICT use***. They are specifically,

1. To find the barriers of using ICT in building construction industry in Sri Lanka
2. To find significant ICT value added activities for building construction industry in Sri Lanka

Both objectives are fixed for Sri Lanka building construction industry context and impact of each objective is to be measured through attitude of the industry people.

2.11 Research Methodology

Under research methodology, it is discussed the formation of research methods and their evaluation processes according to the comments received along with characteristics of the study. As per the objectives specified, research method is formulated. According to Malhothra and Peterson (2006), research methodology comprises with two steps. Step one is to formulate the research design and step two is to doing fieldwork and collecting data pertaining to the research study.

1.11.1 Design of Research Methodology

Since all the factors are intact up to the specifying of objectives, then it is required to proceed to the research design. According to Yin (2003), research design is the crucial factor that should be carried out preciously since all successes of the research will depend on research methodology.

Step 1: Selecting appropriate research category

As mentioned above, desire of the research is to measure the perception of trade people and it is intended to use more variables and its manipulations. Further it is required to determine cause and effect relationship. Therefore it is required to select **explanatory research category**.

Step 2: Selecting appropriate research approach

It is due to quantify the data and generalize the results from sample to the population of interest. Therefore it is required to collect and analyze data, recommend final cause of actions. It leads to select **quantitative approach** for the research work.

Step 3: Selecting of data collection method

Since the quantitative research approach has been selected, **structured questionnaire survey** method is selected as the main data collection instrument. Answering for questions are based on selecting the most appropriate alternative option from the numbers range from 1 – 5 as in Likert scale.

Step 3: Conducting focused interviews

Identified activities belong to the two categories of factors were outlined separately with the intention of forming questionnaire. However, it is required to get **descriptive expert views** in order to qualify the questionnaire before presenting to the industry

people. Four experts those who are having **extensive experience** in the construction field were selected as follows.

- One intellectual from University of Moratuwa, attached to the Building Economics Department
- Two Senior Deputy General Managers from Public Construction Corporations
- One Senior Deputy General Manager from Large private construction firm

Outcomes of the discussions/interviews are as follows:

- All of them emphasized to include the ICT value added activities as resolving activities against the said barriers.
- Tune some questions modifying the presenting manner
- Insist the necessity of measuring reliability and validity of the questions
- Selecting of the sample
- Selecting of the target group for filling the questionnaire

1.11.2 Doing Field Work and Collecting Data

Step 1 : Selecting the sample

Selection of sample was based on important factors

1. Basically it was influenced by the Experts to select the upper grade of the ICTAD registered contractors.
2. Research conducted by Nayanathara et al. (2008) has followed the same approach to select the sample. In fact, our research model is based on the above research

and accordingly same selection procedure was followed. They have justified the selection by appropriating significant factors including:

- Intention of the study is to elicit the knowledge of specialist contractors
- Sample is to be selected from ICTAD registration C1, C2 and C3 belong to the building construction industry
- Except C1, C2, and C3 other contractors pertaining to building construction were dropped due to vacuum in knowledge extraction
- At national level mostly high productivity is expected from upper three grades
- High financial limits allowed by ICTAD
- High ICT activities have been utilized

Table 1.1 – Contractor Grading List for Building Contractors

Contractor Grade	**Financial Limit (Rs. Million)**	**No. of Contractors**
C3	$300.0 \geq X > 100.0$	25
C2	$600.0 \geq X > 300.0$	25
C1	$X \geq 600$	19
	Total for C1 to C3	69

Source - ICTAD Contractor Registration, (2009/2010, pp. 20-78)

Total sample comprises of 69 contractors in grades C1, C2 and C3 pertaining to building construction.

Step 2 : Testing of questionnaire

Before delivering the actual questionnaire it is subject to a pilot run with the intention of getting feedback from industry people.

Step 3 : Reliability and Validity Testing for the Survey Instrument

Two small groups from both public and private sector each comprising 10 participants were selected for pilot run. Purpose of the pilot run is to assure the reliability and validity of the questionnaire. It is measured the internal consistency of the variables and understanding of the concepts of questions by the participants for reliability and validity of the questionnaire respectively.

Step 4 : Data Collection

Final version of the questionnaire was distributed among the contractors pertaining to C1, C2 and C3 grades as mentioned above.

1.12 Limitations

A few limitations have been imposed due to improve the study work and purpose of getting accurate feedback from the trade people. In this study, term construction implies the building construction itself unless otherwise specified. Basically large contractors were chosen because large projects have high potential for productivity improvement and they have more qualified management. Data to be collected only from higher management levels. Example Project Directors/Project Managers/ Project Engineers

1.13 Thesis Chapter Structure

Chapter 2 is dedicated for literature review about ICT and construction productivity while chapter 3 is presenting the research design which is back by theoretical background of the research. Intention of chapter 4 is to present the data analysis based on empirical results: and

finally chapter 5 is reserved to discuss the implication of the results drawn by previous chapter and making any suggestions for further researches.

1.14 Summary

As has been revealed the research purpose then it followed the way of performing subsequent activities and functions pertaining to the said research work. In introduction chapter there has been made an effort to explain the contents of other chapters briefly. Basic structure of the entire thesis has been included to the chapter 1 for reference. Problem statement, significance of the study, general and specific objectives along with the introduction of research methodology are the main themes mentioned in the chapter 1.

CHAPTER 2
LITERATURE REVIEW

2.1 Chapter description on literature review

In this chapter, several important issues, views, key points and studies carried out by the previous researchers are discussed that relevant to the present work. Formulation of the research questionnaire and its variables are totally based on the literature review and focused interviews. Therefore it was concerned to describe the past events in distinct sequence in order to understand the flow of readings.

2.2 Introduction

While it was searching the literature it was found some useful, relevant course of works that can be adapted to my research work. All meaningful studies were listed sequentially in order

to refer at any time and with the intention of getting contribution for my present work. Effort was made to list the relevant literature as in following order.

1. Introduction to building construction industry
2. Definitions for building construction productivity
3. ICT factors affecting building construction productivity
4. Role of ICT in building construction productivity

As the first step to proceed with my survey, my aim was to find the relevant theory in both productivity and technology concerned in construction, as I thought which would be the main theme of my study. Thereby, close studies were taken into consideration through which my study was sharpened. Though such studies were not directly intact with my study but there were some key points which were taken as inputs for my study.

Such key points identified as ICT implementation barriers are listed in table 2.1

Table 2.1 – Identified ICT implementation barriers

Item No.	**Barrier**
01	Financial conditions of the organization
02	Government policies and regulations
03	Inadequate adoptability of technological drivers
04	Management and administration constraints
05	Less training and development of ICT skills
06	Backward situation of workforce

It further revealed some useful value added activities which can potentially influence the construction productivity as mentioned in the table 2.2.

Table 2.2 – Identified value added services

Item No.	**Value added activity**

01	Digitized construction management and administration
02	Transform process from traditional to industrialized
03	Use of ICT tools
04	Expert knowledge sharing
05	Information security

At a latter stage, Experts in the construction industry also emphasized to include value added activities into the research study.

2.3 Definition of Construction Process

Construction is an important business segment in the Sri Lanka industries which has contributed 5.6 % growth in the recent years (Central Bank Annual Report, 2009). As per the Central Bank Annual Report (2009), the growth in this sector came from both government and private sector involvement in construction activities, particularly in condominium projects and private housing projects. The no of building permits issued for construction between January – December 2008 increased to 2,166 compared with 1,297 permits issued in 2007 (Central Bank Financial Statement, 2009). Same statement has stated that total residential building permits issued for construction accounted for major share (88.13%) of the total building permits. But there is an increase in cost of constructions in terms of time, wages, materials etc. force some downsize risks. Therefore improvement in productivity in all aspects of the construction industry is very much important.

As per the definition made by the Chamber of Construction Industry (CCI) Sri Lanka, Construction includes the new building, structures, Additions, alterations, conversions, expansions, reconstruction, renovations, rehabilitations, and major replacements. CCI annual

report (2007) says that building construction represents over 82% of the entire construction industry. But productivity remains dominant issue of construction sector in Sri Lanka. Being a developing country which faces unemployment problems, inflation, resource scarcity seek to utilize resources in such a way to achieve economic targets.

It further reveals that Sri Lanka construction industry work force consists of 51% unskilled workers, 33% masons, 10% carpenters, 1-2% other skilled workers and approximately 80% work force is casually employed.

The study of the past researches revealed that one of the main objectives of the construction industry is to achieve higher productivity. Productivity translates directly into cost and time savings and ultimately into contractors profits or losses. Therefore increased productivity can have a large impact on the overall construction process and significant cost and time savings on the construction projects. Baldwin and Harchaoui (2002) have expressed as a result of a study that building construction industry is in the process of seeking alternative practices through novel management approaches through the application of advanced information and communication technology. They further stressed that effective use of advance information and communication technology would be able to achieve more efficient project executions and to a more productive industry.

It implies that success of construction process thoroughly depends on the visionary of productivity. Accordingly, study of the past events pertaining to construction productivity will be more fruitful. Following paragraphs will describe research studies pertaining to the above concept.

2.4 Construction Productivity

ICT contribution on construction productivity concerned has been defined by Rankin and Luther (2006 p. 1539), '…as a whole, the construction industry is innovative. The very nature of the work requires that technology be applied to a variety of conditions. At the same time, the configuration of this network of organizational structures makes it difficult to effectively disseminate information and knowledge about new technologies and inhibits their application'. As mentioned in the Business Directory (2010), productivity is defined as 'relative measure of the efficiency of a person, machine, factory, system or industry etc. in converting inputs into useful outputs. It is computed by dividing average output per period by the total cost s incurred or resources (capital, energy, material, or personnel) consumed in that period. Productivity is critical determinant of cost efficiency'.

2.4.1 Productivity measuring theory

According to Pavlina (2005), productivity equals value divided by time.

Productivity = Value/Time

According this formula there are two possible ways to maximize the productivity.

- Maximize the Value or/and
- Minimize the time

In order to complicate the situation one can include other factors like energy and resources but making simplicity of time in most cases factors like energy and resources are considered as reducible to time factor approximately. Optimization of time factor that incurred for any venture will bring the least time counter. Accordingly time consumed for fulfillment of activity concerned is less and it is definite to give high productivity yield. He also argues that 'value' fraction of the productivity equation can be appropriated to the 'quality'.

Productivity concept in business ventures is not a modern theory. It goes to the past more than five decades. As per the definition made by European Productivity Agency (1959) 'Productivity is a state of mind ……..an attitude that seeks the continuous improvement of what exists. It is a conviction that once can do better today than yesterday and that tomorrow will be better than today'. It also outlined that applying the most simple mathematics, productivity can be improved by a larger increase of output against a smaller increase in input or it can be improved by increasing output and reducing input so that it is a real challenge for any industry.

Construction process always requires high productivity not only from single aspect but through other connected activities as well. Tangue and George (2002) identify such factors affecting to the productivity as:

> [t]he objective of the construction industry is to achieve higher productivity because productivity translates directly into cost and ultimately into contractors profits or losses. Productivity is the most common measure of performance in the construction industry. This depends on management, material, equipment, manpower etc. These elements make up total on site productivity. Increased productivity can have a large impact on the overall construction process and consequently result in significant cost and time savings on the construction project. Enabling of ICT activities to achieve the productivity is significant.

A recent study (Devis, 2007) has found that productivity falls into three sectors namely, on-site productivity, firm level productivity and industry level productivity.

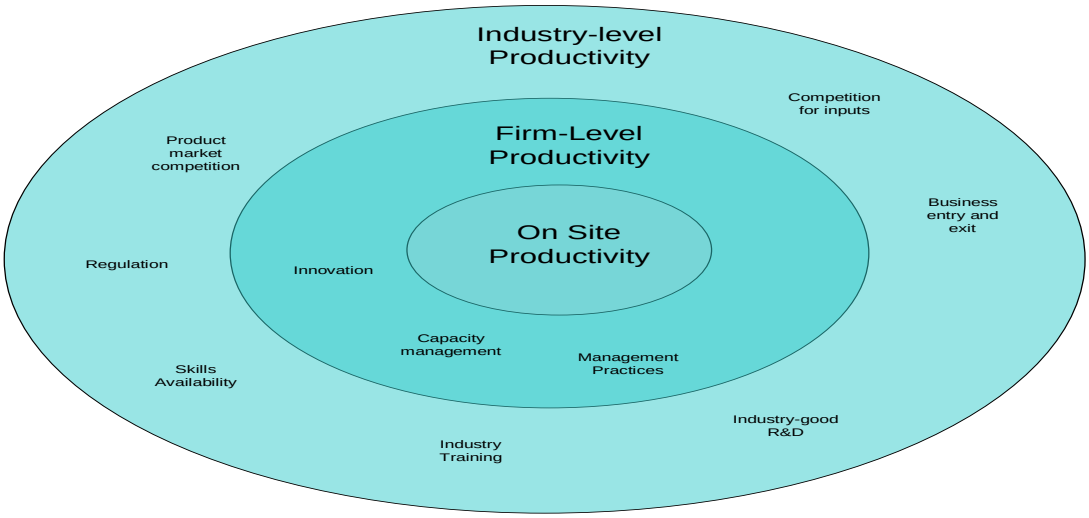

Figure 2.1 - Construction sector productivity as (Devis, 2007)

Devis (2007) also categorizes the work pertaining to each sector as follows:

On site productivity factors - design, material procurement, labour supervision, cost control, weather etc.

Firm level productivity factors - quality of management and business practices etc.

Industry level productivity factors - regulations, competition, investments and skills.

As Devis (2007) identified, first two sectors comprising the activities which can be influenced through ICT enabling processes. Therefore study conducted by Devis (2007) will be important to the content of dissertation.

2.5 **ICT Factors Affecting Construction Productivity**

As the first section of the literature review it was outlined the identification of construction process and some related activities which directly influence the maximization of productivity. In the sense of construction process there is no meaning to study the industry advancements without making any effort to study the productivity measurements in the

matter concerned. One famous argument can be adopted, that **"*one small step for a man, a giant leap for mankind*"** since the mankind exists in digital environment. As an appropriation, even economy has become 'digital' so that 'digital economy' can be found in the everywhere in the contemporary world. Within the digital economy all ventures have become digitized including construction industry. In fact, all business ventures exist in the highly digitized information management era and construction process should go through that environment. Therefore even small change in the process can yield better outcomes giving the significant productivity enhancements which can positively affect to the national GDP growth in the country. Following literature survey reveals how 'ICT' can improve the productivity in any business venture including construction industry.

Unlike the past, ICT capabilities are growing at a high rate as defined by Turban et al. (2008, p. 559) and trend is expected be continued for the foreseeable future too. As revealed, ICT can help to expand power and decline the costs of production and with more extensive ICT applications through which organizations engaged in any business venture can improve their efficiency and effectiveness. Definition extends to the following key points that in regard to the capabilities of ICT:

1. Performing of the existing functions at decreasing cost over time and become more efficient.
2. Creative organizations always find innovative process through ICT to improve price-to-performance ratio and finally become more effective.

Further Turban et al. (2008) describe the advantageous of ICT use as it will be the significant factor of the production and distribution process of almost every product and service. More manual jobs can be automated. Investments made on ICT by the organizations or even

industries have yielded the benefits. These investments have positively increased the productivity, not just in individual organizations, but in the context of national or international economy level.

Under the research conducted by Martikainen (2007) revealed some important factors pertaining to productivity in connection with ICT collaboration.

- Accordingly, In modern growth theory (1986) the volume of
  Production (= quantity x quality) results from invested capital, utilized labour and available new knowledge.
- It has been identified the Total Factor Productivity (TFP) as the major driven force of the growth.
- Productivity = Y / X , where
  Y = output (in euros, tons...); X = input (hours, labour costs...);

Becchetti et al. (2003) has come out of useful conclusions as per the study based on ICT investment and productivity. The study trends to analyze the determinants of ICT investments and impact of information technology on productivity. Sample consists of small and medium sized firms. To test the most relevant theoretical predictions from the ICT literature it has been evaluated the impact of investment in software, hardware and telecommunications of these firms on a series of intermediate variables and on productivity.

Outcomes of the literature survey:

Outcomes of the survey have shown that the effect of ICT investment on firm efficiency can be more clearly detected at firm level data by decomposing it into software and

telecommunications investment. It has been found that telecommunications investment positively affects the creation of new products and processes; on the other hand software investment has caused to increases the demand for skilled workers, average labour productivity and proximity to the optimal production frontier. As the conclusion, the study argues that ICT investment makes facility to modify the trade-off between scale and scope economies. It further suggests that software investment increases that scale of firm operation while telecommunication investment creates flexible options that easing the firm's productive network model in which products and processes are more frequently adopted.

Under the sections 2.1 and 2.4 it was reserved to discuss the maters pertaining definition of construction industry, productivity concepts relate to the construction and ICT capabilities of the improving productivity through literature survey. Identical and relevant concepts, theories and previous similar or close studies were taken into account in order to reveal the real facts. As the final step, it is due to discuss the literature in lengthy manner to reveal the how ICT capabilities are intact with productivity of the construction industry. Since the dissertation is totally dedicated on ICT and construction productivity concern, final step of the literature survey will be very important to identify and quantify the problems encountered by the construction industry while improving productivity in the operation.

Under the digital economy/digital environment, any industry cannot exist unless it is compliant with new technological advancements. Les (2006) states it is important that the impact of technological change on the industry is properly recognized. One area of technological utilization is the increased use of information and communication technology and investment improvement. For any construction, there is a planning and design stage which arises before the

other activities. Entire construction process heavily depends on the planning and design aspects. Through the feasibility study, planning aspect identifies the available resources and opportunities before proceeding to design. Design itself carries out the building up of conceptual diagrams, structures and all over the activities after the planning and before real construction begins. Planning of resources and design of construction bring the effective solution to the construction which implies the significant productivity. One can imagine that how poor planning and design process incorporate to the productivity that of giving low quality. As a collaborative measure it has been identified the role of ICT in this regard as defined by the Koskele, Huovila, and Leinone (2002, p. 34) that construction design process can be conceptualized at least three different ways,

1. As a process of transforming inputs into outputs,
2. As a flow of information through time and space,
3. As a process of generating value for customers.

With view of fortifying the above literature regarding the productivity margin in design aspect, Best and Valence (2000) have found three dimensional CAD modeling systems which could deliver significant productivity improvements, if applied early enough in a project over the conventional method used for coordination between disciplines of the construction industry. Gaining productivity in planning and design process is now straightforward through the IT involvement.

Similar study carried out by Molnar, Andersson and Ekholm (2007) state that ICT can play an essential role in the transformation process of the construction sector from a traditional to an

industrialized process. Study was done in Sweden for multi-storey house building. They have found following outcomes while using computer aided designs,

- Use of project networks,
- Hardware, software and filing,
- ICT used for administrative purposes

Especially by the large contractors, it was resulted an improvement in productivity and quality through ICT collaboration. It is important to verify why Molnar et al. (2007) made such an approach. In most cases construction process is carried out in traditional way that of giving least chance to collaborate with ICT. In fact, ICT can conquer the traditional barriers of the construction process and bring it up to contemporary industrial world which can acquire the real industrialized properties. The weight is given very much in this regard because there is a productivity aspect behind the entire process.

Same concept has been expressed by Soeiro (2008) states that technological developments have influenced significant changes in the some areas of construction industry as follows.

1. Modified the formats of construction management.
2. Tools of ICT are the support for analysis and filtering of information.
3. Electronic processes to allow the use of resources at a lower cost.
4. Electronic processes to allow the shorter period of time.
5. Documents management in a construction site.
6. Database for sub contractor management.

Soeiro (2008) further reveals that ICT can represent a tool of great value in the construction management. The specific training and the formation of using ICT in construction must be

promoted and be implemented as essential way for the modernization and improvement of construction sector.

In addition to the factors revealed above, Hua (2006) outlines a new dimension of the construction productivity through ICT as knowledge management. He emphasizes

> …. in the global marketplace, it is highly critical that businesses know the importance of managing knowledge in order to sustain competitive advantage. Essentially knowledge management promotes an integrated approach to identifying, managing and sharing all the information needs. With the use of IT, various information systems can be set up and integrated with knowledge gathering and analyzing tools for data analysis and dynamic and user querying. These solutions would enable to improve customer services and to create marketable knowledge products.

With reference to these surveys done in Singapore, main recommendation for promoting information technology is, '[c]reate a strategic IT enabled construction industry that strives on interoperability and builds on integrated databases and interactive applications to achieve quantum – leap efficiency with global connectivity' Hua (2006).

It should be mentioned at this stage that all studies, researches are consistent and revealing the need of ICT collaboration to increase the construction productivity.

Saarikko (2008) states 'if you get new design software to be used in the project, initially should evaluate how the users will benefit from it and to see how it add to the productivity of the entire project'. Study further emphasizes, before purchasing software following to be considered,

- How it works with the rest of the world
- How to share designs for Quantity Surveyors and their technologies
- How fast the variations can be communicated through the process
- How the site management can take benefit of the results

However as mentioned in the study, this may be very difficult to evaluate. Thereby, it can be asked from vendor to prove how their solutions add to the whole project productivity. In this scenario productivity improvement totally depends on the available software and vendor's ability to prove it positively.

Information security plays an important role in information management aspect that connected to the construction industry. Thereby, Gren (2008) has conducted several studies and has outlined some meaningful guidelines in accordance with information security aspect pertaining to the construction data. Therefore adherence to the same is fruitful.

