Karlsruhe Institute of Technology

Faculty of Civil Engineering and Environment,
Institute for Technology and Management in
Construction (TMB)

An Integration of a Buffering Assessment Model Using Fuzzy Logic with Lean Management for Improving Highway Construction Process

Zur Erlangung des akademischen Grades eines
DOKTOR-INGENIEURS
von

MSc. Eng. Moataz Awad Mahpoob Farag

Aus Elmenia, Ägypten
19.08.1977

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des Karlsruher Instituts für Technologie (KIT)

genehmigte

DISSERTATION
von

Moataz Awad Mahpoob Farag, M.Sc.

aus Elmenia, Ägypten
19.08.1977

Tag der mündlichen Prüfung:	2nd June 2010
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Karlsruhe 2010

Dissertation genehmigt von der Fakultät für Bauingenieur-, Geo- und Umweltwissenschaften des Karlsruher Instituts für Technologie (KIT) , 2010

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This dissertation is dedicated to:
My parents and my family for their love,
My wife for her endless help and continuous support,
My sons, Ahmed and Adham, for their sweet smiles that give me energy to work.

****

The philosophy of the author in this research is for a couple of points:

1. *Unless you are lucky, you cannot solve any problem completely from the first time: "Continuous Improvement".*

2. *One hand is not enough, so it is necessarily for hand in hand: "Cooperation".*

Acknowledgement

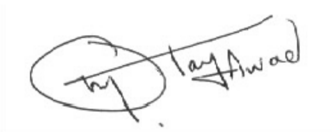
At the Institute für Technologie und Management im Baubetrieb (TMB) of the Karlsruhe Institute für Technology (KIT), the basics, principles, and the idea motivated this research were represented through this dissertation. The second workshop of Lean Construction, which was held in Karlsruhe on January 23rd 2007, was the turning point of my vision towards construction management. I became convinced that most problems, which construction processes suffered from, are due to deficiencies of theory as well as philosophy of management.

I would like to thank those people who contributed to making this work feasible through providing direct help, financing, sharing their knowledge and enthusiasm or simply through their friendship, support, patience and love. They were so many that I am faced with immense task and risk not mentioning someone that deserves at least as much recognition as those presented here. This work was executed in a new city, a new country and a new reality. I will always remember those first cold days of the year in Karlsruhe and all the life, and further, the beauty of this excellent small city and the forests and fields around it. Special thanks go to my country Egypt that allowed me to get the chance of studying in Germany, and provided me the financial support, in the form of my scholarship.

Furthermore, real, cordial, honest and special thanks go to my supervisor, Professor Fritz Gehbauer, director of TMB institute. I learned a lot from him directly and indirectly. He has played an important role in directing my work wisely at critical moments as well as been a vital tool in its execution. Indeed, he has taught me how to learn, think, and search. In addition, I thank Prof. Tarek Abdelhameed for his real cooperation.

I would like to thank Mr. Alaa Khalil for making linguistic amendment to thesis. I want to thank some colleagues from TMB; H. Schlick, M. Ott, Alex. Hofacker and Ailke Heidemann for their help when I was getting settled and for all the talks we had. I would thank my special friend Eng. Ahmed Mostafa Elqady, who works as a project manager of the highway construction sector in Egypt. He provided me with all possible data for current highway projects being under construction, also assisted me in distributing and filling out the questionnaires.

On the other hand, I thank my best life-partner Omnia for her advice, tenderness, and above all for her real love. She always supported and pushed me, and besides, she left her home country to stay with me in Germany. She spent alone for long time while I was being in my work. She really contributed to my success because she never thought about herself. Eventually, I would like to mention my children (Ahmed and Adham), Mother and Father. They really add a special taste to my life, which supported me indirectly.



Moataz A. M. Farag

Karlsruhe, 2010

Abstract

Many construction projects, especially outdoor projects are more sensitive to waste reasons impact, such as highway construction that is significantly sensitive to uncertainty impact. These agents are the main reasons generating both budget and duration overrun. Admittedly, highway construction projects have special attributes, owing to their common execution in an environment characterized by varying degrees of uncertainties. Unfortunately, highway construction projects of Egypt, as the focal point of this research, evidently encounter many waste that make the highway project delivery viewed to consume too much time. The problem concerned by this research is dominated through abilities of achievement for a reliable schedule, mitigation of the influence of uncertainty, and establishing appropriate approaches for Buffer Design and Management (BDM). This research tests the vital role of the buffer mechanism through scheduling, and its benefits for the entire construction process. The more appropriate buffer size, the more reliable schedule.

Hence, the overall objective of this work is to develop a methodology for an integration system framework called 3D-Management System. This objective is established through developing a proper buffers assessment model called FLBM, which is based on fuzzy logic system. FLBM focuses upon increasing the reliability of buffers by considering the intrinsic factors contributing to variability in the execution of a project. Simulation of the model is demonstrated in MATLAB using sample data to verify the model. The results of the simulation give positive feedback reflecting the actual conditions. In the further step, employing collaboratively the model in the course of the implementation of LPS® is demonstrated. This methodology provides a sound and rational framework based on the FLBM as a buffer design tool and LPS® as a production control tool, enhancing the optimization and decision-making process related to buffer design and management in construction through the transparency and cooperation.

A set of scenarios was run over the FLBM in order to validate the model theoretically. Its employment through a case study of a highway construction project

in Egypt was further implemented for the practical validation. The implementation of FLBM to the study project emphasizes its benefits to the master schedule because it indeed allots a specific buffer time to a specific activity proper to activity characteristics, and the degree of uncertainty. Although the implementation of the 3D-Management System framework could not be demonstrated yet, a general consensus on the ability of the proposed system in the course of LPS®, that providing an entire view of the whole process, was reached.

Despite the limitation of data-based the model, which are gathered from the Middle East region, the usability of this system can be globalized. This can be done through the main framework of the system as well as the model of FLBM. However, it should be fed by data of the area, where the model will be applied.

KURZFASSUNG

Viele Bauvorhaben, vor allem diejenigen unter freien Himmel, sind in besonderem Maße anfällig für Verschwendungen. Beispielsweise werden Straßenbauprojekte stark von Un-sicherheiten beeinflusst, die sich als Hauptgründe für Budget- und Bauzeitüberschreitungen erweisen. Allerdings folgen Projekte des Straßenbaus ihren eigenen Regeln, die den speziellen Anforderungen an ein Umfeld mit unterschiedlich ausgeprägten Unsicherheiten geschuldet sind. Bedauerlicherweise sind gerade Projekte in Ägypten, die den Schwerpunkt dieser Forschungsarbeit bilden, von vielfältigen Arten der Verschwendung betroffen. Diese führen zu erhöhten Ausführungsdauern. Die grundlegenden Fragestellungen dieser Forschung ergeben sich aus den Möglichkeiten zum Erreichen von verlässlichen Zeitplänen, der Minderung von Einflüssen durch Unsicherheiten und der Einführung eines geeigneten Vorgehens für das „buffer design and management“ (BDM). Die Haupthypothese, auf der die Untersuchung basiert, überprüft die zentrale Funktion der Pufferzeiten während der Planung und deren Nutzen für den weiteren Bauprozess. Denn, je angemessener die Puffergröße, desto verlässlicher der Zeitplan, wodurch der Bedarf an Pufferzeit wiederum reduziert wird.

Ziel der vorliegenden Arbeit ist, die Methodik eines integrierten Netzwerks, dem sogenannten 3-D-Management System, bestehend aus dem „fuzzy logic buffer modell“ (FLBM) und dem Last Planner System (LPS®), zu entwickeln. Dieses Ziel soll durch die Entwicklung eines passenden Modells zur Bewertung von Pufferzeiten, dem FLBM, das auf der Fuzzy Logic Methode basiert erreicht werden. Das FLBM konzentriert sich auf die Optimierung von Pufferzeiten, indem die Faktoren, die zu Schwankungen in der Ausführung von Bauprojekten führen, berücksichtigt werden. Das Modell wurde in MATLAB simuliert und unter Verwendung von Realdaten überprüft. Die Resultate ergaben ein positives Feedback, bezüglich der Realisierbarkeit des Modells. In einem weiteren Schritt wird die Kombination des FLBM mit dem LPS® untersucht. Diese Kombination schafft ein besseres und rationales System, mit dem FLBM, als Werkzeug für das Ansetzen von Pufferzeiten, und dem LPS®, als Werkzeug der Produktionskontrolle. Transparenz

und Kooperation, durch die Anwendung des LPS®, verbessern die Qualität der Entscheidungsprozesse zur Optimierung von Pufferzeiten und der Produktionssteuerung.

Eine Reihe von Szenarien wurde im FLBM simuliert, um dass Modell theoretisch zu validieren. Durch die Durchführung eines Fallstudienprojektes in Ägypten erfolgte eine praktische Validierung. Die Anwendung des FLBM in dieser Fallstudie zeigte Vorteile in der Erstellung des Rahmenterminplans des Projektes auf. Das Modell weist jeder Aktivität eine spezifische Pufferzeit zu. je nach deren spezifischem Charakter und dem Grad der Unsicherheit. Obwohl nur eine praktisch Implementierung des FLBM, als Teil des 3-D-Management System, durchgeführt werden konnte, wurde über Expertenbefragungen die Eignung des vorgeschlagenen Systems für den Gesamtprozess belegt.

Trotz der Limitierung der Datensammlung auf den Raum des Mittleren Ostens kann das System verallgemeinert werden, da das FLBM als Teil und auch das 3-D-Management System als Ganzes flexibel an die örtlichen Bedingungen angepasst werden können.

TABLE OF CONTENTS[1]

[1] The numbering form of "X-XX" used in dissertation commences from the first chapter up to the end. The first digit indicates the chapter number, where chapter is numbered. The second digits indicate the numbering of pages, which is in a consecutive form and independent of chapter numbering, that is to say, the numbering does not restart each chapter.

In a world that is constantly changing, there is no one subject or set of subjects that will serve you for the foreseeable future, let alone for the rest of your life. The most important skill to acquire now is learning how to learn.

John Naisbitt

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Those who fail to prepare, are preparing to fail.

CHAPTER 1. INTRODUCTION

1.1 INTRODUCTION

Construction process means the mobilization and utilization of capital and specialized resources to accomplish a predefined project on a specific site according to prepared documents of drawings, planning, standards, and contract to satisfy the purpose of the project. Housing, non-residential buildings, highway construction, industrial construction, and other highly technical structures are the common divisions of the term construction. Furthermore, the construction process itself is very complex; it involves a combination of organizations, engineering science, studied anticipations, and estimated risks [RICKETTS '99].

Construction Management is an enterprise that involves many people with diverse interests, talents, cultures, and backgrounds. The owner, the design professional and the contractor comprise the primary triad of parties, but others, such as subcontractors, material suppliers, insurance and bonding companies, attorneys and public agency officials, are vital elements of the project team whose interrelated roles must be coordinated to assure a successful project [BENNETT '03].

The construction sector has long been blamed for poor performance on cost level, productivity improvement, innovation, project completion time, reworks level, customer satisfaction, and other parameters [JØRGENSEN '06].

Explicitly, construction problems are well known to everyone. For example, the construction process has different types of waste that can transform a good project into a bad one. Usually, determining the reasons for waste being produced are poses a challenge for construction managers because most of these reasons are often not visible. Thus, the identification of such reasons and their causes allows management to act in advance to reduce their influence [SERPELL et al. '95]. Construction projects, especially outdoor ones, such as highway constructions, are more sensitive to uncertainty. As a result, both budget and duration can overrun [PAN '05].

1.2 RESEARCH LIMITATION

The major limitation of this work is its focus on the highway projects throughout the phases of planning and control. In addition, this study is concerned with developing countries in the Middle East region, particularly Egypt. This is on account of the high investments of over US$ 500 billion for the infrastructure's development within the next decade. Nearly 105 highway projects of a total capital value of US$ 82.7 billion are constructed within a specific period. The investments value of highway projects in Egypt is among the highest top three countries, as shown in (Figure 1-1). Consequently, the key research aims to engender cooperation between all attempts in a continuous improvement for highway construction management, especially in Egypt.

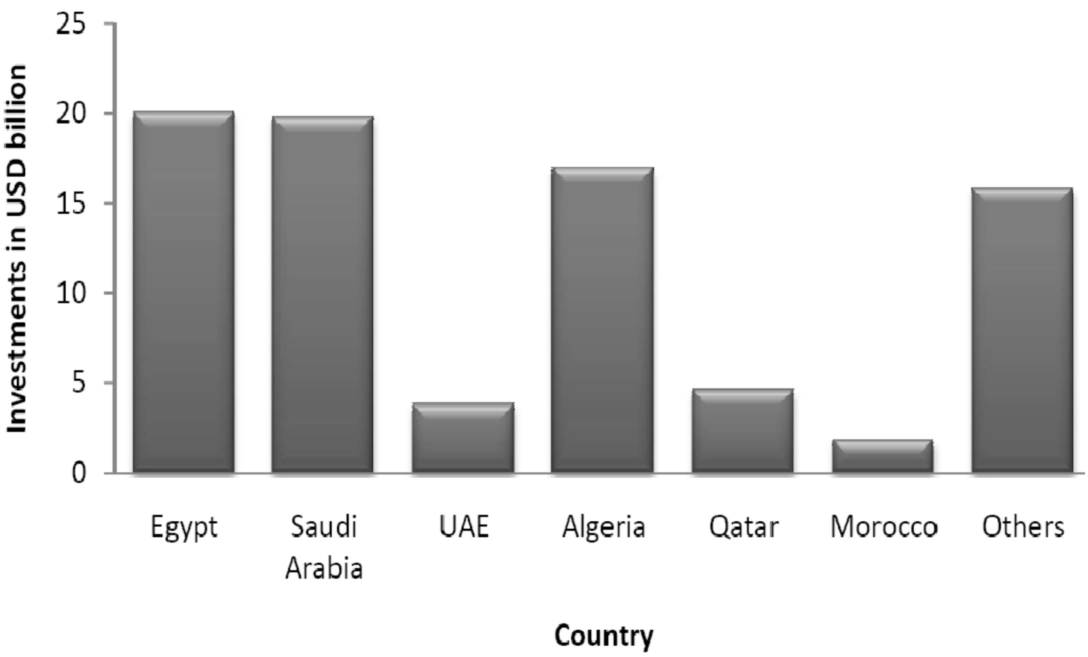


Figure 1-1 Investments of Highway Projects in The Middle East[2]

On the other hand, the research is further only limited to the buffers regarding time. Hence, developing a proper assessment approach for such buffers, used in schedules, is within the scope of the research.

[2] Data on behalf of infrastructure investments are compiled from miscellaneous websites and the Abu Dhabi Investment Co. http://www.investad.ae/en/MENARegion/Infrastructure.aspx

1.3 HIGHWAY CONSTRUCTION PROJECTS OF EGYPT.

1.3.1 Characteristics of the Execution Process

The construction process of highway projects has unique features, which are very similar in all countries, even though construction methods or techniques of highways may vary from one country to another. Namely, as depicted in (Figure 1-2), the highway construction process involves typical continuous, linear activities performed along the horizontal alignment of facility. Cleaning, grubbing, excavation, grading, paving are examples of such activities. These activities are similar and repeatedly performed from unit to unit or station to another one horizontally.

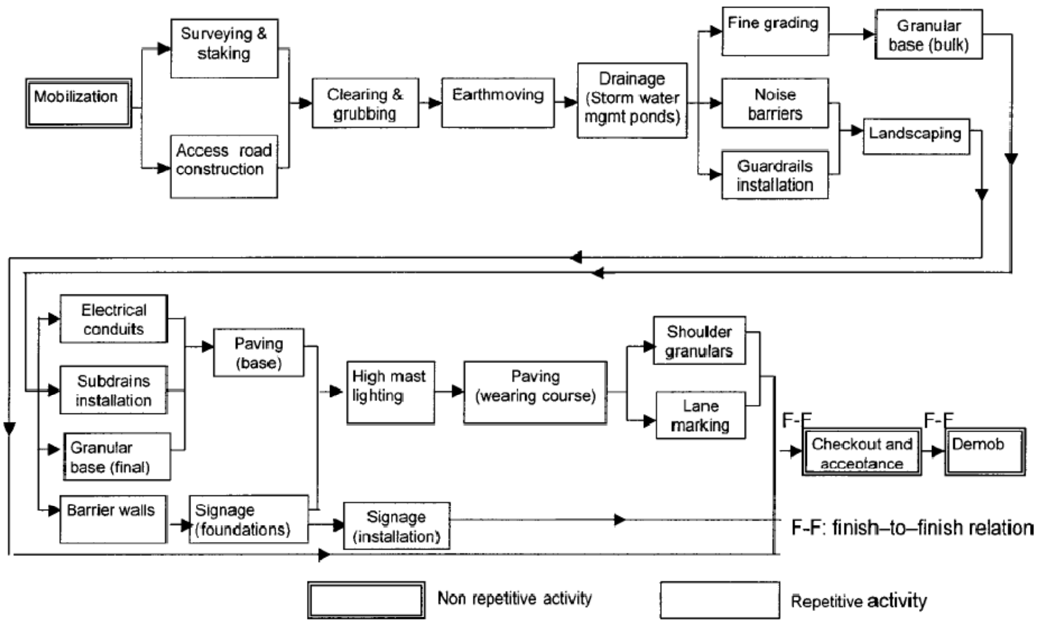


Figure 1-2 Typical Highway Construction Activities [HASSANEIN et al. '04].

Admittedly, highway construction projects have special attributes, owing to the fact that they are commonly executed in an environment characterized by varying degrees of uncertainty. Thus, such projects have been focused on by many researchers [LORTERAPONG et al. '96; EL-RAYES et al. '01; PAN et al. '05b, a; KO '06], who have stated that they experience numerous challenges as they strive for success. Subsequently, a significant impact may influence the scheduling process not only in estimates of the duration for construction activities, but also in calculations related to the network. Weather impact and resource constraints are examples of such uncertainties, which require a stochastic analysis before/during construction for preparing a credible and realistic schedule.

1.3.2 Characteristics of the Management Process

In general, management of the highway construction is a process aiming fundamentally at achieving the maximum profit in the minimum time possible without sacrificing quality. However, the manners in which such a process for highway construction projects is handled varies extensively from one place to another. For instance, the *Alliancing* technique is being used comprehensively nowadays in most types of construction in Australia, One Day One Cycle (DOC) and One Day One Floor/unit (DOF), with respect to the concept of one-piece flow, are examples of management methods employed in repetitive projects of Japan. Moreover, USA, UK, the Netherlands, South Africa, and Brazil have recently moved towards the implementation of the new philosophy of Lean Management through various construction sectors. However, the majority of other countries, especially developing countries, still either have no obvious management vision for highway construction projects, or managing such projects traditionally. So far, the management of highway construction projects in Egypt has had no specific strategy. The same is true for residential and industrial construction projects, which may have a rather clear strategy of management, albeit its ineffectiveness resulting in no significant success.

Recently, the largest road construction companies in the Middle East, particularly in Egypt, have demonstrated a great endeavor to establish the traditional the principles of project management for managing such projects. As it is generally known, the project management body of knowledge (PMBOK) sets up principles of the traditional project management, and also provides an overall summary of the basic flow and interactions among process groups and specific stakeholders as depicted in (Figure 1-3). Nonetheless, the remarkable improvement in the road construction sector is still intangible.

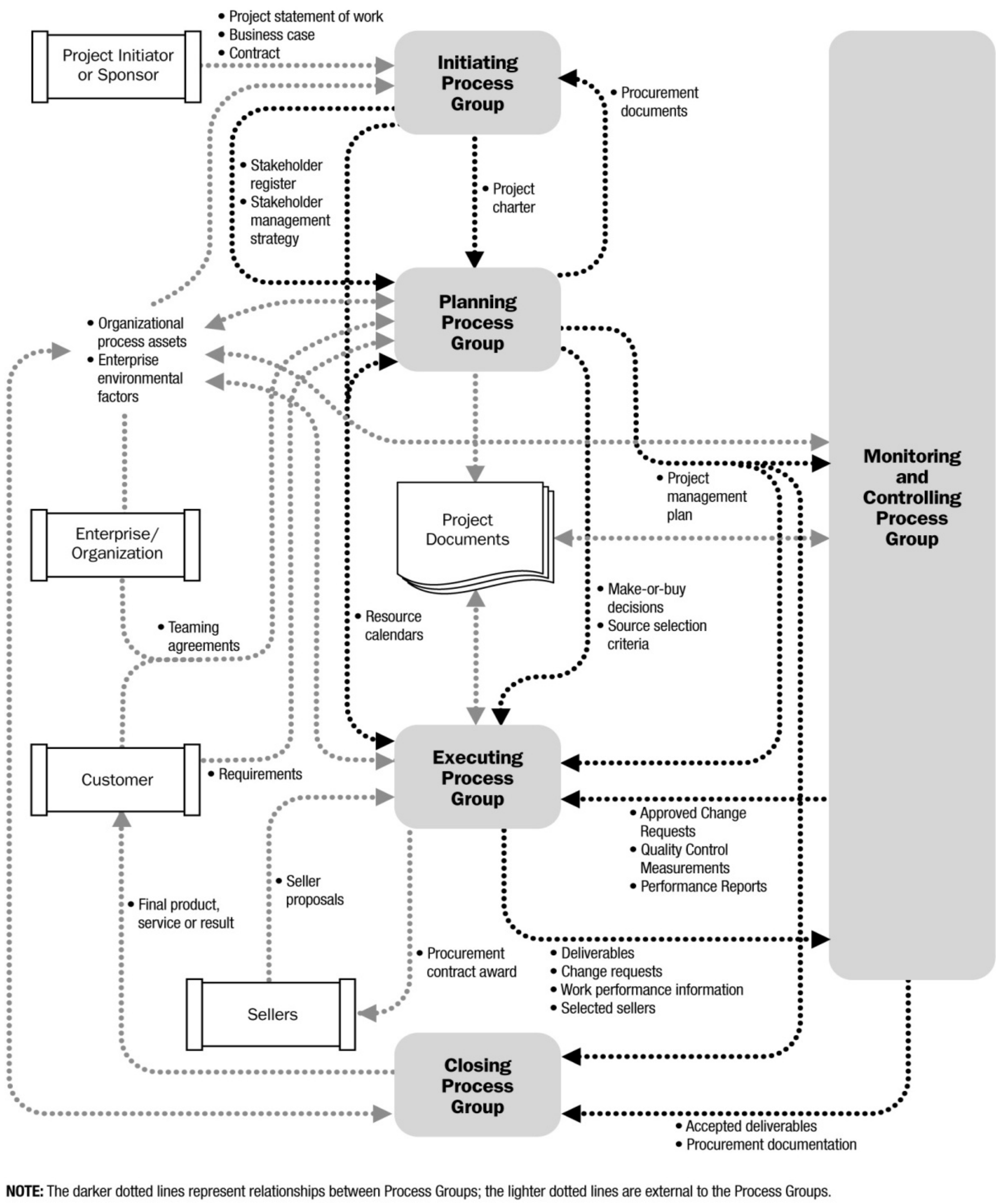


Figure 1-3 Project Management Process Interactions [PROJECT MANAGEMENT INSTITUTE. '08]

The essential deficiencies of the current traditional management system for highway construction in Egypt were characterized as follows [FARAG '08; FARAG et al. '08]:

- Organization
  - Hierarchical organization; command order flow.
  - Collaboration among project members is intangible.
  - Lack of transparency.

- Planning and scheduling
  - Design often differs from reality.
  - Scheduling is usually done in a deterministic form.
  - Scheduling update is not continuously established.
  - Schedule is only an official document; out of consideration through the activities execution.
  - Lack of the knowledge for Buffer Design and Management (BDM).
- Managing of the construction process
  - Random system of management.
  - Personal relationships play a vital role in management, rather than standardization, specifications, quality ...etc.
  - Task performance through predecessor and successor is not regularly monitored throughout the construction.
  - Regular (short-term) meetings of construction partners are rarely organized.
- Resource management
  - Resources have no plan of flow.
  - Push system.
  - Information is often delivered late and insufficient.
- Personnel management
  - Intangible communication between manager and sub-employees.
  - Workers' problems are out of attention.
  - Unfair distribution of incentives; who works equals to who does not.
- Uncertainty management
  - Inefficient dealing with unforeseen conditions.
  - Quantification of uncertainty is based upon non-stochastic calculations.
  - Inconsideration of buffers mechanism into the baseline schedule.
- Target cost has the priority than customer's requirements.
- Bureaucracy/RED TAPE.

1.4 PROBLEM STATEMENT

Crucial to the successful outcome of highway construction and reconstruction projects is the ability to accurately plan, predict, and control the construction process. In regard to highway construction projects in Egypt, as the focal point of the research, even though almost all of them have tried implementing the traditional way of management, they have unfortunately created a great deal of waste. This waste has caused highway project delivery to be seen as too much time consuming. Exacerbating this situation is the funding shortfalls plaguing most highway agencies. Explicitly, the afore-mentioned shortcomings of the current management are essentially contributing to such problems.

A survey has been conducted among highway practitioners to determine the amount of waste facing the construction process of highway projects. The survey points out that waste of time accounts for 44% of the total project duration. As shown in (Figure 1-4), waiting and idle time is the effectual cause of such waste.

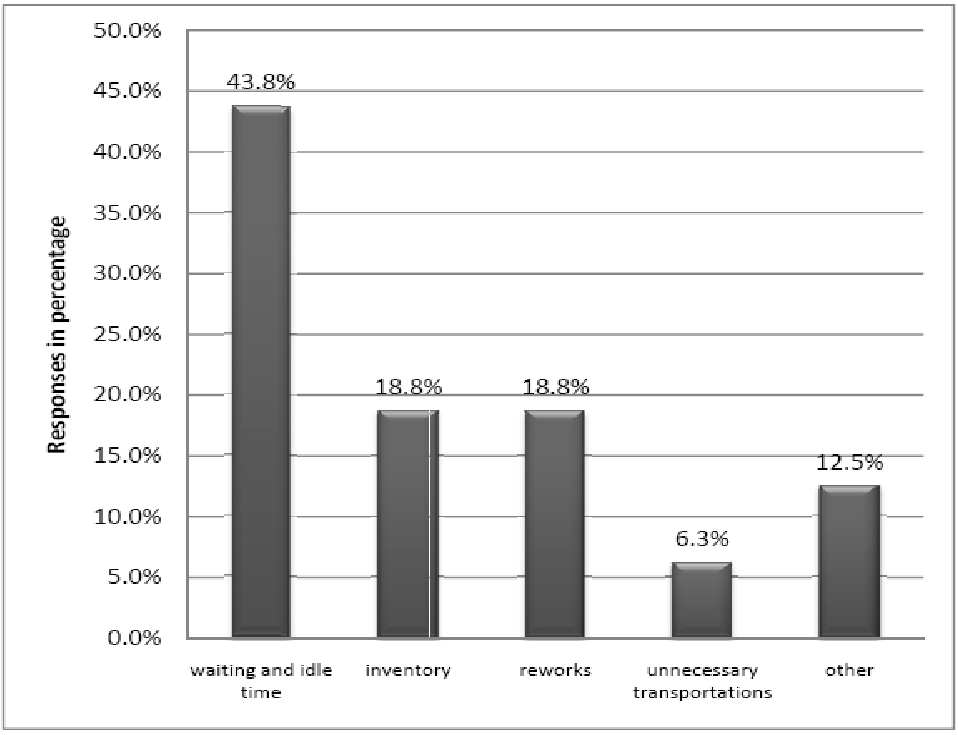


Figure 1-4 Main Root Causes of The Waste of Time in The Highway Construction Process

Uncertainty, poor scheduling, and lack of sufficient management are among the top most important dimensions of waiting and idle time (non-value added time). The problem that this research is concerned is preceded through following the 3HOW questions:

1. How is the mitigation of uncertainty impacts ideally established?
2. How can reliability of scheduling be enhanced?
3. How lean can lean buffers be?

1.5 HYPOTHESES AND METHODS

In general, this research is based on a couple of hypotheses in order to approach the aforementioned problem and to answer the questions of 3HOWs as well. Firstly, this research aims at the examination of the vital role of buffers through scheduling, and its benefits for the entire construction process when appropriates for the actual degree of uncertainty. Then the second hypothesis tests the integration of the proper buffer sizing approach with a more suitable planning and control tool through a modern management philosophy than the traditional.

The first hypothesis regarding the vital role of buffers has been tested by evaluating buffers through building a model that considered significant issues, with respect to the actual degree of uncertainty, which were not found by previous methods. Hence, the reliable schedule is the schedule that reflects the reality considering both foreseen and unforeseen conditions. This consideration may be interpreted as terms of buffer, which is a reserved time added to the normal duration of the activity to absorb the impact of variability. On the other hand, the more appropriate the buffers size, the more reliable the schedule.

Owing to the fact that stand-alone buffer-designing approaches do nothing without an effective management method; an improvement of management techniques should be accomplished. However, it is necessary to upgrade the existing pitiful method of management to another effective method. Regarding that, the second hypothesis is that Lean Construction, as a recent philosophy of management, would change the old-fashioned vision of management and result in a better workflow.

Supposedly, the use of buffer is controversial from a lean production perspective since zero inventories, or non-buffered production systems are desirable. Lean construction has a unique strategy that guarantees the continuous effective control, the satisfaction of customers, the elimination of all types of waste, collaboration and competition spirit, either keeping or reducing the project completion due date, and achieving maximum profit. In fact, lean, as will be explained later in more depth, offers a set of tools for the assistance in fulfilling such goals. This hypothesis has been tested by using the proposed buffering assessment model through the Last Planner System® as an effective lean tool for planning and production control.

1.6 RESEARCH OBJECTIVES

The overall objective of this work is to develop an integration system framework called the 3D-Management system. Whereby 3D refers to the function of this system. Namely, the system works through three dimensions. These dimensions are the hypothetical motives of the problem of waste of time as illustrated in (Figure 1-5). The proposed system is based mainly on the collaborative actions between an adequate control tool of the LPS®, and a proper buffers assessment model.

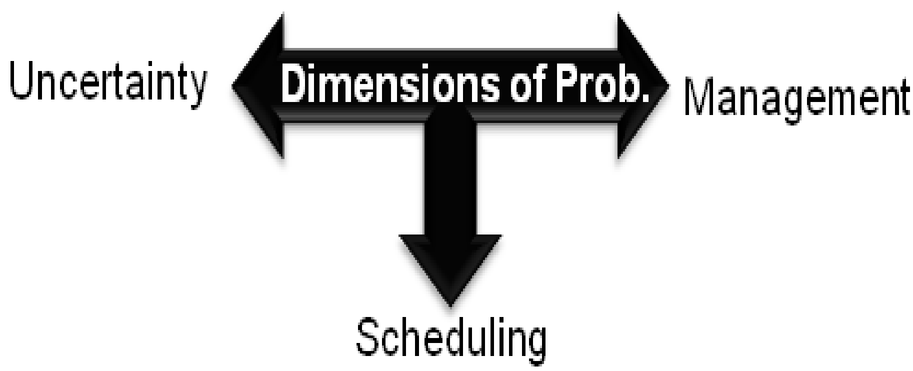


Figure 1-5 Dimensions Motivate Waste of Time in Road Construction Projects

Objectives of research as well as the proposed system framework are expected to steer the following:

- Supply a reliable schedule based on the buffers assessment model, which matches buffers to the degree of uncertainty. This model considers most agents as influencing the design of buffers, and it also is designed by a stochastic tool suitable for real characteristics associated with the nature of highways constructions.
- Withstand the impact of uncertainty, which is the root cause of wasted time, throughout the construction process of highway projects. That can be employed by the cooperation of the LPS®, as a control technique, with the proposed buffers model.
- Achieve a remarkable optimization for the construction process based on the philosophy of "the lower the river". This optimization can be achieved through the integration between the LPS® and the proposed buffers model of FLBM in one system as a cycle. This improvement cycle indicates the working mechanism of the 3D-Management system of LPS® and FLBM. This mechanism is mainly based on re-dimensioning of buffers in an iterative form to match the actual variability. In this way, the level of buffers can be leaned.

1.7 RESEARCH METHODOLOGY

The methodology of this research will be conducted in a sequence as presented in (Figure 1-6).

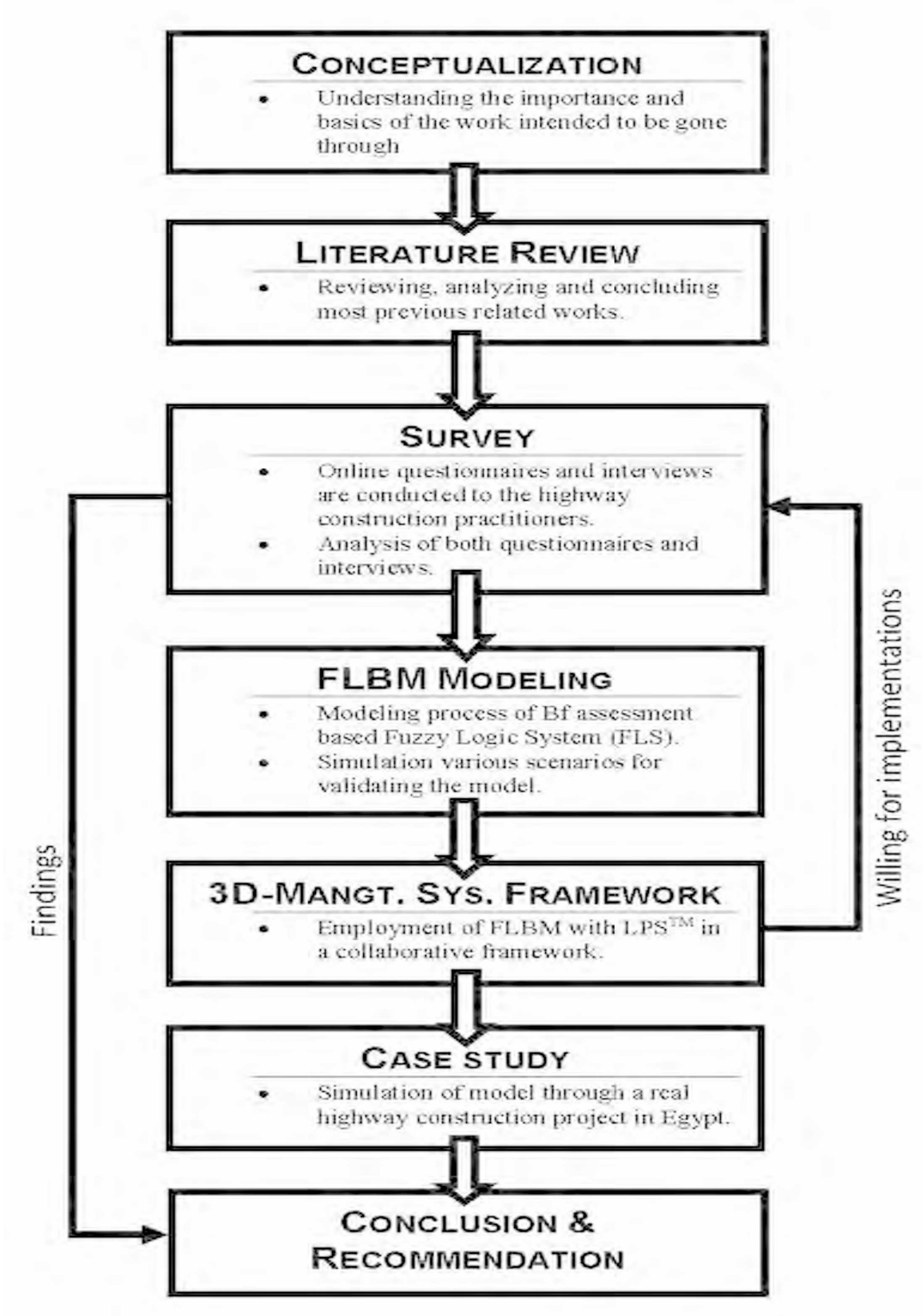


Figure 1-6 The Flow Chart of The Research Methodology

1.8 RESEARCH ORGANIZATION

The dissertation is structured into seven chapters as follows:

In Chapter 1, a brief introduction and contribution of the research are exhibited along with the scope, and objectives of study.

In Chapter 2, basic knowledge, and historical background of the evolution of Lean Management are presented.

Chapter 3 discusses and reviews previous attempts in the issues of uncertainties in construction, buffers design and management approaches (BDM), and the optimization of such approaches through the implementation of Lean Construction concepts.

In Chapter 4, the methodology adopted to get the objectives of the study by developing the Fuzzy-logic buffering Model (FLBM). The basic criteria on which this model is based are addressed further. The modeling process is elaborated through both algorithms and programming of MATLAB software. Moreover, various scenarios are simulated through the proposed model for its validation.

Chapter 5 describes the methodology of the 3D Management system framework. The role of LPS® with the FLBM is further interpreted through the proposed system.

In Chapter 6, the implementation of FLBM to a real highway construction project in Egypt is demonstrated through its master schedule. Findings are compared with the actual performance or actual plan in order to consider the outcome of the model. Likewise, a questionnaire has been conducted to gather feedbacks and expectations related to the proposed framework of the 3D Management.

Chapter 7 presents conclusion to the findings of the study with particular emphasis on the contribution of research and recommendation for future research.

2

Lean Management from Production to Construction

- **Notion of Lean**
- **Rise of lean production**
- **Tools**
- **Lean construction**
- **Buffering in lean perspective**
- **Last Planner system**

The key to the Toyota Way and what makes Toyota stand out is not any of the individual elements.... But what is important is having all the elements together as a system. It must be practiced every day in a very consistent manner not in spurts.
„Taiichi Ohno"

CHAPTER 2. LEAN MANAGEMENT PHILOSOPHY FROM PRODUCTION TO CONSTRUCTION

2.1 LEAN: AN INTRODUCTION

Recent modern world is highly competitive and it is usually the survival of the fittest. Throughout the globe, a great deal of research has been realized to find a suitable management philosophy that could enable a company to survive and succeed, especially in times of recession. Many companies are now resorting to the reliable and effective practice of lean manufacturing, which has been dominant in Japan, US and some parts of Europe. In this chapter, we will dwell on the topic of lean manufacturing, explaining its historical development and how it has changed the manufacturing world today. Gradually we shall move on to our main topic of concern "Lean Construction", which will be explained in detail in the coming chapters.

2.2 DEFINITION

The origin of the "lean principles" can be traced to the Japanese manufacturing industry. The term **lean** was first coined by an IMVP (International Motor Vehicle Program) researcher John Krafcik in a Fall 1988 article. He referred that to be "*Lean means to derive more value by using less of everything*" [KRAFCIK '88].

Though different researchers have their own interpretation of lean, the most common among them is a **"**Production practice that considers the expenditure of resources for any goal other than the creation of value for the end customer to be wasteful, and thus a target for elimination**"**. However, the most suitable definition in the context of this work was given by Bhasin and Burcher, "A philosophy that when implemented reduces the time from customer order to delivery by eliminating sources if waste in production flow" [BHASIN et al. '06]. In order to understand the meaning of the above few lines we need to understand the evolution of the lean principles.

2.3 ORIGIN OF LEAN PRINCIPLES

The credit for the development of lean principles goes to the Toyota Automotive Company in Japan, which revolutionized the way of manufacturing automobiles. The manufacturing industry today has certainly come a long way from the mass production theory as followed by Henry Ford in the US. Before we elaborate on the contributions of Toyota in the development of lean principles, it is important to understand the motives behind the need of a new manufacturing technique when Ford was going great guns in delivering the consumer a cheap and yet efficient product.

Automobile industry emerged into the forefront in the late 19^{th} century. The demands of the consumers were ever changing and to keep pace with these demands required a great amount of research, which was obviously lacking in the industry at that time.

Henry Ford (1863 – 1947) was quick to realize this problem, and eventually established the so-called mass production system in his Ford Motor Company. He developed the assembly lines, which reduced the cost of production and at the same time increased the product quality. That assembly chain enabled a worker to work from a stationary place as all the tools and materials were delivered to him. This enabled the working time on the car to be reduced to a few minutes compared to hours or even days in other companies. This also resulted in lowering the labor costs per car because of the increase in mechanization. Ford took the division of labor in the company to the extreme.

Despite the fact that Ford succeeded in bringing down costs and delivery time, there was a large flaw in his thinking. He thought that there was unlimited demand for his product. He did not give any importance to variety, and hence he thought that the consumer would buy anything that he produces. This led to the ultimate demise of the mass production system.

2.4 RISE OF LEAN PRODUCTION

When Ford was at its pinnacle of success, a Japanese man by the name of Eiji Toyoda set out on a three-month long pilgrimage to the Ford factory in Detroit. During the course of his visit, he declared that the American method of mass production is not suitable for the Japanese market because there were a number of deficiencies in the mass production system. Thus, he along with his production genius Taiichi Ohno developed the Toyota Production System also commonly known as the Lean Production System. However, this was not easy, especially because of the aftermath of World War II and the growing financial slump in Japan. A solution was found to keep Toyota running in which the workers were made part of the Toyota family and guaranteed lifetime employment. Thus, Ohno began with his goal of implementing lean production.

Taiichi Ohno in 1988 said:

“All we are doing is looking at the time line from the moment the customer gives us an order to the point when we collect the cash, and we are reducing that time line by removing the non-value-added waste.”

Anywhere, where work is performed, waste is being generated. Accordingly, Ohno observed that the entire process at Ford was rife with Muda (Japanese for waste). He observed seven types of waste at Ford. With an aim to find solutions to remove this waste, Ohno set out to develop the Toyota Production System. Having already elaborated on the main objectives and listing the aims of lean production, we should have a clear understanding of these seven types of waste, as depicted in (Figure 2-1), which were represented by [WOMACK et al. '91; ALARCÓN '97; WOMACK et al. '03; LIKER '04; WOMACK et al. '05]. Consequently, Ohno and his team developed the Toyota Production System (TPS) or the Lean Production System, with the main motive of removing such waste in production. The main and most fundamental objectives of Lean production mainly aim to continually evolve and improve the current system. It means to design a production system that will deliver a product instantly on order but maintain no intermediate inventories. The main aims of lean production were addressed by [LIKER '04] as follows:

- Eliminating wasted time and resources.
- Building quality into workplace systems.
- Finding low-cost but reliable alternatives to costly new technology.
- Perfecting business processes.
- Building a learning culture for continuous improvement.

Ohno realized that in order to move towards the ultimate goals of no waste and perfection he needed to shift the improvement focus from one activity to the entire delivery system. This system design criteria promoted continuous improvement. An inventory control strategy was developed which replaced central push with distributed pull because Pull was essential to reduce work in process (WIP). Large inventories are required to keep production in push systems because they are unable to cope with uncertainties in the production system, and explicitly large inventories raise the cost of change.

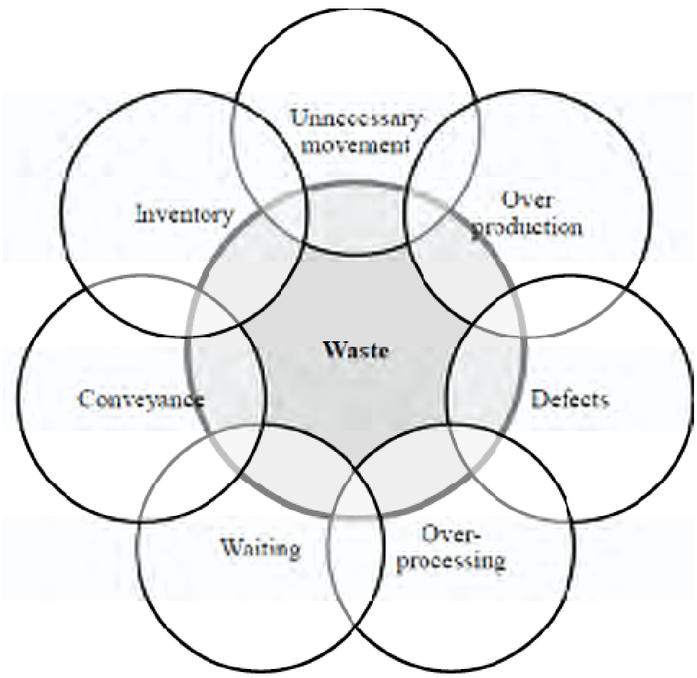


Figure 2-1 Seven forms of waste

The analogy of the TPS is explained in (Figure 2-2). The roof of the house represents the goals of the best quality, lowest cost, and shortest lead-time. Further, the two outer tools and human-related pillars represent ***just-in-time*** and ***jidoka*** respectively. The center of the system is made up of people. Eventually, the foundational element takes place, which includes the need for standardized, stable, reliable processes, also ***heijunka***, which means leveling out the production schedule in both volume and variety. Apart from the fact that each element of the house by itself is critical, more important is the way the elements reinforce each other.

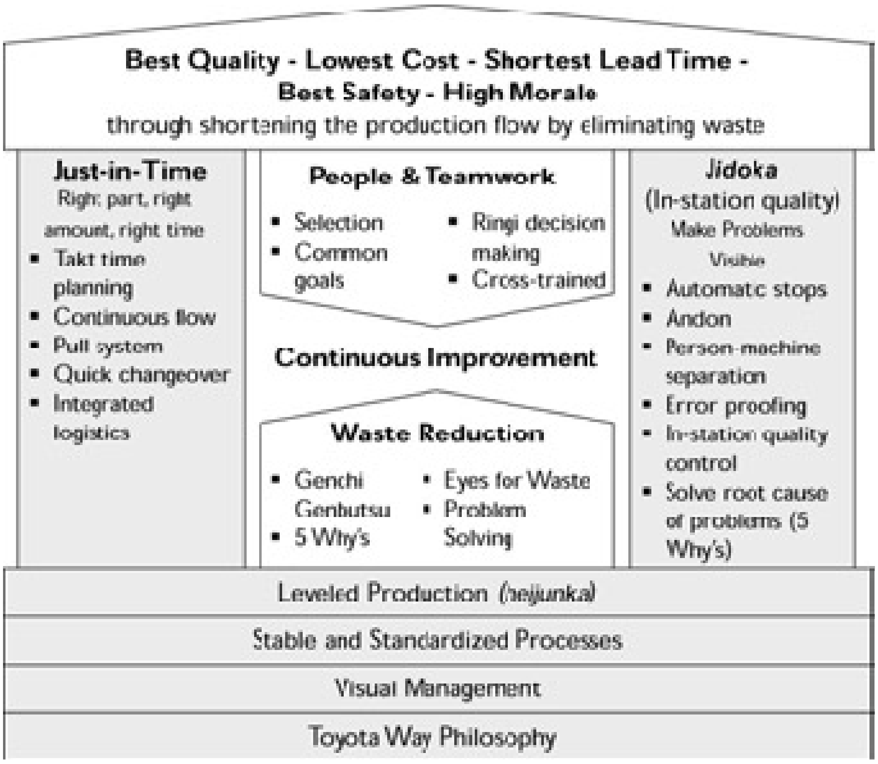


Figure 2-2 House Diagram of The Toyota Production System [LIKER '04]

JIT means removing, as much as possible, the inventory used to buffer operations against problems that may arise in production. The ideal of one-piece flow is to make one unit at a time at the rate of customer demand. Using smaller buffers (removing the safety net) means that problems like quality defects become visible immediately. This reinforces ***jidoka***, which halts the production process. This means workers must treat the problems as urgent and resolve them immediately in order to resume production. At the foundation of the house is stability. In mass production, when a machine goes down, there is no sense of urgency: the maintenance department is scheduled to fix it while the inventory keeps the operations running. By contrast, in lean production, when an operator shuts down equipment to fix a problem, other operations will soon stop producing, creating a crisis.

A high degree of stability is needed so that the system is not constantly stopped. People are at the center of the house because only through continuous improvement can the operation ever attain this needed stability. People are trained to see waste and solve problems at the root cause by repeatedly asking why the problem really occurs.

In summary, the differences between the traditional and lean production methodology are shown in (Table 2-1).

Table 2-1 Traditional Production Vs. Lean Production

	Traditional Production	Lean Production
Scheduling	Forecast – Product is pushed through facility	Customer Order – Product is pulled through facility
Production	Replenish finished goods inventory	Fill customer orders only
Cycle Times	Long – Weeks / Months	Short – Hours / Days
Batch Size	Large batches moving between operations; product is sent ahead of each operation	Small, and based on one-piece flow between operations
Quality Inspection	Sampling – by inspectors	100% - at source by workers
Layout	By department function	By product flow, using cells or lines for product families
Empowerment	Low — little input into how operation is performed	High — has responsibility for identifying and implementing improvements
Inventory Levels	High — large warehouse of finished goods, and central storeroom for in-process staging	Low — small amounts between operations, ship often
Flexibility	Low — difficult to handle and adjust to	High — easy to adjust to and implement
Manufacturing costs	Rising and difficult to control	Stable/decreasing and under control

2.5 TOOLS FOR LEAN PRODUCTION:

Fawaz Abdullah (2003), listed the major tools and techniques for lean manufacturing in the process industry as follows:

2.5.1 Cellular Manufacturing (One-Piece Flow)

Cellular manufacturing is a concept employed to increase the variety of products. The shop floor is further subdivided into cells, which consist of equipment and workstations that are arranged in such an order that maintains a smooth flow of materials and components through the process. Trained operators are assigned to each of the cells. One obvious advantage of arranging people and equipment into cells is the one-piece flow concept, which states that each product moves through the process one unit at a time without sudden interruption, at a pace determined by the customer's need. Some more benefits associated with cellular manufacturing include:

- Inventory reduction
- Reduced transport and material handling
- Better space utilization
- Lead time reduction
- Identification of causes of defects and machine problems
- Improved productivity
- Enhanced teamwork and communication
- Enhanced flexibility and visibility

2.5.2 Continuous Improvement

Continuous improvement or **Kaizen** is another fundamental tool of lean manufacturing. It includes a thorough and systematic approach to gradual, orderly and continuous improvement. It promotes reduction of inventory as well as reduction of defective parts. One of the most effective tools of Kaizen is **5S**, which is often the backbone of an effective lean company. 5S consists of the Japanese words **Seiri** (Sort), **Seiton** (Straighten), **Seiso** (Sweep and Clean), **Seiketsu** (Systemize), and **Shitsuke** (Standardize). The underlying concept behind 5S is to look for waste and then to try to eliminate it.

Seiri, deals with eliminating those items that are not currently being used on a continuous basis. **Seiton** means having the right items in the right area at the right time. Items that do not belong to a given area must not be in that area. **Seiso** deals with cleanliness of the working area. The workplace should look neat, clean, and ready to use for the next shift. All tools and items should be in the right place and nothing should be missing. **Seiketsu** means maintaining a high standard of housekeeping and workplace arrangement. **Shitsuke** specifies the management's accountability to train people to follow housekeeping rules. Management should implement the housekeeping rules in a practiced fashion so that their people can follow them easily.

Taken together, **5S** essentially means good housekeeping and better workplace organization. Kaizen tools such as **5S** not only serve as a means to increase profitability of a firm but also allow companies to reveal potential strengths and capabilities that were hidden before.

2.5.3 Just In Time (JIT)

Just in time is an action, which attempts to eliminate sources of manufacturing waste by producing the right part in the right place at the right time. It enables the company to become highly flexible by adapting to sudden changes in demand market. However, JIT effectiveness depends heavily on having a strategic alliance between buyers and suppliers. Just in time is a critical tool for managing the external activities of a company such as purchasing and distribution. It can be thought of as consisting of three elements: JIT production (JITP), JIT distribution (JITD), and JIT purchasing (JITB).

2.5.3. [I] Just-In-Time Production

Just in time production (JITP) means to produce only when the customer demands, thereby preventing any waste related to overproduction. Thereby, the product is pulled out of the assembly process only when required. The process goes on as each process pulls the needed parts from the preceding process further up stream.

2.5.3. [II] Just-In-Time Distribution

JITD requires the exchange of frequent, small lots of items between suppliers and customers; this calls for an effective transportation management system to manage the inbound and outbound material since there are no reserves. However, under JITD having a full truckload is sometimes difficult due to the frequent delivery of smaller lots, which accordingly result in increased transportation costs. To prevent such problem, a mixed loading strategy is suggested, which enables to have full truckloads, and also an increase in the number of deliveries.

2.5.3. [III] Just-In-Time Purchasing

The idea of JITB is to procure materials as and when required. Under JITP, activities such as supplier selection, product development and production lot sizing become very critical. Customer-supplier form an integral part of JITP in which the suppliers are encouraged to take part in the product development. This serves to be mutually beneficial as the supplier's confidence grows and the customer obtains the technology at a cheaper price. It thus becomes necessary to have a small number of qualified suppliers. Having quality-certified suppliers shifts the inspection function of quality and piece-by-piece count of parts to the supplier's site where the supplier must make sure that parts are defect free before they are transported to the manufacturer's plant.

2.5.4 Production Smoothing

Heijunka, the Japanese word for production smoothing, is where the manufacturers try to keep the production level as constant as possible from day to day. It is a concept adapted from the Toyota Production System, where in order to decrease production cost it became necessary to balance the demand with supply and thereby not overproducing. To achieve constant production levels, the production schedule should be as smooth as possible to effectively produce the right quantity of parts and efficiently utilize work force. Inability to do so leads to waste (such as work-in-process inventory) at the workplace.

2.5.5 Standardization of Work

A crucial principle of waste elimination is the standardization of worker actions. Standardized work basically ensures that each job is organized and is carried out in the most effective manner. This enables to achieve the same level of quality irrespective of the person doing the job. A tool that is used to standardize work is "takt" time. Takt is a German word for beat time and refers to how often a part should be produced in a product family based on the actual customer demand. The target is to produce at a pace nearly equal to the takt time. Takt time is defined by the following relation:

$$Takt\ Time\ TT = \frac{Net\ available\ work\ time}{Customer\ demand}$$

2.6 A PRODUCTION VIEW IN CONSTRUCTION PROCESSES

Construction is a different type of production to manufacturing, and has greater uncertainty and flow variation. However, construction processes have many similarities with manufacturing processes. (Table 2-2) shows a brief comparison of them. From the production point of view, crew tasks within construction activities have equivalent roles as machine tasks in manufacturing processes. Accordingly, many production theories could be applied to construction processes under similar principles [CHUA et al. '01].

Table 2-2 Comparison between Construction and Manufacturing Processes

	Construction	Manufacturing
Elements in Process	Crew tasks	Machine tasks
Input	Time, money, resources, space and information	Time, money, resources, and information
Output	Finished structures	Finished parts
Capacity utilization	Percent Plan Complete (PPC)	Throughput
Bottlenecks	Tasks on critical path	Constraint machines
Principle	No delay on critical path	No idle on constraint machine
Disruption	Task delay	Machine breakdown (or idle)
Prevention	Reliable planning	Maintenance
Management of Work in progress	Buffers Design and Management (BDM).	Inventory management

2.7 LEAN CONSTRUCTION

The traditional method of project management has a long history. It has been used to manage all kinds of construction projects ranging from small residential to immense infrastructural projects like bridges and dams. However, in recent years due to growing domestic and international competition, development of highly complex and uncertain projects this technique of project management has often come under severe criticism. The construction industry has suffered from the problems of low productivity, poor safety, inferior working conditions and most importantly inferior quality. Many have attributed automation and increased computer integration as a solution to the above-mentioned problem [KOSKELA '99]. Hence, there has been little progress in the field of Lean Construction over the years. However, recently many branches of construction industry have started to shift towards the lean production theory.

The main characteristics of the traditional approach are as follows [KARTAM et al. '97]:

- All activities are value-adding activities.
- No distinction is made between processing and flow activities.
- The total cost is estimated on the basis of the basis of the WBS (work breakdown structure).
- No emphasis is given to the importance of resource flows.
- All activities are independent of each other and it is assumed that reducing the cost of each activity will reduce the cost of the project.
- It does not take into consideration the effects of poor quality output and effects of variability and uncertainty.
- Work passes linearly from one process to the other.

Another significant feature or rather a flaw of the CCPM method of project management is the fact that all the cost and time overruns are attributed to the failure of contractors to follow the schedules and budget while construction. No questions are ever raised against the planning, which precedes the construction. It has been observed that the majority of the failures are a result of bad or incomplete planning on the part of planners [BALLARD et al. '97]. Uncertainties are not incorporated into the schedules by the top-level management as the only motive is to win the contract. The schedules are derived from experiences based on the history of other so-called similar projects. Contractors still do not place importance on the fact that all construction processes are different and hence it is not correct to establish detailed schedules at the onset and trying to follow the same. The consequences of such an action are disastrous for the contractor as the quality of the construction is compromised and a great deal of time and money has to be spent on reworking.

The definition of Lean Construction states that it is “A holistic facility design and delivery philosophy with an overarching aim of maximizing value to all stakeholders through systematic, synergistic, and continuous improvements in the contractual arrangements of the product design, the construction process design and methods selection, the supply chain and the workflow reliability of site operations.” [ABDELHAMID et al. '09].

Despite the fact that Lean Construction is the application of lean production principles in the construction industry, the lean production principles cannot be applied directly to the construction industry [KOSKELA '92]. There is a marked difference in the construction industry from its manufacturing counterpart. The main problem that lies in the road towards Lean Construction is that most companies do not see construction as a flow and conversion based process. They believe that all activities are conversion based, and hence they do not try to reduce waste (non- value adding activities) in construction. For instance, waste in construction are identified as follows [SERPELL et al. '95]:

- Waiting for resources
- Travelling time movement (of operator or machine)
- Idle time (of operator or machine)
- Resting
- Rework

In addition, (Figure 2-3) addresses the main causes behind such waste.

Lean Production in Construction in essence tries to reduce the wasteful activities in construction to deliver the product to the owner. Lean construction attempts to remove these flaws by proposing several tools such as the Last Planner System® (LPS®) developed by Glenn Ballard, in order to remove waste and shield the downstream work processed from such imperfections in construction.

Most of the waste listed above is a clear demonstration of a lack of adequate planning. Information about the above-mentioned waste received beforehand can help the project managers to take extra precautions during the execution of the project. One major solution preventing such waste may be increased emphasis on short-term planning as most of this waste is a result of ineffective short-term planning [SERPELL et al. '95].

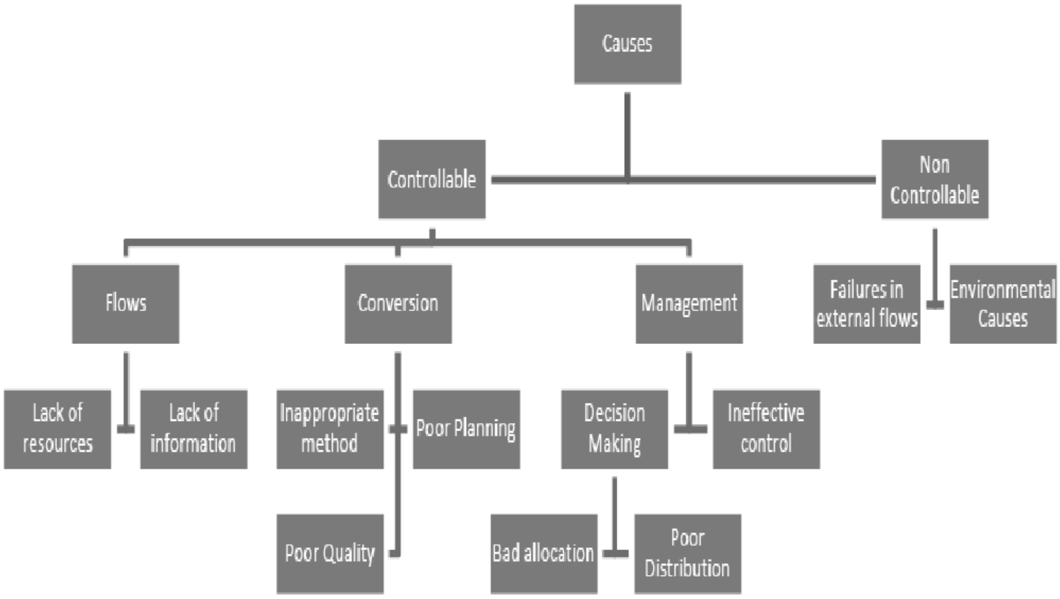


Figure 2-3 Root Causes Result in Waste in The Construction Process

Obviously, the most important tool assisting in building a short-term schedule is the Last Planner System®. However, before beginning with the Last Planner System® we will elaborate on other tools for implementation of Lean Construction.

In general, as represented in (Figure 2-4,a), the traditional project management practices treat all the activities in construction as value-adding activities (those which cannot be removed), and the construction process is a conversion-based process in which one value-adding activity leads to another. This states that as soon as one activity is finished the other should start irrespective of whether the other prerequisites of the activity like materials, labor and equipment are available. This model pressurizes the available resources to act fast, thereby leading to the reduction in quality of the construction. Conversely, Lean Construction, as shown in (Figure 2-4, b), is a flow and conversion based model where a construction process is a collection of conversion processes involving flows of information and materials from one process to the other.

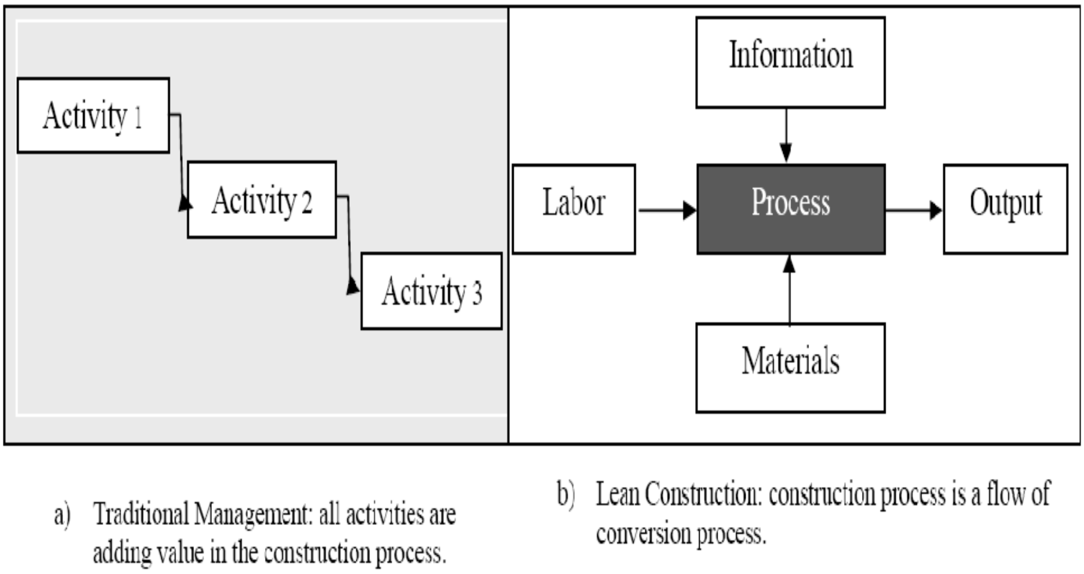


Figure 2-4 Construction Process From The Traditional and Lean Manegement Perspectives

2.8 INVENTORY/BUFFERING IN THE WORLD OF LEAN

In general, the essence of Lean Construction is described as waste elimination, yet it does not sound very convincing. Hopp and Spearman pointed out the fact that while lean is certainly concerned with driving out waste, it represents a more fundamental framework for enhancing efficiency. Therefore, products, services, and goods are produced in lean amounts, only if the production process is accomplished with minimal buffering.