1. Know where all the information is
2. Know who has access to the information
3. Record the use of information
4. After the project, keep the same level of security
5. Have someone to take responsibility over information security.

Information pertaining to any business is precious and it is valid for the construction industry too. Why it is so much important is all information are in digitized form in the contemporary world and it should be protected from any hazard in order to keep the productivity concern. It should be avoided any information losses because misuse of information will directly impact to the productivity. Gren (2008) further drew the attention in different way that, if all the factors concerned in the construction productivity are intact except the training, the expected outcome is not given. Investment of new ICT on construction to be done simultaneously that investing on training aspect people engaged in the organization. Otherwise it can be experienced a decreased level of productivity. Also he added accuracy of quantity control and reporting depends on the information produced. With the development of Building Information Modelling (BIM) combined with the Quantity Information Management (QIM), quantity and cost progress can be monitored and controlled in real time with accuracy and transparency.

One hindered point in the construction industry is the lack of sharing knowledge among experts engages in the industry. Process of sharing knowledge should be intact with collective manner. For the consistency of problem solving, there should be a way of sharing knowledge as required by the situations where arising problem cannot be solved individually. Kazi (2005) states ICT can be used as an effective way for experts to share knowledge and jointly solve problems [using experts of global network, aspect of knowledge sharing]. Therefore ICT is an important tool for improving productivity. What implies the Kazi (2005) argument is that importance of having knowledge based system in the manner of knowledge sharing being crucial in the construction sector. Construction is not limited to a one disciplinary. It consists of several aspects, multiple disciplinary actions. Therefore Kais argument is a valid point in the context of construction productivity because time delayed for any action will make impact of any project duration (since the time is one parameter of productivity measurement).

In order to analyze the present productivity concern in construction industry, it is useful to study the evolution of productivity pattern in the past. Accordingly with the view of identifying evolution pattern of the productivity, Teicholz (2004) has conducted a study and has brought his findings. As per the study reveals productivity of the construction industry has gradually declined over the past 40 years and it is clear that looking at the whole industry there is a significant productivity problem exists. Teicholz (2004) has identified some of the reasons for this problem are adoption of new IT system over last 35 years are standalone models that does not permit improved collaboration among the project team. As an example, each designer uses separate CAD/CAE systems. CPM is independent of cost control, which is independent of project changes to the drawings. In order to resolve the problem, Teicholz (2004) suggests

improved use of IT including the use of 3D CAD during design and the use of internet to improve team productivity is clean area for improvement. The designers can work with intelligent 3D CAD models that can be viewed and shared using browsers.

Data modeling standards will allow rapid and error free sharing of data. Electronic file creation during the project and database creation by the project team is also important uses in a construction project. Therefore using IT is a significant saving in cost and time. We should not expect construction productivity improvements without a significant change in the information tools and collaboration strategies used for design in construction.

It is significant to study how the ICT impact on jobs engaged in construction industry. From planning to design, site preparation to project implementation, there are no. of jobs, no. of personnel engage in construction industry. They are categorically skilled and unskilled in nature. Professionally skilled labour force is intended to use the ICT tools and capabilities. Therefore target group of the ICT use is limited to skilled labour force.

In this context, previous study over the job-oriented ICT usage in construction industry has been conducted by the Oladapo (2006). According to Oladapo (2006), impact of ICT on professional practice has been mainly in making jobs easier for the professions, facilitating decision making and savings in operating costs among others. Some of the major ICT investments are computer–aided designs (CAD), teleworking, video conferencing and electronic data management (EDM) and some of e-activities* (e-tendering, e-procurement etc.). [1] Consequences of these ICT enabled activities are definite time saving as mentioned by Oladapo (2006). Time saving factor implies the definite productivity upgrade in the construction process. As mentioned by the Oladapo

[1] * e-activities are not covered in this study

(2006), another ICT influence activity is the decision making. Similar to the other business ventures, construction industry also requires promptly taken correct and accurate decisions in order to carryout the activities effectively and efficiently. Decision should be taken timely and accurately that enabling to achieve the pre defined business goals. As usual for effective decision making process it is required information. It is in common perception that information in contemporary digital world is heavily based on ICT enabled activities/tools or in databases. Therefore ICT involvement in the decision making process is not marginal for professionals in construction industry and it plays a potential role. On the other hand it generates job opportunities for professionals as well as it gives additional dimension to the professionals as ICT enabled ability in workforce. Study conducted by Oladapo (2006) further reveals that tools of ICT are commonly required in architectural, engineering and quantity surveying practices. Common types of software are word processing, spreadsheet and internet software. Architects and engineers use CAD mostly for design works. Micros Tran and MathCAD software are used for engineering analysis. Also quantity surveyors use WinQS32, QsCAD and CATO. In addition to above there are new areas of ICT innovations. They are,

- Knowledge Management - KM
- Electronic Document Management - EDM
- E business

Ultimately Oladapo (2006) study over use of ICT tools in construction industry summarizes the benefits as:

- Make professionals job easier.
- Facilitate decision making, saving in operating costs.
- Give users competitive advantage over rival factors

- Saves time, Improve documents presentation
- Enhance productivity.

Adoption of ICT for the construction industry is not a totally innovative process. ICT has surpassed some expectations but not merely as to encounter the productivity margins. The real problem exists in that domain is how ICT implementations impact on productivity in construction industry. Form of a research paper Rankin and Luther (2007) express some findings over the above matter concerned. They extensively discuss the innovation and use of ICT for the construction industry. As the methodology, they use general framework that is broad in perspectives. It is presented for the analysis in regard to the innovations and technology adoption in the construction industry. The framework is described in relation to the life cycle of a technological innovation. It consists of two primary perspectives: a macroview (top) and a microview (bottom). Finally they summarize the relevance of framework form of discussion how these interrelated analyses are applicable to the decision-making process within a particular organization along with the mechanisms required by the industry to improve the innovation process. Relevance of the framework is mentioned as that it is comprehensive in its ability to look at information and knowledge flows in support of innovation within the industry and at the interrelationships between micro and macro influences. Accordingly they have identified some distinct gaps among current approaches including lack of quantitative analysis tools, the ability to reflect the dynamic aspect of innovation, and industry knowledge of practical decision-making tools.

Through the study and the analysis of framework that formed by Rankin and Luther (2007) outlines some key points pertaining to the innovation phenomenon.

- The innovation is significantly potential which can enhance the competitive position of the firm within the business environment.
- It can enhance quality, thereby quality reflects the productivity.
- It can increase profit margins giving long stability to the firm.
- It can increase market share accordingly it withdraws the sustainability problem of the firm.

But this phenomenon is fully accepted subject to the following condition that successful adoption of an innovative technology is only possible if a sufficient framework is developed, fully understood, properly applied, and used to its full potential.

The Financial Times, Malaysia (2007) brings some meaningful suggestions in order to enhance the productivity in construction industry. It has discussed the problems pertaining productivity in lengthy but content of the article lacks of professional view point to the problem concerned. However problems and some suggestion over improving productivity in construction industry are useful for other countries in the region. It highlights the some weaknesses in the construction industry delivery system which often result in excessive cost overrun and quality deficiency in the final output. Cost overrun situation and quality deficiency directly impact to the productivity. So as to address the problem, it has been formed the Construction Industry Master Plan (CIMP). One valid point has been mentioned in the article that unlike other business ventures the construction industry does not have a systematic method for collecting and disseminating

information among its industry stakeholders. There are no of promotional activities have been mentioned.

- To form mechanism that promotes knowledge sharing among its diverse industry players.

- To set up a knowledge database for the construction industry would require a huge amount of resources especially in the application of information and communication technology or ICT.

Some of the setbacks in construction industry pertaining ICT are mentioned below as mentioned by the Financial Times, Malaysia (2007).

- A 2005 study by the e-Business W@tch for the European Community confirmed the low ICT uptake as well as the untapped potential for ICT-based developments in the construction sector.[2]
- Although internet access has been enabled, ICT infrastructure has been poorly developed
- Professional ICT skill development or enrolment of IT experts are not taking place
- Construction firms hesitate to adopt ERP solutions to increase productivity.
- There is no proper way to exchange information pertaining to construction industry. It is poorly managed the information sharing and contacting external expert systems in digitized environment.
- Even e-procurement has not matured enough to cater to the industry requirements.
- The customer relation management system is not extended as ICT enabled and on-line sales and marketing systems not intact with current ICT development.

Further it suggests establishing a "IT Strategy Plan for the Construction Sector".

In the literature survey, it becomes much worth how other countries and communities have performed such studies over the proposed productivity increasing process in the construction study. At the critical stages they have come out of better solutions through statistical analysis of the factors that affecting productivity. Therefore studying of similar researches will be helpful to identify the factors affecting in productivity concerned.

[2] Secondary citation e-Business W@tch for the European Community

The European Construction Technology Platform (ECTP) have conducted a research on 'Processes and ICT' in the construction industry (ECTP, 2008). This research has been conducted with some future intentions with the view of strengthening sustainability of the construction industry. The document under the title of 'Vision 2030 & Strategic Research Agenda (SRA)' address the need of conducting research in the field of ICT supported processes in the construction sector. Presenting the strategic research priorities in the domain of "Processes and ICT" in construction is the main theme of this document. In the document SRA addresses process, products, projects, enterprises as four key aspects of construction. Following figure outlines the decomposition of each aspect.

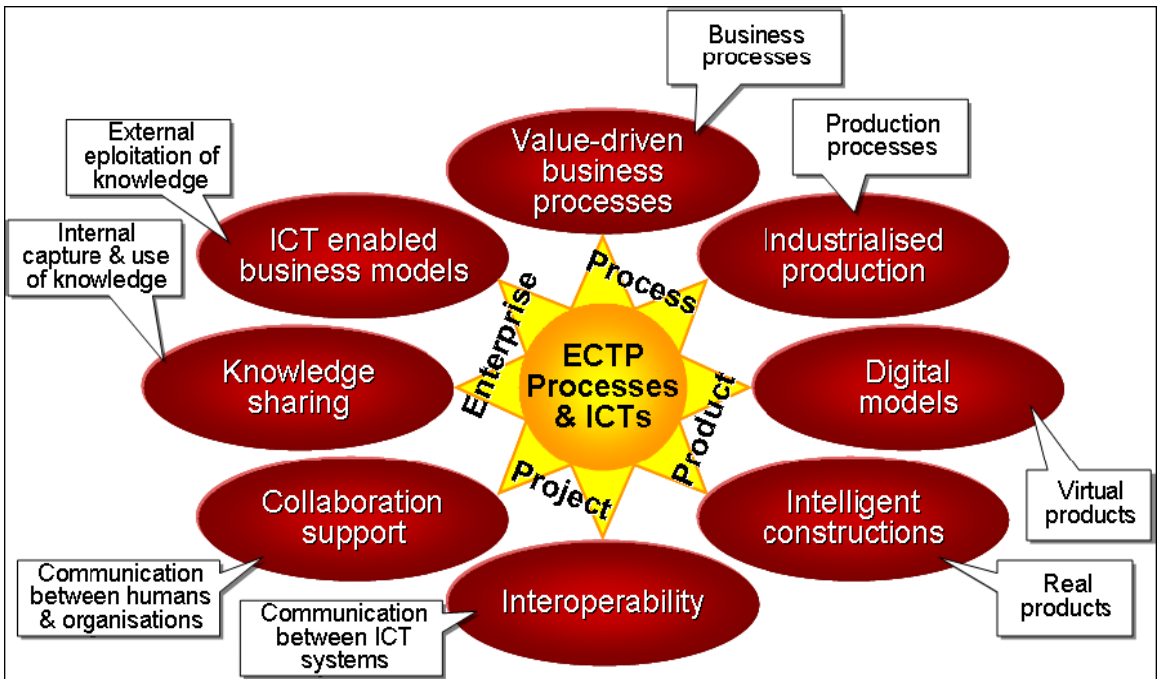

Figure 2.3 - Main themes of the SRA as (ECTP, 2008)

In fact, all identified processes are equally important to the other countries including Sri Lanka. Enhancement of each theme – out of eight implies the productivity gain in the construction industry. Unlike other sectors, construction sector lags significantly behind in

ICT infrastructure, in internal processes, supply-side e-business activities, and electronic marketing and sales (ECTP, 2008, p. 12)[3]. In their document ECTP (2008, p.11), highlights some drawbacks in processes and ICT area:

- Current ICT tools in the construction industry are based mainly on application-specific data or are at low semantic level such as (digital) 2D-drawings and textual specifications. This hampers automation and integration of processes.
- Semantic ("nD") modeling is increasingly supported by proprietary software tools and interoperability standards.
- Sharing semantic data is hampered by insufficient protection of intellectual property.
- Products are designed and delivered to order, with low degree of configurable manufactured components.
- Current constructions are mainly "dumb", poorly documented and difficult to use in an optimized way, while becoming increasingly complex due to use of new technologies.
- Existing intelligent (sub) systems are poorly integrated.

ECTP (2008, p.3) imagines the future vision of processes and ICT in the construction sector as:

- Achieves sustainability in products and processes.
- Considers whole life cycle of its products and services.
- Applies value / performance driven business processes.
- Meets users' and clients' requirements and aspirations.
- Uses innovation, knowledge and ICTs as key assets.
- Operates competitively in the European wide open market.
- Provides products that offer comfortable and healthy working and living environment.
- Is attractive as a working place.

It further quotes the business impact through ICT based-services to get competitive advantage as

1) Creating of new operating models focusing logistic services

[3] Secondary citation - e-Business w@tch (2005).

2) Adapting a structured recording system to store experience and knowledge with the view of improving information management, workflow management, interface management and document management
3) Adapting a structured recording system to store experience and knowledge with the view of improving information management, workflow management, interface management and document management.
4) Implementing risk management system that enabling to equip diagnostic and decision support tools with the intention of identification, analysis, tracking, mitigation, and communication of risks in software-intensive programs.

Through the literature survey it was found very useful Australia-based research pertaining to the 'Use of ICT and Internet-based Construction Project Management (ICPM) which focuses on the potential of ICT to integrate construction project teams (Kajewski et al., 2001). Intention of the study project is to inspire a critical evaluation for the use of ICPM, e-tendering, e-archiving pertaining to project information along with adoption of these innovative ICT solutions. It also adds a new glossary word to the construction jargon 'e-construction' (Kajewski et al., 2001, p. 7&28).

Research objectives as mentioned by (Kajewski et al., 2001) are as follows:

1) Identify the use of online technologies for the design, management and construction projects.
2) Identify ICT resources to improve resource management, support and integrate total project cycle consideration.
3) Increase efficiencies of the projects and reduce overall cost and improve project outcomes

4) Evaluate ICT systems against the above aspects and find how ICT address the problem areas.
5) Identify the ICT implementation barriers in construction sector.
6) '[d]emonstrate the benefits and efficiencies obtained through (ICPM) solutions - thereby stimulating improvements and encouraging the wider adoption of such processes

Mentioning of above objectives is straightforward because all aspects are equally important in the context developing a model in Sri Lanka. For getting the realization of objectives researchers have adopted 'five stage action research cycle methodology that involved some form of collaboration between researcher(s) and practitioners to generate new knowledge useful for both research and practice. As the findings and recommendations research suggests success of the ICT collaboration in the construction industry is directly dependent upon the participation of key members of the project team who are categorized as key project players (including architect, project manager, superintendent and engineers) using the ICT systems regular basis. The underlying concept behind the reveals of study is that the questionnaire or interview should be conducted with the key players (as identified by the study) of the construction project.

Information Technology for the construction simply implies the use of some ICT activities to ease the workload of the project. But there is a potential gravity underling behind the theme. Amor and Betts (n.d.) on the study of 'Information Technology for Construction: Recent Work and Future Directions' make some useful guide lines for the implementation of ICT enabled activities in the construction industry. It is a form research paper that shares the experience of working committee appointed to review the key research issues that have been

addressed in recently reported work and seeking to envisage the future IT-enabled construction projects that might inform future research. As mentioned in the paper defined objectives of the mission are:

- foster, encourage and promote research and development in the application of integrated IT throughout the life-cycle of the design, construction and occupancy of buildings and related facilities;
- proactively encourage the use of IT in Construction through the demonstration of capabilities developed in collaborative research projects; and to
- organise international cooperation in such activities and to promote the communication of these activities and their results.

After reviewing the past experience connected to the construction project activities committee has made some directions towards the future. The scenario includes seven themes in term of construction projects. Five main stages of the project life cycle have brought into account and lists out how ICT allow them to be executed differently.

Table 2.3 - IT-Enabled Changes to Project Processes as (Amor and Betts, n.d.)

Stage in Life Cycle	**IT-enabled Process Changes**
Conception of needs	• Developments in technologies will have a major impact on the reuse of previous project knowledge and experience. • Facility managers will take a more proactive role during the conception of needs. • GIS will assist in site selection and physical positioning of buildings. • Visualization will offer a better understanding of the project.
Tendering and team selection	• Long-term partnering relations will be commonplace. E-tendering and e-business will be major technologies linking the supply chain. • If a model-based approach is to be realized, there will be an ease of information sharing between the parties. Capability in information sharing will be important team selection criteria. • There will be long-term relations with other project participants

Design and briefing	• Visualization tools will improve communications. • Simulation tools will be used. This will allow feasibility studies on usability, environmental impact and constructability of buildings. "what if" analysis can be performed on construction programmes. • Greater reuse of previous, and industry best practice, design solutions will be enabled through knowledge management and organizational learning strategies. • Project models will improve information consistency and enable active notification of design changes for participants. • The use of internet applications such as e-procurement will change business relations. Many of the manufacturing philosophies of material procurement can be adopted. Manufacturers and material suppliers will supply materials just in time by refereeing to the web-based project information board, and will also enable parameterized selection of their products.
Construction	• 3rd generation mobile phones –that can transmit images – will help to visualize the different components of the building in the construction phase. • Intelligent tagging such as bar coding will improve material movement and tracking. • Last minute changes in the construction phase will be captured and submitted to the client. • Integrated performance management on site will reduce non-value adding activities and enhance possibilities for waste reduction and reuse.
Facilities management	• Electronic as built information is used for operations and maintenance of the facility. • Intelligent tagging will become part of the project and form a base for FM activities. • Facilities managers will use their experience and knowledge for the development of conception of needs in future.

2.6 Developing Theoretical Framework Through Literature and Focused Interviews

As has been received no. of research works in the context of my study, it was found a important research work (Nayanathara et al., 2008, pp. 158-167) published by the department of building economics, university of Moratuwa, Sr Lanka. They have given a particular attention in their study in order to identify the key challenges as well as important motivators in construction productivity. It has been identified key driving forces under challenges and motivations respectively in their study titled 'Challenges faced by construction industry in Sri Lanka'. As the methodology, they have used structured questionnaire survey in addition to the descriptive interviews conducted with field experts those who are having extensive experience in the field of building construction industry. Intention of the study is to elicit the knowledge of consultants and specialist contractors that dominating the building construction industry at present to explore their research objectives. The sample has been selected from ICTAD registered contract organizations from Grade 1 to Grade 3 in the field of civil construction. They have selected Grade 1, Grade 2 & Grade 3 contractor list as the sample. For justification of sample selection, followings have been mentioned as the main reasons.

- Vacuum in the knowledge extraction from lower grades
- High financial limits allowed by ICTAD
- High productivity is concerned mainly from upper grades

2.6.1 Identifying the Key Areas

Before proceeding to the study, it has been identified no. of challenges and motivations from previous studies conducted in various aspects in relation to the building construction

productivity. It was persuaded me to make an awareness and key interest in this regard because some identified aspects in their research as relevant to my study. I though the way of conducting the research could be extracted from their research because research environment and culture is same. Though all the identified factors are not relevant to my study, there were some important key indications which were enabling me to use as important areas for my study. Outcome of such areas are mentioned below under category A.

Category A:

- Financial situation of the organization
- Prevailing government policies and practices
- Lack of training and skill development
- Poor Construction management and administration
- Inadequate Technology adaptation
- Not existing in the global network

Apart from that following key areas were identified through literature survey under section 2.5 as mentioned below under Category B.

Category B:

- Digitized construction management and administration
- Transform process from traditional to industrialized
- Use of ICT tools
- Expert knowledge sharing
- Information security

Therefore above factors were considered as key areas in the context of my research study. The other issues recognized as variables were also captured through **literature** as revealed in

section 2.5 and as a **result of focused interviews with industry experts**. As revealed in chapter 3.5.1, **focused interviews were held with industry experts** in order to identify some key areas pertaining to the study along with their connected variables. More details of focused interviews are included in the section 3.5.1 under research methodology. The identified variables through above two factors were grouped into key areas under Category A and Category B in accordance with their relevance to the Key Area. Finally identified Category A and Category B were labeled as two distinct categories: '**ICT implementation barriers**' and '**ICT value added activities**' respectively. Figure 2.4 outlines the identification of variables, key areas and main categories of the research study as per literature review.

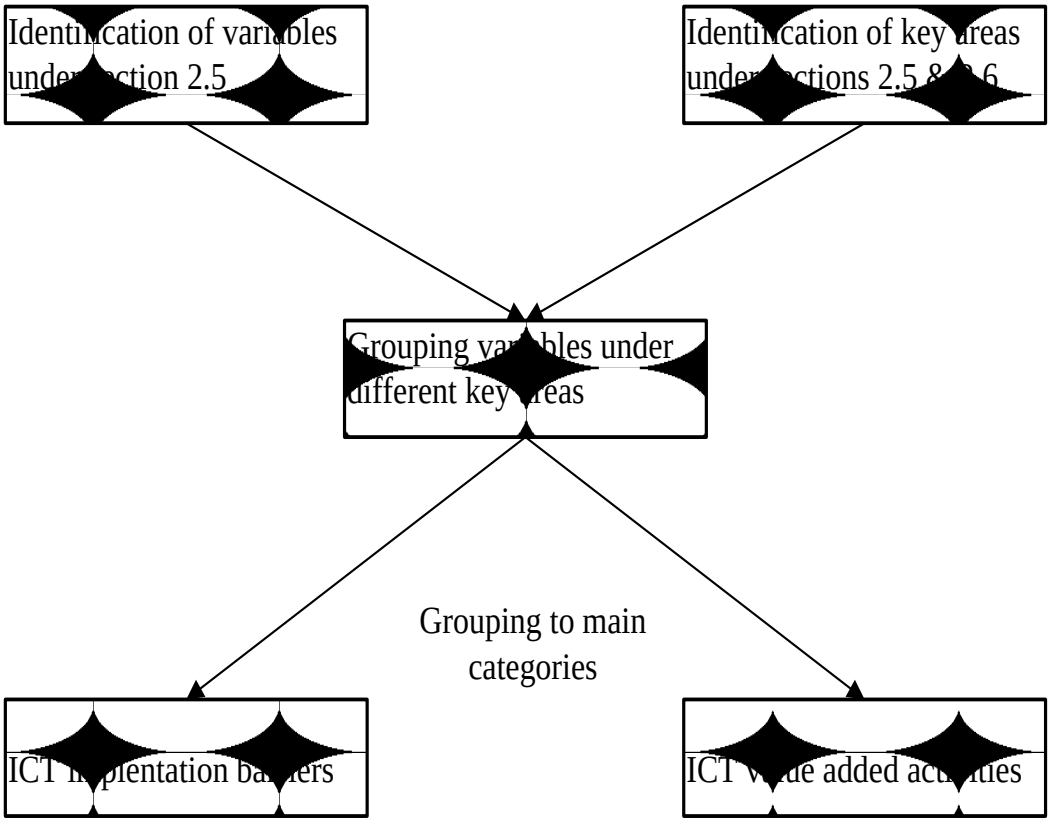

Figure 2.4 – Flow diagram for identifying variables

Therefore selected variables that connected with main two categories are mentioned in the following tables 2.4 and 2.5 respectively.

Table 2.4 – Dependent and Independent Variables under category Barrier

Ref. Key	**Independent Variable**	**Ref. Key**	**Dependent Variable**
BV1	Narrow profit margins	BKF1	Finance Constraint
BV2	Provision of insufficient budget for ICT	BKF1	Finance Constraint
BV3	Less government support	BKF2	Government Policies and Practices
BV4	Low level of ICT infrastructure development	BKF2	Government Policies and Practices
BV5	Weakness in capturing ICT developments	BKF3	Inadequate Technology Adaptation
BV6	Obsolete communication methods	BKF3	Inadequate Technology Adaptation
BV7	More paper based documentation process	BKF4	Poor Construction Management and Administration
BV8	Project planning without ICT	BKF4	Poor Construction Management

	enabled software		and Administration
BV9	Limited funds for manpower development in ICT use	BKF4	Poor Construction Management and Administration
BV10	Scarcity of ICT skills in staff	BKF5	Workforce Resistance
BV11	Workforce resistance to accept ICT enabled activities	BKF5	Workforce Resistance

Table 2.5 – Dependent and Independent Variables under category Value Added Activity

Ref. Key	**Independent Variable**	**Ref. Key**	**Dependent Variable**
VD1	Digitized document management process	VF1	Digitized Construction Management
VD2	Use of databases for subcontractor management	VF1	Digitized Construction Management
VD3	Use of Building Information Modeling (BIM) and Quality Information Management (QIM)	VF1	Digitized Construction Management
VD4	Use of ICT enabled project network systems	VF1	Digitized Construction Management
VD5	Imposing security over accessing data	VF1	Digitized Construction Management
VD6	Use of general purpose software	VF2	Use of ICT Admin Tools
VD7	Use of 3D-CAD for cost-effective designs	VF2	Use of ICT Admin Tools
VD8	Effective project time planning	VF2	Use of ICT Admin Tools

	through Micros Tran and MathCAD		
VD9	Use of WinQS32, QSCAD, and CATO for Quantity Surveying as quality improvement tools	VF2	Use of ICT Admin Tools
VD10	Knowledge sharing through global networks	VF3	Expert Knowledge Sharing
VD11	Electronic file creation during the project period	VF3	Expert Knowledge Sharing

Connectivity of variables, relevant key factor and category of constraint is as in following figure 2.5

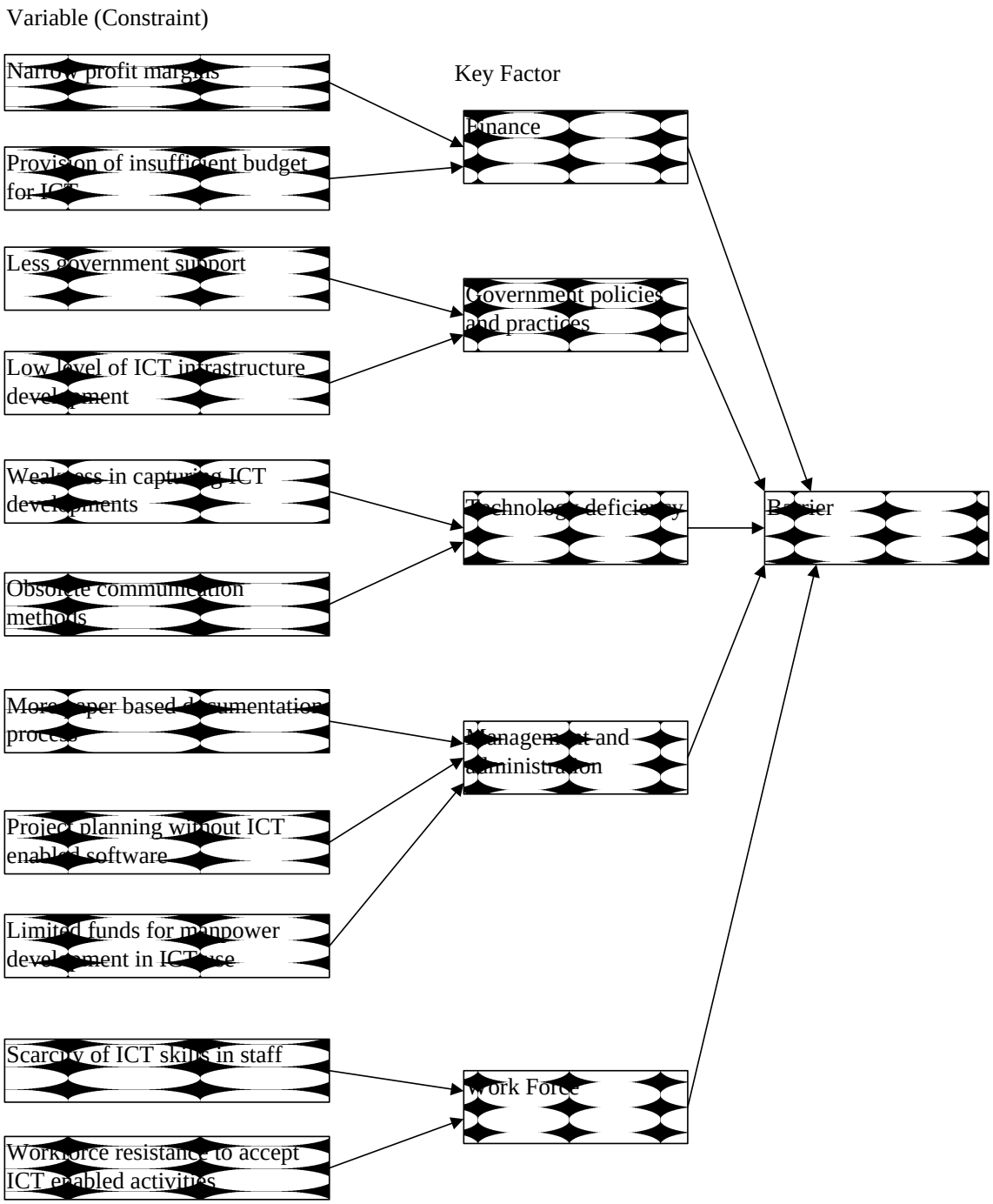

Figure 2.5 – Connectivity diagram for variable, key factor and main category - barrier

Connectivity of variables with relevant key factor and category of value added activity is as in following figure 2.6

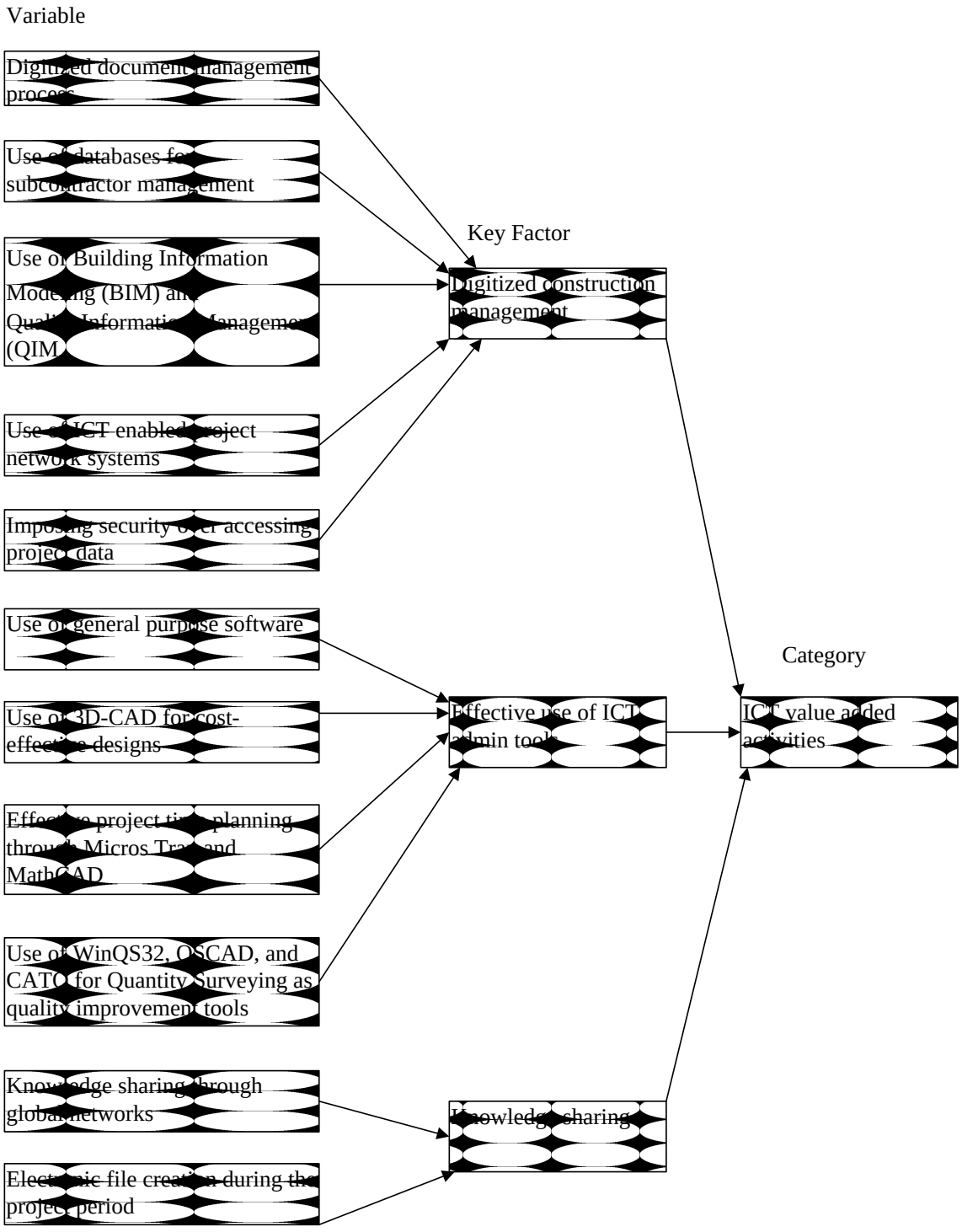

Figure 2.6 - Connectivity diagram for variable, key factor and main category – value added activity

Conceptual Framework of the research study is as in the following figure 2.7

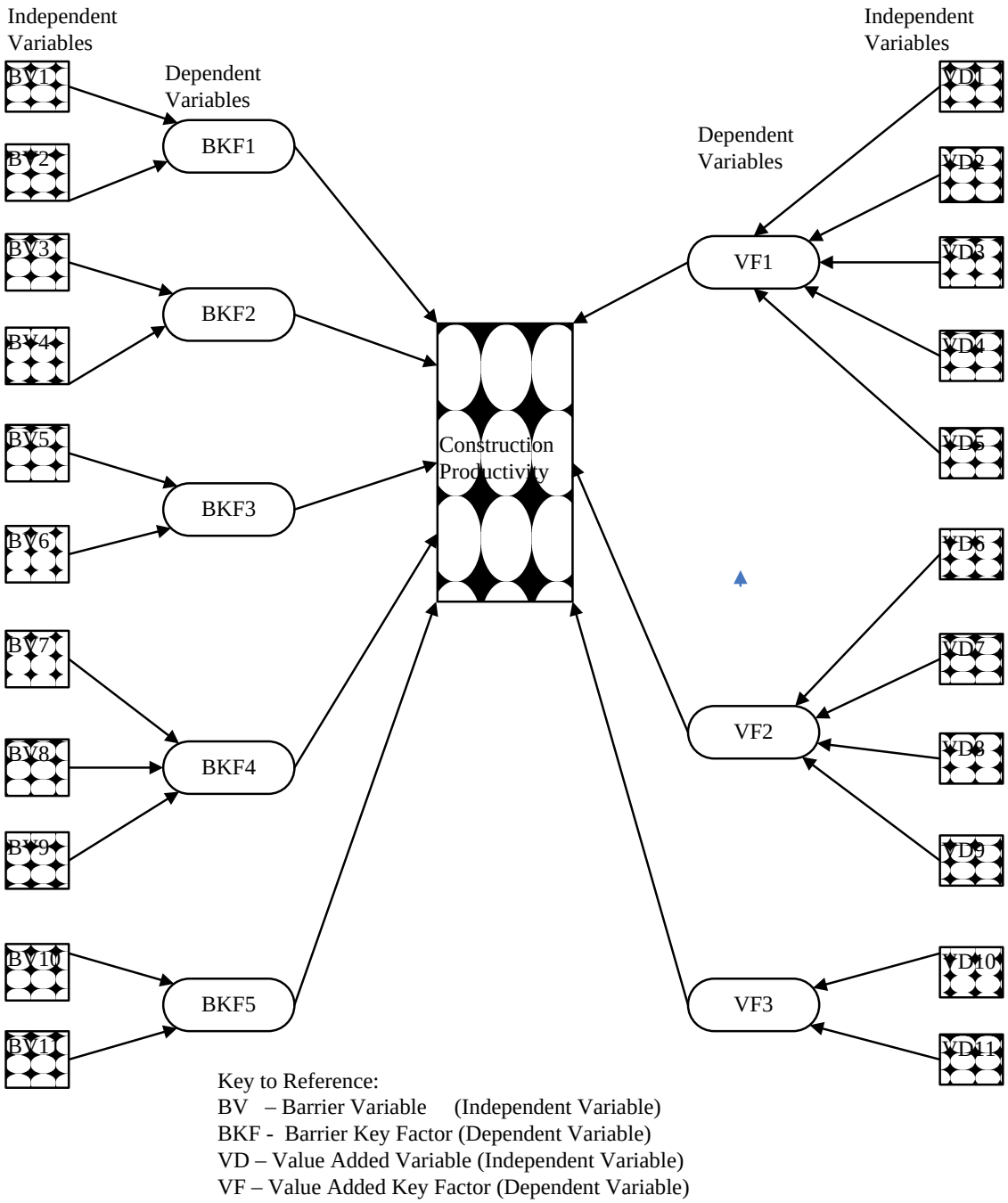

Figure 2.7 – Conceptual Framework of the Research Study

Conceptual framework outlines the connectivity and flow of the variables pertaining to the building construction productivity. Variables appeared under 'Barriers' have been identified as 'Productivity Hindering Factors' while variables under 'ICT Value Added Activities' being identified as 'Productivity Influencing Factors'.

2.7 Differentiation of Variables in Research Study

Sekaran (2000) defines variables as '… anything that can take on differing or varying values. The values can differ at various times for the same object or person, or at the same time for different objects or persons'. Sekaran (2000) further defines that there are four type of variables available.

1. The dependent variable (known as the criterion variable)
2. The independent variable (known as the predictor variable)
3. The moderating variable
4. The intervening variable

As far as concerned the research study, it is important to identify the type of variables that applicable in research instrument – questionnaire. As Sekaran (2000) defines, dependent variable is primary interest to the researcher. The researcher's desire is to understand and describe the dependent variable or to explain its variability. The researcher finally quantifies and measures the variability of dependent variable according to the connected other variables. On the other way, independent variable is basic factor that influences the dependent variable. Therefore if independent variable is present then there should be a dependent variable. Independent variable accounts for the variance of dependent variable. Above definitions can be used to identify the variable types that connected in proposed research work.

As per above criteria, it was identified different type of variables pertaining to the research study. There are two main categories under the research work which impact to the building construction industry. According to the main categories identified variable types and their descriptions are listed. Figure 2.7, conceptual framework of the research study outlines the each and every variable and its connectivity to the other variables. Variable type definition begins from bottom level where basic activities take place.

2.8 Developing Testing Rationale for Variables

At the beginning it was mentioned in the table 2.1 and 2.2 findings of the literature survey which were proposed to use as research key factors. It should be emphasized that some of the variables defined at early stages were omitted and their anticipated indicators were merged to the closely relevant variables. For comprehensive analysis, such decision was taken. As the consequence of merging indicators to the other variables, final two variable set were formed as mentioned in the figure 2-4 as a consequence of literature survey. Then it proceeded to reveal the rationale of found variables and their groupings with intention of testing to prove the significance of their impact in the context of research study.

2.8.1 Testing the ICT implementation barriers in the context of construction productivity:

1. **Factor 1- Finance constraint**

   Finance condition of a construction organization should be sound in order to implement the ICT activities. It is measured through two variables:

   - Narrow profit margins of an organization

- Organizations are not providing sufficient budget for ICT

Each of two variables should be tested to forecast the possibility of being a barrier. As a one unit under Finance constraint, it should be tested for the possibility of being a barrier.

2. **Factor 2 – Government policies and practices**

Under the government policies and practices it is tested the two variables

- Less government support on ICT activities
- Low level of ICT infrastructure development

Each of two variables should be tested to forecast the possibility of being a barrier. As a one unit under Government Policies and practice it should be tested for the possibility of being a barrier.

3. **Factor 3 – Technology deficiency**

There are two variables under Technology deficiency:

- Weaknesses in capturing ICT developments
- Adopting obsolete communication methods

Each of two variables should be tested to forecast the possibility of being a barrier. As a one unit under Technology deficiency it should be tested for possibility of being a barrier.

4. **Factor 4 – Management and administration**

There are three variables under factor 4.

- More paper based documentation process
- Project planning without ICT enabled software
- Limited funds for manpower development in ICT use

Each of three variables should be tested to forecast the possibility of being a barrier. As a one unit under Management and administration it should be tested for possibility of being a barrier.

5. **Factor 5 – Work Force**

   There are two variables under Technology deficiency

   - Scarcity of ICT skills in staff
   - Workforce resistance to accept ICT enabled activities

   Each of two variables should be tested to forecast the possibility of being a barrier. As a one unit under Work Force it should be tested for possibility of being a barrier.

2.8.2 Testing the ICT value added activities in the context of construction productivity:

1. **Factor 1 – Digitized Construction Management**

   There are five variables under the factor digitized construction management

   - Digitized document management process
   - Use of databases for subcontractor management
   - Use of Building Information Modeling (BIM) and Quality information Management (QIM)
   - Use of ICT enabled project network systems
   - Imposing security over accessing data

   Each of five variables should be tested to forecast the possibility of being a value added activity. As a one unit under Digitized construction management it should be tested for possibility of being a value added activity.

2. **Factor 2 – Use of ICT Admin Tools**

   There are four variables under the factor Use of admin tools.

- Use of general purpose software
- Use of 3D-CAD for cost-effective designs
- Project time planning through Micros Tran and MathCAD
- Use of WinQS32, QSCAD, and CATO for Quantity Surveying
- Each of four variables should be tested to forecast the possibility of being a value added activity. As a one unit under Use of ICT Admin Tools it should be tested for possibility of being a value added activity.

3. **Factor 3 – Expert Knowledge Sharing**

There are two variables under factor Expert Knowledge Sharing.

- Knowledge sharing through global networks
- Knowledge Electronic file creation during the project period

Each of two variables should be tested to forecast the possibility of being a value added activity. As a one unit under Expert Knowledge Sharing it should be tested for possibility of being a value added activity.