The less explicit source of buffering is variability, which can take on many forms, including variability in process time, delivery times, yield rates, staffing levels, demand rates, etc.

As described by [Hopp et al. '04], inventory buffers are "evil" because they hide construction problems. Therefore, the heart of lean production as well as Lean Construction, in managing buffers, is to reduce the inventories/buffers to reveal the problems and deal with them. The most famous articulation of this philosophy was Taiichi Ohno's recommendation to 'lower the river to reveal the rocks'; i.e., to periodically reduce the buffers of inventory, capacity, time and money that absorb waste-causing variation in order to stress the production system and reveal where it needs improvement as illustrated in (Figure 2-5). In this articulation, the river is a process which has a problem due to variability (rocks). The higher the water level, the higher the estimation of buffers needs to be in order to safer against variability, yet that leads to more time and cost. On the other hand, Lean Construction focuses on enhancing reliability and predictability of process. Therefore, at the lower water level, proper estimation of buffers can reduce the unnecessary inventories due to the real status, and consequently can reveal the rocks (problems) to be in solvability and enable managers to deal with.

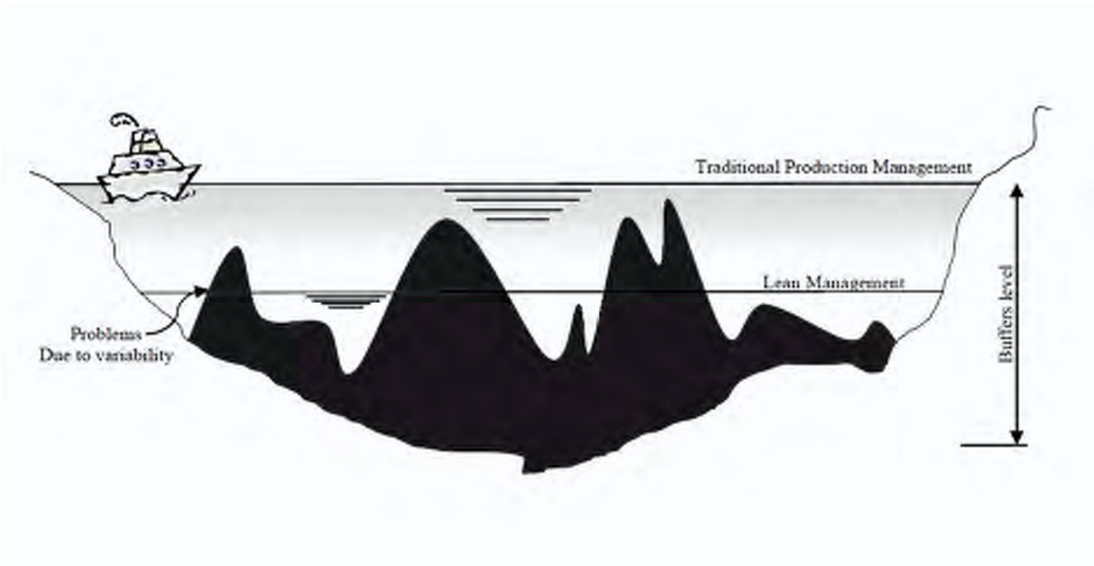


Figure 2-5 The Lower the River Concept of Lean Buffering Management

The management of buffers from the lean viewpoint is an improvement cycle as presented in (Figure 2-6). Ballarad (2008), discussed that the job of buffers is to absorb variability. Once the reduction of variability takes place, the next step is to match buffers to actual variation. Matching buffers to the degree of uncertainty involves first selecting the right type of buffer–inventory, capacity, time or contingency– then locating the buffer appropriately in the process, and finally sizing the buffer. Reducing variability and matching buffers to the remaining variation stabilizes a production system. The next step is to deliberately de-stabilize it by reducing buffers below what is needed to absorb existing variation.

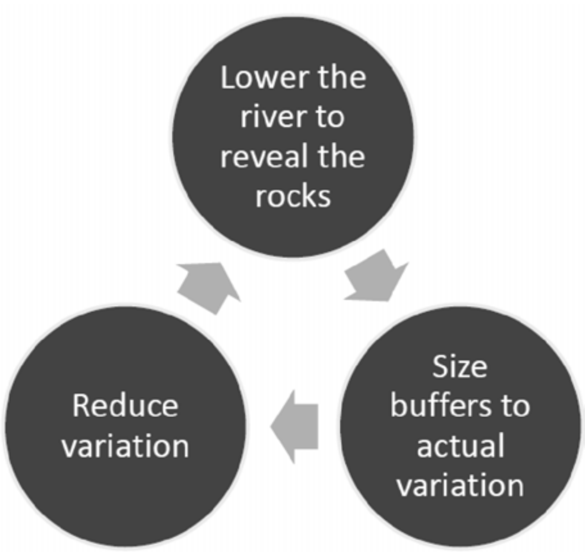


Figure 2-6 Improvement Cycle [BALLARD '08]

2.9 TOOLS FOR LEAN CONSTRUCTION

2.9.1 Pull Approach

This concept is the same as that of lean production. Traditionally, inventories have been managed using the detailed scheduling techniques where the materials are ordered based on the prepared master schedule. With the pull approach, we utilize the concept of Just in Time wherein the inventories are kept to the bare minimum and new inventories are ordered based on the current demand. Stocking of materials is wasteful. Its implementation however requires a good relationship with the suppliers.

Pull technique can be applied at both the strategic and the tactical levels of planning. This was an important part of Ohno's original vision (around 1950). The magic of pull is the maintenance of a WIP cap. While pull systems can take on many forms to suit different sets of circumstances, all of them have in common the fact that releases are regulated according to internal system status in a manner that prevents inventory from growing beyond a specific limit.

In general, Pull is characterized by its benefits of reducing WIP and Cycle time, providing a smoother production flow, improving quality, and reducing cost [HOPP et al. '04].

2.9.1. [I] Push vs. Pull

A *pull system* explicitly limits the amount of work in process. By default, this implies that a *push system* has no explicit limit on the amount of work in process. Hence, the definitions give a black/white distinction of push and pull respectively. However, the real world, as is generally the case, is a matter of shades of gray. Hence, the extent to which a process will gain the advantages of pull relies on how sharply the WIP limit is imposed.

2.9.2 Multifunctional task groups

This concept contradicts the current belief that only specialized workers can produce good quality products. Instead of having a specialty group of workers, a multifunctional task group should produce a number of different products. This makes it possible to produce a more complex or more complete product with one production unit. In multifunctional task groups, the workers do not have to waste time in waiting for each other to complete the work. However, to achieve the principle of multifunctional task groups, personnel need to be trained intensively in recombining thinking and doing (Melles, What do we mean by Lean Production in Construction|[ALARCÓN '97]).

2.9.3 Kaizen (Total Quality Improvement)

Kaizen means to continually look for new ways to improve the process by reducing costs and increasing efficiency. It might involve the management asking the production teams to suggest new ideas regularly. A good implementation of Kaizen implicates cost reduction and zero defects in final products. It includes the 5S principle for site management, which has been described previously.

2.9.4 Benchmarking

It is an essential tool for standardization of activities ultimately leading to good construction quality. New methods evolved by means of continuous improvement need to be benchmarked so that they can be implemented in similar situations and can be improved upon at all sites. This tool promotes achievement of high quality work.

2.9.5 A3 Reports

This tool developed by Toyota heLPS® in the documentation of key results of problem solving in a concise manner. It involves mentioning the theme of the problem, the current situation, any improvements / suggestions and the implementation and follow-up plan, all on a single sheet of A3 size as depicted in (Figure 2-7) [SOBEK et al. '04]. The A3 method is easy to use, comprehend and can be implemented only with a paper and pencil. The size of A3 is assumed to be just enough to be able to highlight the important points for discussion.

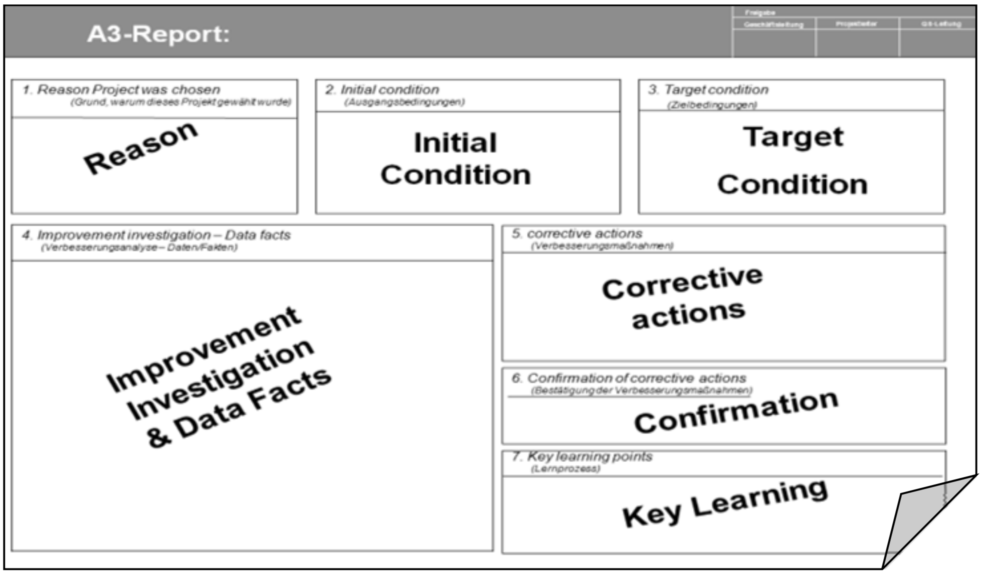


Figure 2-7 Typical Layout of A3-Report

2.9.6 Last Planner System®

This tool in simple words can be taken to be an assimilation of the above-mentioned tools. In addition, it is one of three parameters contributing to the objectives of this study. Although it is discussed in depth in the next section, the main features and objectives for the LPS® are explained briefly as follows [BALLARD '00]:

- Manage and mitigate the variability.
- Assignments and schedules should be sound regarding their prerequisites.
- The completed assignments should be monitored.

- Causes for failure to complete the planned work should be investigated and removed.
- There should be a workable backlog for each crew and production unit.
- The prerequisites of upcoming assignments should be made ready.
- The traditional push based construction process model should be incorporated with pull techniques.
- Traditional project control focuses on hierarchical decision-making and thus the decision-making process lies in the hands of only a few and often decision makers are unaware of the ground realities. Decision-making powers should be well distributed among the project team.

2.10 ANATOMY OF LAST PLANNER SYSTEM®

LPS® was developed by Glenn Ballard and Greg Howell as a production planning and control system to assist in developing foresight, smoothing variations in construction workflow. Furthermore, it aims to reduce/remove the uncertainties plaguing construction processes.

2.10.1 LPS® concept

The "Last Planner" is the person or team that produces construction assignments of work to be carried out. The "assignment plan" is unique by being a production plan that drives direct work, not production of other plans. Ballard argued that Last Planner production control system "is a philosophy, rules and procedures, and a set of tools that facilitate the implementation of those procedures" [KALSAAS et al. '09].

Furthermore, the Last Planner System® (LPS®), as shown in (Figure 2-8), aims to shift the focus of control from the workers to the flow of work that links them together. The two main objectives of LPS® are to make better assignments to direct workers through continuous learning and amended action, and to cause the work to flow across production units in the best achievable sequence and rate [MOHAMMED et al. '05].

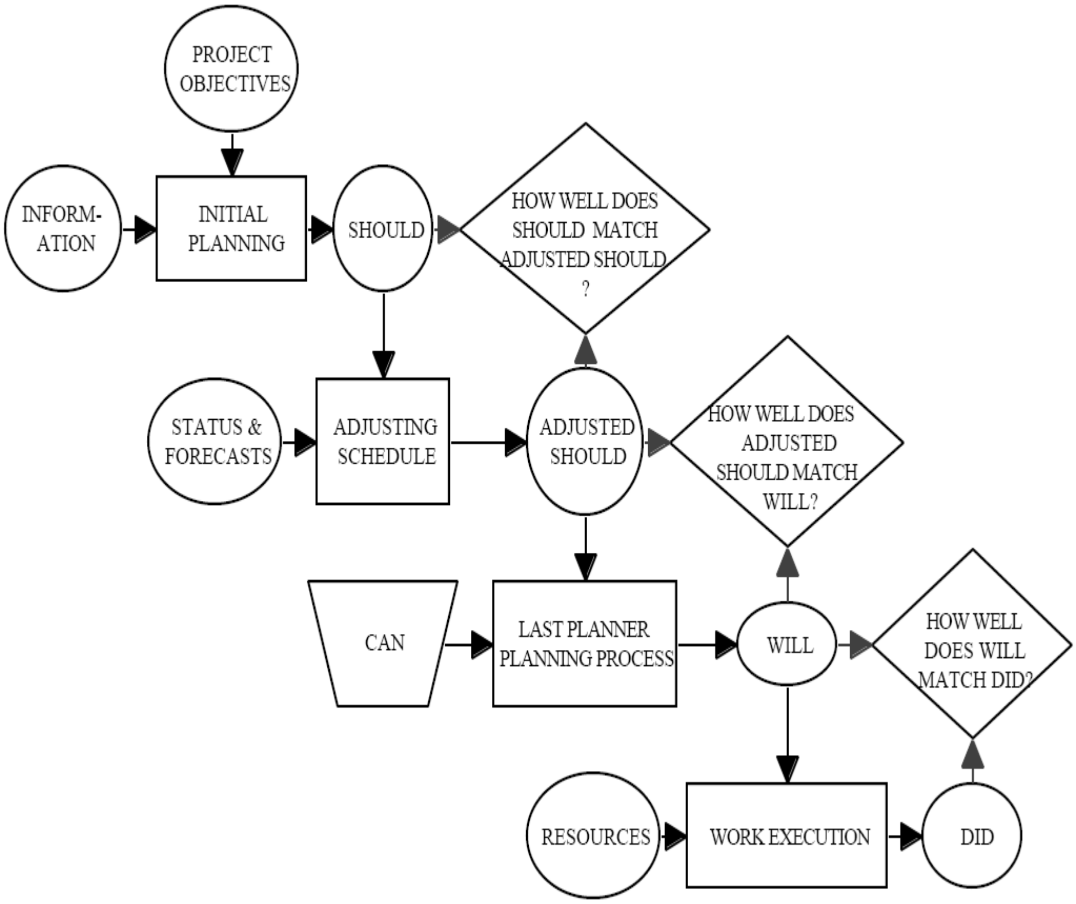


Figure 2-8 Last Planner System® [BALLARD et al. '95].

2.10.2 Principles, Functions, and tools of the LPS®

The Last Planner System® of production planning and control can be characterized in terms of the principles that guide thinking and action, the functions it enables to be performed, and the methods or tools used to apply those principles and perform those functions [BALLARD et al. '09].

2.10.2. [I] PRINCIPLES

- Plan in greater detail as you get closer to doing the work.
- Produce plans collaboratively with those who will do the work.
- Reveal and remove constraints on planned tasks as a team.
- Make and secure reliable promises.
- Learn from breakdowns.

2.10.2. [II] FUNCTIONS

- Collaborative planning
- Making ready
    - Constraints identification and removal
    - Task breakdown
    - Operations design
    - Releasing
    - Committing
    - Learning

2.10.2. [III] METHODS AND TOOLS

- Reverse phase scheduling (aka 'pull planning', 'pull scheduling', 'phase scheduling', stickies-on-a-wall)
- Constraints analysis; constraint logs; risk registers
- Task hierarchy: phase/process/operation/steps
- First run studies
- Daily meeting
- Reliable promising
- Metrics
    - Percent Plan/Promises Complete (PPC)
    - Tasks made ready
    - Tasks anticipated
- 5 Whys analysis

It is obvious, from the prior description of the Last Planner System® and its, principles, functions, and tools as well, that LPS® is distinguished from other project management approaches by providing:

- A systematic approach to the making and keeping of commitments;
- Making tasks ready;
- Collaborative short-term work planning.

2.10.3 LPS® framework

As represented in (Figure 2-9), the Last Planner System® is generally comprised through three levels of planning, strategic, tactical, and operational. LPS® essentially focuses on making a 6-8 weeks lookahead schedule with detailed weekly plans in discussion with the last planners (persons who actually execute the work) based on the current situations. The activities from the master schedule are broken down into details. Assignments are prepared for the workers to perform accordingly. Ballard (2000) suggested that assignments should satisfy the following criteria before being allocated to the workers:

- Work should be clearly defined.
- Work should be sequenced properly.
- All prerequisites for the work should be available and the constraints should be released.
- Work should be sized based on the availability of the crew.

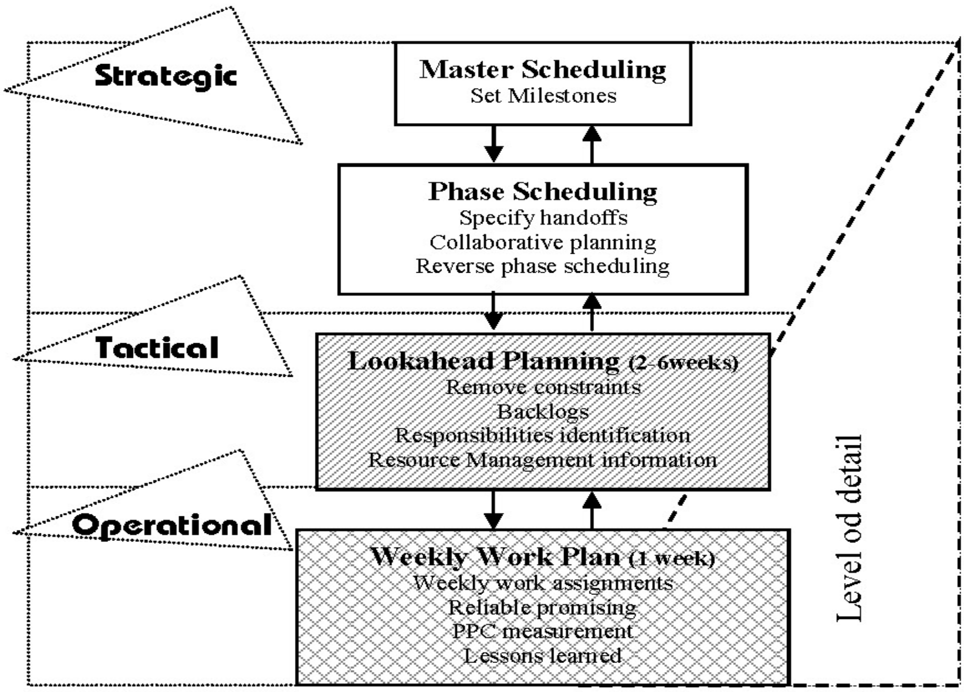


Figure 2-9 Last Planner System® comprising the levels of planning processes [HAMZEH et al. '08]

Consequently, assignments that fulfill the above criteria are entered to the workable backlog. All the other assignments are postponed until the time they are ready (released from constraints). In this way, the workers are never overloaded; they only do what they promised and this helps to keep a track of the productivity. Failure to keep commitments is investigated so that it can be avoided in future. Thus, the performance can be measured by a factor known as PPC (percent planned complete). Most Lean Construction tools, mentioned above in sec 2.9, are used in the Last Planner System®. Namely, the Last Planner System® involves the pull approach to form a workable backlog it utilizes the just in time tool, since all the persons involved in the project sit together to form the look ahead schedule continuous improvement is built into the process. Thus, the Last Planner System® serves to successfully withstand uncertainties in the construction process.

2.10.4 Look ahead process

The lookahead process involves explosion, screening, and making ready processes. The **explosion** process involves exploding the activities mentioned in the master schedule in details to identify all the prerequisites for the activity before it enters the look-ahead window. The **screening** process is used for determining the status of tasks there in the look-ahead window based on their prerequisites (constraints).

Eventually, in the **make-ready process**, the lead time (time from order to delivery) is estimated, the prerequisites are pulled and the work is executed. This process requires a high amount of caution, as the ordering times have to be estimated reliably to prevent any inventory from building up at site. The status of the consuming activity should be matched with the ordering times of resources. The make-ready work then enters the workable backlog so that the scheduled work can begin. The work is monitored by using PPC (Percent of Planned Complete) and the inability to achieve a high PPC is examined for process improvement and to prevent the problems from re-occurring.

2.10.5 Schedule Buffers and Workable Backlog

In this section, we shall understand the role of Last Planner System® in building the reliability in the schedule by the continuous replacement of the schedule buffers with the workable backlog.

In the current construction practices, schedule buffers are allotted to activities to counter uncertainties. These buffers are allotted on the basis of the past experience of the company. The allotted buffers are often too small or too large. Hence, there is a need for an accurate prediction of the activity buffer times. The LPS® replaces the schedule buffer with the plan buffer. The plan buffer is the workable backlog that needs to be maintained in order for an activity to start. Activities should be free of constraints to be able to enter the workable backlog.

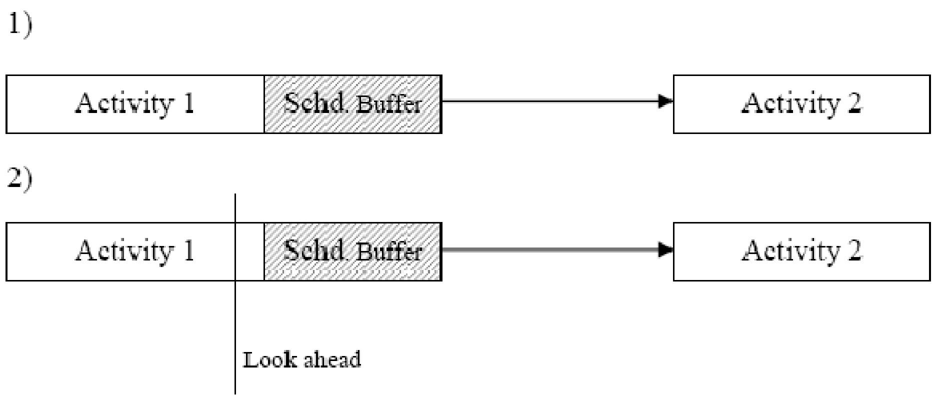


Figure 2-10 Typical Schedule Buffers (Bfs) Strategy of Activities

As illustrated in (Figure 2-10), an example of a part of the master schedule for a construction project involving a significant buffer has been allotted to Activity 1.

For instance, in the lookahead process, the project management team came to the conclusion that the schedule buffer will not be required, and it could be pull Activity 2. This is only possible with the LPS®, which uses the workable backlog to shield downstream activities from being affected by the upstream uncertainties.

2.10.6 LPS® involving project planning

One of the most significant aspects of Last Planner System® is a regular production planning meeting. The purpose of such meeting is to plan the work that is going to be performed by taking into consideration the work that is currently performed and in the knowledge of work that can be done. Through the planning meeting, any inter-dependencies are explored. Hence, in order to achieve a collaborative production planning, it ought to be considered to not plan to do a task if it cannot be done, and vice versa. Consequently, the benefits of the planning meeting in the context of Last Planner are [MOSSMAN '08]:

- Better preparation of supplier because they know what is expected of them;
- Commitments maintenance for the customers concerns.

2.11 LEAN PRINCIPLES TO THE CONSTRUCTION PROCESS

Now after going through the tools of Lean Construction we are sufficiently equipped to discuss how to apply the Lean Construction principles to the construction process. The construction process is considered in three consecutive phases of design, planning and execution.

2.11.1 Lean for Design

In order to implement lean to the design phase, building of design models should be demonstrated by the integration of the three concepts of Lean Construction (design as conversion, design as flow and design as value generation). Hence, a set of guidelines was proposed to establish the integration process as follows [BALLARD et al. '98; TZORTZOPOULOS et al. '99]:

1. Having some degree of flexibility in the sequence of design activities.
2. Not defining activities in a fine level of detail and encouraging team work.
3. Involvement of designers in joint solutions.
4. Direct interactions between designers and customers.
5. Explicit and healthy client-supplier relationship.
6. Always working with a set of design alternatives.

2.11.2 Lean for Planning

In fact, the construction planning process most prevalent today is that of developing a single plan and adhering to it for the entire duration. Such plans are seldom reviewed during the execution stage, and also the corrective actions only include adjusting the original schedules to actual performance. In order to improve the planning process, a shift towards contingency planning should be broadly accomplished, which includes preparation of several detailed plans prior to execution for different project environments. Consequently, the need for reviewing the original plan against problems will disappear [FANIRAN et al. '97].

2.11.3 Lean for Execution

This stage involves utilizing of the last planner tool (described above) of Lean Construction for execution of the project. Implementation of Lean Construction for execution improves the performance by changing the way work is done, as opposed to managing the conditions in which it is done. Moreover, the implementation process is performed through four levels as expressed in the following lines [BALLARD et al. '94]:

1. **Working the plan:** At this level, making the plan the standard of performance for work execution is accomplished. In order to achieve standardization of plan, understanding goals should be more important for performance than participating in goal setting. As a result, it is improving plan quality that is the reason for involving direct workers in planning; especially in planning how to do the work.

2. **Implications for project control:** Control is established through identifying variances, and proactive control of plan quality.

3. **Removing obstacles:** Identifying reasons why planned work does not get done, and studying the utilization of resources are demonstrated at this level in order to shield the execution process from the inflow variability.

4. **Changing how we do the work:** In fact, theory comes before policy, policy comes before training and training comes prior to implementation. However,

Lean Construction theory will soon provide a movement into the policy phase. An important feature of this phase is to integrate all performance dimensions into work process design, with safety first, then quality, time and cost. Furthermore, procurement must work with construction on timing of deliveries. The goal is for construction to release resources for delivery just when needed. This reduces inventory and space requirements.

2.12 RESUME

Lean construction with its tools may have a significant role in eliminating waste experienced the construction process, particularly in the highway construction process in Egypt. Variability is the most fundamental factor influencing the execution of such projects. From the lean perspective, the buffers approach is a key solution for either resisting, or removing the impact of uncertainties. The heart of lean production in managing buffers is to reduce the inventories/buffers to reveal the problems and deal with. Therefore, the management of buffers is an improvement cycle of matching buffers due to the actual degree of uncertainty, lower the river to reveal the rocks, and reduce the variation. Hence, it is obvious that in the modern manufacturing environment, the buffers should principally be as small as possible, i.e., lean. However, how lean can lean buffers be? In other words, how small can work in process buffers be to ensure the desired production rate of the overall process? The answer to this question is revealed through the next chapters.

The Last Planner System® is the most important Lean Construction tool for planning and production control as well. LPS® provides a suitable environment to enhance the buffers design and management, reliability and predictability of process, and the continuity of the workflow. That can be achieved through the transparency and cooperation between all construction parties involved in the LPS® meeting.

3 Literature Review

- **Uncertainty and variability**
- **Scheduling under variation**
- **Buffers mechanism for the degree of variation**
- **Buffers design and management**

In a real sense, people who have read good literature have lived more than people who cannot or will not read. It is not true that we have only one life to live; if we can read, we can live as many more lives and as many kinds of lives as we wish.
"S.I. Hayakawa"

CHAPTER 3. LITERATURE REVIEW

3.1 PREFACE

In general, construction projects are normally executed in an environment characterized by varying degree of uncertainties, especially in highway construction projects. These cause such projects to face numerous challenges as they strive for success. Subsequently, the scheduling process may experience a significant impact not only on estimating the duration of construction activities, but also on calculations related to the network [LORTERAPONG et al. '96; EL-RAYES et al. '01; PAN '05; PAN et al. '05b; KO '06].

Owing to the fact that the influence of uncertainty in the construction industry has been of increasing concern over the past four decades since the report by the Tavistock Institute (1966), managing uncertainty has been at the heart of improvement for the project performance [SKITMORE et al. '89].

3.1.1 Notion of Uncertainty

The notion of uncertainty is quite ambiguous, subjective, and context dependent. Imprecise, outdated or incomplete information, the inability to accurately model the impact of possible or unforeseen conditions, or insufficient control actions are such examples among the causes of uncertainty.

3.1.2 Sources of Uncertainty

(Figure 3-1) illustrates taxonomy of uncertainty sources based on strategic, tactical, and operational levels. Strategic sources level of uncertainty is related with a main effect on decisions made over long-term planning horizons. For instance, eternal or exogenous uncertainties resulting from environmental conditions, competitors, and governmental restrictions are examples. Whereas, tactical uncertainties cover several sources of uncertainty that may alter decisions over medium-term planning horizons such as disturbance in information and material flow. Operational uncertainties comprise uncertainties primarily affecting detailed short-term decisions such as variable processing times, yield ratios, operators absenteeism, and equipment availability. Besides, because of the interactions between these different levels of decision-making, uncertainties from one level may affect decisions made in other levels.

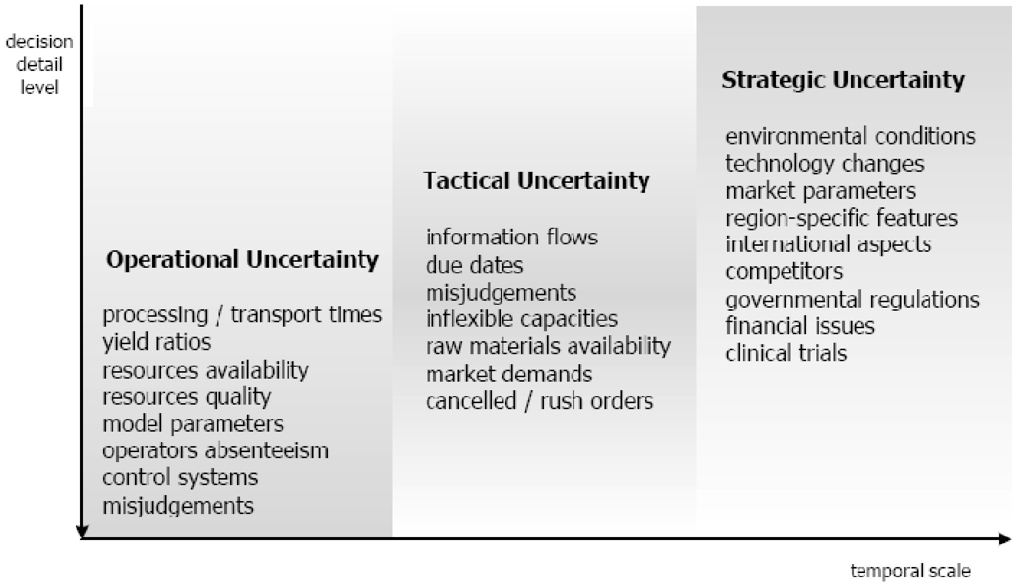


Figure 3-1 Taxonomy of Uncertainty Sources [TEIXIDOR '06].