2.9 Comments to close the chapter literature review

It is worthwhile to mentioned at this stage, it was heavily motivated me to continue the study through this literature survey. As I thought revealing the factors behind the theme is very crucial as well as important to the industry. Further to mention, all factors found through this literature survey are not possible to study extensively. Only the relevant factors that I thought as important were chosen for my study. I feel that remaining factors should fall under separate research study because such factors should be discussed extensively.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Research Method

In this chapter it is discussed the formation of research methods and their evaluation processes according to the comments received in relation to the characteristics of the study. There will be a discussion of the method chosen in our research study. It has been emphasized the checking of reliability and validity of the research instrument.

3.2 Planning Research Methodology

As William (2001) emphasized, in the event of identifying the problem and fixing of research objectives are completed then it is necessary to indicate how the research objectives would be achieved. There may be different ways to approach the research design. However, basic marketing research process which consists of six steps is adopted for the research design. In fact, this process is a general one and it can be used for designing of any research functional area for example finance, marketing and so forth.

(Malhothra and Peterson, 2006). Figure 3.1 outlines the research process as specified by Malhothra and Peterson (2006). In chapter 2, it was developed an approach to the problem identified through literature review. Basically, it includes all required aspects for the research work formulating an analytical framework and model, research questions, hypotheses and information needed.

According to Yin (2003), research design should include five factors, which are

1. study questions
2. its propositions
3. its units of analysis
4. the logic linking the data to propositions and
5. the criteria for interpreting the findings.

As Yin (2003) revealed, we are in the process of presenting the research design, sampling and data collection methods. Based on the collected data we would analyze same in different ways in order to make meaningful conclusions along with the limitations entailed and emphasizing the further research requirements. For the benefit of industry, we hope such processes would be important and meaningful in the context of developing new pathways to achieve the desired industry objectives.

3.3 Formulating the Research Design

Achieving of research objectives there should be a strategy which is enforced by the researcher's desire. The formulated strategy over the achieving research objectives will reflect the researcher's willingness to prove the concept statistically behind the research. In fact, it is a logical approach proving of how the research purpose is co-related with researcher's desire as mentioned by the Eriksson and Wiedersheim (1997) cited from Khoshoie (2005). According to Zikmund (2000), any research work will fall into one of three different categories;

- Exploratory (ambiguous problem)
- Descriptive aware of problem
- Explanatory of casual research (clearly defined problem)

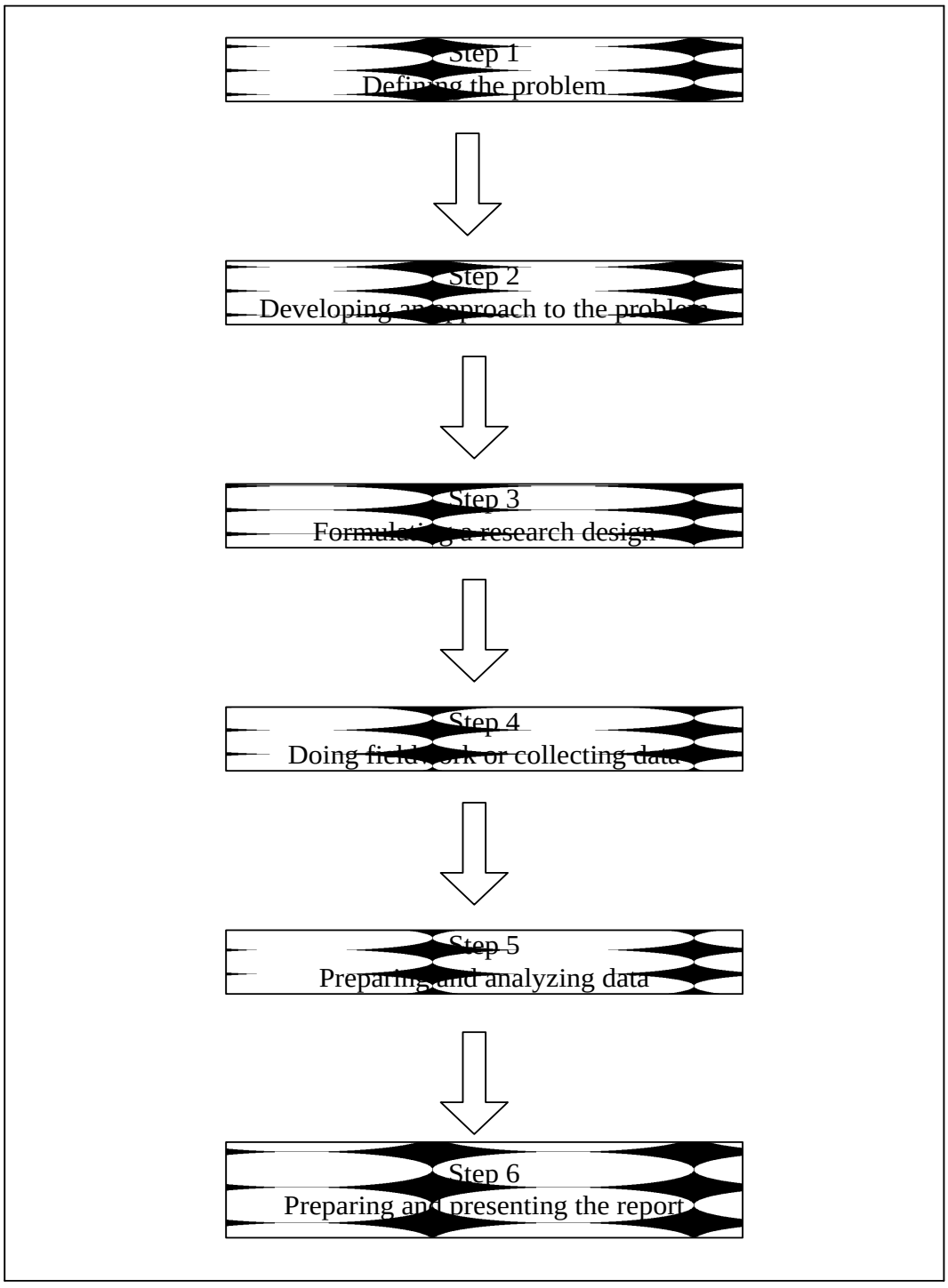

Figure 3.1 - Phases of research process

Source: Basic marketing research, Malhothra and Peterson (2006) as cited by Abadi (2010)

3.3.1 Selecting Appropriate Research Category

As revealed above, according to the previous researches one research category should be selected in order to continue the proposed research work. Therefore it would be more meaningful explaining the each category briefly.

3.3.2 Exploratory Research

If the problem is broad and not specifically defined researchers use exploratory research method as preliminary step considering its flexibility (Gali, 2003). Both Yin (1994) and Khoshoie (2005) have emphasized that an exploratory study should be designed by stating the purpose and criteria to judge exploration successful.

3.3.3 Descriptive Research

If the main objective of the research is to describe something, thereby descriptive research method is used usually market characteristics or functions. According to Malhothra and Peterson (2006) it tries to find answers for the questions in form of who, what, when, where and sometimes how. View of the Zikmund (2000) regarding the descriptive research is done when the research problem is known and but researcher is not fully aware of the situation.

3.3.4 Explanatory Research

If the study aims to explain certain phenomena from variety of perspectives or situations with given set of events, thereby explanatory research method is appropriated (Yin, 1994). ‘Explanatory research is goes beyond description and attempts to explain the reasons for the phenomenon that the descriptive study only observed. In explanatory research, the

researcher should use theories or at least hypotheses which account for the forces that caused a certain phenomenon to occur', (Cooper and Schiendler, 2003).

Table 3.1 Comparison of basic research as Malhotra and Peterson (2006), p.74

	Exploratory	**Descriptive**	**Explanatory**
Objective	Discovery of Ideas and insights	Describe market characteristics or functions	Determine cause and effect relationship
Characteristic	Flexible, versatile	Marked by the prior formulation of specific hypotheses	Manipulation of one or more independent variables
Method	Expert surveys Pilot surveys Secondary data Qualitative research	Secondary data Surveys Panels Observational and other data	Experiments

3.3.5 Appropriating the Relevant Research Category

In chapter 2, under paragraph 2.6 - 'Developing of research model through literature' it was identified the research purpose which emerged as the result of literature review. Fixing of objectives and finding of research question were also based on the reveal of literature. Therefore such factors have paved the way to identify the appropriate research methodology. Accordingly, it implies to select the **explanatory research method** as appropriate one.

3.4 Definition for Research Approach

After defining the research category (3.3 – 3.3.4), it is required to select the appropriate research approach in order to continue the research work. For this purpose there are some previous researches and their opinions for the selecting over appropriate one would be more significant. Potter and Wetherell (1987) defines it as, 'An research approach is a particular kind of perspective on research that is conducted by scholars who are trying to examine a phenomenon, develop insights and report these insights to others. No. of authors (Yin 1993; Holme and Solvang 1991) describe it as, 'in social science there are two types of research approaches to choose for conducting research which are quantitative or qualitative'. It is further emphasized that quantitative research approach is selective and distance to the object while qualitative approach is characterized by proximity to the object of research (Holme and Solvang, 1991; Rasooli, 2005). . Comparing these two approaches, it is difficult to say which one is better because both of these approaches are having their own strengths and weaknesses and neither one of the approaches can be held better than the other (Yin 1994 cited from Rasooli (2005).

3.4.1 Quantitative Research Approach

Quantitative research approach transforms collected data into numbers and amounts for subsequent statistical analysis. Reading of previous researches reveal that quantitative research approaches tend to be more structured and formulized while it is aggressive of making tangible results. Most significant feature of this approach is its ability of characterizes by studying few variables on large number of entities (Holme & Solvang, 1991, cited by Khoshoie, 2005). Quantitative research approach is always intensively associated

with natural science mode of research; where data are quantifiable and obtained from samples and observations looking for relationships (Tull and Hawkins, 1990, cited by Roosli, 2005).

3.4.2 Qualitative Research Approach

Goal of the Qualitative research approach is to get the better understanding of the phenomenon being studied; they also tend to be relatively more flexible under this approach where researcher tries to isolate more specific things in order to create more complete understanding about the situation (Yin, 1994). Qualitative research is the search for knowledge which is subject to investigate, interpret and understand the phenomena by the means of an inside perspective (Rasooli, 2005). Unlike the quantitative approach, characteristics of qualitative research approach are largely based on researcher's own description, emption as well as reactions. Further it is the closeness to the respondent or to the source from which data are collected (Holme and Solvang, 1991, cited by Khoshoie, 2005). As discussed above differences of these two approaches are outlined as in the following 3.2 table.

3.4.3 Selecting the Appropriate Research Approach

In our research study it is focused to reveal the perception of industry people in the context of information and communication technology factors and how they affect to building construction industry in Sri Lanka. Therefore it is required to gather ideas from industry people in order to quantify the collected ideas and generalizing same in meaningful manner based on the sample data. Process consists of structured approach and data analysis would be

in statistical form. As outlined in above table 3.2, conforming to Malhotra and Peterson (2006, p.151) our research work falls into the **quantitative approach.**

Table 3.2 Qualitative vs. quantitative research

	Qualitative Research	**Quantitative Research**
Objective	To gain a qualitative understanding of the underlying reasons and motivations	To quantify the data and generalize the results from sample to the population of interest
Sample	Small no of non representative cases	Large no of representative cases
Data Collection	Unstructured	Structured
Data Analysis	Non statistical	Statistical
Outcome	Develop a richer understanding	Recommend final cause of action

Source - Malhotra and Peterson, 2006, p. 151

3.5 Orientation of the Research Problem

As Turbun et al. (2008) mentioned, most ventures are struggling to survive in the environment they exist because of the rapid development of the technology. Day by day technologies are updated; accordingly businesses are compelled to align with technological developments. On such situations they have to confront a survival problem unless otherwise they are not getting the competitive advantage of available technological advancements. Building construction industry is also in same process because it is required to increase the productivity in terms of cost, time and quality. In this context, ICT will play an important role that giving through its tools, practices and applications. Though such factors are

efficiently utilized in international arena at present, in Sri Lanka construction industry context it is still hindering the utilization of ICT to improve the productivity (Dimuth and Navaratne, 2006). Having seen the situation, it was compelled to take an insight view of the problem concerned.

3.5.1 Motivation on Research Area

Having identified the problem area and subsequent literature survey it was given a strong impression of conducting the study. In order to get it influenced, no of discussions were held with industry people whether the study area is important. Outcomes of the discussions were outstanding and favourable in achieving the study goals. After giving the basic awareness regarding the matter concerned they appeared as positive towards the research and emphasized necessity of having such study in Sri Lanka context. Identified key personnel were selected and held discussions for their opinions. Such discussions were held as pre-requirement of the research before preparing the survey instrument. Concept behind the negotiations was to get the impact of their feelings whether such study is worth full or not.

3.6 Approach to Prepare the Data Collection Instrument

Before preparing the data collection instrument it is important to go through some important concepts which are adopting various approaches to be intact with data collection function. Therefore background reading of previous studies should be taken into consideration. According to Yin (2003), six sources have been identified as data collection means. He further defined the sources as, documentation, archival records, interviews, direct observations, participant observation and physical artifacts. Table 3.3 outlines the selection criteria of appropriate data collection instrument.

Table 3.3 – Data Collection Sources as cited in Yin (2003)

Source of Evidence	**Description**
Documentation	Variety of documents can be used. For example, statistics, registrations, official publications, letters, news papers, journal publications, and barouches. Documents are mostly used for secondary data.
Archival Records	These are the types of organizational records, service records, maps and charts etc. Archival records are used in computerized form and as in secondary data
Interviews	Interviews are open-ended in nature where key respondents are interrogated for facts of matters as well as for important opinions. Otherwise interview will be a focused-interview for short time period. Moreover the interview can entail more structured questions, along the time of a format survey.
Direct Observation	This includes the observation of meetings, sidewalk activities, factory work and class room work etc. Observational evidence is often useful in providing additional information for the topic of the research study concerned. More than one observer can be used to focus the same event at same time for reliability of the observation.
Participant Observation	It is special mode of observation where observer dose not act as in passive mode. Observer himself takes the variety of roles within the case study situation
Physical Artifacts	It is physical or cultural artifact, a technological device, tool or instrument or some other physical evidence. It has been used extensively in anthropological research

It should be assured whether the data is to be collected from a person of an organization or directly from organization. If Data is collected on individual basis focusing a particular person then interview is the best method and if data is collected on organizational basis thereby questionnaire method is appropriate (Yin, 2003). According to Sekaran (2000) collected data can be further grouped into two categories as primary data and secondary data. In collecting primary data purpose of researcher's specific and respondent's specific ideas on specific issues are sought while secondary data collection is on the intention of getting already collected data by some other party for the research purpose (Khoshoie, 2005).

Considering the facts revealed above, pertaining to the previous studies and nature of the research, both focused interviews and questionnaire method were selected. Focus interviews were conducted with industry experts with intention of preparing and tuning the questionnaire (on personal basis) and questionnaire survey was used to collect industry data at industry level (organizational basis).

3.6.1 Conducting Focused Interviews with Industry Experts

As the first step, basic structure of the questionnaire was prepared according to the facts revealed under chapter 2 – section 2.6. Structure of the initial questionnaire comprises of following sections

- Section 1 - Organizational data
- Section 2 - Variables/Key areas/Barriers
- Section 3 - Variables/Key areas/ICT value add activity

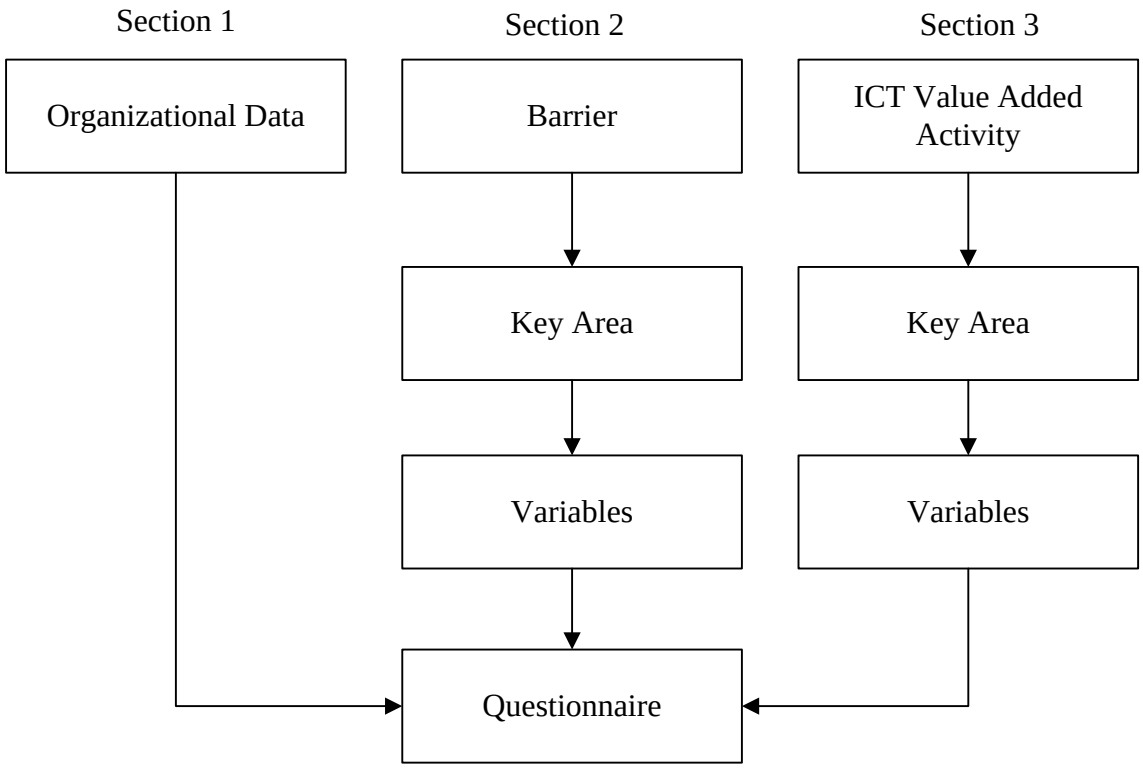

Figure 3.2 – Flow diagram of the initial questionnaire

After formulation of the initial questionnaire then it was presented to the industry experts in the relevant filed. While selecting the Experts, following facts were taken into consideration:

- Having extensive industry experience
- Holding a senior position relevant to the field
- Presently engage in the industry
- Professionally qualified (having Charted Status or above)
- High ICT use in their organizations for construction

As per the criteria, following personnel were selected

1. One Senior Lecturer attached to the Department of Building Economics, University of Moratuwa, Sri Lanka

- Having excellent theoretical background and more research experience pertaining to the proposed research area.

2. One Deputy General Manager from State Engineering Corporation of Sri Lanka
   - Having very good theoretical background and handful experience in industry
3. One Deputy General Manager from State Development & Construction Corporation
   - Having very good theoretical background and handful experience in industry
4. One Deputy General Manager from Access Eng. (Pvt) Ltd.
   - Having very good theoretical background and handful experience in industry

Appointments made in advance with above Experts, I got opportunities to meet and discuss the matters pertaining to research questionnaire. The initial questionnaire prepared as in figure 3.2 was taken into consideration. In fact, such discussions were held in form of focused interviews whereby I had to get some points cleared and acquiring their precious views and ideas in relate to my questionnaire. All of their views are almost same and their tendency over my questionnaire was positive in respect to the manner in which I presented. However, most outstanding change they requested was to keep the questionnaire as far as in logical manner because presenting of findings should be in logical form. That is to minimize the contradictions among questions presenting for the response.

Outcomes of the focused interviews are as follows:

1. All of them emphasized to include the ICT value added activities as resolving activities against the said barriers.
2. Merge some variables where same meaning is implying
3. Less no questions to be presented
4. Tune some questions to be more meaningful
5. Insist the necessity of measuring reliability and validity of the questions through a pilot run
6. Guide line for selecting the sample
7. To collect data, ICTAD registration to be followed
8. Selecting of the target group for filling the questionnaire

3.6.2 Adjusting the Questionnaire to Match the Outcomes

All other remaining functions pertaining to research methodology were organized as per the outcomes of focused interview. Therefore all outcomes were considered before finalizing the final version of the questionnaire.

1. All necessary ICT value added activities were included to the questionnaire.
2. Some questions were merge into one variable, and some variables were taken into same key factor in order to increase the understanding
3. As consequently with no. 2 action, no in questionnaire were reduced
4. Modified some variable names to be more meaningful. Further to mention that indicated key factors were removed from the questionnaire because respondent's point of view key areas are not important. After the data

collection, in accordance with sequence of questions it is possible to group data under relevant key factor for data analysis**.** ***Remaining outcome factors (5 -8) are discussed separately*****.**

After removal of Key Factors Questionnaire model is as follows.