3.2 REPRESENTATION OF UNCERTAINTY

Statistical forecasting techniques relying on the analysis of historical data and/or market indicators are commonly used in combination with human judgment for the representation of the uncertainty. Obviously, no single methodology exists to model all kinds of uncertainty, yet it depends on the context and the information available. The main approaches considered for a formal representation of the uncertainty associated to model parameters and constraints involve *probabilistic methods* and *fuzzy set theory*. The probabilistic description of the uncertainty is based on probability theory or stationary random processes, and constitutes the most widely used method for this purpose. Fundamentally, this approach based on scenario-based and distribution-based representations associate a probability distribution function with the uncertain data.

On the other hand, fuzzy sets have to be defined for each uncertain variable, based generally on subjective judgment and managerial experience. Fuzzy approaches provide a simple representation of the uncertainty, which is practical in particular when little information is available [TEIXIDOR '06].

3.3 TYPES OF UNCERTAINTY

Ward et. al (2001), presented aspects of uncertainty, in six areas, that should be addressed in any project context as listed in (Table 3-1). In principle, all of these types of uncertainty could be addressed within comprehensive project management throughout the project life cycle (PLC).

Table 3-1 Types Of Uncertainty [WARD et al. '01]

Uncertainty type	Description
Design and logistics	The nature of the project deliverable and the process for producing it is a fundamental aspect of project uncertainty. Much of this uncertainty is removed in pre-execution stages of the project life cycle (PLC) by attempting to specify what is to be done, how, when, and by whom, at what cost. In principle, a significant amount of this uncertainty may persist through much of the PLC.
Fundamental relationships	A pervasive source of uncertainty is the multiplicity of people, business units, and organizations involved in a project. The relationships between the various parties may be complex, and may, or may not involve formal contracts. The involvement of multiple parties in a project introduces uncertainty arising from ambiguity about roles and responsibilities, and uncertainty associated with moral hazard and adverse selection considerations.
Objectives and priorities	An aim of improving project performance presupposes clarity about project objectives and the relative priorities between objectives and acceptable trade-offs. The implications of uncertainty related to the nature of objectives and relative priorities need to be managed as much as uncertainty about what is achievable.
Variability	An obvious area of uncertainty is the size of project parameters such as time cost and quality related to particular activities. For instance, how much time and effort will be required to complete a particular activity is unknown. The source of this uncertainty is often a lack of knowledge about what needs to be done and how, rather than a set of specific risk events or conditions.
Basis of estimates	An important area of uncertainty relates to the basis for estimates produced by project parties. For example, it is often necessary to rely on subjective estimates for probabilities in the absence of sufficient relevant statistical data for determining probabilities 'objectively'. Uncertainty about the basis of estimates may depend on who produced them, what form they are in, why, how and when they were produced, and from what resources and experience base.
Conditional nature of estimates	A particularly important source of uncertainty concerns the assumptions used to generate estimates. The need to note assumptions about resources choices and methods of working is well understood. However, estimates also ought to clearly indicate the extent to which they have been adjusted to allow for assumptions about the incidence of possible changes in project context and scope, and bias during the estimating process.

3.4 UNCERTAINTY MANAGEMENT

Uncertainty management is not just about managing perceived threats, opportunities and their implications; it is about identifying and managing the many sources and types of uncertainty. The identification process of uncertainty would induce identification of a wider set of responses for managing particular sources of uncertainty. Uncertainty management implies exploring and understanding the motives of project uncertainty prior to managing it [WARD et al. '03].

Miscellaneous methodologies for simulation and optimization of planning under uncertainty have been developed based on different criteria, and modeling philosophies. Though these methodologies are different in their techniques, they have a typical sequence of the development. Namely, they commonly start with the characterization of uncertainty; secondly, the definition of the formal measure for the assessment of the robustness and flexibility of decision in the context of the uncertainty takes place. Eventually, the implementation of an optimization algorithm in terms of the robustness criterion is established in order to improve the decision-making.

3.4.1. [I] Characterization of uncertainty

The characterization of uncertainty in any process system is a critical technical challenge. As detailed above, a few approaches are possible for this: statistical or probabilistic, and Fuzzy Logic approach. The latter one differs from the former methods in the formalism used to model the uncertainty.

3.4.1. [II] Optimization

In principle, optimization under uncertainty has several methodologies that can be categorized in line with the methods used to represent uncertainty as outlined in (Figure 3-2). Hence, Teixidor (2006), generated a schematic representation of a decision-making process in scheduling under uncertainty, as illustrated in (Figure 3-3). That representation provides a special emphasis on stochastic and robust optimization for being the basis of the modeling systems.

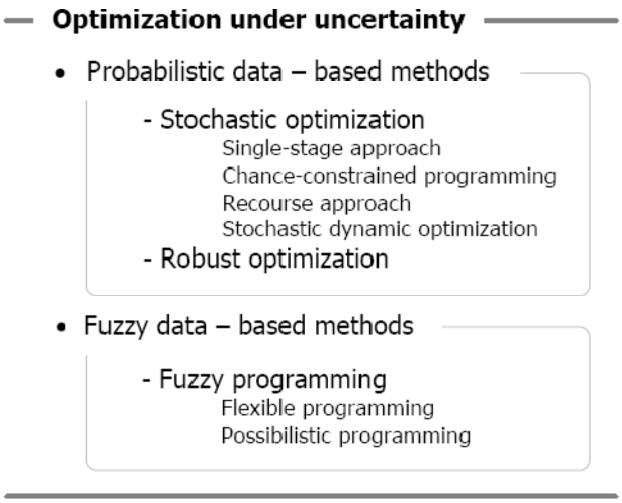


Figure 3-2 Methods Of Optimization Under Uncertainty [TEIXIDOR '06].

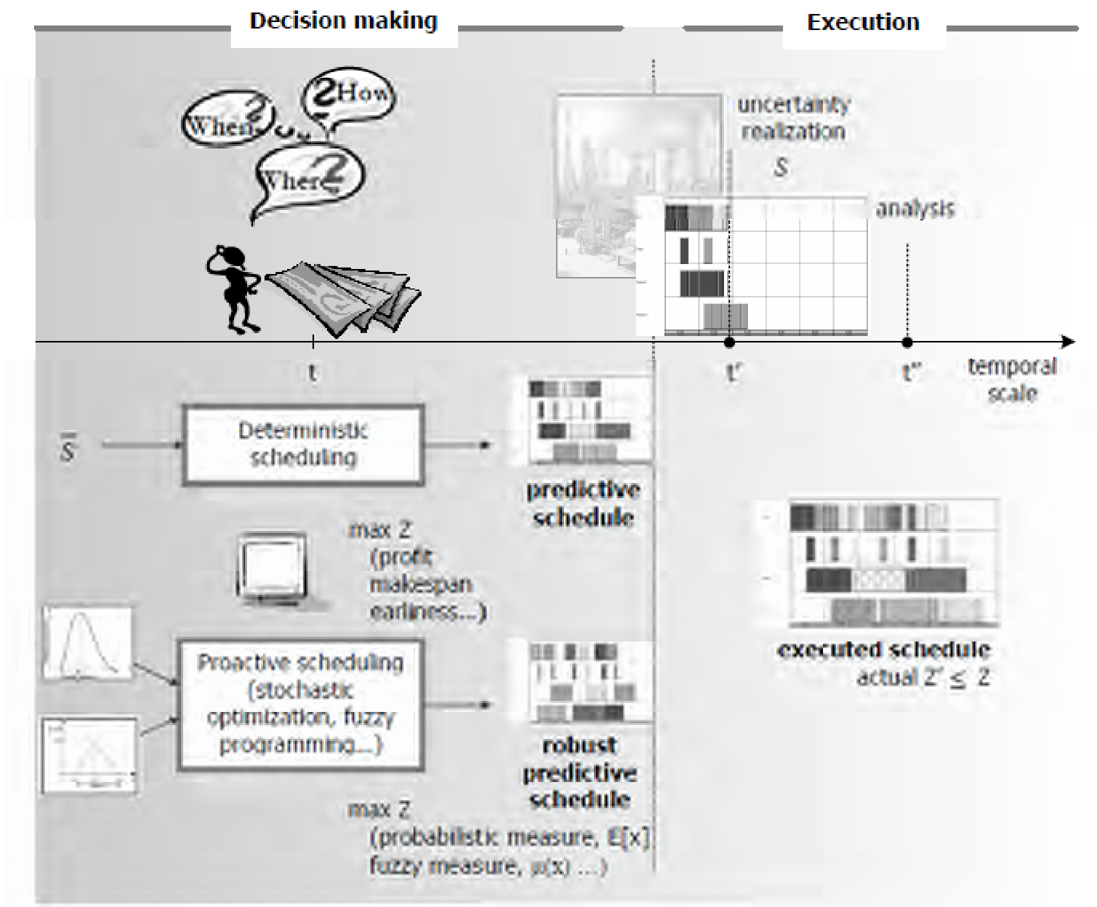


Figure 3-3 Decision-Making Framework For Scheduling Under Uncertainty [TEIXIDOR '06].

3.5 SCHEDULING UNDER UNCERTAINTY

Scheduling is a crucial system for planning, managing and controlling the execution of projects. Scheduling the construction is not recent; it is known that as far back as when the first large Egyptian pyramids were built, their constructors planned a method of managing the construction. Namely, they numbered the stones and delivered them to the site, at the right time and in the right sequence [CACHADINHA '02].

The research on project scheduling has broadly expanded over the last few decades. The vast majority of these research have focused on exact and sub-optimal procedures for constructing a workable schedule, assuming complete information and a static deterministic problem environment. The resulting schedule, often referred to as *master-schedule*, serves as the baseline for the execution of the project.

During execution, however, the project is subject to considerable uncertainty that may result in numerous schedule disruptions.

In 1986, Morris generated the earliest attempt towards the consideration of uncertainty, when he surveyed a heterogeneous sample of large projects, and then provided ample evidence of the influence of uncertainty in such contexts. One clear implication of Morris' work is that the lessons convey information, as listed in (Figure 3-4), which may be used to define decision-making strategies where the impact of uncertainty is minimized.

On the other hand, a project risk action management, as a tool for managing uncertainty, was developed in order to improve the quality and results of project management considerably through a consideration of project risks. The major characteristics of the project risk action management through the lifetime of the project are addressed as follows [BERKELEY et al. '91]:

- During the initial planning phase, it provides an assessment of the project uncertainties.
- This assessment is essential before any irrecoverable commitment.

- It identifies the major sources of project risk drivers. The project plan may then be revised, or management may devise effective contingency responses.
- It provides management with an objective basis for comparing alternative management plans to reduce the project risks.
- It provides a regular surveillance of the actual process throughout the execution of the project. This enables management action to be refined early enough so that contingency actions are significant.

Three years later, a theoretical approach for the quantification and management of uncertainty in activity duration networks was developed. The main functions of this approach are to [RANASINGHE '94]:

1. Quantify the uncertainty of activity durations using the elicited belief of the analyst/expert.
2. Allocate the management contingency for the project duration as the difference between a risk-adjusted target duration (set for a desired probability of success) and the expected value.
3. Allocate engineering allowance for an individual path as the difference between expected value for project duration and expected value for that path duration.
4. Distribute the total contingency available for individual paths to the activities on those paths based on their percentage contributions to the variance of that path duration.
5. Consider contingency available for unforeseen events as the minimum duration of all the allocations to an activity.
6. Measure and treat the probability of success of each activity as the initial benchmark for management of uncertainty in activity duration network.
7. Transfer some of the contingency from activity durations that have a greater probability of success to those which have a greater probability of failure, thereby bringing more sophistication to the management process.

Task complexity

2. Divide project into easily handleable parts with minimum and clear interface
11. Simplify specifications.
13. Simplify design.
26. Simplify financial arrangements.
27. Simplify organization.
28. Simplify legal arrangements.
32. Minimize number of contracts.

Procedural uncertainty

8. Minimize technical uncertainty.
9. Plan actions carefully.
10. Flexible design needed.
12. Avoid late design changes.
18. Long projects should be phased.
20. Ensure adequate funding.
23. Take strategic action when exchange rates change.
29. Avoid competitive bidding.
38. Adequate risk assessment needed.
39. Clarify schedules.

Psychological regret

3. Assess impact of project on environment and people.
22. Ensure sponsors truly interested.
25. Legal arrangements should be fair.
33. Fair allocation of risk needed.
42. One person or group should have overall authority.
43. Motivated and experienced team needed.
44. Participative decision making with socially orientated leadership needed.

Stress

5. Unrushed commitment needed.
19. Avoid rushed initial definition/design/development.
30. Avoid rushed bidding.
35. Good attitudes and relations needed.

Schema veridicality

1. Project definition to be well investigated, communicated and agreed.
4. Minimize conflict of participants' objectives.
15. Government to give clear objectives.
21. Terminate project if necessary.
23. Legal arrangements should be clear.
36. Clear advice from clients needed.
37. Appropriate organization needed.
41. Clear and comprehensive organization needed.
45. Good communication needed.

Schema generality

6. Planning to allow for future phases, logistics, geographical uncertainties, interdependent design/production.
16. Government to allow flexible management.
31. Consider other than lowest bid.
40. Devise back-up strategies.

Schema stability

7. Care needed in forecasting important events and risky situations.
14. Establish government commitment.
17. Government to monitor progress and ensure continuity.
34. Consider appointing contractor earlier.

Figure 3-4 A List of Morris' Lessons Towards Unecrtainty Management [Skitmore et al. '89].

The use of Fuzzy approaches has proved to be the most significant development in managing uncertainty when imprecision and inconsistency of data are presented.

Accordingly, during the last decade, artificial intelligence techniques applying to scheduling systems have developed considerably, with some transference into industrial applications from academic research [KONAR et al. '96; BURROWS et al. '97].

In case of disruptions, feedback between the local and global levels of scheduling is essential. Global level data are normally aggregated, imprecise, or estimated. Within a multi-site scheduling system based on fuzzy, a consideration of the adequate modeling and processing of imprecise data for global-level scheduling was modeled as depicted in (Figure 3-5). The function of such system is to create a robust prescription for the local scheduling systems, which heLPS® to reduce the effort of coordination and rescheduling [SAUER et al. '98].

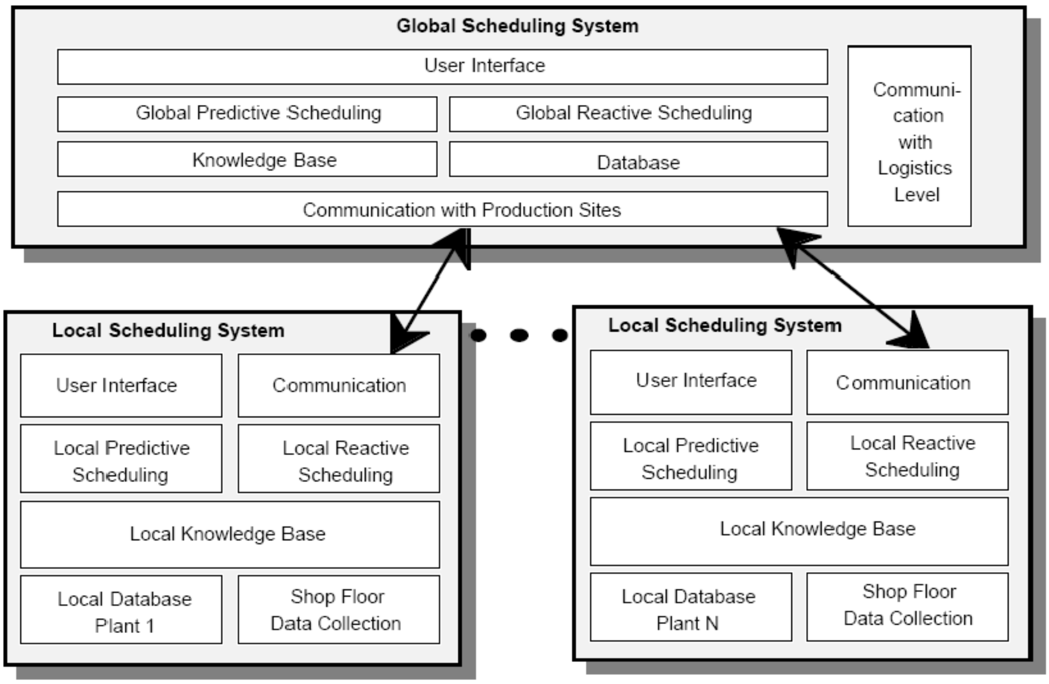


Figure 3-5 The Multi-Site Scheduling System Architecture [SAUER et al. '98].

The main attributes of the multi-site scheduling procedure can be obviously understood in the following steps:

1. A global-level schedule with an initial distribution of internal orders to local production sites is generated (global predictive scheduling).
2. Based on the global schedule, the local plants draw up their detailed local production schedules (local predictive scheduling).
3. In case of local disruptions, the local reactive scheduler first tries to remedy them locally by interactive repair (local reactive scheduling).
4. If problems cannot be solved on the local level or the modified local schedule influences other local schedules (inter-plant dependencies), the global level has to be called again. Global scheduling can then cause a redistribution of internal orders to local plants and adjust the global schedule (global reactive scheduling).
5. The local plants adjust to the changes in the global schedule.

In order to achieve congruence of the global schedule and its local transpositions, steps 3 to 5 might be done more than once to maintain consistency.

Confessedly, a predictable scheduling approach is so presented that it can absorb disruptions or uncertainties without affecting planned activities, and provides a significant improvement in predictability at the expense of very little degradation in realized schedule. The effects of disruptions on planned activities are measured by the difference between planned and realized job completion times. In particular, the insertion of idle time into a schedule in a controlled manner does not result in significant deterioration of the primary performance measure if coupled with appropriate mechanisms for handling disruptions [MEHTA et al. '99].

The year 2002 witnessed some significant studies focusing on management of uncertainty. Apart from expression of uncertainty, ambiguity and complexity in terms of information adequacy, identifying three fundamental project management strategies as shown in (Table 3-2), were illustrated [PICH et al. '02].

In 2003, Eck argued that algorithms used in the traditional and the most advanced planning (APS) systems commonly use deterministic models and data. In these deterministic models uncertain, variable, incomplete or even incorrect data is presented by the expected or worst-case value. Then sensitivity analysis is applied afterwards, as a reactive approach because herewith only the impacts of fluctuations in the data of the solution are studied. In practice, this leads to nervous planning, which anticipates quasi real-time of changes.

Table 3-2 Fundamental Project Management Strategies [PICH et al. '02]

	Planning Systems	Coordination and Incentives	Monitoring Systems
Instructionism	***Critical Path Planning*** • Task scheduling • Buffers (e.g., budget or schedule "contingencies") • Simulation ***Risk Management*** • Risk lists • Preventive actions • Contingency plan (dynamic programming, decision tree)	***Critical Path Planning*** • Target setting • Work structure, responsibilities • Coordination in hierarchy ***Risk Management*** • Contingent targets and • contracts • Mutual adjustment according to events	***Critical Path Planning*** • Target achievement • Progress tracking (e.g., % complete) ***Risk Management*** • Contingent target achievement (per tree branch) • Monitor risk realization
Learning	• Overall vision • Detailed plan only for next tasks, then high level logic based on hypotheses • Plan learning actions • Provide capacity for re planning	• Long-term relationships with stakeholders, • Flexible and lateral coordination in mutual interest • Upward incentives (no punishment for failure due to uncontrollable events) • Incentives for good process	• Scan for new events • Track assured • achievements • Track quality of process used in addition to outcomes • Explicitly evaluate what has been learned
Selectionism	• Plan multiple trial projects • Plan performance hurdle for the "winner"	• "Winner" shares upside with "Losers" (all contribute, as winner cannot be predicted)	• Sharing of intermediate results among projects (learning) • Performance of trial projects versus hurdle

In order to find solutions that are less sensitive to uncertainties of the parameters, he advocated the need for a proactive approach that is named 'Robust Planning'. This means that uncertainties should be included in the model and that the algorithms should strive for specific reduction of the variability.

Furthermore, Eck emphasized the suitability of the tactical-level (medium-term) planning to deal with the causes of uncertainty of the three planning levels. At the operational level (short-term), there is not much time to react to fluctuations of uncertain parameters, and at the strategic level, many phenomena are too variable to base a long-term decision on. Hence, in order to implement such a proactive or robust planning successfully, he proposed a stepwise approach throughout the three levels of planning as illustrated in (Figure 3-6).

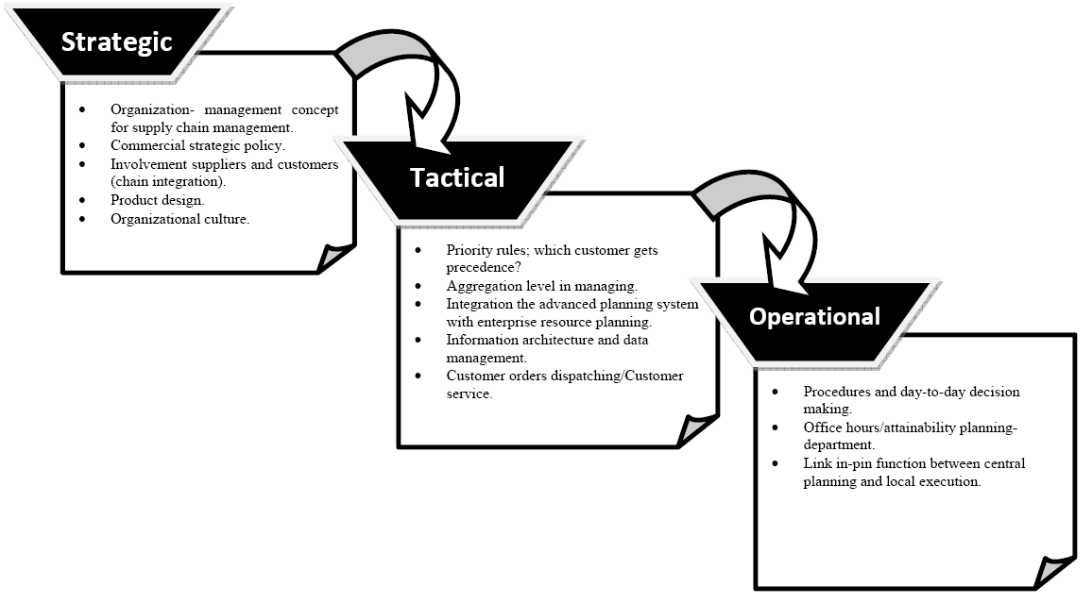


Figure 3-6 The Stepwise Approach For Implantation of The Robust Planning [ECK '03].

In principle, generating a baseline schedule before the start of the project is comprehensively practiced by the management decision. This can be established through either using a deterministic schedule or a proactive one. Recently, the critical chain schedule/buffer management (CC/BM) methodology has attracted much attention because it is certainly an important "eye-opener". The basic of CC/BM methodology is the direct application of the theory of constraints (TOC) [GOLDRATT '97], are briefly summarized in the following [HERROELEN et al. '04]:

- Aggressive median or average activity duration estimates.
- No activity due dates.
- No project milestones.
- No multi-tasking.
- Scheduling objectives ¼ minimize makespan; minimize WIP.
- Determine a precedence and resource feasible baseline schedule.
- Identify the critical chain.
- Aggregate uncertainty allowances into buffers.

- Keep the baseline schedule and the critical chain fixed during project execution.
- Determine an early start based non-buffered projected schedule and report early completions.
- Use the buffers as a proactive warning mechanism during schedule execution.

Existing approaches, as mentioned previously, to the problem of scheduling projects under uncertainty were surveyed by [HERROELEN et al. '05]. As a result, they pointed out that the methodologies for stochastic project scheduling essentially view the scheduling problem as a multi-stage decision process. Scheduling policies are used to define which activities are to be started at random decision points through time, based on the observed past and prior knowledge about the processing time distributions. Furthermore, they advocated the fuzzy project scheduling approaches that reject the use of probability distributions for the activity durations, yet relies on membership functions that may be difficult to generate. Such advocates argue that probability distributions for the activity durations are unknown because of a lack of historical data. Besides, in a non-repetitive or even unique setting, project management is often confronted with judgmental statements that are vague and imprecise.

In addition, they eventually emphasized that the buffer insertion approach, the fundamental ingredient of Goldratt's critical chain methodology [GOLDRATT '97], is gaining increasing popularity among project management practitioners. In short, the stability of scheduling under uncertainty aims in essence at minimizing the expected weight deviation of the actual from the planned activity start times when exactly one activity duration disruption is anticipated.

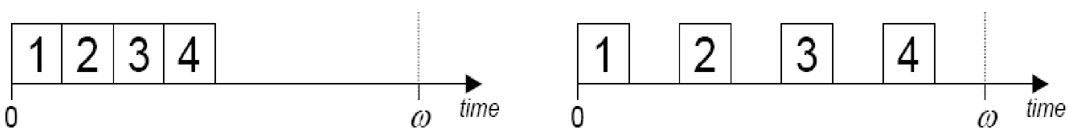


Figure 3-7 Stable and an Unstable Schedule [LEVS '03]

As represented in (Figure 3-7), the schedule at the left side of the figure is unstable and is not sensitive to any fluctuations in the activity durations. Whereas the schedule at the right side of the figure is more stable because reserved times (Buffer) are inserted at key points in the project schedule to act as a shock absorbers in order to protect the project end date "ω" against variability.

3.6 EMBRACING UNCERTAINTY IN LEAN CONSTRUCTION

Embracing uncertainty is a major aspect of Lean Construction. Furthermore, embracing uncertainty brings additional benefits and opportunities for improving the construction process addressed by Ballard and Howell (1994), as illustrated in (Figure 3-8). They advocated that as delivery variation declines, so does the size of backlogs required to initiate work without risk of interruption, thus advancing phase initiation. More optimum sequences can further be selected and better matching of labor resources can be accomplished, with a more certain in-flow of work.

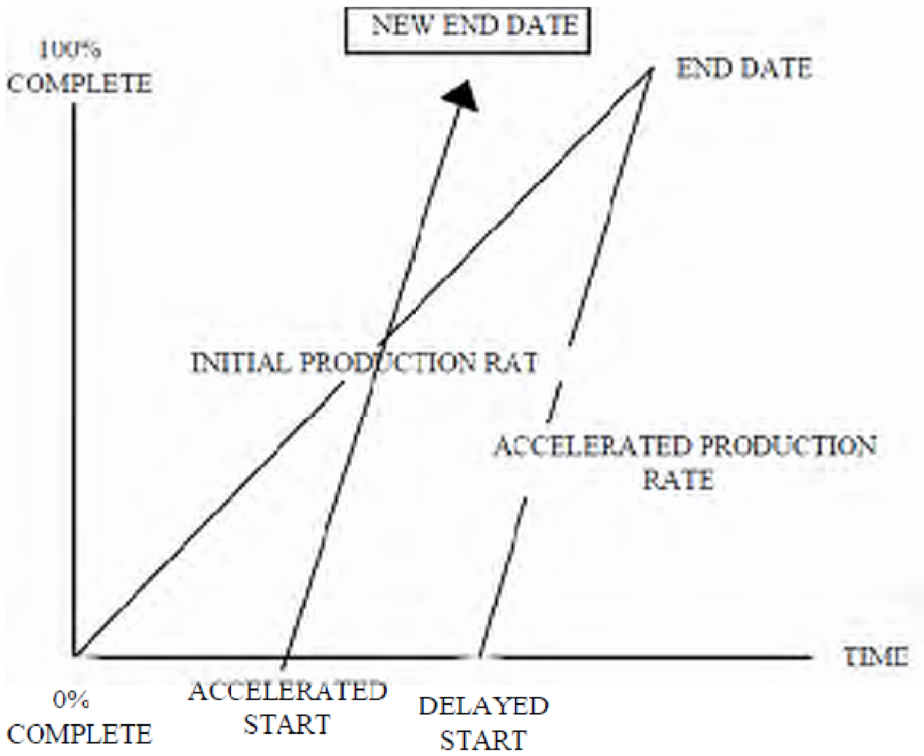


Figure 3-8 Embracing uncertainty in lean standpoint: Reduce variation and then start sooner [BALLARD et al. '94]

Lean construction looks at a construction project as a production system realizing the dependences and variations through supply and assembly chains of construction, and effectively managing process uncertainties [CHOO '03]. Choo (2003) pointed out that the most significant step towards minimizing the effect of uncertainty is to declare its existence and explicitly represent it. He also discussed that uncertainty in project scope and design changes might increase or decrease work shown in the master schedule. Besides, uncertainties involving resources can also influence the schedule. Hence, he advocated that the significant role of the Last Planner System® in improving the planning system reliability by identifying the causes of uncertainty and eliminating these causes as much as possible. Under lean thinking, improvement is possible by reducing uncertainty in workflow, thus, eliminating the need for intermediate backlogs.

Abdelhamid et al. (2009) formulated a 2-step framework for embracing uncertainty in a construction setting. These two steps are monitoring the environment in the production phase, and learning the Observe-Orient-Decide-Act loop, which will be in depth explained at the end of this Chapter, by introducing perturbations into the system to avoid complacency. They discussed that uncertainty should be embraced by construction teams to move from troubleshooting to reactive consolidation of what the team has achieved by using the OODA loop during the Weekly Work Planning phase of the Last Planner System. Hence, through the first step, the process would begin with observing and acquiring sufficient knowledge of external and internal conditions. At this point, the team might re-orient itself and make an action resulting in a new observations, which will in turn restart the loop.

Owing to inability of any simulations to replicate all the situations that a team may encounter, Abdelhamid et al. advocated that the team would still be ready to embrace uncertainty by cultivating situations where the use of OODA loop is triggered. Therefore, through the second step, they proposed a set of guidelines to engage team in OODA-loop cycles. Using 5-Whys approach, and make performance expectations broad, general, and fuzzy are such examples of those guidelines.

In the Lean Construction paradigm, constrains refer to anything that prevents a task from being performed. Obviously, uncertainties result in generating such constrains. Lookahead planning is the core process of LPS® that goes through all the constraints for each activity in the period leading up to the scheduled start of that activity and resolving or removing each one. Accordingly, Davis (2009) pointed out that a well run lookahead process would ideally recognize ahead of time that a constraint is not going to be removed in time, which provides an advance warning to the managers to take action. This action needs to address the two problems of the delay by making other work ready for the work crews that would otherwise have nothing to do and re-planning other parts of the project to bring it back on schedule and keep the reliability of the schedule high. Hence, he developed an algorithm based on a risk model for building a master schedule for a project that is arranged in such a way as to maximize the ability of managers at later times to rearrange the schedule with minimum effect on the planning reliability of later activities and on the overall project duration. This algorithm does something similar in that it tends to schedule risky activities earlier, so that if they are delayed it has less impact on the project finishing time. In addition, buffers are still possible to be allotted to schedule activities after using the algorithm in strategic places if desired [DAVIS '09].

3.7 UNCERTAINTY AND BUFFERING MANAGEMENT

As commonly known, construction is a different type of production than manufacturing, and has greater uncertainty and flow variability. Construction is schedule-driven. Given a well-structured schedule, if everyone keeps to his part of the schedule, the work flows smoothly and maximum performance is achieved. However, as known for all, it is rare that projects perform precisely to their original schedule. If a schedule has sufficient slack in the impacted activities, changes may not impact end dates. When there is little or no slack, players are pressured to make it up in accelerated production [BALLARD et al. '95].

The buffers issue has been advocated as a significant solution to withstand variability for most fields. For instance, in the last G-20 summit of 2009, because of the financial crisis, world leaders took credit for pulling the economy “back from the brink” and promised a new world order for tighter financial regulation and more inclusive global governance to protect the world from future meltdowns. The group of 20 leaders , shown in (Figure 3-9), pledged to set up more rigorous financial rules that would cut down on some of the risky behavior. The important rule among these was the use of buffers to cushion against future downturns. In addition, the group of 20 leaders reached a consensus on the importance of that risky behaviors, and difference in accounting standards, as degree of variability, should be considered when determining the size of the buffers.

Responding to variability is a major aspect of Lean Production Theory (LPT). Buffers between operations are an important tool because they allow two activities to proceed independently. Buffers can serve at least three functions in relation to shielding work by providing a workable backlog [HOWELL et al. '94]:

1. To compensate for differing average rates of supply and use between the two activities;
2. To compensate for uncertainty in the actual rates of supply and use;
3. To allow differing work sequences by supplier and using activity.

As valuable as buffers are, they are costly, hard to size, and hardly an optimal solution. The costs associated with buffers include storage space, double handling, inventory management, loss prevention, buffer fill time, and idle inventory. Buffers are hard to size because the actual supply and use rates are unknown.


SUNDAY, SEPTEMBER 27, 2009

G-20 vows more regulation

Agrees to become lead group in tackling intl economic issues

Prime Minister Yukio Hatoyama, second from left in second row, poses with other Group of 20 leaders and dignitaries in Pittsburgh on Friday at the G-20 summit meeting.

Gist of statement

Figure 3-9 G-20 World Leaders Towords Tackling The Financial Crisis [REUTERS '09].

3.7.1 Anatomy of Buffer Management

Although, the Last Planner System® contributes to reducing and controlling a significant part of the reasons behind variability and uncertainty, buffers are proposed as a part of the needed additional action complementing Last Planner System® [GONZÁLEZ et al. '06b].

3.7.2 Definitions of Buffers

The term of buffer has no explicit meaning; it has various definitions based upon the field under consideration. For instance, in physical science it is considered as a solution, which resists the change in pH upon addition of small amounts of acid or base, or upon dilution. In electronic sciences, it has a different consideration, which is a routine or storage medium used to compensate for a difference in the rate of flow of data between devices.

On the other hand, buffers in production systems compensate for overflow, and they may be characterized by location, size, product mix, criticality, etc. They are also influenced by the difficulty in forecasting the available capacity and production demand [ALVES et al. '03, '04; WIKIPEDIA '09; ZÜLCH et al. '09].

There are three common types of buffer which can be applied in the construction industry [HOPP et al. '04]:

- *Inventory:* Work in Progress (WIP), and finished goods located in the supply chain.
- *Capacity:* Resource allocation in order to absorb actual production demand problem.
- *Time:* Reserved time added to baseline schedule in order to absorb the demand of variability, and protects critical path against variation in time of non-critical activities through the construction process.

Alarcón and Ashley (1999) reported the improvements in schedules and costs due to use of buffers in construction project process. Apart from up to 20% improvement in schedule, 17% in cost [GONZÁLEZ et al. '06a].

3.7.3 Buffer History

Buffering is a common technique used in project planning. The traditional project management technique has encountered a great deal of criticism. One point of criticism is that planning and control methodologies remain imperfect. In spite of the fact that project managers use a time contingency (traditional schedule buffer) to guarantee the completion time of either an activity or a project, they often fail to meet the target time and cost [SHOU et al. '00; PARK et al. '04]. Some of the shortcomings are the inadequacy of allocation of buffer and its sizing, which have been addressed and focused on by many researchers [BALLARD et al. '95; HOWELL et al. '96; GOLDRATT '97; GARDINER et al. '98; RADOVILSKY '98; PATRICK '99; SHOU et al. '00; LEACH '02; ALVES et al. '03; LEUS '03; ALVES et al. '04; PARK et al. '04; GONZÁLEZ et al. '06a; KO '06; LI et al. '07; ROGALSKA et al. '07; WIKIPEDIA '09]. Deficiencies of the traditional schedule buffers are summarized as follows [BALLARD et al. '95; HOWELL et al. '96; SHOU et al. '00; PARK et al. '04; LI et al. '07]:

- Lack of activity characteristics.
- Inefficient sizing.
- Losses at merging point.
- Bad allocation.
- Lack of uncertainty levels.
- Disregard of the believable degree of the activity duration assumption.

3.7.4 Schedule buffer functions and types

Simply, a schedule buffer is represented as time added to project duration. Even though schedule buffers between suppliers and construction may shield the contractor from the impact of late delivery, the shielding is expensive both in terms of time and cost. In order to tackle this problem, Ballard and Howell (1995) suggested that schedule buffers should be placed after processes with variable output.

Obviously, most scholars generally agree with the common types of buffers used through the scheduling.

Admittedly, with schedule buffers, as illustrated on the right-hand side of (Figure 3-10), projects will, on average, under-run by the bias amount and only rare projects will over-run the cost and schedule estimates. Process improvement should work to reduce both variability and bias over the long term. Uncertainty reduction focuses on the work processes within the tasks, while bias reduction concerns with improving the project estimation and delivery process.

Even when they have variant methodologies for managing schedule buffers by either sizing or allocating. As addressed in much of the literature [BALLARD et al. '95; GOLDRATT '97; GARDINER et al. '98; RADOVILSKY '98; SHOU et al. '00; ALVES et al. '03; LEUS '03; ALVES et al. '04; PARK et al. '04; GONZÁLEZ et al. '06a; KO '06; LI et al. '07; ROGALSKA et al. '07], there are three common types of schedule buffers. The first is the feeding buffer (FB), which is inserted wherever a non-CC-task feeds into a CC-task. The size of the FB is based on the uncertainty in the feeding chain it is associated with. The second is the resource buffer (RB), which is regarded as an early warning mechanism. It further guarantees resources will be available when needed to enable CC-task to start either on time or early. The third is the drum buffer, which assures that a drum resource is not starved for work if the drum resource is available early. It goes in the project chain immediately upstream of the first use of the drum resource in the project. You can size it as a feeding buffer for the chain of tasks that precede it, or you can use a standard duration. When beginning CCPM, you can leave this buffer out with minimal damage.

On the other hand, Ballard and Howell (1995), and Park and Peňa-Mora (2004) further represented that schedule buffers do not replace plan buffers, which are necessarily implemented immediately even when the schedule buffers are in place. Plan buffers are the outputs of a make-ready process and they can also be considered as Workable Backlogs (WB). Moreover, they determine what CAN be done as distinct from what SHOULD be done. In the following section, different methodologies for sizing schedule buffers are addressed in detail.

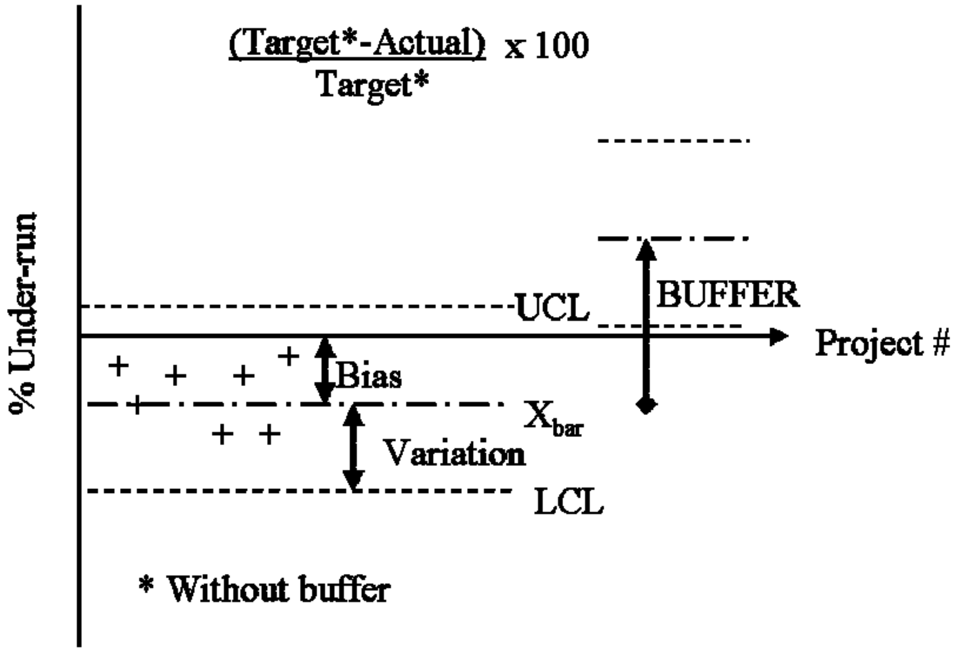


Figure 3-10 Control Chart For Effective Project Delivery Process [LEACH '02].

On the other hand, Ballard and Howell (1995), and Park and Peňa-Mora (2004) further represented that schedule buffers do not replace plan buffers, which are necessarily implemented immediately even when the schedule buffers are in place. Plan buffers are the outputs of a make-ready process and they can also be considered as Workable Backlogs (WB). Moreover, they determine what CAN be done as distinct from what SHOULD be done. In the following section, different methodologies for sizing schedule buffers are addressed in detail.

3.7.5 Design and Management Approaches of Buffer

One of the current practices of time buffer is that the float time of non-critical activities in a construction schedule is usually used to distribute scarce resources and protect the critical path against uncertainty in non-critical activities. Float time fails to protect the schedule's critical path from variability and uncertainty when activities durations have been inadequately estimated. Over the past few decades, new management approaches have had a high potential for the development of buffer design and management in construction [GONZÁLEZ et al. '06b].

Undoubtedly, some of the most significant deficiencies in buffers management (BM) are how to precisely size buffers and then allocate them properly. Inefficiency in the sizing of buffers often results in unnecessarily added time (waste), and consequently, fails to protect the project schedule performance. Approaches to identify the size of the time buffer presented in sources are very empirical. In the following sub-section, different methodologies employed for sizing schedule buffers have been elaborated.

3.7.5. [I] Sense of experience

The total time buffer size should be set at approximately either 50% or 25% of the total production lead-time.

3.7.5. [II] PERT method

In PERT estimating procedures, the responsible functional managers are required to evaluate the activities and submit their estimates. According to the beta probability distribution curve the calculation of the expected activity duration is based upon a set of three point estimates (o, m, and p) as shown in (Figure 3-11). For calculating buffers in the PERT approach, first the standard deviation for the sum as the square root of the sum of the squares (SSQ) of the standard deviation of each element included in the sum is calculated. Hence, the total duration including buffer is recommended to add two or three standard deviations to the estimated duration as illustrated in (Figure 3-12).

3.7.5. [III] CCPM method

Critical Chain Project Management buffer sizing uses the same statistical principles as PERT, but only two time estimates are used for the task duration: Most likely and a Low Risk estimate. SSQ is used to size buffer, along with a minimum project buffer size of 25% of the critical chain. (Figure 3-13) represents an example of buffer sizing using CCPM technique.

$$\text{Buffer} = \left[\sum_i \left(\Delta t_i \right)^2\right]^{\frac{1}{2}} \qquad \text{............ (1)}$$

3.7.5. [IV] Goldratt method

This approach estimates safely that critical chains as well as feeding chains are calculated by using 50% of the safe estimations as activity durations. Consequently, feeding or project buffers are taken as half of the sum of the safety time cut from the chains. (Figure 3-14) shows the procedures of placing project buffers PB and feeding buffers FB with respect to the safety time [RADOVILSKY '98].

$$\text{Buffer} = \frac{1}{2}\sum_{i} t_{0.5}^{i} \qquad \text{............ (2)}$$

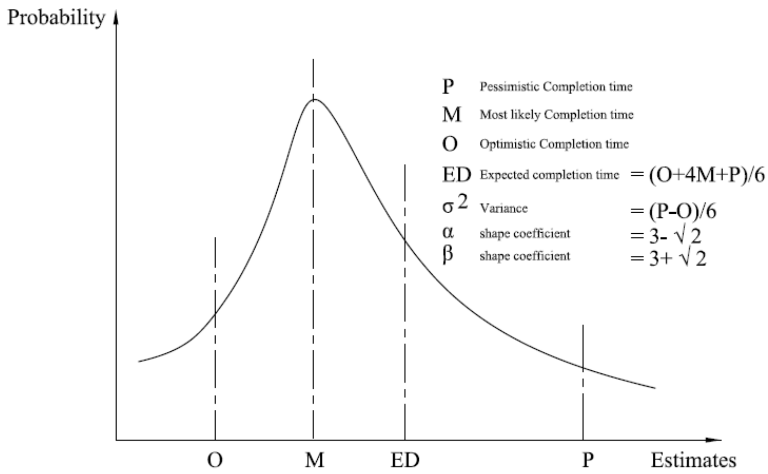


Figure 3-11 Beta Distribution of Activity Completion Time

Task	O	M	P	Xbar	s	s^2
1	2	5	10	5.33	1.33	1.78
2	3	5	12	5.83	1.50	2.25
3	4	6	8	6.00	0.67	0.44
4	7	10	15	10.33	1.33	1.78
Totals		CPM	**45**	27.50	2.50	6.25
			3*s	7.50		
			PERT	**35.00**		

Figure 3-12 Example Of Calculating Buffers In Pert Technique [LEACH '02].

Task	M	P	u	u^2
1	5	10	5	25
2	5	12	7	49
3	6	8	2	4
4	10	15	5	25
	26			103
SSQ	10			
CCPM	**36**			

Figure 3-13 Example Of Calculating Buffers In Ccpm Technique [LEACH '02].

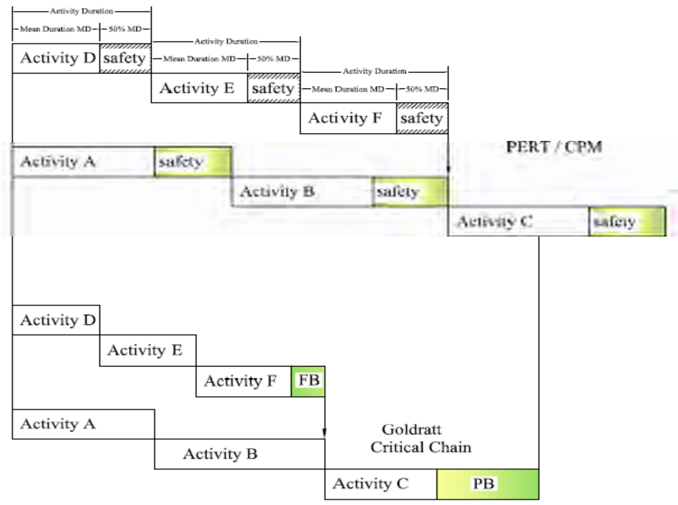


Figure 3-14 PB and FB Regarding The Safety Time in The Critical and Feeding Chain Respectively [SHOU et al. '00].

3.7.5. [V] Modified Goldratt method

This method uses the deviation between $t^i_{0.9}$ and $t^i_{0.5}$ to evaluate the buffer size. Where $t^i_{0.9}$ and $t^i_{0.5}$denote the 90% and 50% estimation time of completing the project on time respectively [RADOVILSKY '98].

$$\text{Buffer} = \frac{1}{2}\sum_{i} \Delta t_i \qquad \text{............. (3)}$$

$$\Delta t_i = S_i - A_i = t^i_{0.9} - t^i_{0.5}$$

Owing to the fact that most of probability distributions for activities durations are unknown due to the lack of historical data, the shortcomings of these methods is clearly visible. In order to tackle this problem regarding imprecise and uncertain information, fuzzy logic (FL) has been proven as an effective method to process such information. Fuzzy logic was first developed by Zadeh in the 1960s for representing uncertain and imprecise information. Fuzzy logic (FL) simulates the high-level human decision-making process, which aims at modeling the imprecise modes of reasoning to make rational decisions in an environment of uncertainty and imprecision [KO '06].

As described above, traditional approaches to size buffers are mainly based on assumptions that do not consider the project stability as related to its dynamic, complex and non-linear nature. In the following section, current attempts at sizing buffers in construction will be outlined. These attempts tried to consider omissions of the previous traditional approaches to be more effective and appropriate to the reality.

3.7.6 Buffers design (size-allocation) models

Most literature of project management recommends project schedule and budget estimates include specific buffers as allowances for a contingency reserve. Buffer size allocation in construction has been studied quantitatively for over 10 years and numerous publications are available.

The literature on buffer size allocation can be classified in two directions. The first seeks the optimal allocation of buffers, and the second seeks the smallest or the proper assessment of buffers size. In general, each of these directions may have two methods of solution: (i) algorithmic; and (ii) rule-based. Algorithmic methods lead to a computer code that provides a solution to a corresponding formulation. Rule-based methods give simple rules for either the best or good (i.e., near-optimal) solution of each formulation.

As discussed above, Goldratt's method of estimating average activity time and project buffer is regarded as improper in most cases because of its arbitrary assumption. Shou et al. (2000), proposed a new method to estimate the size of project buffers, taking into account the different uncertainties and types of projects and the risk attitude of management. They consider that method better than Goldratt's suggestion to take one-half of the project duration as the project buffer. First, they considered the different uncertainties of all the activities on the critical chain while Goldratt simply neglected this fundamental truth. Furthermore, the method considers the risk attitude and allows managers to choose different safety levels in different types of projects, while Goldratt did not care about the types of projects.

In 2006, González et al. presented a conceptual model framework, as depicted in (Figure 3-15), for the Design of Buffers in Building Repetitive Projects considering the role of lean production and management philosophy and specific Information Technologies (IT) tools and processes.

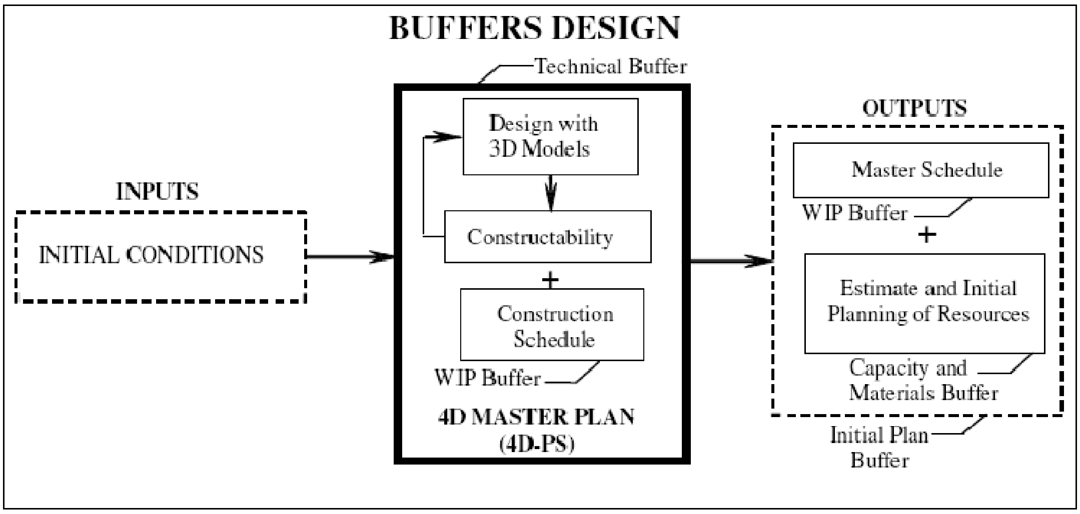


Figure 3-15 Conceptual Model For The Design Of Buffers In Building Repetitive Projects [GONZÁLEZ et al. '06b].

Client requirements, general characteristics of the project, required estimated costs and duration, needed resources, available resources, and other initial requirements are such examples of inputs to the conceptual model. The main heart in the model structure is the 4D Planning and Scheduling (4D-PS). Namely, the general project design components and the higher-level milestone construction schedule are represented through product models (i.e. 3D) and process models (i.e. 4D). The 4D-PS work process is used to unveil uncertainty not only through product and process model visualization, yet allowing project stakeholders to digitally “construct” the project several times into the computer during early stages of the project.

Using this approach, construction experience is incorporated early in the project with unprecedented emphasis and the precision of the resulting estimations contribute to reduce the initial project uncertainty. Throughout the 4D-PS visualization, the WIP buffers as an output of the proposed model, results from a refining process of the original project schedule.

As illustrated in (Figure 3-16), the proposal of González et al. focused on estimating the contingencies for each group of repetitive activities in the project as the minimum duration of them multiplied by 1/3 (CCPM), this is equal to 17% of the minimum duration.

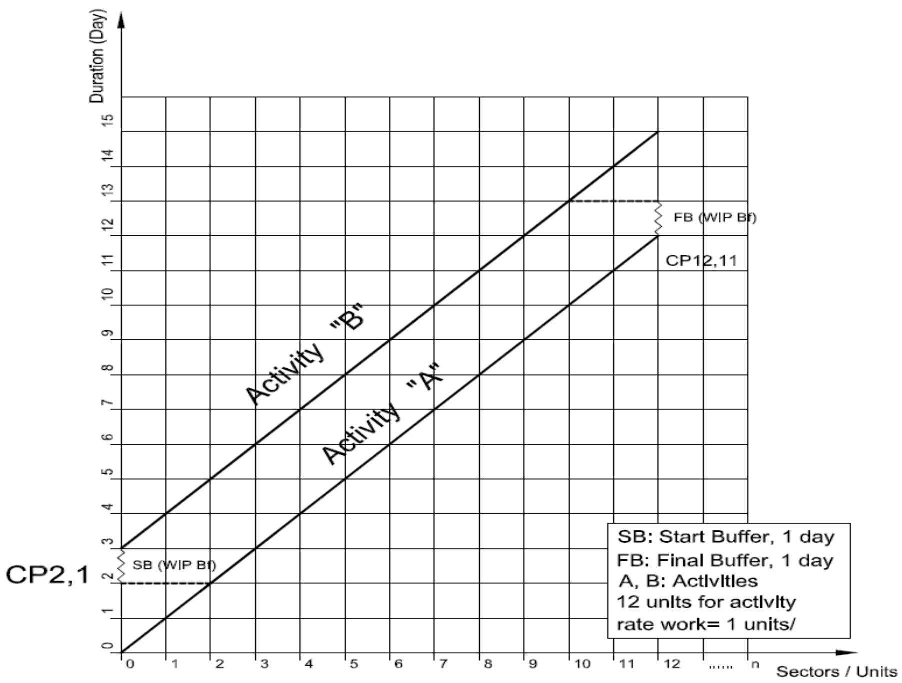


Figure 3-16 WIP/Contingencies Buffers For Buildings Repetitive Projects[GONZÁLEZ et al. '06b].

Construction practitioners and researchers have proposed buffering approaches for different production situations, but these approaches have faced practical limitations in their application. A multi-objective analytic model (MAM) is proposed to develop a graphical solution for the design of Work-In-Process (WIP) Bf in order to overcome these practical limitations to Bf application, being demonstrated through the scheduling of repetitive building projects.

The MAM was developed as nomographs using only two production variables: time and production rates. This framework allowed for a simple and practical method of designing WIP Bf for scheduling repetitive building projects with independence of cost. The framework is supported by evidence from the SO case studies. This statement was demonstrated through cost improvements obtained in the project examples after application of the MAM. It was apparent that the use of MAM reduced the interdependencies between processes for a given level of variability.

Multi-objective analytic modeling is based on Simulation-Optimization (SO) modeling and Pareto Fronts concepts. Simulation-Optimization framework uses Evolutionary Strategies (ES) as the optimization search approach, which allows for the design of optimum WIP Bf sizes by optimizing different project objectives (e.g., project cost, time and productivity) [GONZÁLEZ et al. '09b].

The simulation-optimization (SO) approach was established via discrete event simulation (DES) software for finding the best combination of input variables, whereas the Bf size was one of the decision variables. On the other hand, González and Alarcón introduced a Multi-objective Analytic Model (MAM) as a mathematical output of SO modeling for designing Bfs at the master schedule level (long-term). They demonstrated the SO model based on a set of inputs as follows:

1. Number of sequential process placed on the critical path.
2. Expected duration by production unit, μ_D.
3. Standard deviation associated with the expected duration,σ_D.
4. Variability levels by using the coefficient of variation of process duration (σ_D/ μ_D).

3.7.6. [I] Buffer design models based Fuzzy Logic

In 1965, Zadeh [ZADEH '65] introduced the concept of a fuzzy set as a model of a vague fact. Since its commencement, the theory of fuzzy sets has evolved in many directions, and is currently finding applications in a wide variety of fields. In the construction field, fuzzy set theory was developed specially to deal with uncertainties that are not statistical in nature. The first paper addressing the project-scheduling problem with a fuzzy point of view was by Chanas and Kamburowski (1981) and was published in the early 1980s. Afterwards, fuzzy logic was used by several researchers for construction project planning and scheduling [LESSMANN et al. '94; NASUTION '94b; LORTERAPONG et al. '96; HAPKE et al. '97; WANG '99; LEU et al. '01; PAN et al. '03; BEGOVICHA et al. '05; CHEN et al. '05; GANOUD et al. '05; OLIVEROS et al. '05; PAN et al. '05b, a].

Furthermore, the use of fuzzy logic theory in buffers design has been extensively discussed in the field of IP networks control and management. However, attempts at the use of fuzzy logic in buffers design are still few in the field of the construction management.

In general, buffers evaluation model (BEM) is an attempt of the buffers sizing using fuzzy logic concepts. Modeling buffers using FL typically flows through four phases as shown in (Figure 3-17). Firstly, the fuzzification process is carried out to convert the input values into linguistic variables. During this scale mapping, membership functions are used to define the relationships between input variables and linguistic variables. Secondly, rules that connect between input and output variables are established using expert knowledge. Tertiary, the fuzzy inference engine has the capacity of inferring results using fuzzy implication and fuzzy rules. For a given set of fuzzy rules, a composition operator infers the fuzzy results from both fuzzy input set and fuzzy relations. Finally, a reversing of fuzzification process called defuzzification is done, which produces a crisp output from fuzzy inferences. It identifies the time buffer for demand variability.

The year 2006 witnessed one of the pioneering attempts towards the improvement of fuzzy buffer management. That research was demonstrated to protect precast fabricators against the impact of demand variability. A time buffer was then analyzed using fuzzy logic to avoid fabricators losing capacity. Since some characteristics of a project indeed have more chances inducing demand variability, three factors were identified in the buffers assessment model based on the experts' survey: the function of the building, the number of ownership, and the type of used precast element used [KO '06].

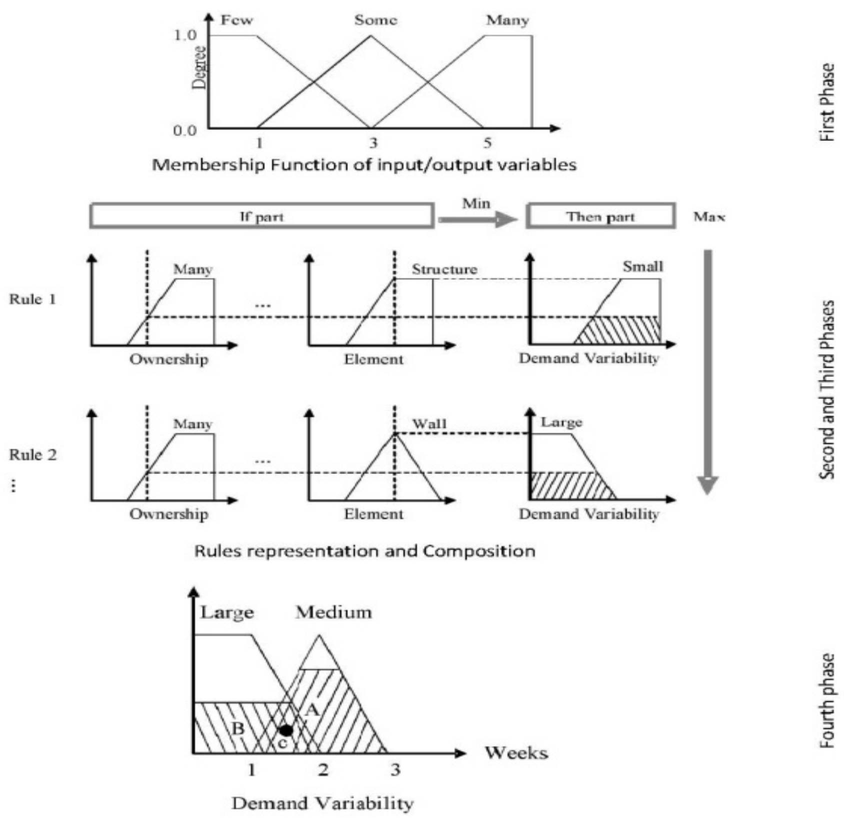


Figure 3-17 Using Fuzzy Logic (FL) in Buffering Evaluation [KO '06].

One year later, a fuzzy method was tested to estimate the buffer size in critical chain scheduling to reduce uncertainty degree. The test was to analyze the principles of project buffer under the comparison of critical chain and classical network scheduling techniques. The test resulted in that the evaluation based on fuzzy technique can improve the performance of project schedule [LI et al. '07].

3.7.7 Buffer Management

Buffer Management is a process that deals with buffers effectively in order to enable managing the execution of the project, predicting the shape of project once it gets started without a specific due date to be tracked. Moreover, buffer management provides the focus for schedule management, avoids unnecessary distraction, and allows recovery planning to take place when needed, but well before the project is in trouble. In principle, the implementation of buffer management process has a certain strategy through building and controlling the projects. The following are the main features of this strategy [PATRICK '99]:

- **Stop spreading safety, hidden and wasted in the tasks.** This can only happen effectively when resources trust management and project owners to accept that their tasks' target durations are not commitments and that the buffers are sufficient to protect the project.

- **Stop the behaviors that waste time in the project.**

- **Avoid resource multi-tasking and the lead-time multiplication.** Management must take responsibility for protecting resources from competing priorities that drive multi-tasking.

- **Account properly for resource contention.** When building project schedules, project managers must realize resource dependency is as real as task dependency when determining what is critical for the project.

- **Track the consumption and replenishment of buffers.** The project team must plan and act to recover as dictated by buffer status, but only when necessary.

During the last few decades, new management philosophies have been developed more rigorously as well as scientific strategies to deal with variability and uncertainty in production management. These approaches have a high potential for the development of a systematic approach to buffer management in construction. However, up to 2006, González et al. observed the fact that these approaches have no formal methodologies for managing schedule buffers in construction as explained in (Table 3-3).