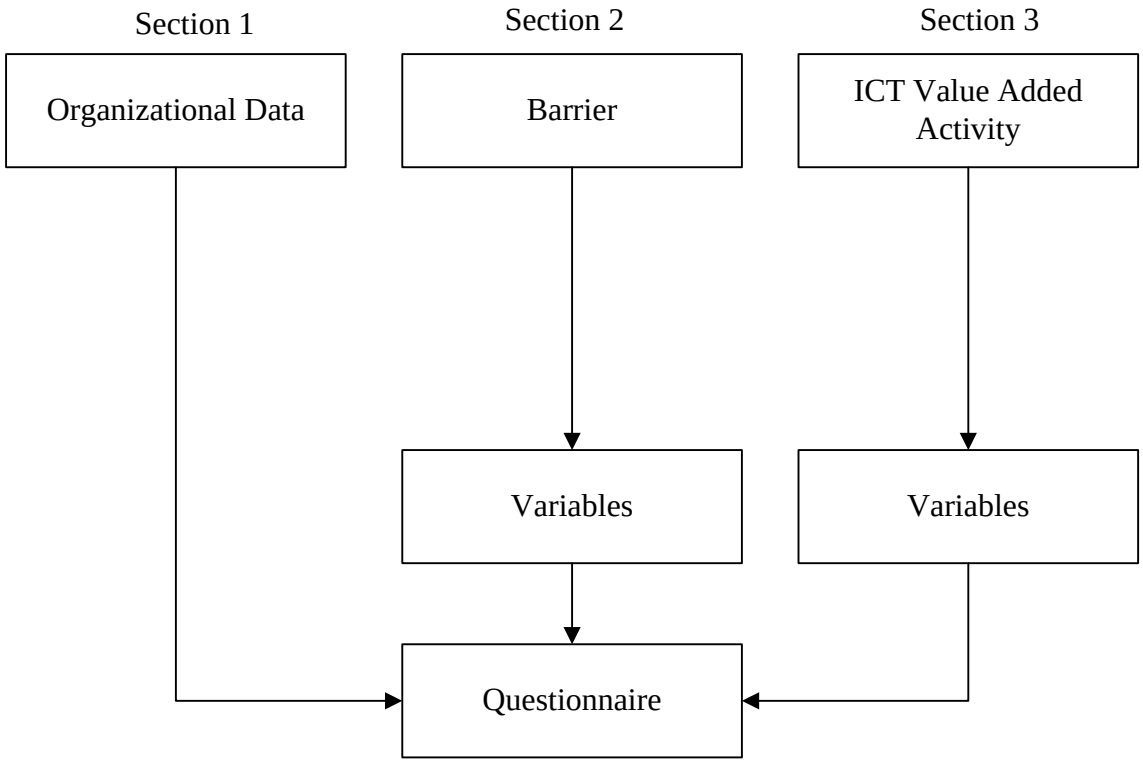

Figure 3.2 – Flow diagram of the adjusted questionnaire

3.6.3 Structure of the Survey Instrument - Questionnaire

As per the expert view the questionnaire was restructured in order to meet the changes effectively. After making changes structure of the questionnaire appeared as follows

Section 1:

Section 1 of the questionnaire comprises of organizational and personal data relevant to respondent and organization which is being considered under survey. Question no. 1 & 2 and 5 are reserved for organizational data background data, indicating organization's name,

ICTAD classified grade under the specialty area of building construction and company experience in the building construction industry. Questions 3 - 5 reflect the personal data pertaining to respondent.

Question 3 - Qualification level of the respondent
Question 4 - Age of the respondent
Question 5 - Experience in building construction industry

Section 2:

Questions 7 – 17 are included in section 2 for the variables identified under category barrier. It is due to cross/mark the appropriate alternative answer within the range of 1 – 5 that prepared according to the Likert scale as mentioned below.

1 - Strongly Disagree
2 - Disagree
3 - Moderate
4 - Agree
5 - Strongly Agree

Section 3:

Questions 18 – 28 are included in section 3 for the variables identified under category ICT value added activities. It is also due to cross/mark the appropriate alternative answer within the range of 1 – 5 that prepared according to the Likert scale as mentioned below.

1 - Not Effective at All
2 - Not Effective
3 - Moderate
4 - Effective
5 - Very Effective

Intention of having three sections in the questionnaire is to make facility for easy analyzing of the responds received from participant. Under the 'General getup' concept it was concentrated to make the amendments for

- **Appearance of the questionnaire**

  It was designed to have a pleasant and elegant appearance.
- **Length of the questionnaire**

  Length of the questionnaire was limited to only two and half a page.
- **Introduction to respondents**

  At the beginning it was made an short introduction for the purpose of questionnaire
- **Instructions to completion**.

  Each section is carrying instructions for the perfection of relevant sections.

3.7 Conducting Pilot Run

One set of critical expert view was conducted before proceeding to the pilot run to assure a firm data collection procedure. Due adjustments to the survey instrument were revealed by the pilot run before proceeding to actual data collection. According to the implications received from pilot run it was able to adjust the data collection procedure, nature of the questionnaire, respondents' attitude towards the research and finally checking reliability and validity of the survey instrument etc. Reliability and validity of data received through survey instrument should be precious in order to get the real feedback from respondents at latter stage.

Adjusted questionnaire under section 3.5.3 was used for pilot run. A strategy was developed in relation to the pilot run which was expected to perform with high degree of reliability and validly. Twenty no. of participants were selected from both public and private sector building construction contractors (belong to ICTAD grade C1, C2 and C3) and each group comprised of ten participants. All participants are directly connected with industry and belong to the categories of Project Director/Project Manager/Project Engineer. Hand delivery system was

used to distribute the questionnaire after briefing required purpose of the study. Researcher personally attended to the data collection and after some time it was collected with short notice. Since the survey was personally handled one, it was positively responded by the participants.

Table 3.4 – Participants' Details of Pilot Run

Group	Description	No of Questionnaires Delivered	No. of Responded
A	Public Sector	10	09
B	Private Sector	10	07

As has been delivered questionnaire manually, it was decided to collect the perfected questionnaires also manually expecting the high return rate. However under unavailability of the persons at the time collecting questionnaires, 03 nos. were missing – one from public sector and 02 from private sector organizations. All the participants are project personnel and belonging to the category of Project Director/Project Engineer. However it was encountered some problem of collecting data because of their busy schedules. Some participants called for clarifications on certain issues and finally it was cleared. It was gained some important perceptions while it was conducting the pilot run before proceeding to actual data collection.

1. Participants are highly motivated if desired person is close to the participant
2. They considered the filling of questionnaire is honored gesture to the selected category concerned
3. How make it pleasure to work with bunch of Professionals because they did the requested function enthusiastically.

4. It was noticed that private sector project personnel are extremely busy compare to the public sector since they are covering all functionalities pertaining to the construction project.

Experience gained through pilot run for prospective data collection:

1. It should be given impression to the participants that researcher is closely monitoring the activity and available to clarify any matter regarding the filling of questionnaire at any time.
2. Making due respect to the participants because target group is highly qualified experienced professionals in industry.
3. They are very understandable in the context of research works.
4. Researcher should adjust to work with extremely busy participants as far as getting the work done.

It is important to explore the underlie theories behind the pilot run and its implications on research work. The main objective of the pilot run is to check the stability and consistency of the research work and assure the reliability and validity of survey instrument. According to the perception in the problem context and attitude of the respondent, the questionnaire is marked or crossed appropriate number appeared in likert scale. Through the pilot run it is required to verify that survey instrument is accurately measuring the variable, accordingly concept behind the variable is accurately being measured. Preciously developed instruments are giving better and accurate results and will ensure the quality of the research. Therefore it is significant to make sure that the survey instrument developed for the research indeed measures the variables as required by the researcher. In fact it gives the ‘goodness’ of the measures.

3.7.1 Theories behind the Reliability and Validity

It is worthwhile at this stage to review the theoretical background as Sekaran (2000) describes in the context of above two aspects. Regarding to a measure, reliability indicates consistent measurement across time and across the various items in the instrument without bias. In fact, reliability is an indication for measure's stability and consistency of the instrument measures the variables with the 'goodness' of the measure. Sekaran (2000) also defines the **validity** of the measuring instrument as, '… when we ask a set of questions (i.e. develop a measuring instrument) with the hope that we are tapping the concept, how can we reasonably certain that we are indeed measuring the concept we set out to do and not something else'.

3.7.2 Conducting Reliability Test

Conducting the reliability test is based on the pilot run which was organized with intention of setting the test environment. It was selected ***inter-item consistency reliability*** test for above aspect. In fact, this is a consistency test over the respondents' answers against the questionnaire's alternative options. The most popular "Cronbach's Coefficient Alpha' (Cronbach, 1951) which is used for multi-point scale items was selected as the appropriate one. Alpha coefficient ranges in value from 0 to 1 and may be used to describe the reliability of factors extracted from multi-point formatted questionnaires or scales (Reynaldo and Santos, 1999). Nunnaly **(1978) has indicated 0.7 to be an acceptable reliability coefficient** but lower thresholds are sometimes used in the literature. Hatcher (1994) comments on the Cronbach's Alpha: an Index of Reliability as, 'If you were giving an evaluation survey, would it not be nice to know that the instrument you are using will always elicit consistent

and reliable response even if questions were replaced with other similar questions? When you have a variable generated from such a set of questions that return a stable response, then your variable is said to be reliable. Cronbach's alpha is an index of reliability associated with the variation accounted for by the true score of the "underlying construct." Construct is the hypothetical variable that is being measured'. To explain the Cronbach's coefficient it is required to assess the degree of internal consistency among a set of independent variables that grouped under relevant dependent variables. However, questions from 01 to 06 were omitted from the reliability test since the set belongs to the personal and organizational data and coefficient is not expected from that section. Table 3.5 outlines the Cronbatch's Alpha values under reliability test for selected Group A and Group B.

Table 3.5 – Achieved Alpha Values by Group A and Group B

Question Nos.	**Dependent Variable**	**No. of Test Items**	**Alpha Value Group A**	**Alpha Value Group B**
07,08	Finance Constraint	02	0.825	0.813
09,10	Government Policies and Practices	02	0.783	0.804
11,12	Inadequate Technology Adaptation	02	0.802	0.796
13,14,15	Poor Construction Management and Administration	03	0.801	0.789
16,17	Workforce Resistance	02	0.792	0.788
18,19,20,21,22	Digitized Construction Management	05	0.821	0.803
23,24,25,26	Use of ICT Admin Tools	04	0.851	0.864
27,28	Expert Knowledge Sharing	02	0.831	0.879

As per Nunnaly (1978), calculated alpha value for each dependent variable should be more than 0.7. Accordingly Group A and Group B fulfill the requirement. Therefore it can be assured that reliability of the questionnaire instrument conforms to the standard.

3.7.3 Ascertaining the Validity Measurement

Under validity test it should be assured that we are measuring the concept that we have set out to do and respondent's reaction is same as that we expect. Therefore it is meaningful to select two different groups for validity test and to monitor their responding pattern for each variable. According to the table 3.5, there is no similarity between Group A and Group B in respect to the responding for questions. It is noticeable that there is no exact matching between same variables under different group testing. However difference is marginal and it is within acceptable margin. It implies that although they are equally sensitive for the problem concerned, their attitudes are differing from each other. Accordingly, it can be assured that measuring concept is valid for both groups. Outcome of the test can be generalized that validity of the questionnaire instrument is giving the 'goodness' of measurement.

3.8 Selecting of Data Collection Source

As guidance given by the Experts, ICTAD contractor registration for year 2010 was taken into account. As per the selected theoretical framework mentioned in section 2.6 same procedure has been followed. ICTAD contractor registration is annually updated and categorized the contractors according to their financial limits and considering the performances in previous years. All the information pertaining to contractor context is

included in this register. One objective of the ICTAD is to monitor the contractors' performance.

3.9 Selecting Target Group for Filling Questionnaire

Persons filling the questionnaire should have sound understanding of the matters concerned in questionnaire. If they are not aware of one side of the matter then there will be a problem of getting real perception of the questions. In fact, this questionnaire is dual purpose through which it is expected that respondents are having knowledge pertaining to both factors: construction productivity and impact of ICT. Industry Expert also emphasized that ***Project Directors***, ***Project Managers and Project Engineers*** are ideal persons to fill the questionnaire. They are in balance position in between the technology and construction with ambition of hoping to increase productivity. According to the theoretical framework selected, there is another constraint prevails that Contractors those who are not having high financial limits in their businesses are not capable of filling this questionnaire because of the limited ICT use in respective businesses.

3.10 Sample Selection Procedure

Sample selection is also a reflection of literature how the previous studies have conducted such things in logical manner. There should be a logical approach and a rationale behind the matter that sample selection is to be fair enough to accept the procedure without any hesitation. In fact, sample should represent the all properties of the population without any doubt. According to Sekaran (2000), selecting a sub set of a population is called sampling. It is to collect sufficient no of elements within a population. Sekaran (2000) further reveals that there are two types of sampling: probability sampling and non-probability sampling. In

probability sampling, there is an opportunity/chance for every element of the population being selected and non-probability sampling there is no such predetermined opportunity for being selected as object in the sample. Non-probability sampling method is used in instances where data collection is more expensive (Khoshoie, 2005). Why sample selection is so important? It is a natural question that every one is concerned in the sample selection. In fact, in the context of research study, the sample selection is crucial because based on the sample evidence through test statistics some properties are generalized for whole population. Therefore incorrect sample selection will cause to produce inaccurate decisions based on sample test results. Under section 3.6 it was discussed the selection of data source relevant to my research study. In fact, ICTAD annual contract registration is the most reliable data source available at present in Sri Lanka. All contractors are due to register annually in accordance with their financial ability. All particulars pertaining contractors have been included in the contractor registration. Financial limit of a contract and corresponding grades listed in table 3.4.

For any contract concerned, all contractors should act within their financial limits. For example, contractor belongs to lower financial limit is not allowed to bid for high range contracts. In fact, this is a pre-qualify method of contractors which is carried out by ICTAD on behalf of the government with the intention of resolving contract conflicts. According to the scale, contractors are grouped into three distinct categories as mentioned in above 3.4 table. Three different scalar categories are large, medium and small depending on their financial limits. Previous contractor grades comprise of ‘M’ code but it has been amended in 2009/2010 registration as ‘C’. Part of a M3 has been merged to new category ‘C4’ and rest of

the M3 has been recognized as ‘C3’. On this point onward it is recognized the ‘C’ code in the research study in place of old ‘M’ codes.

Table 3.4 – Contractor Grading List

Scale	**Contractor Grade**	**Financial Limit (Rs. Million)**	**No. of Contractors**
Small	C10	$1.0 \geq X \geq 0.5$	30
Small	C9	$2.0 \geq X > 1.0$	91
Small	C8	$5.0 \geq X > 2.0$	253
Small	C7	$10.0 \geq X > 5.0$	1008
Medium	C6	$25.0 \geq X > 10.0$	350
Medium	C5	$50.0 \geq X > 25.0$	182
Medium	C4	$100.0 \geq X > 50.0$	120
Large	C3	$300.0 \geq X > 100.0$	53
Large	C2	$600.0 \geq X > 300.0$	31
Large	C1	$X \geq 600$	33
		Total for C1 to C10	2151

Source - ICTAD Contractor Registration, (2009/2010, pp. 20-78)

3.10.1 Specialized Areas of Contracts

Some distinct specialized areas in contracts have been recognized by the ICTAD for bidding purpose. Accordingly particular contractor can bid for any prospective contract if that specialized area is under purview and bid amount is within his pre-defined financial limit. Therefore it should be considered two factors before bidding for any contract, if that contract area has been approved and bid amount is within his approved financial limit.

For an example, following case is mentioned below.

ICTAD REG/No – 121; Business Name: - Nawaloka Construction Company Ltd.

Table 3.5 – Example for Contractor Specialized Areas and Relevant Grades

Specialty	Grade	Valid Upto
Building Construction	C1	12/06/2010
Highway Construction	C1	12/06/2010
Bridge Construction	C2	12/06/2010
Irrigation & Land Drain	C3	12/06/2010
Water Supply & Drainage	C5	12/06/2010
Dredging & Reclamation	C5	12/06/2010

Source – ICTAD Contractor Registration (2009/2010)

According to the table 3.5, it reveals how contractors are graded against the specialty of construction areas. No of construction categories have been identified by the ICTAD and accordingly same contractor is categorized into different grades as considering their performance in that particular specialty. Therefore one contractor belongs to C1 under building construction specialty, may fall into 'C3' under irrigation construction specialty.

3.10.2 Justification for Sample Selection

As mentioned in the section 3.5.1, under 'Conducting Focused Interviews with Industry Experts' valuable instructions and guide lines were received from Industry Experts in order to select the appropriate sample. At the focused interview one of my questions was 'What criteria should I adopt to select the sample for such research study'? Without any hesitation, they emphasized to have large scale grades C1, C2 and C3 to be selected as sample. There was an important rationale behind their argument that upper grades are consisting of high productivity concerned contractors and they are presently utilizing modern technology aspects for their businesses effectively. Therefore it is:

- Easily measurable the ICT use
- Knowledgeable for their use
- High funding ability for such events
- Existing in large scale grade.

Theoretical framework in section 2.6 and its sample selection is also enforced by the above expert view therefore adoption of sample selection for present study can be justified on that directive. It should be impressed again that the present study has followed same theoretical background and research model because the research has been conducted over Sri Lanka construction industry with the view of 'Identifying challenges and motivations faced by Sri Lanka construction industry'. For the sample selection and justification it has mentioned following criteria:

- Intention of the study is to elicit the knowledge of specialist contractors
- Sample is to be selected from ICTAD registered large scale contractors - C1, C2 and C3 belong to the building construction industry
- Except C1, C2, and C3 other contractors pertaining to building construction were dropped due to vacuum in knowledge extraction. Most of them are subcontractors and they work under the purview of C1, C2 and C3.
- At national level, mostly high productivity is expected from upper three grades
- High financial limits are only allowed to the large scale by ICTAD
- Presently high ICT activities have been utilized

Since the same research model and methodology is followed, it was decided to select the C1, C2 and C3 grades from ICTAD registration pertaining to the specialty area – building construction as the sample.

3.11 Actual Data Collection

Previous section 3.9 was dedicated to describe the sample selection and to identify the elements pertaining to the sample. As per the justification for sample selection under section 3.9.2, contractors in grade C1, C2 and C3 were selected for data collection. Validated and reliability checked survey instrument – questionnaire was available at this stage. Before proceeding actual data collection, all the particulars pertaining to C1, C2 and C3 contractors belongs to the specialty area – building construction were extracted from the ICTAD 2009/2010 directory.

Table 3.4 – Contractor Grading List for Building Contractors

Contractor Grade	**Financial Limit (Rs. Million)**	**No. of Contractors**
C3	$300.0 \geq X > 100.0$	25
C2	$600.0 \geq X > 300.0$	25
C1	$X \geq 600$	19
	Total for C1 to C3	69

Source - ICTAD Contractor Registration, (2009/2010, pp. 20-78)

Procedure of data collection comprised with following steps.

1. Prepared the listing of contractors belong to the grades of C1, C2 and C3 in building construction specialty.
2. As per the contact details mentioned in the ICTAD directory questionnaires were posted to all 69 contractors as identified in the grade of C1, C2 and C3 pertaining to building construction. Covering letter was attached to the questionnaire requesting the target person and mentioning the return date. All the available

communication mediums (telephone, fax, email and cellular phones were also used to convey the message).

3. As far as possible and availability of opportunity it was made an effort to establish a connection with contact person and accordingly with target person. Purpose of this approach was to influence the target person in filling and returning the questionnaire as soon as possible.
4. Clarifications were made as requested by the participants.

3.11.1 Receiving of Filled Questionnaires

Respondents used different ways to return the perfected questionnaires

1. Some of them returned the questionnaire by post
2. Part of the participants used e-mail (As mentioned in the covering letter)
3. Through fax (As mentioned in the covering letter)
4. Manual collection as informed

Table 3.5 – Responding details of participants

Contractor Grade	**Dispatch Nos.**	**Received Nos.**	**Removed Nos. (Incomplete)**	**Actual Figure**
C1	25	19	0	19
C2	25	17	1	16
C3	19	13	2	11
Total		49	3	**46**

Three questionnaires were omitted due to incompletion of filling and accordingly acceptable received questionnaires, 46 were taken to further analysis under chapter 4.

3.12 Verifications and Validations for Questionnaire Data

After receiving data, it is required to convert the paper based data into magnetic form (form of soft copy) on which the analysis of further works are to be carried out. Following steps are included in the preparation of data and input procedure.

1. **Questionnaires were classified according to the ICTAD grade**.

   C1 - 19

   C2 - 16

   C3 - 11

2. **Assigned the serial no in sequential order starting from C1.**

   C1 → 01 – 19

   C2 → 20 – 35

   C3 → 36 – 46

3. **Organizing for data entry in worksheet – Excel (Microsoft Office Package)**

   Organization/Company name is not relevant for data entry except references. Therefore Question No. 1 is removed from data entry.

   Put the labels for column headers starting from Q2 to Q28 sequentially in respect to the Nos. in questionnaire.

4. **Data entry section 1**

   Q2 is entered as in the worksheet

   Q3, Qualification level is numbered from 1 to 5

   Appropriate no is entered to the Q3. In worksheet every cell in the column is restricted (cell no 01 – 47) to the entry of no in 1-6 range

   Q4 is also entered in numerical for range in 1-4

   Q5 is to be entered in numerically range of 1-5

   Q6 is to be entered in range 1-4 numerically

   All cells are formatted to restrict the input of irrelevant data, out of bound values

5. **Data entry for section 2**

   There are 11 questions have been included in the section 2. All answers are in Likert scale format from 1 to 5. There for Q7 – Q17 are to be entered in numerical form 1- 5 subject to the restriction range 1-5.