Recently, a few attempts have worked not only in the direction of improving the schedule buffers design, but also in setting up a framework for managing buffers effectively based on the concepts of Lean Construction approach. In 2009, the international group of Lean Construction took the priority in developing the buffer management in formal frameworks.

Table 3-3 Buffer Management Approaches [GONZÁLEZ et al. '06b].

Approaches	Buffer Type	Observation	Research (Source)
Lean Construction	Contingencies	Through Reliability and Stability Buffering, a proactive approach is achieved that try to solve problems before they impact in a successor activity (wave effect).	Lee et al (2003)
TOC		A Project Buffer (Final Contingency) is considered after the project activities finish date and the critical chain is defined considering resources technical dependencies and critical path. This method poses a reactive approach (Lee et al, 2003) that overestimates the project duration with Feed Buffers (Buffers of non-critical activities) and produce problems when leveling resources (Herroelen et al, 2002). Leach (2003) corrects the size of the project buffer increasing it in an additional percentage to compensate estimation biases.	Goldratt (1997), Shou et al. (2000)
Lean Construction	WIP	There are not formal methodologies for Designing and Managing WIP Buffers in construction. González and Alarcón (2003) give the following recommendations for WIP Buffer Management: a) Establish reliable compromises related to the size of project WIP, b)Intensify supervision at the jobsite, c)Define work packages adequately, and d)Use Last Planner principles. Techniques for repetitive projects like Line of Balance (LOB) are very beneficial to manage WIP.	Alarcón and Ashley (1999), Sakamoto et al (2002), Tommelein et al (1998), González and Alarcón (2003).
TOC		TOC techniques propose the establishment of material and WIP Buffers so that the system bottleneck will not reduce the entire system performance. Minimum inventories levels can be established by knowing the times required for setup, repairing, etc. These techniques are more intuitive than JIT but allow faster implementations.	Goldratt and Cox (1986, 1996), Godratt (1990).
Lean Construction	Plan	Reliable assignments reduce variability and uncertainty, and increase reliability in the production flow using the Last Planner technique. Plan Buffers are materialized through intermediate planning that produce Workable Backlogs.	Ballard et al. (1994, 1995), Ballard (2000)

As discussed in the previous chapter, the effective buffers management way is achieved once it is performed through an improvement cycle. This cycle meets the main goal of Lean Construction to eliminate waste and reduce buffers as interpreted by Ballard (2008).

Abdelhamid et al. (2009) advocated the needs for the sudden emergence of the situation and the dynamic nature of its evolution to be addressed with flexibility based on an appropriate assessment of the issues at hand. Therefore, they presented the Observe-Orient-Decide-Act (OODA) loop as the theoretical interpretation framework by which to influence the performance of self-managed teams in construction. Thus, they proposed a framework to manage the uncertainty-based OODA loop from the lean perspective.

In order to develop such framework, they initially conducted a survey to consider that construction professionals reached a consensus on the need for both better planning and adopting various lean principles. The positive impact on workflow reliability by the effective handling of unforeseen uncertainties was presented. The framework was mainly based on a pair of steps for embracing uncertainty in construction setting, and besides, it is founded on the Last Planner System®® with an OODA loop overlay during the Weekly Work Plan as illustrated in (Figure 3-18). The first step was to monitor the environment in the production phase, whereas the second step focused on learning the OODA loop by introducing perturbations into the system to avoid complacency.

The OODA loop is based upon four phases: firstly is *observe*, secondly is *orient*, thirdly is *decision*, and finally is consequent *action*. The first step of observe is established in order to acquire sufficient knowledge for making a decision. Furthermore, this step requires recognition of unfolding events and feedbacks from the various other stages. They explained the second step, the most complex part in the loop, as the orientation of the information, by utilizing previous experiences, waiting for all new information and cultural traditions of the organization. Though the necessity for need is in the first two steps, the step with respect to decision is needed only when we are not sure what to do.

They found such framework play an intrinsic role in advancing the performance of production planning and control as one of the key enablers in achieving the Lean Construction vision. However, further efforts it is still needed to integrate OODA-loop thinking as part of construction teams' daily activities. Moreover, both of the suggested steps of the framework need to be validated; they also recommended finding other methods to deal with uncertainties.

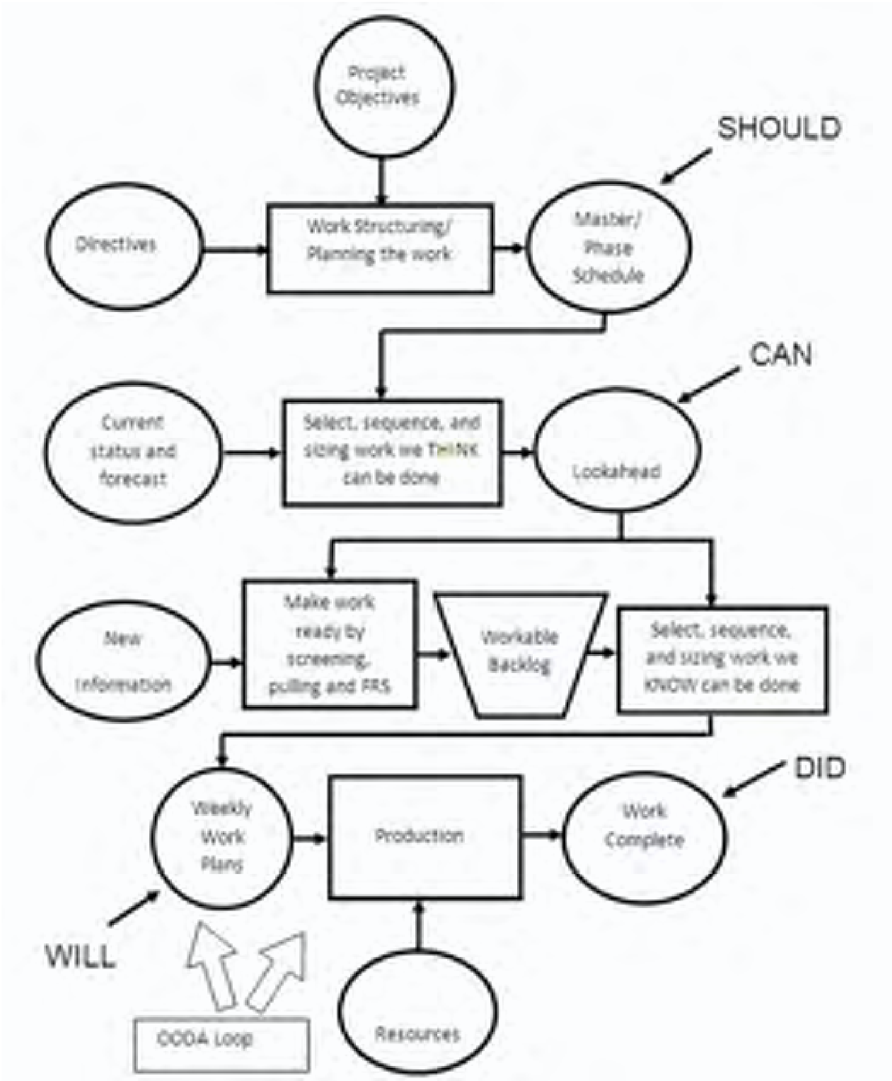


Figure 3-18 The Framework of Use The OODA Loop In Tandem With The LPS® [ABDELHAMID et al. '09]

González et al. (2009) proposed further a conceptual approximation for an integrated buffer (Bf) design and management methodology using Work-In-Process buffer (WIP) in repetitive projects. The Bf design component used the Multi-objective Analytic Model (MAM) and Simulation-Optimization (SO) modeling, whereas the Bf management component used the Rational Commitment Model (RCM). They advocated that a production system without Bf implies a production system without throughput, even though the use of Bf is controversial from a lean production perspective since the lean ideal suggests that zero inventories, or non-buffered production system are desirable.

They presented that master plan (long-term period), lookahead plan (medium-term), and work plan (short-term) are the three planning hierarchy levels for construction planning suitable to scheduling, which are progressively more detailed from top to bottom. Furthermore, they presented the fact that the size of Bfs is influenced by two key characteristics. These key characteristics are workflow variability and process interdependence. Workflow variability of a process was represented by the duration PDF, impacts of succeeding process. As depicted in (Figure 3-19), an example of a repetitive project of “n” processes P_1, P_2, P_3, …, P_{n-1}, P_n with average production rates and standard deviation called m_1, m_2, m_3, …, m_{n-1}, m_n (unit/day) and SD_1, SD_2, SD_3,..., SD_{n-1}, SD_n, respectively. In addition, the location and size of WIP Bf for this project are shown in terms of WIP $Bf_{1,2}$, WIP $Bf_{2,3}$, WIP $Bf_{3,4}$, …, WIP $Bf_{n-2,n-1}$, WIP $Bf_{n-1,n}$ and T $Bf_{1,2}$, T $Bf_{2,3}$, T $Bf_{3,4}$, …, T $Bf_{n-2,n-1}$, T $Bf_{n-1,n}$, respectively.

At a lookahead plan level (medium-term), they presented that the design of Bfs is more dynamic where are directly used SO models. In this stage, they reported the former stage feedbacks from site production to update simultaneously a lookahead plan that holds the designed Bfs. Finally, they developed the way of modeling the framework in the last stage of work plan level (short-term), that allows predicting the progress of weekly work using historical site information.

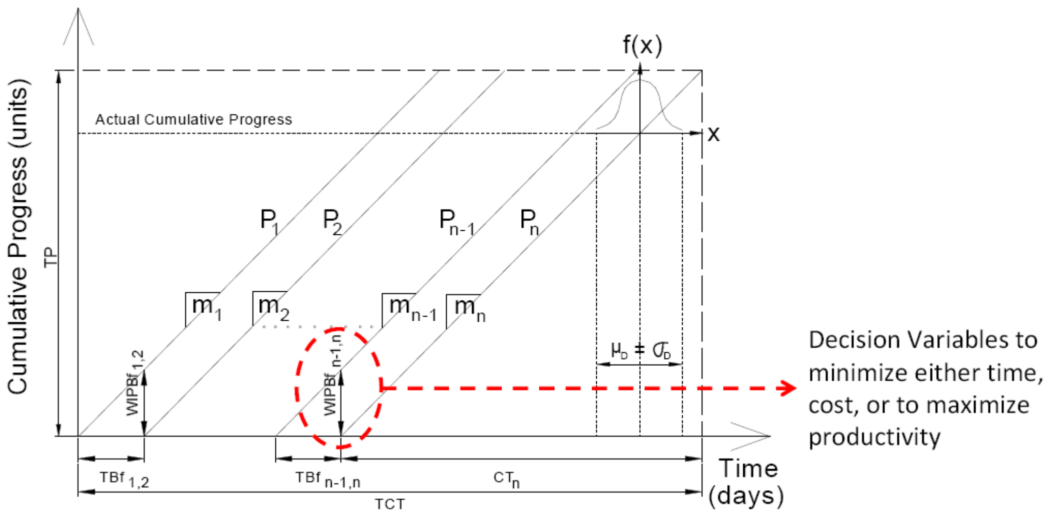


Figure 3-19 The Model For WIP Bf Characterized by The Duration PDF And N Processes [GONZÁLEZ et al. '09a].

In the same year of 2009, Olano et al. revealed the flaws of the traditional management for construction projects through planning, execution, and control processes. Firstly, they presented that the planning process is executed by persons unfamiliar with the execution nature for tasks on site. Secondly, it is regarded that the necessary resources for the execution process of the tasks exist at the moment of the task, and the process is pushing the tasks for their execution, which added to uncertainty usually leads to being behind schedule. The control process may provide reactive indexes, identification of problems. However, this process is not capable of identifying the reasons and root causes that generated the deviation. Therefore, they advocated the necessity of managing both flow and transformation in order to maximize the project management effectiveness. They adapted proactive indicators to measure the workflow efficiency and short-term plan as the Percentage Plan Complete (PPC), and likewise, reactive indicators measure the effectiveness of the project management as the Schedule Performance Index (SPI).

They implemented project control tools and methodologies based on both Earned Value Analysis (EVA) and the Last Planner System®, for pair of highway construction projects were developed in Peru. The former technique provides a monitoring of the progress of the project by means of the Schedule Performance Index (SPI), whereas the latter technique of LPS® increases the planning reliability by means of Percentage Plane Complete (PPC) through the identification and release of inherent constraints.

Hence, they observed an improvement in the SPI of the project, when the workflow reliability was improved through the increment of the PPC. Moreover, they found that the implementation of EVA as a traditional management methodology independently is inefficient for the activities performance under uncertainty. As a result, and according to the findings, they advocated that both methodologies must be managed simultaneously to ensure project success.

3.8 CONCLUSION

Albeit the fact that project managers use a time contingency (traditional schedule buffer) to guarantee the completion time of either an activity or a project, they often fail to meet the target time and cost [SHOU et al. '00; PARK et al. '04]. Some of the shortcomings are- the inadequacy of allocation of buffer and its sizing, which was addressed and focused on by many researchers [BALLARD et al. '95; HOWELL et al. '96; GOLDRATT '97; GARDINER et al. '98; RADOVILSKY '98; PATRICK '99; SHOU et al. '00; LEACH '02; ALVES et al. '03; LEUS '03; ALVES et al. '04; PARK et al. '04; GONZÁLEZ et al. '06a; KO '06; LI et al. '07; ROGALSKA et al. '07; WIKIPEDIA '09]. In conclusion, deficiencies of the previous traditional methods concerning schedule buffers are summarized as follows [BALLARD et al. '95; HOWELL et al. '96; SHOU et al. '00; PARK et al. '04; LI et al. '07]:

- Lack of activity characteristics.
- Regardless of uncertainty levels.
- Neglect of the degree of confidence of the activity duration assumption.
- Inefficient sizing.
- Losses at merging point.
- Bad allocation.
- Improper distribution of buffers.

In addition, beyond approach based on fuzzy logic, others explicitly need a massive pile of data to be able to draw initially the probability distribution function. However, in many cases, the distribution of probability of an activity is impossible to determine because of the lack of historical data. Despite the remarkable success of using the fuzzy logic approach in evaluating buffers properly, more efforts are still needed that are focused on the influence of many factors on many activities in a project such as weather, labor skills, equipment, and management quality [LONG et al. '08].

Therefore, it is recommended to extensively focus on an approach based on Fuzzy logic as a much more appropriate technique for such topics, particularly in highway construction projects due to the combination of the random and incompletely defined nature for activity durations. For the same reason, developing a model based on fuzzy logic for computing the buffer is considered, and most of the flaws addressed in previous approaches are tackled in this model.

Hence, the elements of the improvement cycle is demonstrated through this research. Firstly, the matching buffers to the actual degree of uncertainty is accomplished by developing the Fuzzy-logic buffering Model (FLBM) as a quantitative model for sizing buffers as a lean level of buffering (LLB). The integration of this model with an LPS® in one collaborative system enables managers to optimize the process as well as buffers in a cycle.

4

Fuzzy Logic Buffering Model (FLBM)

- Fuzzy Logic System
- Architecture of fuzzy logic
- Modelling of FLBM
- Criteria-based model
- Theoretical validation

Ask a man which way he is going to vote, and he will probably tell you. Ask him, however, why, and vagueness is all.
"Bernard Levin"

CHAPTER 4. FUZZY LOGIC-BUFFERING MODEL (FLBM)

4.1 OVERVIEW

Schedule planning plays an intrinsic role in project management enabling a construction process to be more transparent and manageable. Hence, this has been a topic of great interest since the very beginning of operational research. Enhancing the reliability of scheduling is key to achieving a stable construction flow. Generally, a project schedule is defined as a complex set of precedence-related activities that have to be executed using certain resources. Further, apart from the fact that project scheduling is aimed at deciding which activity should be executed at a certain time, and when to start (and finish), it aims at deciding the allocation of the specific resources to the project activities [LEUS '03]. In the real world, traditional scheduling tools are not suitable for producing a robust work schedule [CHUA et al. '99].

Many project-scheduling problems are often inherently uncertain due to the vagueness in activity duration times. Uncertainty in an activity associated with randomness was traditionally handled by stochastic approaches using probabilistic-based PERT technique. However, in many cases, the distribution of probability of an activity is impossible to be determined because of the lack of historical data. They further argued, and still do, that the project-scheduling problem is not a domain that suits the axiomatic associated with the probability theory [BONNAL et al. '04]. Many scholars [BLOCKLEY '79b; AYYUB et al. '84; LESSMANN et al. '94; NASUTION '94a; LORTERAPONG et al. '96; WANG '99; SLOWINSKI et al. '00; CACHADINHA '02; LEUS '03; PAN et al. '03; BONNAL et al. '04; GANOUD et al. '05; HERROELEN et al. '05; OLIVEROS et al. '05; PAN et al. '05a, b; LI et al. '07], recommend Fuzzy approaches to be much more appropriate techniques for project scheduling, particularly in highway construction projects due to the combination of random and the incompletely defined nature of activity durations. In the same direction, it has also been advocated that fuzzy approach is the best tool for reaching the most likely correct decision when the objective is to reconcile different judgments about effective means to a common aim, and the most equitable method of determining a resultant of divergent desires [GARCÍA-LAPRESTA et al. '01].

The random nature of activity durations has been the subject of many research efforts. In this chapter, we tackle the development of a pre-computed baseline schedule with the objective of guaranteeing the stability of the activity durations. This stability can be produced when the baseline schedule can absorb variability undergoing the process. In order to achieve that, we develop a Fuzzy model to evaluate the project buffer size taking into consideration the level of uncertainty, type of activity, believable degree of the baseline duration assumption. This chapter flows through introducing elements regarding the model. One of these elements is buffer as the output of the model; another element is Fuzzy Logic (FL) as a technique used in the modeling, and finally methodology of the proposed model and the outcomes are derived.

4.2 FUZZY LOGIC SYSTEM (THEORETICAL BACKGROUND)

As represented in the previous chapter of the buffer history, many deficiencies have plagued the traditional approaches with respect to buffers design and management. Despite the remarkable success of using the fuzzy logic approach in evaluating buffers properly, more efforts are needed focused on the influence of many factors on many activities in a project such as weather, labor skills, equipment, and management quality, ……etc. [LONG et al. '08].

In the following sections, a Fuzzy-Logic Buffering Model (FLBM) is developed to calculate the buffer size of the project. Consequently, that may reduce the entire project buffer time, which finally leads to either reduction in the total project duration or meeting the project completion date. The first part based on using FL to estimate the buffer size is established within this chapter. Most of the shortcomings and miss parameters revealed in previous traditional approaches, particularly the fuzzy approaches are remedied through this model. The fuzzy-logic buffering model FLBM focuses upon the reality of buffers, which result from taking into consideration most of the factors that share the execution of a project. For instance, average activity duration, types and characteristics of activities, level of uncertainty, and the degree of confidence in estimates of the activity duration.

4.2.1 Fuzzy Logic complements Probability theory

Although, Probability is defined theoretically as a way of expressing knowledge, or belief that an event will occur or has occurred, some philosophers of mathematics argue that we have never understood the meaning of probability. In principle, it is used extensively in areas of study such as mathematics, statistics, finance, management, science, and philosophy to draw conclusions about the likelihood of potential events and the underlying mechanics of complex systems. The underlying "first principle" of probability is randomness. This randomness presupposes our ability to measure and order the random space. Moreover, the main core of probability is the probability distribution functions (PDF).

On the other hand, fuzzy logic is a calculus of compatibility. Unlike probability based on frequency distributions in a random set, fuzzy logic deals with describing the characteristics of properties. Fuzzy logic describes properties that have continuously varying values by associating partitions of these values with a semantic label. Thus, the reasons why classical probability theory falls short of providing a comprehensive methodology for dealing with uncertainty and imprecision are addressed by [ZADEH '65, '84; KOSKO '90; ZADEH '95]:

1. Probability theory does not support the concept of the fuzzy event.
2. Probability theory offers no techniques for dealing with fuzzy quantifiers like *many, most, several, few*.
3. Probability theory is insufficiently expressive as a meaning-representation language.

Thus, probability theory is much less effective in those fields in which the dependencies between variables are not well defined. Moreover, it is not able to model uncertainty in the highway construction process because of the lack of historical data, which results in inability to build the PDF.

4.2.2 Fuzzy logic concepts

As is generally known, fuzzy logic was described nearly 50 years ago by Zedah. Fuzzy logic provides a method of reducing as well as explaining system complexity. The fuzzy sets are simply considered as functions that map a value, which might be a member of the set to a number between zero and one, indicating its actual degree of membership. A degree of zero means that the value is not in the set, and vice versa, a degree of one means that the value is completely representative of the set.

(Figure 4-1) represents the typical structure of the entire fuzzy logic system as well as its elements, which will elaborately be explained through the next few lines. The center of fuzzy logic technique is the idea of a linguistic variable; this allows the knowledgeable engineer to write expressive statements about related concepts. The following are some examples of linguistic variables using the fuzzy set: *VERY SIGNIFICANT, SIGNIFICANT, SOMEWHAT SIGNIFICANT, SLIGHTLY SIGNIFICANT, AND NOT SIGNIFICANT*. Hence, a linguistic variable encapsulates the properties of approximate or imprecise concepts in a systematic and computationally beneficial way [COX '94].

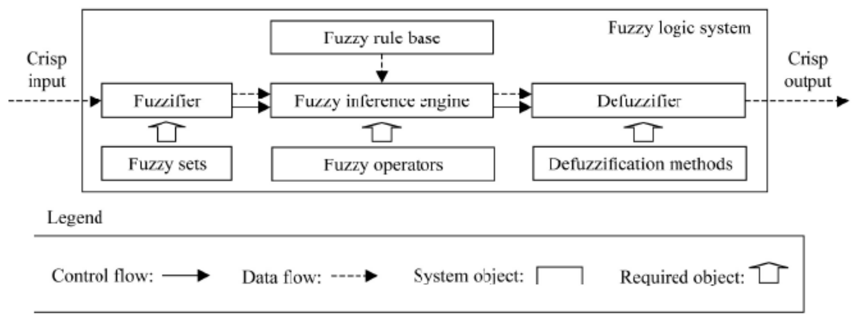


Figure 4-1 Typical Fuzzy Logic System [KO '06].

4.2.3 Benefits of a fuzzy logic system

While the fuzzy logic systems are shown to be universal approximating tools to algebra functions, it is not this attribute that distinctly makes them valuable in understanding new or evolving problems. Hence, the primary benefits of fuzzy system theory are addressed in the following points [COX '94; BAUER '01; ROSS '04]:

- Approximate system behavior where analytic functions or numerical relations do not exist.
- Model highly complex business problem.
- Improve cognitive modeling of expert systems.
- Model systems involving multiple experts.
- Reduce model complexity
- Improve dealing of uncertainty, imprecision and possibilities that are not statistical in nature.

As mentioned antecedently, construction projects are normally executed in an outdoor environment characterized by various degrees of uncertainty. In addition, it is commonly known that no two construction projects are alike. The conditions for executing those projects at the activity level may also vary from one project to another. Therefore, statistical methods, which are primarily based on observations and historical data, fail to handle a problem’s often inherent uncertainty due to the vagueness of activity durations. Consequently, the fuzzy logic techniques have interested several researchers for construction projects [BLOCKLEY '79a; AYYUB et al. '84; COX '94; NASUTION '94a; KONAR et al. '96; LORTERAPONG et al. '96; HAPKE et al. '97; WANG '99; LEU et al. '01; CACHADINHA '02; LEUS '03; PAN et al. '03; ADENSO-DÍAZ et al. '04; BONNAL et al. '04; ROSS '04; FARAG '05; GANOUD et al. '05; HERROELEN et al. '05; OLIVEROS et al. '05; PAN et al. '05a, b; KO '06; SHULL '06; SINGH et al. '06; BOJADZIEV et al. '07; LI et al. '07; ABDEL-LATEEF et al. '08; LONG et al. '08]. They advocated using fuzzy logic in construction planning and scheduling due to its evident ability in dealing with uncertainties and imprecision that results from a lack of historical data.

4.2.4 Structure of Fuzzy Logic System (FLS)

A fuzzy set is a class of objects with a continuum of grades of membership. Underlying the surface of the fuzzy region is the universe of values that we map back to this membership array. The total allowable universe of values is called the domain of the fuzzy set. The domain is a set of real numbers, increasing monotonically from left to right. The values can be both positive and negative. You can select the domain to represent the complete operating range of values for the fuzzy set within the context of your model. A model variable is often described in terms of its fuzzy space. This space is generally composed of multiple, overlapping fuzzy sets describing a semantic partition of the variable's allowable problem state [COX '94]. Such a set is characterized by a membership (characteristic) function, which *assigns* to each object a grade of membership ranging between zero and one [ZADEH '65]. The characteristics function reflects two-valued space:

$$\mu_A(x) = \begin{cases} 1 & x \in A \\ 0 & x \notin A \end{cases} \quad \text{............. (4)}$$

The value $\mu_F(x)$ is considered as the degree of membership of object x to the fuzzy set A. This represents that membership function for the set is zero if x is not an element in A, and the membership function is one if x is an element in A. Owing to the fact that there are only two states, the transition between these states is always crisp. For instance, (Figure 4-2) shows the described properties of the universe of discourse (UD) through an example of a variable of "*Temperature*."

In essence, any subset A may be represented by m discrete values (or continuous intervals) of x together with membership function $\mu_A(x)$ as follows:

$$A = [x_1|\mu_A(x_1),\ x_2|\mu_A(x_2), x_3|\mu_A(x_3), \ldots\ldots(x_m|\mu_A(x_m)] \quad \text{............. (5)}$$

which, "=" should be interpreted as (is defined to be), and "|" is a delimiter.

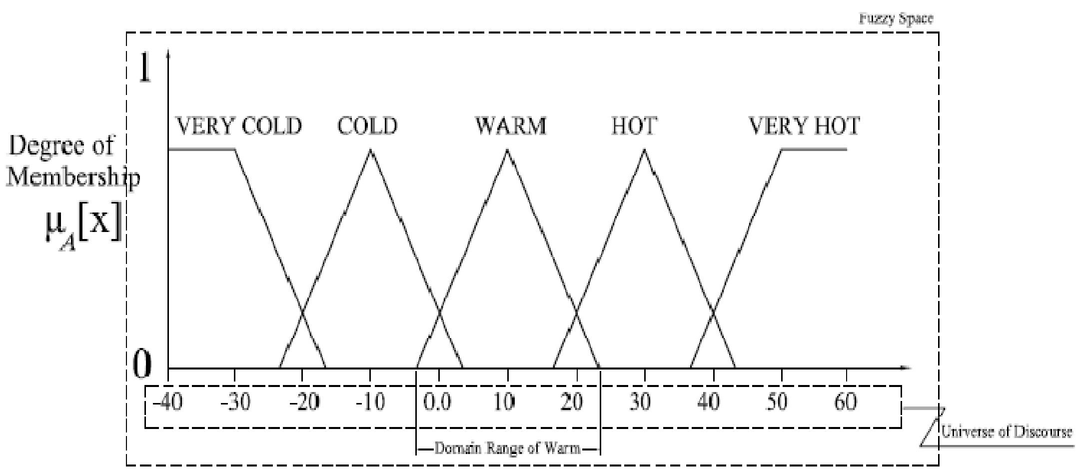


Figure 4-2 The Universe of Discourse (UD) For Temperature

4.2.4. [I] Fuzzy sets operations

Generally, as illustrated in (Figure 4-3), there are four basic set operations, that can be performed on classical crisp sets. For instance,

Let A= (a_1, b_1, c_1, d_1…), and B= (a_2, b_2, c_2, d_2…), then:

As clearly shown, the intersection of sets A and B (A∩B) contains all the elements that appear in both sets A ***AND*** B. The union of sets A and B (A∪B) contains all the elements that appear in either set A ***OR*** B. Another kind of union, called fuzzy exclusive-OR, and represented by A⊕ B, contains all the elements that are in A or in B, but not in both.

Intersection $\text{mĭn}(A,B) = [\wedge(a_1, a_2), \wedge(b_1, b_2), \wedge(c_1, c_2), \wedge(d_1, d_2),\ldots\ldots]$ .... (6)

Union $\text{măx}(A,B) = [\vee(a_1, a_2), \vee(b_1, b_2), \vee(c_1, c_2), \vee(d_1, d_2),\ldots\ldots]$ .... (7)

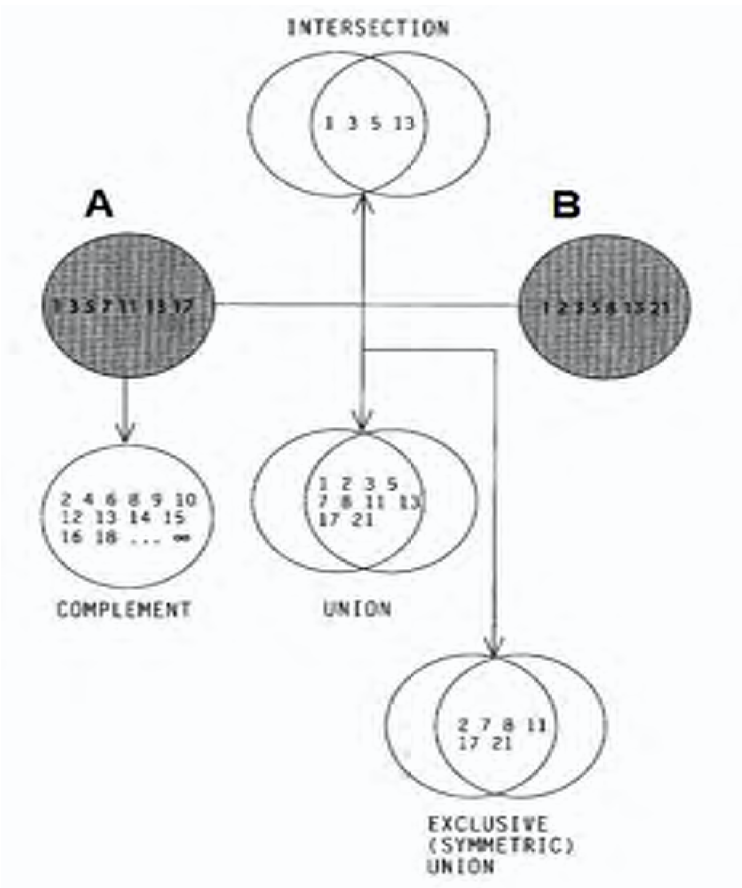


Figure 4-3 Basic Operations on Crisp Sets

The conventional fuzzy logic operations primarily defined by Zadeh are thought out in fuzzy logic sets as well as in the previous example of classical crisp sets. Apart from, the expressing fuzzy operations in the following equations 8, 9, and 10, (Figure 4-4) shows these operations performed on fuzzy logic sets.