6. **Data entry for section 3**

   Procedure is as same as above in respect to the cell range Q18 – Q28

   Nos. entry restriction is also as above range from 1-5

   According to the restriction imposed under data entry it can be assured that out of bound values are not entered into the worksheet. But there is another problem that although out of bounds values are not entered, in bound incorrect values are possible to be entered. As the remedy, it is decided to re-enter the data by another person and secondly data are subject to verify in hardcopy format against the entered values. Accordingly all error prone activities have been minimized and validity and accuracy of data were assured.

3.13 Summary of the Chapter Three

Under the research design, it was outlined the research methodology relevant to this research work. Sampling procedure has been explained while justifying the methodology as per the selected research theory. Relevant theories behind the every concept were mentioned in order to make a logical approach. Reliability and validity of the survey instrument was proved as per the previous researches and form of questionnaire, expert views and pilot runs also included in the chapter. Therefore next step is to proceed to the chapter 4 for further analysis of data and producing of results.

CHAPTER 4
RESEARCH DATA ANALYSIS & RESULTS

4.1 Research Data Analysis & Results

As mentioned in the chapter 3 under Research Methodology' it was mentioned the way of achieving the objectives specified. After conducting the filed work, data were collected and converted into magnetic format assuring the accuracy and validity. In this chapter, it is presented the results of analysis and findings pertaining to the collected data.

4.2 Measures of the Analysis

In the context of analysis, it is worthwhile to examine the theoretical background of the research, validated by previous researches. Accordingly, it can be assured the reliability of the analysis and findings because same methodologies have been carried in preceding researches. While forming the theoretical background for the research concerned, it was based on the selected theoretical research model as described in section 2.6 in the context of identifying 'challenges and motivators faced by Sri Lanka construction industry'. Since the same theoretical framework has been adapted for my research, analytical approach should also be same. After collecting data from the representative sample, the next step is to analyze the data in order to test the research hypotheses. However before the analysis is done there are some prerequisites to be carried out in order to assure the correctness and accuracy of the analysis concerned. It further reveals that data are reasonably good for the analysis. As Sekaran (2000) defines these measures are:

1. Getting data for analysis
2. Getting a feel for the data
3. Testing the goodness of data
4. Testing the hypotheses.

As for the concern of above four actions, 1, 2 and 3 have been fulfilled under chapter 3, section 3.11, 'Verification and Validation for Questionnaire Data'. Therefore theoretical approach for above 1, 2 and 3 has been completed and option 4 is to be carried out under chapter 4 – data analysis.

4.3 Research Data Analysis

In preceding chapters, it was formulated and designed the background work for the research and carried out the functional areas like data collection, cleaning of data, validations and verifications etc. in order to assure the smooth flow off the study. It has now approached to the area of data analysis which is to be carried out more preciously. It should be emphasized that precision of the analyses is very important because outcomes of the analyses will be crucial factors in the context of forecasting the properties of population. In this study, it is due to perform two types of analysis that descriptive analysis and inferential analysis. For the software based analysis, it is used 'Statistical Package for Social Science' (SPSS) version 13.0.

4.4 Descriptive Analysis of Organizational Data

There are 06 questions pertaining to the organizational and personal data in questionnaire under section 1, from question number 1 to 6. For the analysis point of view, there is no impact of the question 1; accordingly it is removed from the further analysis. As the first question number 2 is considered under descriptive analysis.

4.4.1 Responded Contractor Details

Table 4.1 – Contractors' Responding Analysis

Contractor Grade	Responded Nos.	Responded/ Total %
C1	19	41.3
C2	16	34.8
C3	11	23.9
Total	46	

Altogether 46 have responded to the survey, filling and returning the questionnaire. 19 contractors from grade C1, 16 contractors from grade C2 and 11 contractors from grade C3 have responded. Pictorial form of the responded details is as following figure 4.2.

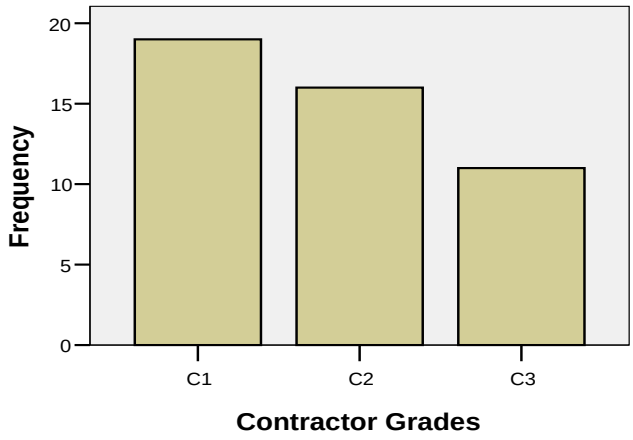

Figure 4.1 – Contractor Response Details

4.4.2 Responders Qualification Levels

Question Number 3 under section 1 of the questionnaire carries the particulars pertaining to the qualification levels of the respondents. Table 4.2 and Figure 4.2 present the details as follows.

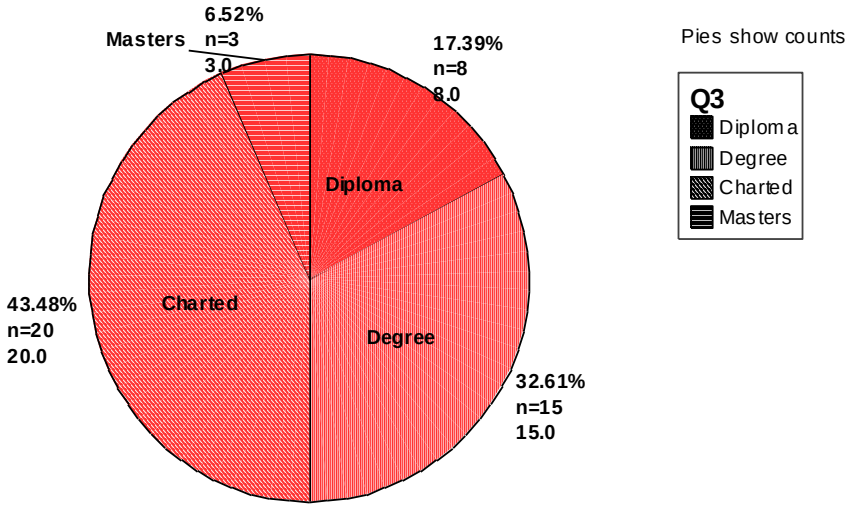

Figure 4.2 – Pictorial Form of Qualification Level of Respondents

Table 4.2 – Qualification Levels of the Respondents

Category	Frequency	%
Diploma	8	17.4
Degree	15	32.6
Charted	20	43.5
Masters	3	6.5
Total	46	100.0

According to the table 4.2 43.5% personnel hold the charted status and only 17.4% are holding diploma level qualifications. As per the qualification level 82.6% are holding degree or above degree qualification levels from the total respondents.

4.4.3 Age Analysis of Respondents

Question number 4 under section 1 of the questionnaire holds the age particulars of the respondents. Figure 4.3 and Table 4.3 present the details as follows.

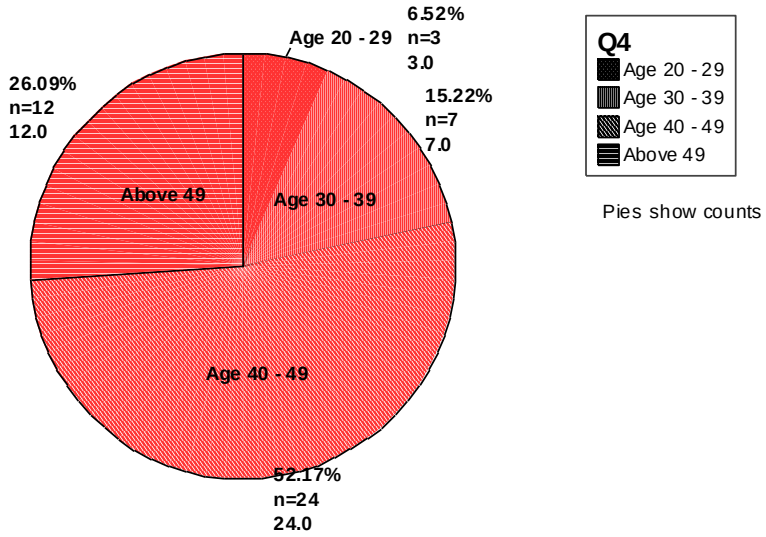

Figure 4.3 – Pictorial Form of the Respondents' Age

Table 4.3 – Respondents' Age Analysis

Range	Frequency	Percent	Cumulative Percent
Age 20 - 29	3	6.5	6.5
Age 30 - 39	7	15.2	21.7
Age 40 - 49	24	52.2	73.9
Above 49	12	26.1	100.0
Total	46	100.0	

As per the table 4.3 highest no. of respondents are representing the 40 – 49 age group that of 52.2% of the total no. of respondents.

4.4.4 Respondents' Experience Analysis

Question number 5 holds the particulars pertaining to the respondents experience in the relevant industry. Figure 4.4 and Table 4.4 present the details as follows.

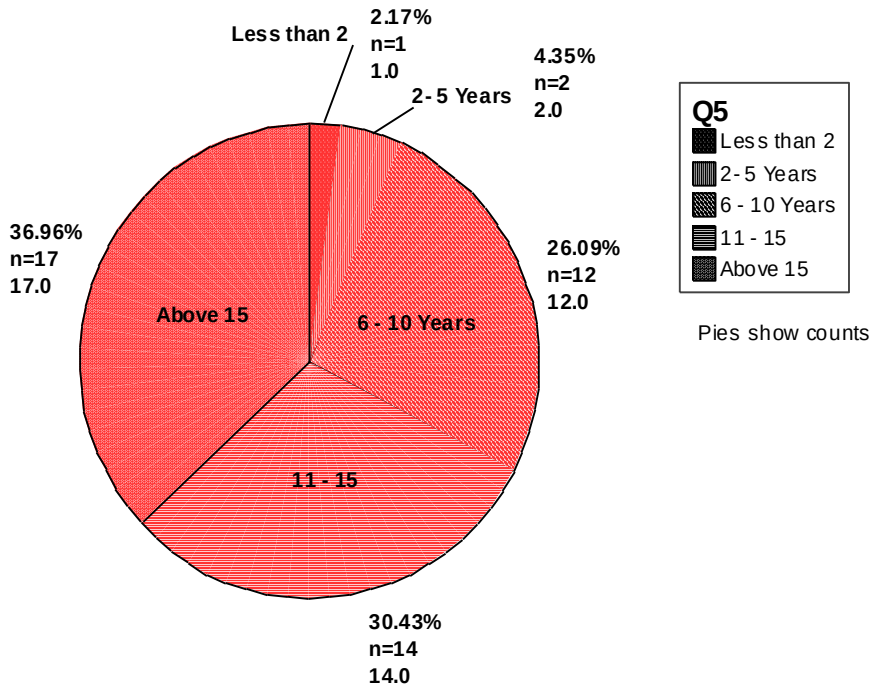

Figure 4.4 – Pictorial Form of Respondents Experience Analysis

Table 4.4 – Respondents Experience Analysis

Range	Frequency	Percentage	Cumulative Percentage
Less than 2	1	2.2	2.2
2- 5 Years	2	4.3	6.5
6 - 10 Years	12	26.1	32.6
11 - 15	14	30.4	63.0
Above 15	17	37.0	100.0
Total	46	100.0	

As table 4.4 reveals 37% of respondents are having more than 15 years of experience and in range 11 -15 comprises with 30.4% of experienced respondents. Accordingly both Above 15 and 11 – 15 ranges contribute for total of 57.4% of experience of respondents.

4.4.5 Analysis of Company Experience in the Industry

Question number 6 brings the particulars pertaining to the company experience in the building construction industry. Following figure 4.5 and Table 4.5 outline the analysis.

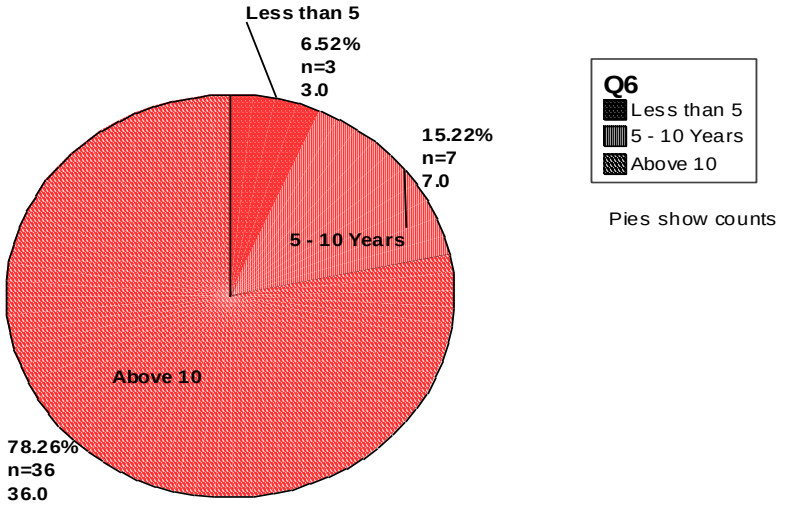

Figure 4.5 – Analysis of Company Experience in the Industry

Table 4.5 – Company Experience in the Industry

Range	Frequency	Percent	Cumulative Percent
Less than 5	3	6.5	6.5
5 - 10 Years	7	15.2	21.7
Above 10	36	78.3	100.0
Total	46	100.0	

According to the data analysis as summarized in the table 4.5, companies having experience more than 10 years have made the largest contribution.

4.5 Adopting the Testing Procedure

There are 46 elements under the testing for hypotheses. Before that it should be mentioned the relevant theory underlie with the testing concept. As per the **Central Limit Theorem**, distribution of the sample can be considered as normal if the sample size (n) is large enough ($n \geq 30$), and mean of the sample has a normal distribution'. Since that selected sample is having 46 elements, it can be determined that it consists of normal distribution accordingly ***t-test*** can be appropriated and ***p-value*** can be used to check the null hypothesis. Ronald (1998), through a research paper has declared the acceptable range of p-values in the context of hypothesis testing. Table 4.6 outlines the p-value status.

Table 4.6 – P-value Definition as Ronald (1998)

P-value Range	**Description**
$P > 0.10$	No evidence against the null hypothesis. The data appear to be consistent with the null hypothesis
$0.05 < P < 0.10$	Weak evidence against the null hypothesis in favor of the alternative
$0.01 < P < 0.05$	Moderate evidence against the null hypothesis in favor of the alternative
$0.001 < P < 0.01$	Strong evidence against the null hypothesis in favor of the alternative
$P < 0.001$	Very strong evidence against the null hypothesis in favor of the alternative.

Therefore P-value is used to determine the results by comparing this value with Type I error (i.e. 0.05) whereby P-value is less than 0.05, then null hypothesis is rejected.

4.6 Testing Hypotheses for Section- 2 Variables

Section of 2 of the questionnaire comprises of the questions 7 – 17 pertaining to the identifying of ICT implementation barriers in relation to building construction industry in Sri Lanka. Testing rationale for above aspect was mentioned under chapter 2, section 2.8.1. In this section it is due to evaluate the acceptance of research hypotheses by using the collected data through questionnaires. Each hypothesis mentioned under 2.8.1 is tested separately and as compound elements under defined key factors. Questions (7-17) appear in section-2 fall into the category of identifying ICT implementation barriers in the construction industry. Responding mode for above 7 -17 questions were as per the Likert scale 1 – 5 alternative selections.

1 - Strongly Disagree
2 - Disagree
3 - Moderate
4 - Agree
5 - Strongly Agree

(See Appendix A for Questionnaire format)

To test the null hypothesis $H_0: \mu \leq \mu_0$ against the alternative hypothesis $H_1: \mu > \mu_0$ where μ_0 is the population mean. μ_0 is the critical rating above which the issue was considered as moderate. In this analysis μ_0 was fixed at 3, because by definition given, rating scale 3 is moderate. Then the testing of hypotheses for all questions 7 – 17 should be in form of:

$H_0: \mu \leq 3$; $H_1: \mu > 3$

Where, H_0 is the null hypothesis and H_1 is the alternative hypothesis.

For acceptance a measure as barrier, it should be greater than 3.

4.6.1 Data Analysis for Question Number 7

H_0: Narrow profit margin of the organization is **not a barrier**

H_1: Narrow profit margin of the organization is a barrier

Table 4.7 – Test statistics for question number 7

Variable	**No. of Respondents**	**Mean**	**Standard Deviation**	**t-statistic**	**p-value**
Narrow Profit Margin of a organization	46	3.5435	0.72131	5.110	0.0000

Narrow profit margin of the organization has a mean of 3.5435 which is greater than the recognized value of 3. It implies that probability of the acceptance of alternative hypothesis is high. Therefore we will use the p-value for evaluating the result.

The p-value is compared with the probability of Type I error which is usually considered as 0.05. The p-value is lower than 0.05 conclude in rejecting the null hypothesis. As the test statistic reveals p-value (0.0000) < 0.05. Since the p-value < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that 'Narrow profit margin of an organization' is a barrier.

4.6.2 Data Analysis for Question Number 8

H_0: Organizations are not providing sufficient budget for ICT is not a barrier

H_1: Organizations are not providing sufficient budget for ICT is a barrier

Table 4.8 – Test statistics for question number 8

Variable	No. of Respondents	Mean	Standard Deviation	t-statistic	p-value
Organizations are not providing sufficient budget for ICT	46	3.6304	0.71051	6.018	0.0000

The test statistic mean 3.6304 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0000) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0000 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that 'Organizations are not providing sufficient budget for ICT is a barrier.

4.6.3 Data Analysis for Finance Constraint (Question 7 + Question 8)

Finance constraint is the dependent variable of above two variables. It should be determined the test statistics of above finance constraint.

H_0: Finance constraint is not a barrier

H_1: Finance constraint is a barrier

Table 4.9 – Test Statistics for Finance Constraint

Variable	No. of Respondents	Mean	Standard Deviation	t-statistic	p-value
Finance Constraint	46	3.5870	0.63512	6.268	0.0000

The test statistic mean 3.5870 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0000) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0000 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that 'Finance Constraint' is a barrier.

4.6.4 Data Analysis for Question Number 9

H_0: Less government support on ICT activities is not a barrier

H_1: Less government support on ICT activities is a barrier

Table 4.10 – Test statistics for question number 9

Variable	**No. of Respondents**	**Mean**	**Standard Deviation**	**t-statistic**	**p-value**
Less government support on ICT activities	46	3.5435	0.78050	4.723	0.0000

The test statistic mean 3.5435 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0000) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0000 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that '*Less government support on ICT activities*' is a barrier.

4.6.5 Data Analysis for Question Number 10

H_0: Low level of ICT infrastructure development is not a barrier

H_1: Low level of ICT infrastructure development is a barrier

Table 4.11 – Test statistics for question number 10

Variable	No. of Respondents	Mean	Standard Deviation	t-statistic	p-value
Low level of ICT infrastructure development	46	3.5652	0.83406	4.596	0.0000

The test statistic mean 3.5652 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0000) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0000 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that **'Low level of ICT infrastructure development is a barrier'.**

4.6.6 Data Analysis for Government Policies & Practices (Question 9 + Question 10)

Government Policies & Practices is dependent variable of the questions 9 and 10.

H_0: Government Policies & Practices is not a barrier

H_1: Government Policies & Practices is a barrier

Table 4.12 – Test statistics for Government Policies & Practices

Variable	No. of Respondents	Mean	Standard Deviation	t-statistic	p-value
Government Policies & Practices	46	3.5543	0.73203	5.136	0.0000

The test statistic mean 3.5543 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0000) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0000 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

***Therefore we can conclude that '*Government Policies & Practices' is a barrier.**

4.6.7 Data Analysis for Question Number 11

H_0: Weaknesses in capturing ICT developments is not a barrier

H_1: Weaknesses in capturing ICT developments is a barrier

Table 4.13 – Test statistics for question 11

Variable	No. of Respondents	Mean	Standard Deviation	t-statistic	p-value
Weaknesses in capturing ICT developments	46	3.3913	0.77397	3.429	0.0005

The test statistic mean 3.3913 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0005) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0005 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

***Therefore we can conclude that 'Weaknesses in capturing ICT developments' is a barrier*.**

4.6.8 Data Analysis for Question Number 12

H_0: Adopting obsolete communication methods is not a barrier

H_1: Adopting obsolete communication methods is a barrier

Table 4.13 – Test statistics for question number 12

Variable	No. of Respondents	Mean	Standard Deviation	t-statistic	p-value
Adopting obsolete communication methods	46	3.5652	0. .71963	5.327	0.0000

The test statistic mean 3.5652 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0000) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0000 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that 'Adopting obsolete communication methods' is a barrier.

4.6.9 Data Analysis for Technology deficiency (Question 11 + Question 12)

Technology deficiency is dependent variable of question no. 11 and question no. 12

H_0: Technology deficiency is not a barrier

H_1: Technology deficiency is a barrier

Table 4.14 – Test statistics for Technology deficiency

Variable	No. of Respondents	Mean	Standard Deviation	t-statistic	p-value
Technology deficiency	46	3.4783	0.68278	4.751	0.0000

The test statistic mean 3.4783 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0000) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0000 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that 'Technology deficiency' is a barrier.

4.6.10 Data Analysis for Question Number 13

H_0: More paper based document process is not a barrier

H_1: More paper based document process is a barrier

Table 4.15 – Test statistics for question number 13

Variable	No. of Respondents	Mean	Standard Deviation	t-statistic	p-value
More paper based document process	46	3.8913	0.84927	7.118	0.0000

The test statistic mean 3.8913 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0000) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0000 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that 'More paper based document process' is a barrier.

4.6.11 Data Analysis for Question Number 14

H_0: Project planning without ICT enabled software is not a barrier

H_1: Project planning without ICT enabled software is a barrier

Table 4.16 – Test statistics for question number 14

Variable	No. of Respondents	Mean	Standard Deviation	t-statistic	p-value
Project planning without ICT enabled software	46	3.7391	0.82825	6.053	0.0000

The test statistic mean 3.7391 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0000) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0000 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that 'Project planning without ICT enabled software' is a barrier.

4.6.12 Data Analysis for Question Number 15

H_0: Limited funds for manpower development in ICT use is not a barrier

H_1: Limited funds for manpower development in ICT use is a barrier

Table 4.17 – Test statistics for question number 15

Variable	**No. of Respondents**	**Mean**	**Standard Deviation**	**t-statistic**	**p-value**
Limited funds for manpower development in ICT use	46	3.6087	0.80217	5.147	0.0000

The test statistic mean 3.6087 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0000) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0000 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that '**Limited funds for manpower development in ICT use**' ***is a barrier***.

4.6.13 Data Analysis for Management and administration (Q 13 + Q14 + Q 15)

Management and administration is a dependent variable of question 13, 14 and 15.

H_0: Management and administration is not a barrier

H_1: Management and administration use is a barrier

Table 4.18 – Test statistics for Management and administration

Variable	No. of Respondents	Mean	Standard Deviation	t-statistic	p-value
Management and administration	46	3.7464	0.64093	7.898	0.0000

The test statistic mean 3.7464 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0000) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0000 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that* '*Management and administration*' *is a barrier.

4.6.14 Data Analysis for Question Number 16

H_0: Scarcity of ICT skills in staff is not a barrier

H_1: Scarcity of ICT skills in staff use is a barrier

Table 4.19 – Test statistics for question number 16

Variable	No. of Respondents	Mean	Standard Deviation	t-statistic	p-value
Scarcity of ICT skills in staff	46	3.6739	0.76170	6.001	0.0000

The test statistic mean 3.6739 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0000) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0000 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that '<u>Scarcity of ICT skills in staff</u>' is a barrier

4.6.15 Data Analysis for Question 17

H_0: Workforce resistance to accept ICT enabled activities is not a barrier
H_1: Workforce resistance to accept ICT enabled activities is a barrier

Table 4.20 – Test statistics for question number 17

Variable	**No. of Respondents**	**Mean**	**Standard Deviation**	**t-statistic**	**p-value**
Workforce resistance to accept ICT enabled activities	46	3.4565	0.83550	3.706	0.0005

The test statistic mean 3.4565 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0005) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0005 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that '<u>Workforce resistance to accept ICT enabled activities</u>' is a barrier

4.6.16 Data Analysis for Work Force (Question No. 16 + Question 17)

Work Force is a dependent variable of questions16 and 17

H_0: Workforce is not a barrier

H_1: Workforce is a barrier

Table 4.21 – Test statistics for Workforce

Variable	No. of Respondents	Mean	Standard Deviation	t-statistic	p-value
Workforce	46	3.5652	0.71187	5.385	0.0000

The test statistic mean 3.5652 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0000) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0000 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that* '*Workforce' is a barrier.

4.7 Testing Hypotheses for Section- 3 Variables.

Question nos. 18 - 28 under section 3 falls to the category of identifying ICT value added activities for the construction industry. Responding mode for above 18 - 28 questions were as per the Likert scale 1 – 5 alternative selections.

1 - Not Effective at All
2 - Not Effective
3 - Moderate
4 - Effective
5 - Very Effective

To test the null hypothesis $H_{0:}\mu \leq \mu_0$ against the alternative hypothesis $H_1:\mu > \mu_0$ where μ_0 is the population mean. μ_0 is the critical rating above which the issue was considered as moderate. In this analysis μ_0 was fixed at 3, because by definition given, rating scale 3 is moderate. Then we will have hypotheses for all the questions 18 - 28:

$H_0:\mu \leq 3$; $H_1:\mu > 3$

Where, H_0 is the null hypothesis and H_1 is the alternative hypothesis. For acceptance a measure as ICT value added activity, it should be greater than 3.

4.7.1 Data Analysis for Question Number 18

H_0: Digitized document management process is not an ICT value added activity

H_1: Digitized document management process is an ICT value added activity

Table 4.22 – Test statistics for question number 18

Variable	No. of Respondents	Mean	Standard Deviation	t-statistic	p-value
Digitized document management process	46	3.8043	1.04604	5.215	0.0000

Digitized document management process has a mean of 3.8043 which is greater than the recognized value of 3. It implies that probability of the acceptance of alternative hypothesis is high. Therefore we will use the p-value for evaluating the result. The p-value is compared with the probability of Type I error which is usually considered as 0.05. The p-value is lower than 0.05 concludes in rejecting the null hypothesis. As the test statistic reveals p-value (0.0000) < 0.05. Since the p-value < 0.05, the null hypothesis - H0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that 'Digitized document management process' is an ICT value added activity.

4.7.2 Data Analysis for Question Number 19

H_0: Use of databases for subcontractor management is not an ICT value added activity

H_1: Use of databases for subcontractor management is an ICT value added activity

Table 4.23 – Test statistics for Question 19

Variable	No. of Respondents	Mean	Standard Deviation	t-statistic	p-value
Use of databases for subcontractor management	46	3.8913	0.84927	7.118	0.0000

The test statistic mean 3.8913 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0000) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0000 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that 'Use of databases for subcontractor management' is an ICT value added activity.

4.7.3 Data Analysis for Question Number 20

H_0: Use of Building Information Modeling (BIM) and Quality information Management (QIM) is not an ICT value added activity

H_1: Use of Building Information Modeling (BIM) and Quality information Management (QIM) is an ICT value added activity

Table 4.24 – Test statistics for question number 20

Variable	No. of Respondents	Mean	Standard Deviation	t-statistic	p-value
Use of (BIM) and (QIM)	46	4.2174	0.72765	11.347	0.0000

The test statistic mean 4.2174 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0000) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0000 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that 'Use of Building Information Modeling (BIM) and Quality information Management (QIM) is an ICT value added activity.

4.7.4 Data Analysis for Question Number 21

H_0: Use of ICT enabled project network systems is not an ICT value added activity
H_1: Use of ICT enabled project network systems is an ICT value added activity

Table 4.25 – Test statistics for question Number 21

Variable	No. of Respondents	Mean	Standard Deviation	t-statistic	p-value
Use of ICT enabled project network systems	46	3.8478	0.69817	8.236	0.0000

The test statistic mean 3.8478 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0000) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0000 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that 'Use of ICT enabled project network systems' is an ICT value added activity.

4.7.5 Data Analysis for Question Number 22

H_0: Imposing security over accessing data is not an ICT value added activity

H_1: Imposing security over accessing data is an ICT value added activity

Table 4.26 – Test statistics for question number 22

Variable	No. of Respondents	Mean	Standard Deviation	t-statistic	p-value
Imposing security over accessing data	46	3.2174	1.13359	1.301	0.1500

The test statistic mean is 3.2174 < 3.500 and it indicates that probability of rejecting null hypothesis is critical. The p-value (0.1500) > 0.05 indicates the rejection of alternative hypothesis and acceptance of the null hypothesis. Since the p-value 0.1500 > 0.05, the null hypothesis - H_0 is accepted and Alternative hypothesis - H_1 is rejected

Therefore we can conclude that 'Imposing security over accessing data' is not an ICT value added activity.

4.7.6 Data Analysis for Digitized Construction Management (Question 18 + Question 19 + Question 20 + Question 21 + Question 22)

Digitized Construction Management is a dependent variable under Q. 18, 19, 20, 21 & 22

H_0: Digitized Construction Management is **not a ICT value added activity**

H_1: Digitized Construction Management is a ICT value added activity

Table 4.27 – Test statistics for Digitized Construction Management

Variable	No. of Respondents	Mean	Standard Deviation	t-statistic	p-value
Digitized Construction Management	46	3.7957	0.59552	9.062	0.0000

The test statistic mean 3.7957 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0000) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0000 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that 'Digitized Construction Management' ' is a ICT value added activity.

4.7.7 Data Analysis for Question Number 23

H_0: Use of General Purpose Software is not an ICT value added activity

H_1: Use of General Purpose Software is an ICT value added activity

Table 4.28 – Test statistics for question number 23

Variable	No. of Respondents	Mean	Standard Deviation	t-statistic	p-value
Use of General Purpose Software	46	3.9565	0.66522	9.752	0.0000

The test statistic mean 3.9565 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0000) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0000 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that 'Use of General Purpose Software' is an ICT value added activity.

4.7.8 Data Analysis for Question Number 24

H_0: Use of 3D-CAD for cost-effective designs is not an ICT value added activity

H_1: Use of 3D-CAD for cost-effective designs is an ICT value added activity

Table 4.29 – Test statistics for Question 24

Variable	No. of Respondents	Mean	Standard Deviation	t-statistic	p-value
Use of 3D-CAD for cost-effective designs	46	4.2174	0.72765	11.347	0.0000

The test statistic mean 4.2174 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0000) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0000 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that 'Use of 3D-CAD for cost-effective designs' is a ICT value added activity.

4.7.9 Data Analysis for Question Number 25

H_0: Project time planning through Micros Tran and MathCAD is not an ICT value added activity

H_1: Project time planning through Micros Tran and MathCAD is a ICT value added activity

Table 4.30 – Test statistics for Question No. 25

Variable	No. of Respondents	Mean	Standard Deviation	t-statistic	p-value
Project time planning through Micros Tran and MathCAD	46	3.9565	0.86811	7.473	0.0000

The test statistic mean 3.9565 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0000) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0000 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that 'Project time planning through Micros Tran and MathCAD' is an ICT value added activity.

4.7.10 Data Analysis for Question Number 26

H_0: Use of WinQS32, QSCAD, and CATO for Quantity Surveying is not an ICT value added activity

H_1: Use of WinQS32, QSCAD, and CATO for Quantity Surveying is an ICT value added activity

Table 4.31 – Test statistics for question number 26

Variable	No. of Respondents	Mean	Standard Deviation	t-statistic	p-value
Use of WinQS32, QSCAD, and CATO for Quantity Surveying	46	4.1087	.79522	9.456	0.0000

The test statistic mean 4.1087 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0000) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0000 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that 'Use of WinQS32, QSCAD, and CATO for Quantity Surveying' is a ICT value added activity.

4.7.11 Data Analysis for Use of ICT Admin Tools (Question 23 + Question 24 + Question 25 + Question 26)

Use of ICT Admin Tools is a depended variable of Questions 23, 24, 25 and 26

H_0: Use of ICT Admin Tools is not an ICT value added activity

H_1: Use of ICT Admin Tools is an ICT value added activity

Table 4.32 – Test statistics for Use of ICT Admin Tools

Variable	No. of Respondents	Mean	Standard Deviation	t-statistic	p-value
Use of ICT Admin Tools	46	4.0598	0.57297	12.545	0.0000

The test statistic mean 4.0598 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0000) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0000 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that 'Use of ICT Admin Tools' is an ICT value added activity.

4.7.12 Question Number 27

H_0: Knowledge sharing through global networks not an ICT value added activity

H_1: Knowledge sharing through global networks is an ICT value added activity

Table 4.33 – Test statistics for question number 27

Variable	No. of Respondents	Mean	Standard Deviation	t-statistic	p-value
Knowledge sharing through global networks	46	3.9783	.77428	8.569	0.0000

The test statistic mean 3.9783 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0000) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0000 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that 'Knowledge sharing through global networks' is a ICT value added activity.

4.7.13 Data Analysis for Question Number 28

H_0: Electronic knowledge file creation during the project time is not an ICT value added activity

H_1: Electronic knowledge file creation during the project time is a ICT value added activity

Table 4.34 – Test statistics for question number 28

Variable	**No. of Respondents**	**Mean**	**Standard Deviation**	**t-statistic**	**p-value**
Electronic knowledge file creation during the project time	46	4.1087	0.79522	9.456	0.0000

The test statistic mean 4.1087 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0000) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0000 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that 'Electronic knowledge file creation during the project time' is an ICT value added activity.

4.7.14 Data Analysis for Expert knowledge sharing (Question 27 + Question 28)

Expert knowledge sharing is a dependent variable of Questions 27 and 28

H_0: Expert knowledge sharing is not an ICT value added activity

H_1: Expert knowledge sharing is a ICT value added activity

Table 4.35 – Test statistics for Expert knowledge sharing

Variable	No. of Respondents	Mean	Standard Deviation	t-statistic	p-value
Expert knowledge sharing	46	4.0435	0.70574	10.028	0.0000

The test statistic mean 4.0435 indicates that probability of accepting the alternative hypothesis is positive. The p-value (0.0000) < 0.05 indicates the rejection of null hypothesis. Since the p-value 0.0000 < 0.05, the null hypothesis - H_0 is rejected and Alternative hypothesis - H_1 is accepted.

Therefore we can conclude that 'Expert knowledge sharing' is an ICT value added activity.

4.8 Summary

Questionnaire data were analyzed under three sections separately as appeared in the questionnaire. SPSS version 13.0 was used to analyze data. T-test and p-value approach were used to test the hypotheses. Section 1 contains the descriptive analysis of the questionnaire while section 2 and section 3 reveal the data pertaining to 'barriers and value added activities respectively in relation to the ICT implementations in building construction industry in Sri Lanka. Analyses were made in order to identify the potential parameters pertaining to both 'barriers' and 'value added activities' with the intention of discussing in chapter 5.

CHAPTER 5
DISCUSSION, CONCLUSIONS & RECOMMENDATIONS

5.1 Definition for Chapter Structure

Preceding chapters we had some lengthy discussions over, identifying the research problem, reviewing the relevant theories through literature, making approach to the research problem through methodology, data collection as proving the matter concerned and finally analyzing same data on meaningful ways to forecast some futuristic evens. In this research concerned, it is due to discuss the matters as data analysis reveals. In this chapter we are going to summarize the facts revealed through analysis.

5.2 Discussion over Analysis

. It is worthwhile to define the analysis at this stage with view of getting real impact of the results. As far as concerned about the research work, it is required to justify the results obtained though analysis because such results are intended to represent the entire population. Reason for that phenomenon is all research work is based on sample data. As far as concerned about the results obtained through analysis on collected data, it is due to place meaningful observations as findings which would be useful in futuristic manner. The overall prime objective of the study is to reveal the factors behind the building construction productivity whether they are fallen into different categories. These categories naturally belong to two distinct avenues, namely ‘barriers in ICT implementations’ or ‘value added activities’ that influence the productivity negatively or positively in relation to the building

construction industry in Sri Lanka. As revealed in the preceding chapters through literature, ICT is not only the factor affecting productivity but it will be the most crucial factor in futuristic manner (Dimuth and Navaratne, 2006).

Therefore conducting the comprehensive discussions over data analysis will be worth full in order to reveal the properties of the ICT enabled activities.

5.3 Proceeding to Discuss Section 1 Data

Section 1 data of the questionnaire comprises of organizational and personal data that concerned about the contractors and respondents respectively those who were supposed to fill the questionnaire. Such descriptive data contain the particulars of organization's name, ICTAD classified grade, qualification level of the respondent, age, years of experience along with company experience in the relevant trade. However question number 1 of the section 1 was removed from the further analysis since it is not having any impact on the study. Generalization of the individual data is not intended in this study and generalization of common ideas is the objective of this study.

5.3.1 Contractor Details

Table 5.1 – Contractor Responding Details

Contractor Grade	Registered No. Of Contractors	Responded Nos.	Responded/ Registered %	Responded/ Total %
C1	25	19	76	41.3
C2	25	16	64	34.8
C3	19	11	58	23.9
Total	69	46		100

Above 5.1 table was derived from chapter 4, table 4.1 in relation to the responded details. Values of this table should be compared with target population of the research concerned. Target population comprises of each grade under the column title registered no. contractors. According to the year 2010 ICTAD classification all C1, C2 and C3 belong to the large scale category. Highest number of response against the registered sum (74%) has been recorded from C1 while 64% and 58% from C2 and C3 respectively. 41.3% of the responded total is contributed by C1 grade while other two grades are contributing 58.7%. Accordingly we can build up the rationale as per the sample that highest grade is more sensitive than other two because among the three grades, C1 is high potential for identifying and implementing ICT activities to the construction activities. If it is same as the described, at least tendency over ICT matter concerned is significant.

5.3.2 Responders' Qualification Levels

Table 5.2 – Qualification Level of the Respondents

Category	Frequency	%
Diploma	8	17.4
Degree	15	32.6
Charted	20	43.5
Masters	3	6.5
Total	46	100.0

It is worthwhile to notice that 43.5% contribution of the study survey has been made by Charted Professionals. There are 32.6% degree holders in the sample. One Acceptable phenomenon is that before receiving of Charted status, it should be completed the degree level qualification along with proven service record in design criteria. Therefore altogether,

they contribute 76.1% share of the total. The figure of 76.1% implies the accuracy of the selection which is envisaged the research model as adopted sampling mechanism. Main two reasons that mentioned over sample selection are;

- Knowledge extraction problem
- High productivity is expected from large scale

Therefore both reasons can be justified at this stage according to the responded qualification levels.

5.3.3 Respondents' Age Analysis

Table 5.3 – Respondents Age Analysis

Range	Frequency	Percent	Cumulative Percent
Age 20 - 29	3	6.5	6.5
Age 30 - 39	7	15.2	21.7
Age 40 - 49	24	52.2	73.9
Above 49	12	26.1	100.0
Total	46	100.0	

Altogether 78.3% of the total is represented by age group 40 – 49 and above 49. Maturity comes with the age. Age represents the maturity. These two age groups are highly motivated to the problem concerned and therefore their willingness remains in high degree to the problem area. At this stage it is difficult to forecast their impressions over identifying the barriers and value added activities. However their willingness to address the main issue is positive. This does not mean that age groups below 40 years are not positive but their representing factor is less compare to the higher age groups. In experience, matured people know in what extent the productivity is important than young people.

5.3.4 Respondents' Experience Analysis

Table 5.4 - Respondents' Experience Analysis

Range	Frequency	Percentage	Cumulative Percentage
Less than 2	1	2.2	2.2
2- 5 Years	2	4.3	6.5
6 - 10 Years	12	26.1	32.6
11 - 15	14	30.4	63.0
Above 15	17	37.0	100.0
Total	46	100.0	

Only 6.5% are having experience 5 years or less while others are contributing 93.5%.

In fact, these results reflect phenomenon that selected sample comprising with handful experience in the industry accordingly perception in the problem concerned remains in high degree. Once again, it can be determined the sample selection is accurate and correct in relation to the problem concern because real or approximate impact be expected from such sample. It implies that people selected in sample are thorough in trade and very much concerned in productivity.

5.3.4 Company Experience in the Industry

Table 5.5 – Company Experience

Range	Frequency	Percent	Cum. Percent
Less than 5	3	6.5	6.5
5 - 10 Years	7	15.2	21.7
Above 10	36	78.3	100.0
Total	46	100.0	

Above 10 years range has made 78.3% contribution by itself so that our sample is having very good track record pertaining to the experience. With the extensive experience in the industry, they have contributed to the research survey. Though industry people are responding the questionnaire, they well equipped with experience of their representing firm because they are having the impression over productivity in relation to their own firm. As revealed above in relation to the all aspects it has been secured the sample selection criteria and its precision. One can argue why it is so important. Because all forward analyses are really based on the sample and its properties. We have selected the sample reasonably. Results of all above analysis confirm the reliability of sample selection.

5.4 Proceeding to Discuss Section 2 Analyses - Barriers

At this stage, it has been justified the sample selection. As per the facts revealed in the preceding section 5.3, responses and their properties were summarized under distinct subheadings. But real impact of the individuals for problem concerned is actually dealt with section 2 of the questionnaire data. Since the sample selection is reasonable, further analyses can be carried out preciously. So far it was discussed the descriptive analyses and it is due to discuss the inferential analyses under section 2. Logically formulated hypotheses were tested against the collected data that fall under section-2. Section 2 has been dedicated to represent the ICT implementation barriers in relation to productivity of building construction industry. Under chapter 4- ‘data analyses’, it was mentioned set testing values and their criteria with supporting literature. Therefore, it can be assured that information produced through various test approaches are correct and contain high significance. Studying of such responses from industry professionals will make facility to forecast some useful definitions towards the set objectives.

5.4.1 Discussing Financial Constraint

Table 5.6 – Test statistics for Finance Constraint

Variable	Mean	STD	t-statistic	p-value
Narrow Profit Margin of a organization	3.5435	0.72131	5.110	0.0000
Organizations are not providing sufficient budget for ICT	3.6304	0.71051	6.018	0.0000

Under the key factor, Financial Constraint there is two variables. Financial constraint is the dependent variable against the independent variables of

- Narrow Profit Margin of a organization
- Organizations are not providing sufficient budget for ICT

Properties of each variable has been measured separately and along as one variable under 'Financial Constraint'. As per the analysis both variables have been identified as barriers. It is important to identify the potential barrier under Finance constraint. Table has been formed as per the t-test values. Respondents' point of view both two factors are barriers and second option has been rated as most significant barrier. Respondents identified the 'insufficient budget provision as a crucial factor against implementation of ICT activities. Most probably respondents' idea is that, although funds are available, organizations are not providing sufficient funds for the ICT aspects. Respondents are the industry professionals those who are working under constructions firms. Accordingly, their view regarding the matter must be accurate. Otherwise they should have selected the first option that organizations are not having sufficient profit margins. As far as concerned about the organization second option impact heavily because according to the respondents first option is having less significant in the context of problem concerned.