Intersection	$\mu_{A \cap B}[x] = \min(\mu_A[x], \mu_B[x])$	$\forall\, x \in U$	.... (8)
Union	$\mu_{A \cup B}[x] = \max(\mu_A[x], \mu_B[x])$	$\forall\, x \in U$	.... (9)
Complement	$\mu_{\sim A}[x] = 1 - \mu_A[x]$	$\forall\, x \in U$	.... (10)

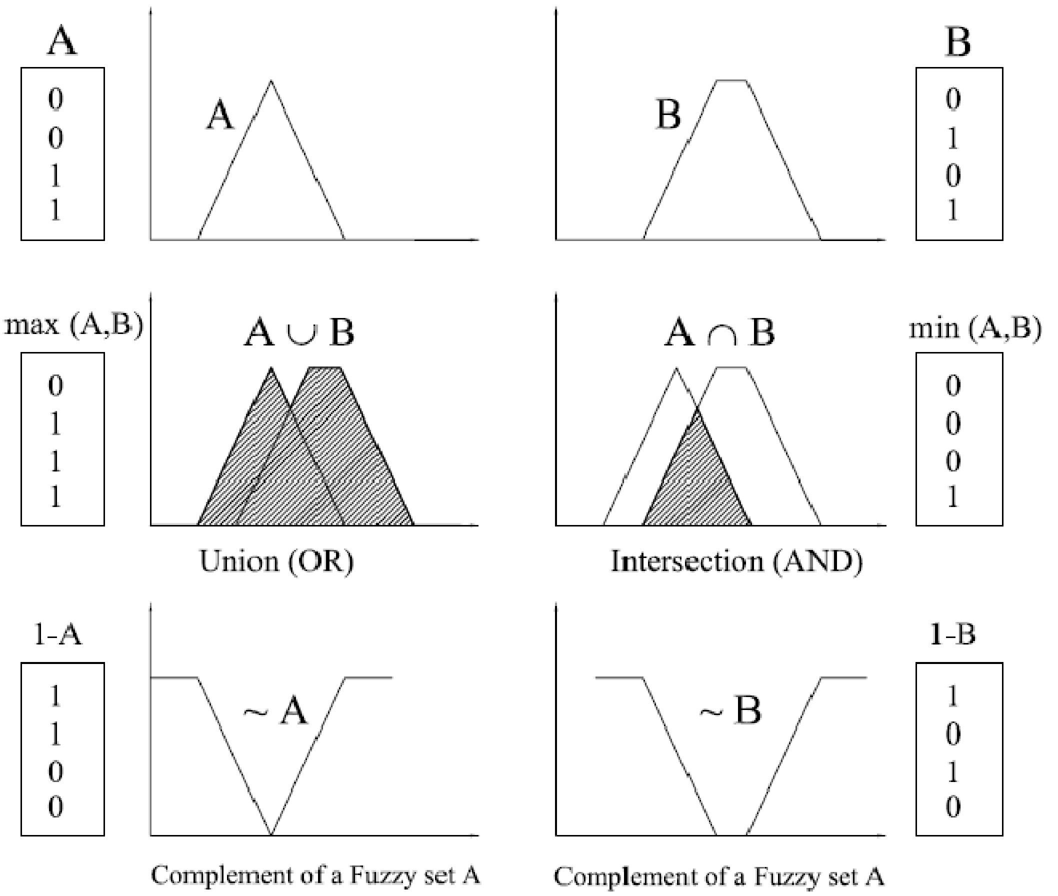


Figure 4-4 Basic Operations on Fuzzy Logic Sets

4.2.4. [II] Fuzzy set membership functions

The membership function describes the degree of membership of the different elements of the fuzzy set in the universe of discourse. There are miscellaneous membership function forms, and some of them are presented in (Figure 4-5). The selection of the form of membership function is subjective and based upon the context and the base set. Namely, if this set consists of many values, or if the base set is a continuum, then a *parametric representation* is appropriate. For a parametric representation, functions that can be adapted by changing the parameters are used. Piecewise linear membership functions are preferred because of their simplicity and efficiency with respect to computability. Mostly these are triangular or trapezoidal functions, which are defined by three and four parameters respectively. For practical reasons, triangular and trapezoidal functions are the most commonly used in engineering applications. Furthermore, membership functions can be symmetrical or asymmetrical. They are typically defined on a one-dimensional universe, yet they can certainly be described on a multidimensional (or *n*-dimensional) universe [ROSS '04].

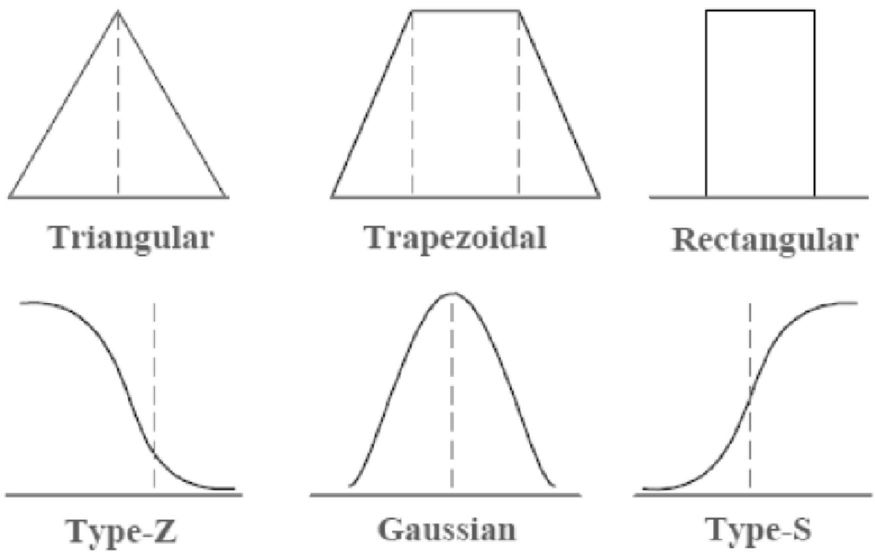


Figure 4-5 Typical Fuzzy Set Membership Function Shapes [SHULL '06].

For converting a series of individual fuzzy controls into one continuous and smooth surface, each fuzzy set in a membership must, to some degree, overlap its neighboring set. Generally, there is no precise mathematical formula for determining the minimum or maximum degree of overlap, but this interference pattern should reflect the semantics of the associated control or output variable. Hence, experts stated that the overlap for triangle-to-triangle and trapezoid-to-triangle fuzzy regions averages approximately between 25% and 50% of the fuzzy set base, which is based upon the modeling concepts and the intrinsic degree of imprecision associated with the two neighboring states [COX '94].

4.2.4. [III] Fuzzification-Inference-Defuzzification

Once the membership functions are clearly defined, the ***Fuzzification*** process takes a real time input value, such as temperature's example, and compares it with the stored membership function information to produce fuzzy input values. The first step in fuzzification is to assign fuzzy labels in the universe of discourse (UD) to each of the crisp inputs as illustrated in the example of (Figure 4-2). Each crisp input into a fuzzy system can have multiple labels assigned to it. In general, the greater the number of labels assigned to describe an input variable, the higher the resolution of the resultant fuzzy control system, culminating in a smoother response.

Next comes the ***Fuzzy Inference System (FIS)***; in this process the fuzzy logic based systems use rules to represent the relationship between observations and actions. These rules consist of a precondition IF and a consequence THEN. In general, a fuzzy relation, R, or Cartesian-product, A x B, between two fuzzy subsets A (subset of universe *X*) and B (subset of a universe *Y*) has the following interpreted functions in equations (11 and 12):

$$\mu_R(x_i, y_i) = \mu_{AxB}(x_i, y_i) = \min \mu_A(x_i), \mu_B(y_i) \quad \text{............ (11)}$$

$$R = AxB = A \left\{ \begin{matrix} x_1 \\ x_1 \\ \vdots \\ x_n \end{matrix} \left[\overbrace{\begin{matrix} y_1 & y_2 & \cdots & y_m \\ \mu_R(x_1, y_1) & \mu_R(x_1, y_2) & \cdots & \mu_R(x_1, y_m) \\ \mu_R(x_2, y_1) & \mu_R(x_2, y_2) & \cdots & \mu_R(x_2, y_m) \\ \vdots & \vdots & \ddots & \vdots \\ \mu_R(x_n, y_1) & \mu_R(x_n, y_2) & \cdots & \mu_R(x_n, y_m) \end{matrix}}^{B} \right] \right\} \quad \text{............ (12)}$$

With the notation, $\mu_R(x_i, y_i)$ indicates the support, or membership, value for the ordered pair (x_i, y_i), and is a measure of association between x_i, and y_i. It is computed as the minimum value of the membership values $\mu_A(x_i)$ and $\mu_B(y_i)$. Thus, fuzzy rule inference consists of two consecutive steps, which are inference and composition.

Inference is responsible for determining the fuzzy subset of each output variable for each rule. The most important types of fuzzy inference method are Mamadani's, and Sugeno fuzzy inference methods. Consider a domain described by a function $y = f(x1, x2)$, a *Mamdani* type FIS in this domain would consist of rules of the form "IF *x*1 is low AND *x*2 is medium THEN *y* is high,'' where low, medium and high are linguistic terms with functional forms like Gaussian, Sigmoid, etc., also known as membership functions. A Sugeno type FIS in this domain would consist of rules of the form "IF *x*1 is low AND *x*2 is medium THEN *y* = *f*1*(x*1*, x*2*)*," where low and medium are linguistic terms with functional context. The difference between the two FIS is the form of consequents.

In Mamdani type FIS the output membership function can be defined independent of the premise parameters; whereas in Sugeno type FIS each output membership function is a function of the inputs. Moreover, Mamadani's method has widespread acceptance because it is well suited to human input and easy to form as compared to Sugeno method, which requires a large number of rules have to be employed to approximate periodic or highly oscillatory functions [KOTHAMASU et al. '07; SIVANANDAM et al. '07].

Composition, which combines the fuzzy subsets for each output variable into a single fuzzy subset. This is usually, but not always, done by using the fuzzy "OR" operation.

Eventually, the ***Defuzzification*** process, which is intended to come up with a single crisp output from fuzzy inference system (FIS). It begins in the wake of composition of the fuzzy output set. In this stage, the fuzzy output set is converted to a crisp number by either the Centroid or Maximum method as computed by equations 13 and 14 respectively [SIVANANDAM et al. '07]. *Centroid* method takes the output distribution and finds its center of mass to come up with a crisp number, whereas the Maximum method takes the output distribution and finds its mean of maxima to come up with one crisp number. All these processes are explained in (Figure 4-6).

$$z = \frac{\sum_{j=1}^{q} Z_j u_c(Z_j)}{\sum_{j=1}^{q} u_c(Z_j)} \quad \text{............ (13)}$$

Where z is the center of mass and u_c is the membership in class c at value z_j.

$$z = \sum_{j=1}^{l} \frac{z_j}{l} \quad \text{............ (14)}$$

Where z is the mean of maximum, and z_j is the point at which the membership function is the maximum, and l is the number of times the output distribution reaches the maximum level.

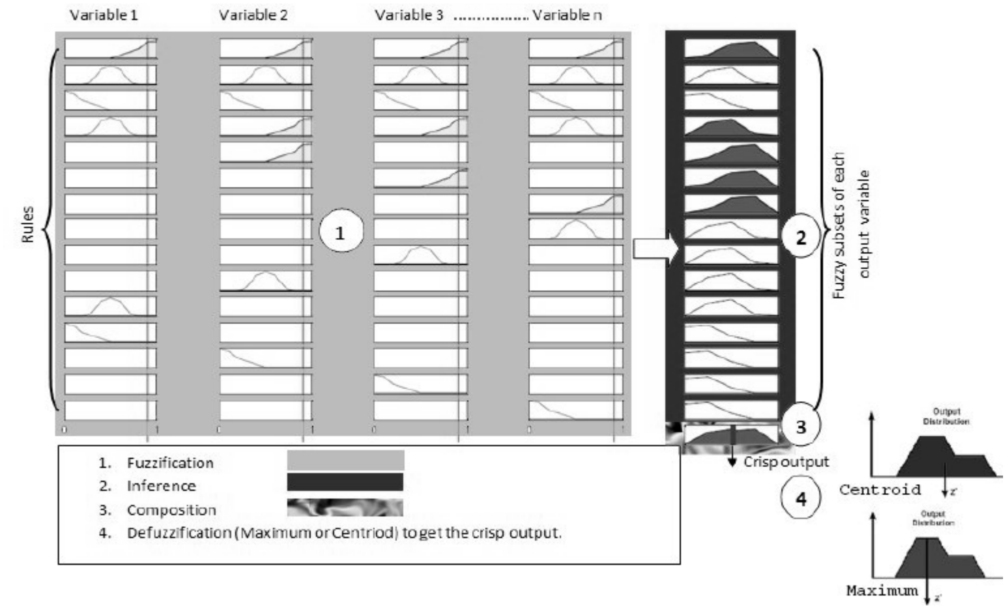


Figure 4-6 Processes of Fuzzy Logic System

4.3 FUZZY LOGIC-BUFFERING MODEL (FLBM)

4.3.1 Conceptual and Modeling Framework

The FLBM is developed using fuzzy logic. This part of the research explains the methodology of FLBM using its different elements. As mentioned above, the main objective of this model is to evaluate schedule buffers size properly to protect the execution of a project against the impact of both uncertainty and imprecision. Most of shortcomings addressed by many researchers as highlighted in the beginning of this chapter are taken into the consideration in building the FLBM. Essentially, there are seven fundamental stages in the construction of FLBM as shown in (Figure 4-7). These steps are:

1. Determining the relevant input and output variables;
2. Defining linguistic values;
3. Constructing membership function;
4. Determining the fuzzy rules:
5. Determining the approximate reasoning;
6. Computing crisp output (defuzzify); and
7. Assessing the model performance.

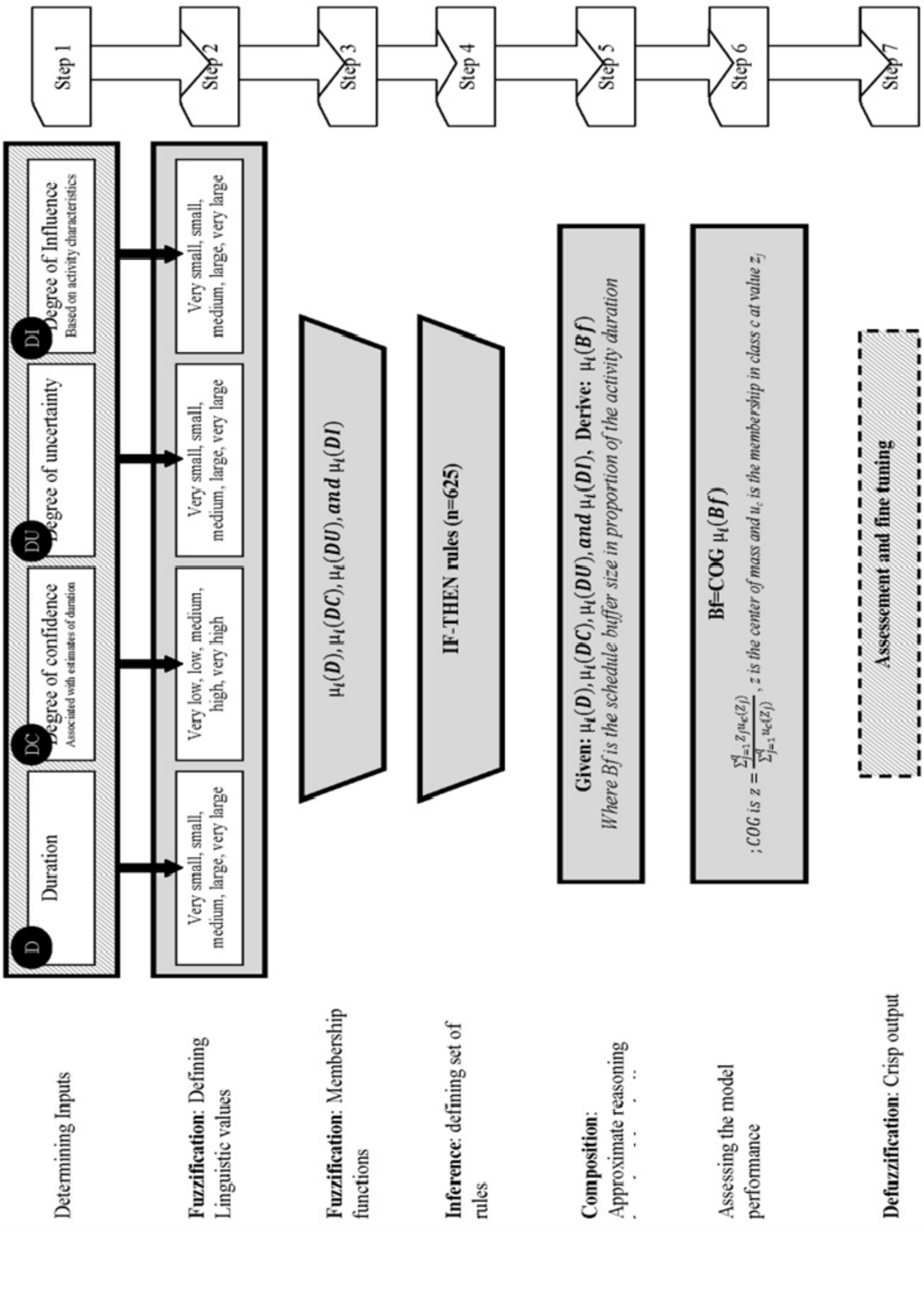


Figure 4-7 Scheme of development of FLBM (adapted from Azadi, et al. 2009, p.196)

4.3.2 Data-Based Model

The data used in developing the FLBM depends on the findings of experts resulting from the literature reviewing related to such topics, and a form of survey. This survey was conducted to find out the real data that may have a positive impact on making this model more trustful. The survey was divided into in-depth interviews and an online questionnaire[3], which has been limited to only academic researchers and companies working in the highway construction sector. Furthermore, it was done through four countries of the Middle East area, yet the vast majority was for Egypt. The announcement was sent to around 187 specialists; 41 responses were received. While 76% of respondents in highway construction companies who responded positively, only a mere 10% of academic researchers responded. The reason they stated was that academicians have no precise answers, *"they think but do not precisely know"*, for questions related to reality. In this survey, we review the influence level degree of uncertainty for project activities. Furthermore, different causes of uncertainties are characterized.

Analysis of both the survey and literature review results [ASSAF et al. '95; AL-MOMANI '00; ODEH et al. '02; RALPH et al. '02; FARAG '05; ASSAF et al. '06; MAJID '06; AHN et al. '07; ABDEL-LATEEF et al. '08; ALSEHAIMI et al. '08] assist in forming the input variables of the model and the rules established to link the inputs and outputs. Namely, the survey was carried out in the forms of questionnaire and interviews. The aim of the questionnaire was only to gather information about the input variables of the model that affect the buffer's sizing. On the other hand, interviews with construction practitioners through open-ended questions were to formulate relationships that linked the input variables to the buffers size. These relationships were to build the fuzzy-rules set of the fuzzy model.

4.3.2. [I] Analyzing questionnaire-based

For the questionnaire-based survey, the data collected was imported into MS Excel for analysis. It is observed that the average size of surveyed projects is about 20

[3] URL: http://www.kwiksurveys.com/online-survey.php?surveyID=HKJJH_ed285d92

million US$. It is further observed that the average experience period for respondents in highway construction sector is around 15 years. That leads the results to provide credible and trusty findings, in spite of the limited sample size. The outcome of the survey, as shown in (Figure 4-8), points at the fact that most of highway projects overrun the due dates by approximately 50%, also the percent plan complete (PPC) could not run over 52.7% of the planned.

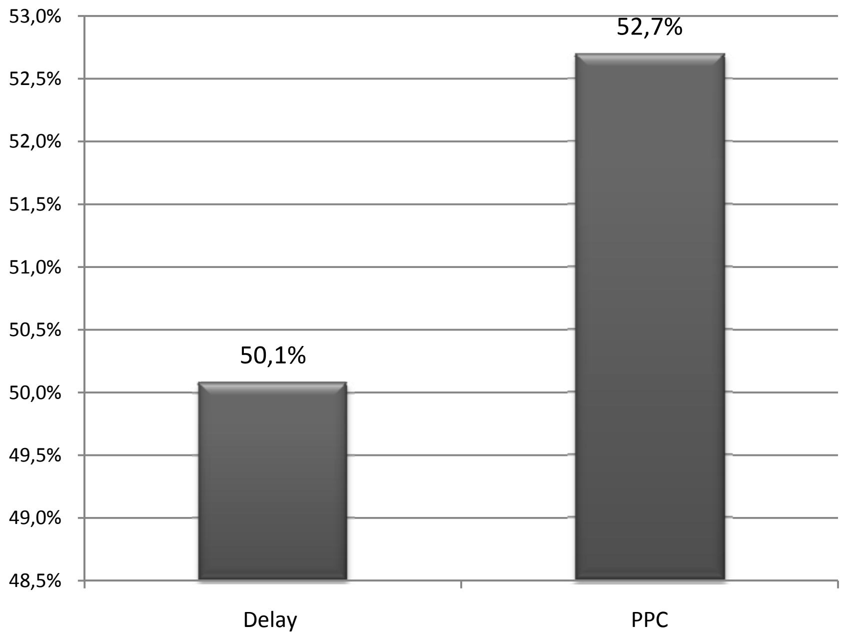


Figure 4-8 Delay and PPC in Highway Projects of Egypt

The statistical analysis based on the degree of the common uncertain factors, which are encountered during the execution of the highway construction, is illustrated in (Figure 4-9).

It is clearly shown in (Figure 4-9) that equipment breakdown, as an uncertain event, has the highest degree of uncertainty. Likewise, a subsequent overrun of the activity duration may be more massive once an activity experiences this uncertain event. On the other hand, buffers that follow activities reeling under the impact of equipment breakdown consequently have a larger size rather than those impacted by another factor. Moreover, another uncertain factor based on the length of a performed sector has the minimum degree of uncertainty, and thus the buffer, which should absorb the impact of such an uncertain factor should be very small. In-between, weather impacts, design errors, late delivery of material, and other uncertain events take place proportionately.

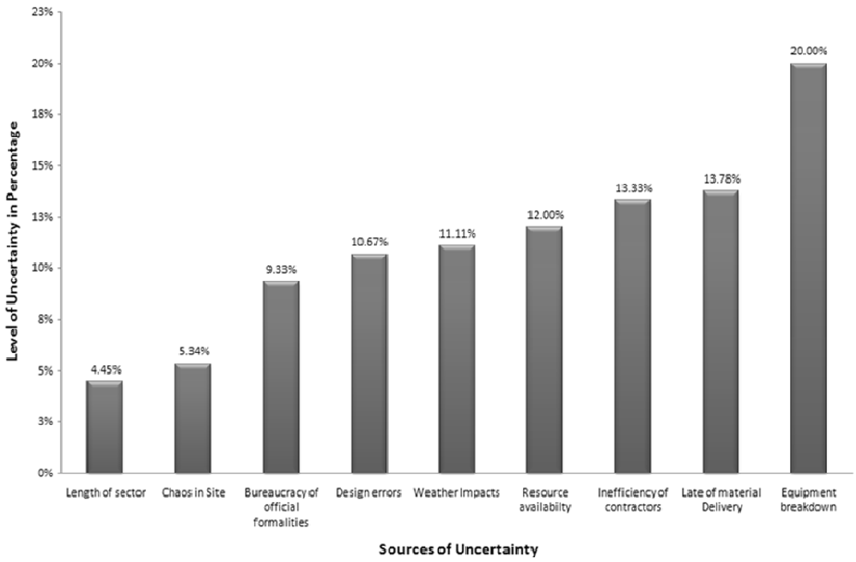


Figure 4-9 Level of Uncertainty Regarding Source Factors Highway Construction of Egypt

In logic, buffer size should be affected by activity characteristics. For instance, suppose that the weather is windy (uncertain event) and earthmoving or paving work are being executed, earthmoving activity may be affected more significantly than surveying works due to the difference of the influence degree for such activities, which results from their different characteristics. Hence, in this situation, the influence degree provides an additional indication for the buffer sizing to the degree of uncertainty.

(Figure 4-10) represents the statistical analysis concerning the influence degree associated with each activity based on its unique characteristics. As represented, earthmoving is the most vulnerable activity influenced by uncertainty, which consequently affects its allotted buffer size. Another example that characteristics of the activity of paving result in lower influence under uncertainty rather both earthmoving and base-works activities.

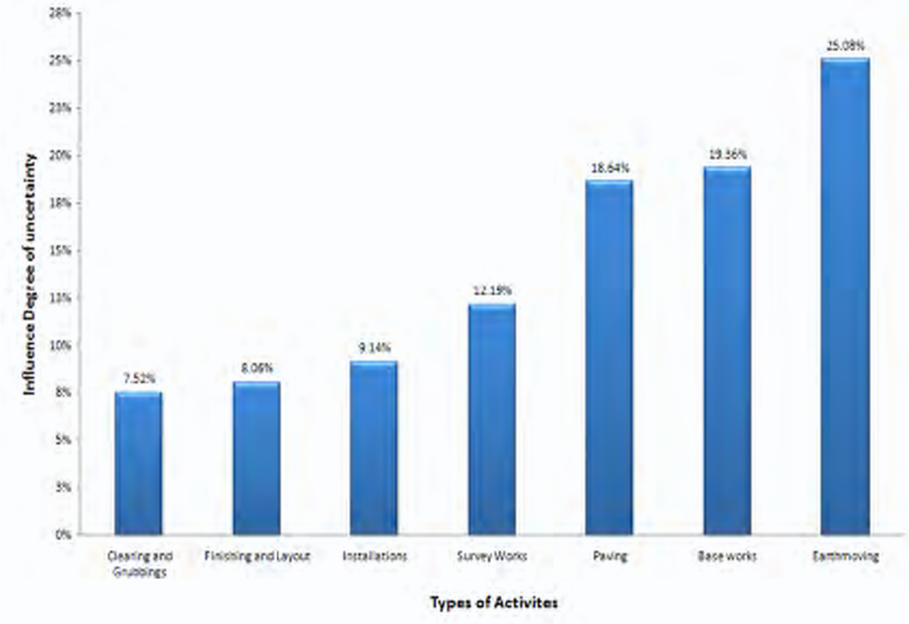


Figure 4-10 Influence Level of Uncertainty on The Highway Construction Activities

4.3.2. [II] Analyzing interviews-based

For the interviews-based survey, the interview was in form of three open-ended questions as listed in (Table 4-1). The first open-ended question was posed to formulate the fuzzy-rules set, yet the second open-ended question was to measure the validity theoretically based on a set of buffer sizes by running conceptual scenarios as shown at the end of this chapter. The last open-ended question was posed to practitioners after explaining the model results by both running a set of scenarios and testing model through a real case study, as discussed later. This open-ended question was included because of our inability to test the integration of LPS® and the model practically over a real case study.

It is important to note that interviews were frequently conducted via the telephone. This was because telephone interviews were easily rescheduled and as such offer more flexibility, and respondents felt less committed. Admittedly, telephone interviews are not always of benefit of qualitative researcher. However, there are some circumstances when telephoning may be very effective in the context of process-based research [EASTERBY-SMITH et al. '08 |p. 144:145].

Table 4-1 The three open-ended questions-based the interview

Questions	At which phase research, was it used?
1. How do you think about the reasonable relationships linking the four-input variables from one side with the buffers size from the other side?	Prior to modeling FLBM.
2. How could you see the credibility of the results with respect to the buffer size through the conceptual scenarios?	After finishing the model
3. What may you except the improvement of the construction process for case-study project if the buffering model would be integrated with LPS® in one system?	After building the integration system and use the model for a real case-study.

The responses have been analyzed for a qualitative data to reach some conclusions. The main steps, that were usually undertaken, are in a sequence summarized as follows:

1. Read through the responses to get a feeling for the data.
2. Create response categories to develop categories for the different themes. For instance, with a question asking for people's feedback on the creditability of FLBM, comments would be probably grouped into categories such as "content", "results", "design", etc.
3. Label each comment with one or several categories. This is what is called "coding", which has been done in an Excel sheet with responses in one column and category (s) in the next column.
4. Identifying the patterns and trends: once the data was studied and categories determined, the next step was to see what categories were related.
5. Writing up the analysis: Once the data has been analyzed and identified, write a summary as a descriptive text incorporating comments directly from the respondents.

4.3.3 Input Variables from a Local View

According to previous analysis of the Egyptian data, the membership functions of the model are generated for the degree of uncertainty and the degree of influence as shown in (Figure 4-11, and Figure 4-12) respectively.

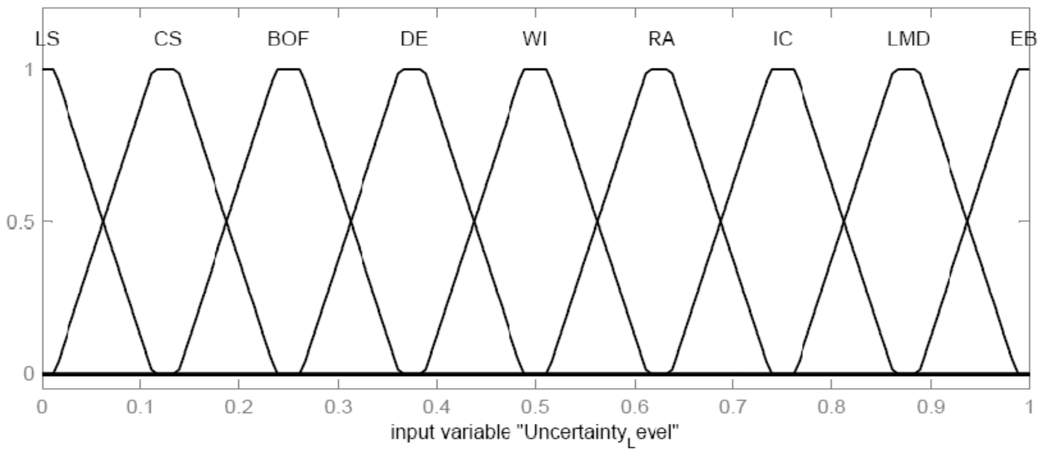


Figure 4-11 Membership Function of Uncertainty Level based on the Egyptian data

Obviously, each uncertain event, as shown in (Figure 4-10), has a different impact level on activity duration. For instance, weather impact, as an uncertain event, has a higher impact level on an activity than the impact of design errors. These values appear as different uncertain events such that each has a unique domain of uncertainty level. Activity undergoes inefficiency of contractor means that duration of this activity might be increased, and consequently, the following buffer time. On the other hand, when the performance of such activity encounters equipment breakdown the activity duration might have the most significant increase because of the significant degree of variability. Values of membership functions, as shown in (Figure 4-11), are expressed in equations (15-23):

Length of Sector (LS)	=	[0|1 0.05|0.8 0.1|0.1 0.15|0]	.... (15)
Chaos in Site (CS)	=	[0.05|0 0.0833|0.1 0.1167|0.8 0.15|1 0.183|0.8 0.2167|0.1 0.25|0]	.... (16)
Bureaucracy of Official Formalities (BOF)	=	[0.15|0 0.183|0.1 0.2167|0.8 0.25|1 0.283|0.8 0.3167|0.1 0.35|0]	.... (17)
Design Errors (DE)	=	[0.25|0 0.283|0.1 0.3167|0.8 0.35|1 0.383|0.8 0.4167|0.1 0.45|0]	.... (18)
Weather Impact (WI)	=	[0.35|0 0.383|0.1 0.4167|0.8 0.45|1 0.483|0.8 0.5167|0.1 0.55|0]	.... (19)
Resource availability (RA)	=	[0.45|0 0.4917|0.1 0.53|0.8 0.575|1 0.6167|0.8 0.6583|0.1 0.7|0]	.... (20)
Inefficiency of Contractor (IC)	=	[0.575|0 0.6167|0.1 0.6583|0.8 0.7|1 0.7417|0.8 0.783|0.1 0.825|0]	.... (21)
Late of Material Delivery (LMD)	=	[0.7|0 0.7417|0.1 0.783|0.8 0.825|1 0.867|0.8 0.9083|0.1 0.95|0]	.... (22)
Equipment Breakdown (EB)	=	[0.825|0 0.883|0.1 0.9417|0.8 1|1]	.... (23)

Direction of Increase

For the other input of the degree of influence, it is commonly known that the influence degree of an activity at the same uncertain condition varies from one activity type to another. In Goldratt's suggestions, all types of activities have one-half duration as the safety time regardless of their uncertainty level and unique characteristics. Obviously, as far as low degree of uncertainty for activities is concerned, the safety time of one-half duration is too much and to some high uncertainty activities the one-half duration safety may be just not enough. For example, the earthmoving activity should have a higher safety time than the installation works, even at the same factor and the same uncertainty level. In this input variable, the influence degree of the impact of uncertainty is expressed either mathematically or graphically as well as both uncertainty level and activity duration variables as depicted in (Figure 4-12), and expressed in equations (24-30):.