5.4.2 Government Policies & Practices

Table 5.7 – Test statistics for Government policies and practices

Variable	Mean	STD	t-statistic	p-value
Less government support on ICT activities	3.5435	0.78050	4.723	0.0000
Low level of ICT infrastructure development	3.5652	0.83406	4.596	0.0000

As the name implies 'Government' is the sole agency for any country to introduce and implement laws and make facilities for development. Further it should maintain the existing or on-going processes without any interruption. To accomplish such phenomenon government of any country should have good set of policies and continuous good practices over the current trends. Thereby, 'Government Policies and Practices' play very important role in the context of achieving national level objectives. Therefore it can be considered that identified key factor 'Government policies and practices' is also very much important in the study of identifying ICT implementation barriers in the building construction industry. 'Government policies and practices' is the dependent variable and other two are independent variables. According to the statistics, respondents have identified all two variables as barriers. Further t-statistic implies that 'Less government support on ICT activities as the most crucial one. Though government in Sri Lanka has made some initiatives to promote ICT activities at national level, there is no any impact to the construction sector. Respondents think that government is not in the process of directing its resources for the development ICT activities in building construction industry. Respondents' idea for the second option – 'low level ICT infrastructure development' is a subset of the first option. Study conducted by Nayanathara et al. (2008) has also emphasized the situation as above.

5.4.3 Technology Deficiency

Table 5.8 – Test statistics for Technology deficiency

Variable	Mean	STD	t-statistic	p-value
Weaknesses in capturing ICT developments	3.3913	0.77397	3.429	0.0005
Adopting obsolete communication methods	3.5652	0. .71963	5.327	0.0000

There are two situations that happen over utilization of technology for any industry. One aspect is not using technology at all and other option is to use technology inadequately. The term 'Technology deficiency' falls into second option where although technology is available, but it is not utilizing in any productive way. Therefore, there are no any extensive productivity gains through such ICT usage. Dimuth and Navaratne (2006) have clearly expressed this phenomenon that ICT would be the crucial facilitator of the future construction productivity. In the present study, 'Technology deficiency' is the dependent variable and other two are independent variables. Among the two independent variables, 'Adopting obsolete communication methods' has been rated as the most significant one by the respondents. Though first option is theoretically potential, respondents are not willing to accept that because problem is in their side. At present, there are massive promotional aspects are intact with communication developments, but proper usage of such aspects are in lesser extent therefore it is still remaining the fact 'Adopting obsolete communication methods' in construction process. But as a whole, 'Adopting obsolete communication methods' is a super shade of the 'Weaknesses in capturing ICT developments' although respondents have given more gravity on latter one.

5.4.4 Management and Administration

Table 5.9 – Test statistics for Management & Administration

Variable	Mean	STD	t-statistic	p-value
More paper based document process	3.8913	0.84927	7.118	0.0000
Project planning without ICT enabled software	3.7391	0.82825	6.053	0.0000
Limited funds for manpower development in ICT use	3.6087	0.80217	5.147	0.0000

There are three independent variables that have been grouped under the dependent variable 'Management and Administration'. These three options have been identified as management and administration aspects since the options are required more managerial direction. In turn, effective overcome of such variables in the construction industry implies better management and administration aspect. Therefore analysis over three options is significant in order to quantify the gravity of 'Management and Administration'. All three options under 'Management & Administration' have been identified by the respondents. They have critically identified the 'More paper based document processes as the most significant barrier. However, their thought is correct because before proceeding high-end ICT activities, initial ICT enabled activities should be activated. All three options are important though first option is significantly identified. 'Project planning without ICT enabled software' and 'Limited funds for manpower development in ICT use' follow the first option respectively. However, third option has been considered as the least significant barrier. Effective project planning means enhancement of productivity. Manpower development in the ICT use is also an important factor that affects to the construction productivity.

5.4.5 Workforce

Table 5.10 – Test statistics for Workforce

Variable	Mean	STD	t-statistic	p-value
Scarcity of ICT skills in staff	3.6739	0.76170	6.001	0.0000
Workforce resistance to accept ICT enabled activities	3.4565	0.83550	3.706	0.0005

As per the analysis, it is revealed that 'Work Force' is also potential when it is considered as a barrier. However it contains two options 'Scarcity of ICT skills in staff' and 'Workforce resistance to accept ICT enabled activities' respectively. Test statistics can be considered in order to gain an idea how they affect to the construction productivity that hindering as barriers. Although most of the ICT enabled facilities are available, if the staff is not capable of performing well through available resources, there is no point of expecting much productivity enhancements. If it is viewed in any angle, workforce of an organization is critically important in the context of productivity concerned. Among the other factors, workforce is entirely consisting of human resource and it is the very difficult factor to utilize in any manner. There are number of other relevant factors are behind the human resource such as motivation and direction etc. that connected with workforce of an organization. Among the two options under Workforce, respondents have critically identified that 'scarcity of ICT skills in staff' as the main barrier. Reasons accounted for that can be mentioned as follows:

- Although resources are available, staff was not given proper training for ICT activities
- Most people involved in construction process are not ICT enabled professionals. Except few training received in university, they have been trained for

implementation of mostly for civil works. They are not having any extensive training on ICT tools.

For any ICT implementation, even other than for construction, workforce initially keeps resistance against the innovations. This resistance can be generalized for construction as well since it directly impacts to construction productivity.

5.5 Discussion on Section 3 Analyses – ICT Value Added Activities

Under 5.4, it was discussed the inferences of ICT implementation barriers and their effects to the industry. On the other way, problem is such, and then alternative measures should be taken in order to overcome such instances. It comprises of

- Identifying the real problem area
- Measuring its impact to the industry (for productivity)
- Finding alternative measures
- Evaluating alternative measures
- Recommending the suitable one

(William, 2001)

This methodology is common for any business concerned and it is also applicable to the building construction industry. This is the main reason for identifying ICT value added activities while identifying 'ICT implantation barriers'. These two factors are in negative directions in nature and hindering each one from isolating the industry from productivity concern. As Lankathilake (2007) revealed, these are the future challenges and perspectives that Sri Lanka construction industry has to forego in the productivity problem concerned. As has been revealed the barriers of ICT implementations, it is a foremost requirement to find the meaningful and effective alternatives to overcome such aspects. Evaluation of such alternatives in the form of ICT value added activities are discussed in following sections.

5.5.1 Digitized Construction Management

Table 5.11 – Test statistics for Digitized Construction Management

Variable	Mean	STD	t-statistic	p-value
Use of (BIM) and (QIM)	4.2174	0.72765	11.347	0.0000
Use of ICT enabled project network systems	3.8478	0.69817	8.236	0.0000
Use of databases for subcontractor management	3.8913	0.84927	7.118	0.0000
Digitized document management process	3.8043	1.04604	5.215	0.0000

One variable 'Imposing security over accessing data' removed from the analysis because alternative hypothesis was rejected. Remaining four factors were taken into consideration

All options are having good mean values and t-statistics and precision is good. Use of two software BIM – Building Information Modeling and QIM – Quality Information has received very good response from the industry people. It was mentioned under data collection, what target group should be selected. It has reflected the matter that selected group for data collection is absolutely correct. Projects Directors/Project Managers/Project Engineers are the real target group because all of them are knowledgeable for the problems concerned as well as they are having the ideas of how to overcome such issues through technology collaboration. Professionals are always intact with technology drivers. The next potential option is 'Use of ICT enabled project network systems' which has been rated as second significant one. Since the t-static is higher, other options are also significant and more important in the context of productivity. Professionals are really intact with fixing the real problem areas with weighted magnitude.

5.5.2 Use of ICT Admin Tools

Table 5.12 – Test statistics for Use of ICT Admin Tools

Variable	Mean	STD	t-statistic	p-value
Use of 3D-CAD for cost-effective designs	4.2174	0.72765	11.347	0.0000
Use of General Purpose Software	3.9565	0.66522	9.752	0.0000
Use of WinQS32, QSCAD, and CATO for Quantity Surveying	4.1087	.79522	9.456	0.0000
Project time planning through Micros Tran and MathCAD	3.9565	0.86811	7.473	0.0000

Use of ICT Admin Tools is the dependent variable of the other independent variables included in the table. Accordingly 'Use of ICT Admin Tools' depends on the other factors as influence. According to the analysis, it is very clear that among the four variables, 'Use of 3D-CAD' has received very good recognition. Industry people accurately select what they exactly want and what they don't want. They are technology people and born to adapt he technology drivers for their respective work. They are having very good analytical approach so that they accurately measure requirement. Use of other software tools are also very effective as revealed in the questionnaire survey while discussing with participants some software are new to Sri Lanka building industry context. Therefore they have given less magnitude to such factors. However all are effective in use for productivity concern.

5.5.3 Expert Knowledge Sharing

Table 5.13 – Test statistics for Expert Knowledge Sharing

Variable	Mean	STD	t-statistic	p-value
Knowledge sharing through global networks	3.9783	0.77428	8.569	0.0000
Electronic knowledge file creation during the project time	4.1087	0.79522	9.456	0.0000

Expert Knowledge Sharing is the dependent variable and other two factors are independent variables. Test data reveals how respondents have concentrated on the two aspects. In my opinion, Knowledge sharing through global network should be the most important one but it is not in same way. As the reason for this situation either they have incorrectly interpreted my question or purposely they have turned down it. However they have not rejected but considered as less important. These concepts are very productive measures for any industry, any business but construction is lacking to adopt the innovation while other ventures are practicing effectively.

5.6 Conclusion

Under sections 4 and 5 along with subsections of same, it was extensively discussed the testing statistics of questionnaire data. Intention of doing same analysis was to identify the significant factors that affecting the construction productivity in means of ‘barriers’ or ‘value added activities’. The function was totally based on questionnaire data conducted form of survey among industry professionals those who are presently working in large scale construction firms. Their impression, feedback were quantified and analyzed as required by the study in order to forecast the future trends that construction industry should take over in

advance with the intention of maximizing productivity. Accordingly, identifying of such events and their behaviour become apparent for future successes in the industry. One important thing should be taken into account that as Turban et al. (2008, p. 559) told that total economy operates under digital environment so that construction industry is also to grasp same for better outcomes.

Before proceeding to the study, it was extensively examined the relevant studies, theories that previously conducted over construction productivity as well as ICT usage in construction processes. It should be mentioned at this stage that there were only few studies have been carried out in Sri Lanka context, but there were number of researches available in international level. Researches have conducted several researches to find the connectivity between construction productivity and ICT use. Becchetti et al. (2003), Les (2006) and Molnar, Andersson and Ekholm (2007) are some of the leading researchers that contributed lot to the industry. Factors revealed by them and others were taken as the variables and key factors of the present study. It would be fruitful to discuss the main key factors and their significances under both categories 'barriers' and 'value added activities' as the last lap.

5.6.1 Main Areas under Barriers

Table 5.14 – Test statistics for main barriers

Variable	Mean	STD	t-statistic	p-value
Management and administration	3.7464	0.64093	7.898	0.0000
Finance Constraint	3.5870	0.63512	6.268	0.0000
Workforce	3.5652	0.71187	5.385	0.0000
Government Policies & Practices	3.5543	0.73203	5.136	0.0000
Technology deficiency	3.4783	0.68278	4.751	0.0000

All five main areas were formed through independent variables as described earlier. Magnitude of the dependent variable was assigned by the respective independent variables which are considered under the main area. In fact, these factors outside the questionnaire and accordingly respondents are not aware of such events. They are wholly formed internally in order to forecast the testing status as one unit. Although identifying of all main barriers are important, the most significant barriers are crucial in the context of industry. Compare to the others, 'Management & Administration' is outstanding because of the high t-value and also high mean value. Respondents have expressed their strong feeling in this regard because all other processes are being hindered by the 'Management & Administration' process. Respondents have accurately measured the gravity of the hindering factors. Their perception, ability and wide experience are absolutely intact with the problem concerned. This phenomenon brings some important industry-wide reveals such as:

- Selected participants are really on target
- Their perceptions on issues very high
- These problems have affected them seriously
- They have expressed their 'dislike' strongly

Therefore it is required to be identified by the relevant authorities the gravity of the problem and respond to it effectively.

5.6.2 Main Areas Under ICT Value Added Activities

Table 5.15 – Test statistics for Main Areas of ICT Value Added Activities

Variable	**Mean**	**STD**	**t-statistic**	**p-value**
Use of ICT Admin Tools	4.0598	0.57297	12.545	0.0000
Expert knowledge sharing	4.0435	0.70574	10.028	0.0000
Digitized Construction Management	3.7957	0.59552	9.062	0.0000

At the conclusion stage it should be identified the significant 'ICT value added activities' appeared as key factors which can positively influence the productivity. Thereby, it can be segregated the ICT value added key factors according to their respective t-value. 'Use of ICT Admin Tools' is leading the group compare to the other factors. Because there are some important facilities have been included under 'Use of ICT Admin Tools'. As per the analysis it contains very high t-statistic (12.545). It implies how potentially it is important to the construction productivity. 'Use of ICT Admin Tools' consists of purely handling of software based ICT activities in form of tools which are exactly maximizing the productivity. Industry people know how to take up and utilize these resources in order to get their targets fulfilled efficiently. This is the key point that we have to realize if it is expecting high productivity gains, then apparently implementation of such key factors should be taken into consideration. However, it should be emphasized that as per the analysis the use of 'ICT value added activities are outstanding in the construction productivity concerned and respondents have strongly selected most tangible cost-effective factors sequentially as important.

As the measure of conclusion, one can raise the question of what direction should they select in order to overcome the productivity problem. In fact, this study was conduct under distinct objectives. It comprises of general as well as specific objectives which were set out at the beginning of the research. But study was initiated at earlier stages before research work commenced. It was somewhat fortunate that it was enabling to surpass the study work with the finding of rich literature pertaining to the problem concerned at the latter stage which was able to switch to the research work. As the result of this study, it has been able to reveal extremely important conclusions as findings. Therefore reader should be capable of selecting appropriate pathways in order to match with their industry requirements.

5.7 Recommendations

Extensive analysis and discussions were held in preceding sections in order to identify the potential ICT factors under various headings that affect to the building construction productivity in Sri Lanka. It was discussed several important issues pertaining to the specific objectives as set in chapter 1. Accordingly, it was able to reveal effective findings and to emphasize the main barriers of ICT implementations along with the ICT value added activities which can potentially influence the construction productivity. However, it is important to mention at this stage that theoretical background impact on this study. Nayanathara et al. (2008) have conducted the study over construction industry in Sri Lanka with the view of identifying 'challenges and future perspectives' analyzing the ideas of experts and industry professionals. Outcomes of the study were 'barriers' which are hindering the construction productivity and 'motivators' which have been identified as influencing factors for construction productivity. They have conducted their research on that basis along with 'barriers' and 'motivators'. Analysis were made through questionnaire data responded by the industry experts and contractors those who having high financial limits in their contracts. Sample selection was made through ICTAD registration comprising the higher grades C1, C2 and C3. Present study is in the same manner which implies the carryings out of sample selection and methodology in same manner. As mentioned in their research, 'adaptation of low level ICT usage in construction industry', 'financial constraint', 'management and administration aspects' and 'workforce' were identified as key factors which were subsequently used for my research. Other variables were derived from literature survey and grouped under the key factors that enabling to analyze at latter stage. How significant the identified variables and key factors in the building construction industry context were measured through questionnaire survey with participation of high end

contractors. Selecting of high end contractors are due to the following reasons as well as enforced by the selected theoretical model.

- Easily measurable the ICT use
- Knowledgeable for their use
- High funding ability for such events
- Existing in large scale grade
- At national level, mostly high productivity is expected from upper three grades
- Intention of the study is to elicit the knowledge of specialist contractors
- Except C1, C2, and C3 other contractors pertaining to building construction were dropped due to vacuum in knowledge extraction. Most of them are subcontractors and they work under the purview of C1, C2 and C3.

Therefore, it should be emphasized that if there is any intention to cover entire population then the sample selection should be in random form and should compare the results with present study. However reasons mentioned above for justification over sample selection cannot be marginalized. As it impressed at present there is no need to generalize the outcomes since the lower grades are not compatible with ICT enabled activities.

It is noticeable that some identified variables have not been signified by the industry experts as at expected level. Though the issues seems to be crucial in the problem domain, responding for same remain with low magnitude. Therefore it should be conducted further studies over responding pattern whether the question equipped for that particular issues are not important in Sri Lanka building construction industry. However, such issues are not particular to the Sri Lanka and such factors were derived through international level literature survey. Most probably, such factors may be important in that particular arena at international

level though Sri Lanka building construction industry is not giving much attention in this regard at present. Adopted following issues are listed below for further reference.

Table 5.16 – Less priority given ICT barriers

Variable	Mean	STD	t-statistic	p-value
Weaknesses in capturing ICT developments	3.3913	0.77397	3.429	0.0005
Workforce resistance to accept ICT enabled activities	3.4565	0.83550	3.706	0.0005

Therefore it is recommended to conduct the research studies over above issues whether the irrelevancy is specific to the Sri Lanka construction industry. But it should not be limited to the building construction arena and it should be widen the research area to whole construction as well. If there is a any research to be initiated then prospective researches can adopt the present research study as the theoretical model since potential 'barriers' and 'value added activities' have been identified by now. However research work can be limited only one aspect of 'barriers' or 'value added activities' in the productivity concerned on construction industry. Revealed issues and facts are not fixed therefore further researches may comprise with unrevealed factors in this study. In fact, there is a significant research requirement in Sri Lanka construction industry in the problem domain because it is not available relevant research studies at present. Finally, it is to be mentioned that new theory has been formulated after striving of heavy works so that interested parties can continue same for better prospects of Sri Lanka construction productivity.

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Appendix A Serial No:_____
(For Office Use Only)

Questionnaire for Project Directors/Project Managers/Project Engineers

The purpose of this survey is to 'Identify the ICT implementation barriers and ICT value added activities in relation to Building Construction Productivity in Sri Lanka'. Your participation in this research survey is highly appreciated.

Section 1: Company & Respondent Profile.

Please fill in the blank or tick '√' in the appropriate box as shown

1. Organization/Company Name
   :……...

2. Grade (As per ICTAD classified) :……

3. Level of qualification

Diploma	Degree	Charted	Masters	Above Masters

4. Age

20 – 29	30 -39	40 - 49	Above 49

5. Years experience in building construction field

Less than 2	2- 5	6 – 10	11 – 15	Above 15

6. Company experience in building construction industry

Less than 5	5 – 10	Above 10 years

Section 2: Identifying the ICT implementing barriers (ICT – Information and Communication Technology)

Please mark appropriate answer alternative with 'X' and respond to all the statements.

1 – Strongly disagree
2 – Disagree
3 – No idea
4 – Agree
5 – Strongly agree

7. Organization's Narrow profit margins act as a ICT implementation barrier
   (1) (2) (3) (4) (5)

8. Organizations are not providing sufficient budget for ICT
   (1) (2) (3) (4) (5)

9. Due to less government support on construction affects ICT activities
   (1) (2) (3) (4) (5)

10. Low level of ICT infrastructure development in the country
    (1) (2) (3) (4) (5)
11. Weaknesses in capturing ICT developments for project works
    (1) (2) (3) (4) (5)
12. Adopting obsolete communication methods
    (1) (2) (3) (4) (5)
13. More paper based documentation processes
    (1) (2) (3) (4) (5)
14. Project planning without ICT enabled software
    (1) (2) (3) (4) (5)
15. Organizations are allocating limited funds for manpower development
    (1) (2) (3) (4) (5)
16. Scarcity of ICT skills in staff
    (1) (2) (3) (4) (5)
17. Resistance of workforce to accept ICT enabled activities engaged
    (1) (2) (3) (4) (5)

Section 3: Identifying ICT Value Added Service in building construction industry which can improve the productivity

Please mark appropriate answer alternative with 'X' and respond to all the statements.

1 – Not effective at all
2 – Not effective
3 – Moderate
4 – Effective
5 – Very effective

18. Digitized documents management activities
    (1) (2) (3) (4) (5)
19. Using of databases for subcontractor management
    (1) (2) (3) (4) (5)
20. Use of Building Information Modeling (BIM) and Quantity Information Management (QIM)
    (1) (2) (3) (4) (5)
21. Use of ICT enabled project network systems
    (1) (2) (3) (4) (5)
22. Imposing security and restrictions over accessing data
    (1) (2) (3) (4) (5)
23. Use of general purpose software
    (1) (2) (3) (4) (5)
24. Use of 3D-CAD for cost-effective designs
    (1) (2) (3) (4) (5)

25. Project time planning through Micros Tran and MathCAD
    (1) (2) (3) (4) (5)
26. Use of WinQS32, QSCAD, and CATO for Quantity Surveying
    (1) (2) (3) (4) (5)
27. Knowledge sharing through global networks
    (1) (2) (3) (4) (5)
28. Electronic knowledge file creation during the project time
    (1) (2) (3) (4) (5)

Thank You for the Participation