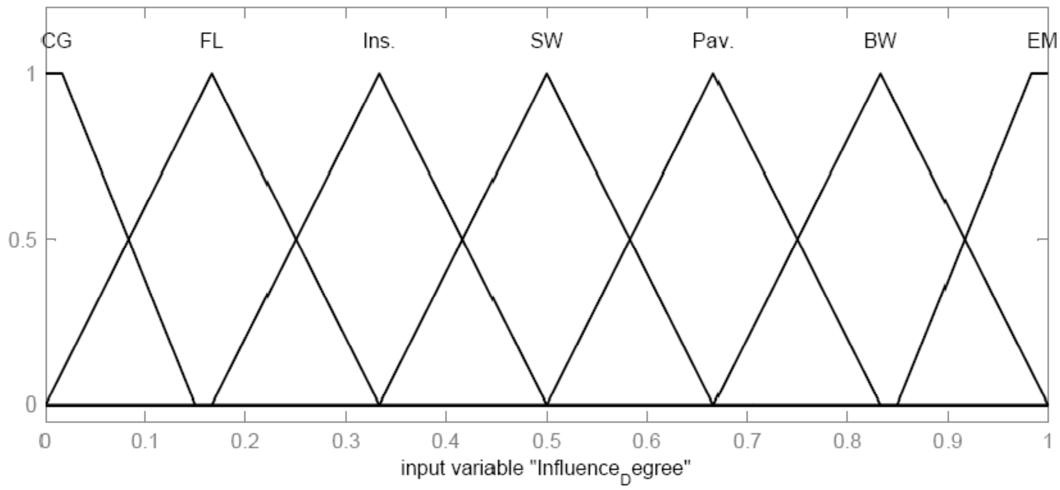


Figure 4-12 Membership Function of the Influence degree based on the Egyptian data

Clearing and Grubbing **(CG)**	=	[0|1 0.05|0.8 0.1|0.1 0.15|1]	.... (24)
Finishing and Layout **(FL)**	=	[0|0 0.055|0.1 0.11|0.8 0.166|1 0.22|0.8 0.278|0.1 0.33|0]	.... (25)
Installations works **(Ins.)**	=	[0.167|0 0.23|0.1 0.278|0.8 0.33|1 0.389|0.8 0.45|0.1 0.5|0]	.... (26)
Survey Works **(SW)**	=	[0.33|0 0.388|0.1 0.44|0.8 0.5|1 0.55|0.8 0.611|0.1 0.66|0]	.... (27)
Paving **(Pav.)**	=	[0.5|0 0.55|0.1 0.61|0.8 0.66|1 0.7222|0.8 0.78|0.1 0.83|0]	.... (28)
Base Works **(BW)**	=	[0.67|0 0.72|0.1 0.78|0.8 0.834|1 0.89|0.8 0.945|0.1 1|0]	.... (29)
Earthmoving **(EM)**	=	[0.85|0 0.9|0.1 0.95|0.8 1|1]	.... (30)

4.3.3. [I] Towards Globalization of FLBM

As previously presented, in both data analysis and subsequent membership functions, the model may be only valid for usability in the Middle East region, particularly in Egypt. Therefore, in order to globalize the model to be internationally applicable, we should go towards the generalization of membership functions to be not specific for certain areas. For instance, rainfall as a weather impact factor has a higher degree of uncertainty for some countries such as Germany, yet it has a lower degree of uncertainty for other countries, which lie in dry climate regions. Although rules used in the model were also collected from the survey conducted to the Middle East, they are valid for all countries because of their logical interpretation.

The selection of the shape of the membership functions as well as the specific associated hedges was based on recommendation of both previous related literature and experts. In addition, the overlapping for the linguistic variables was chosen at the completeness of 0.5 ($\varepsilon = 0.5$), as referred in (Figure 4-13). At this level of the overlapping, a certain robustness may be given to the fuzzy controller. Moreover, at the completeness $\varepsilon = 0.5$, for every value of the input there is always a dominant rule with a membership grade for that input exceeds than or equals to 0.5. Explicitly, when completeness decreases there are more regions in the universe of discourse characterized by a low maximal truth degree of the rules they activate, thus creating the risk of an inefficient control. On the other side, when completeness increases, there are zones characterized by some useless, if not harmful, redundancy [BOUCHON-MEUNIER et al. '07].

From this viewpoint, the author formulates the entire elements of the fuzzy-logic buffering model in general form of membership functions, rules, and criteria. This formulation leads the model to be internationally applicable. In the wake of development of FLBM, it will be run through conceptual scenarios to be theoretically validated. In the further step, it will be applied to a real case study in Egypt in order to be validated from the practical side.

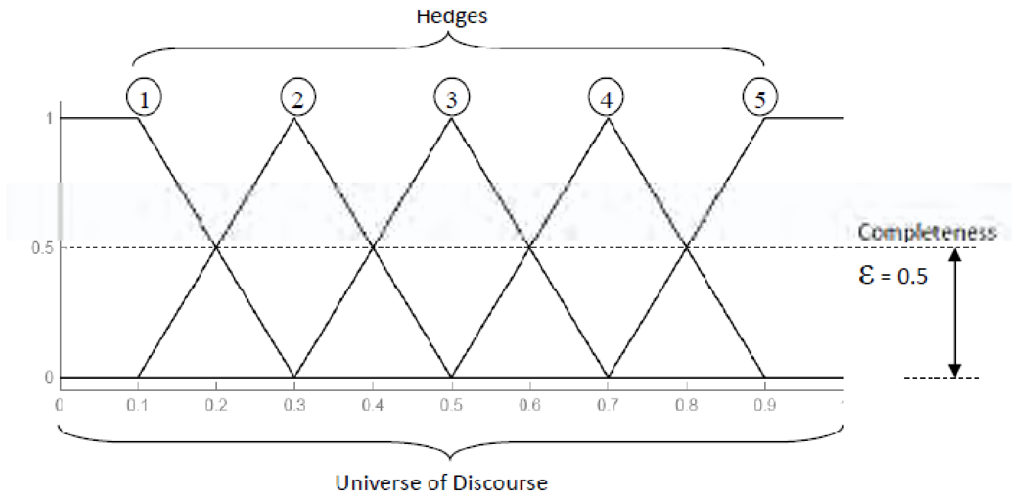


Figure 4-13 Typical membership function for input variables and the degree of overlapping

4.3.4 FLBM Criteria

The main criteria that control the FLBM are as follows:

- Input variables are independently defined.
- Input / Output variables are linguistically expressed in the shape of membership functions.
- The characteristics of input membership functions as well as the rules lean on the results of the conducted survey.
- Triangles and trapezoid membership function types are used in FLBM, which is based upon the literature review.
- Modeling process is simulated in MATLAB program.
- Fuzzy inference system (FIS) is based on Mamdani's method.
- Moreover, "*OR*" operator is used in the composition process to get the maximum value, whereas "*AND*" is used in the combination with the fuzzified inputs according to rules to establish a rule strength.
- *Centroid* technique is employed to come up with crisp output number.

4.3.5 Input/ Output Variables as General

This model is based on a set of inputs to enable buffer sizing to be more realistic and reliable. There are four input variables: the duration of activity, the degree of confidence, uncertainty level, and the degree of influence.

Evidently, considering the activity duration alone is not the most crucial element in buffer sizing. Activity duration may play an intrinsic role in sizing buffer properly when the degree of confidence associated with the duration is considered simultaneously. Some of the activities have duration either quite less or much more than the actual duration. The degree of confidence assists in amending this feeble estimate of duration. (Figure 4-14) illustrates an example of a couple of activities A and B has a precedence relation of FS.

The initial planning estimates the total duration of both activities is 9 weeks, which neglects the impact of variability. As shown, the duration of activity A has been estimated as two weeks, which is much more less than the acceptable duration of such activity from the experts' standpoint that believes it should be performed in 4 weeks. In contrast, the duration of activity B has been estimated as 7 weeks, which is much greater than reasonable duration as 3.5 weeks.

From a traditional view, enabling this plan to be capable of absorbing the impact of variability, a buffer should be allocated for each activity size approximately one half of the activity duration regardless of the length of duration of this activity, the degree of confidence, and whether the activity is influenced significantly by this variability or not. Therefore, the schedule based on traditional buffer (Bf) assessment may extend to 12 weeks. However, Activity A ends at 4 weeks, and then, Activity B ends at 10.5 weeks. This emphasizes that if we do not consider the confidence degree related to estimating the activity duration that may lead to unnecessary time and cost.

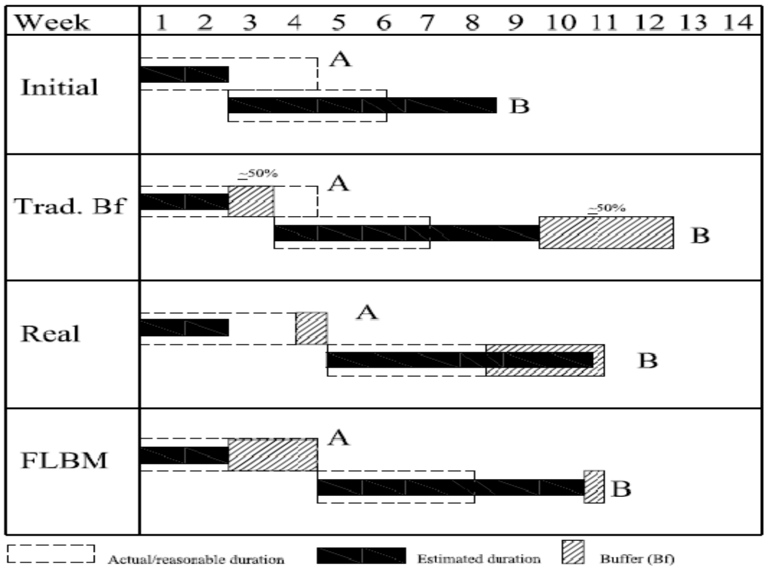


Figure 4-14 Effect of Activity Duration and Its Degree of Confidence

Owing to the fact that activity duration and degree of confidence are essential elements in FLBM, the Bf size becomes much more realistic. For instance, activity A has less duration than reasonable, which means that the degree of confidence for this estimate is very low. Hence, more Bf size should be considered to compensate for the shortage of duration. Conversely, Bf size should be considered as short as possible for activity B of the very low confidence degree to control any unnecessary extent in the duration. Through the following lines, the membership functions will be represented graphically and mathematically for each input variable of FLBM.

Prior to go in depth on the membership functions and the mathematical expression with respect to the four input variables as well as the output variable, it should be considered that the duration is one of the most important inputs to the model. The value added to the model outcomes by considering the duration is resulted from providing estimates to the experts and the experts then response to its judgment. Therefore, the focus on the duration, as one input to the model, is because of its importance at the level of production. That because, at the level of production, the cost is already known, whereas the duration is not. In addition, the degree of confidence of activity duration may judge the estimates of the duration through the execution process according to any emerged variations. The independency, as a logic of Fuzzy system, is the relation between the duration and the confidence degree.

Namely, the model can be worked out without the duration size, yet that will lead to inefficiency to the model outcomes.

4.3.5. [I] Activity Duration

As shown in (Figure 4-15), Activity duration is described into five linguistic subsets; very short (*VS*), short (*S*), medium (*M*), long (*L*), and very long (*VL*) duration. The mathematical expression is elaborated in the following equations (31 to 35):

VS= [0|1, 0.1|1, 0.2|0.5, 0.3|0] .... (31)

S= [0.1|0 0.2|0.5 0.3|1 0.4|0.5 0.5|0] .... (32)

M= [0.3|0 0.4|0.5 0.5|1 0.6|0.5 0.7|0] .... (33)

L= [0.5|0 0.6|0.5 0.7|1 0.8|0.5 0.9|0] .... (34)

VL= [0.7|0 0.8|0.5 0.9|1 1|1] .... (35)

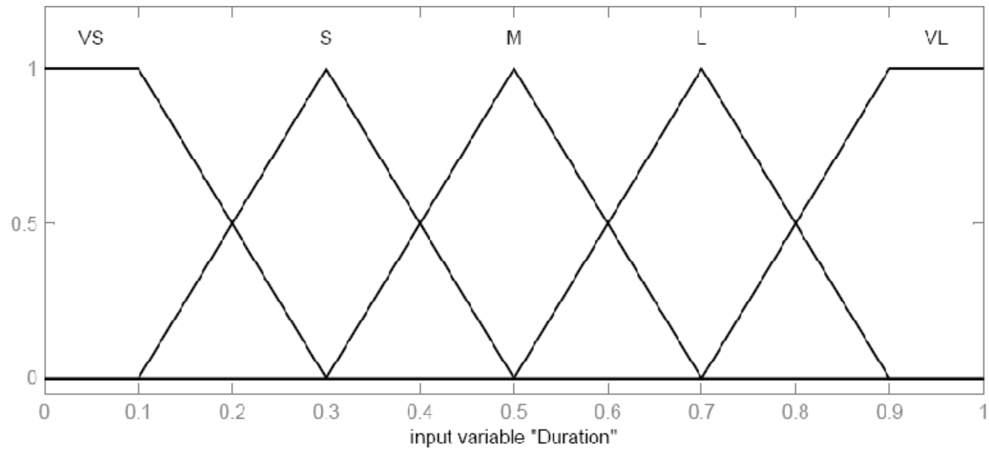


Figure 4-15 Membership Function of Activity Duration

4.3.5. [II] Degree of confidence

The term of degree of confidence indicates the deviation degree of the planned durations from what should have been estimated. For example, an activity has a planned duration of three weeks, whereas the experts advocate that the estimated duration is not reliable because it should have approximately been a couple of weeks. Hence, the ratio of the deviated estimates (one week) to the normal activity duration equals 33%, which indicates a low degree of confidence. Thus greater degree of confidence, the smaller deviation, and vice versa. Universe of discourse (UD) of this variable starts from very high degree of confidence (zero deviation), and ends with very low degree of confidence (100% deviation).

Membership function of the input variable of degree of confidence is linguistically described using the triangle. As shown in (Figure 4-16), it has five linguistic values such as very low (*VL*), Low (*L*), medium (*M*), High (*H*), Very High (*VH*). They are defined mathematically in the following equations (36 to 40):

VH= [0|1, 0.1|1, 0.2|0.5, 0.3|0] .... (36)

H= [0.1|0 0.2|0.5 0.3|1 0.4|0.5 0.5|0] .... (37)

M= [0.3|0 0.4|0.5 0.5|1 0.6|0.5 0.7|0] .... (38)

L= [0.5|0 0.6|0.5 0.7|1 0.8|0.5 0.9|0] .... (39)

VL= [0.7|0 0.8|0.5 0.9|1 1|1] .... (40)

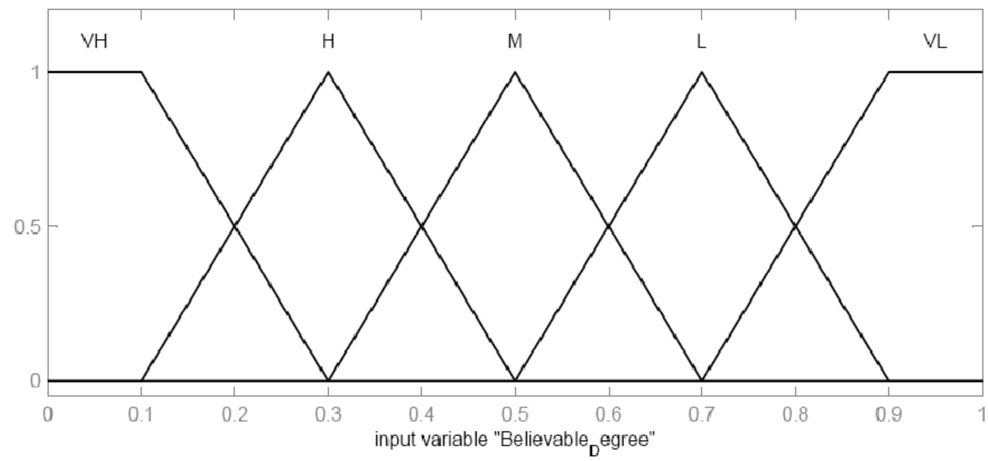


Figure 4-16 Membership Function of The Degree of Confidence of The Activity Duration Estimates

4.3.5. [III] Uncertainty Level

Explicitly, every uncertain event has a different impact level on the activity duration. In highway construction environment, weather impact, as an uncertain event, has a higher impact level on an activity, than the impact of design errors. Hence, membership function of this input variable has many underlying values of uncertainty levels. The membership function considered in activity duration is shown in (Figure 4-17). The membership function of this input variable is similar linguistically described using the triangle. It has five linguistic values of Very Low (*VL*), Low (*L*), Medium (*M*), High (*H*), Very High (*VH*). It has the same mathematical expression as shown in equations (36 to 40).

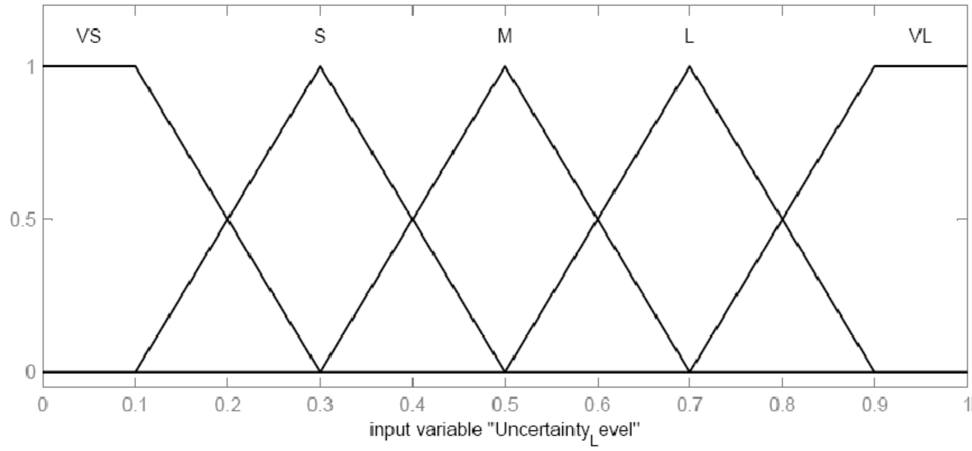


Figure 4-17 Membership Function of Uncertainty Level

4.3.5. [IV] Degree of Influence

Similar to what was mentioned about the degree of influence variable in (section 4.3.3), (Figure 4-18) expresses its general form of the membership function. Moreover, the linguistic expressions for the membership function are similar to both uncertainty level and activity duration. Further, it has the same mathematical expression as shown in equations (36 to 40).

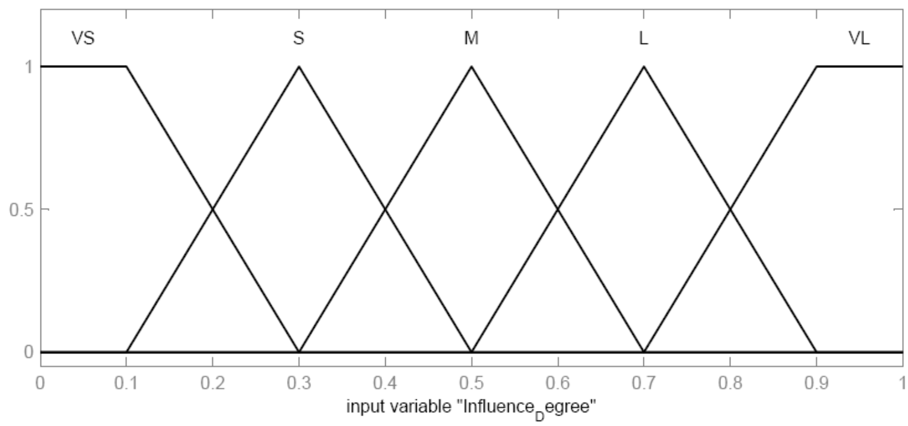


Figure 4-18 Membership Function of Influence Degree

4.3.5. [V] Buffer Time

Buffer time is the output variable in FLBM, which is expressed by membership function as shown in (Figure 4-19). This membership function shows that the buffers time of a project equals neither one-half, as suggested by Goldratt, nor any certain proportion of the project duration. The size of buffers varies from one project to the other as well as from one activity to another different activity. Sizing of buffers is expressed through five subsets of buffer sizes. Namely, it may be of very short, short, medium, large and very large size. Equations (25-29) describe the subsets of buffers time's membership functions.

VS= [0|1 9.375|0.5 18.75|0] .... (41)

S= [0|0 18.75|1 37.5|0] .... (42)

M= [18.75|0 37.5|1 56.25|0] .... (43)

L= [37.5|0 56.25|1 75|0] .... (44)

VL= [56.25|0 75|1] .... (45)

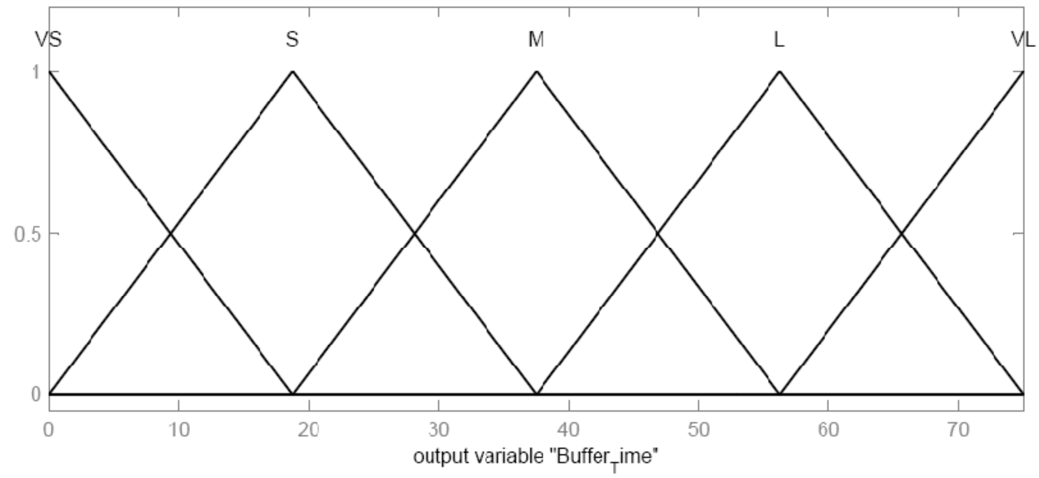


Figure 4-19 Membership Function of The Output Variable of The Buffer Time

4.3.6 FLBM Rules

As stated above, rules are developed in order to describe the interrelationship between probability of input variables and their consequent impact on the buffer size. These rules are representations of expert knowledge and are often expressed using syntax forms. A set of fuzzy rules, consisting of 625 rules for FLBM, were identified by interviewing experts in the highway construction sector (Appendix A). A sample of the rules created for the fuzzy-logic-buffering model (FLBM) is represented in

(Figure 4-20). To know what these rules mean, the highlighted rule is taken as an example. In this example, the interrelationship which the output is based on is that, ***IF*** *duration* is very small (VS) ***AND*** the *degree of confidence* related to its estimation is very low (VL) ***AND*** *uncertainty level* has a medium effect (M) ***AND*** the activity has very high *influence degree* (VH) ***THEN*** the consequent buffer size should be very large.

As commonly known, rule execution weights provide the model designer with a way of a concentrating force in the rule set. In most of the fuzzy models you can weigh the importance of rules by supplying a weight multiplier. By default, rules have weight of [1.0]; this indicates that the truth inherent in these rules is multiplied by [1.0], and as a result, the force of those rules is not reduced. However, consider the instance when a rule has a weight of [0.8], then the truth value of that rule is multiplied by [0.8], which, in effect, reduces its force by 20%.

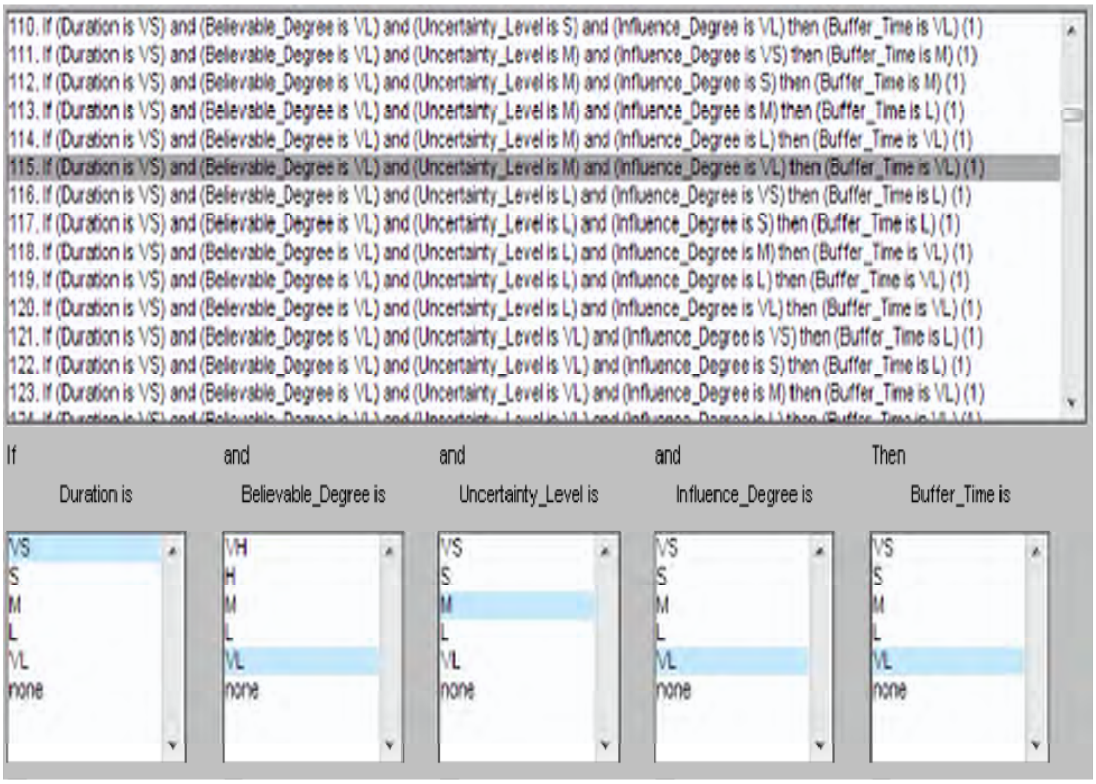


Figure 4-20 Fuzzy Rules For FLBM

4.3.7 Scenarios

Having available a large set of input–output data, the performance of the system can be evaluated and parameters of the system can be fine-tuned in order to achieve a low generalization error. In such a data-rich situation, a training set is used to fit the models, a validation set is used to estimate the prediction error for model selection and a test set is used for assessing the generalization error of the final model chosen. If, like in our case, no large data sets are available, the best way to assess model performance and fine-tune the system is based on experts' judgments. By using different real inputs and observing crisp outputs, judgment is possible by experts. They can assess several scenarios and conclude whether the performance of the model is (not) reasonable [AZADI et al. '09].

Table 4-2 Scenarios

Scenario	Duration		Degree of Confidence		Uncertainty level		Influence Degree		Buffer
	Major	Minor	Major	Minor	Major	Minor	Major	Minor	(%)
1.	Very small	Less	Very High	Less	Very small	Less	Very small	Less	**6.0 %**
2.	Small	Slightly Less	Medium	Slightly Less	Very large	Normal	Small	Slightly Less	**28.0 %**
3.	Medium	Less	High	More	Small	Less	Very small	Normal	**6.4 %**
4.	Very large	Less	Low	More	Large	Less	Large	Normal	**37.5 %**
5.	Small	Less	Medium	Less	Very large	More	Very large	More	**69.0 %**
6.	Small	Less	Medium	Less	Very small	More	Very large	More	**69.0 %**
7.	Very small	Less	Very Low	Less	Medium	More	Very small	More	**56.3 %**
8.	Very small	More	Very Low	More	Very small	Less	Very small	Slightly more	**28.1 %**
9.	Medium	Slightly more	High	Slightly more	Small	Normal	Very large	Normal	**46.9 %**
10.	Medium	Slightly more	High	Slightly more	Small	Less	Very large	Normal	**31.1 %**
11.	Larg	Less	Low	More	Large	Normal	Very small	Slightly Less	**18.8 %**
12.	Large	Normal	Very High	Normal	Medium	Slightly Less	Very large	Normal	**49.8 %**
13.	Large	Normal	Very High	Normal	Small	Slightly Less	Very small	Normal	**16.3 %**
14.	Large	More	Very High	Slightly Less	Medium	Slightly Less	Very small	Normal	**25.2 %**
15.	Small	Less	High	Less	Very small	More	Very small	More	**18.8 %**
16.	Small	Less	Low	Slightly Less	Medium	More	Very small	More	**46.9 %**
17.	Very small	Less	Very Low	Less	Very small	Normal	Small	More	**37.5 %**
18.	Very small	Less	Very Low	Less	Very small	More	Small	More	**56.3 %**
19.	Very small	More	Very Low	More	Very small	Less	Very small	Slightly more	**28.1 %**
20.	Medium	Normal	Medium	Less	Very small	Normal	Very large	Less	**42.9 %**
21.	Small	Less	Low	Slightly Less	Medium	Normal	Very large	More	**67.9 %**
22.	Small	Less	Low	Slightly Less	Medium	Slightly more	Very large	Slightly Less	**46.9 %**
23.	Small	More	Low	Slightly Less	Medium	Slightly more	Very large	Slightly Less	**37.5 %**
24.	Medium	More	Medium	Less	Very small	Slightly more	Very small	Slightly Less	**7.1 %**
25.	Medium	More	Medium	Less	Very small	Slightly more	Small	Slightly Less	**16.3 %**
26.	Medium	More	High	Slightly Less	Small	Slightly more	Small	Slightly Less	**18.8 %**

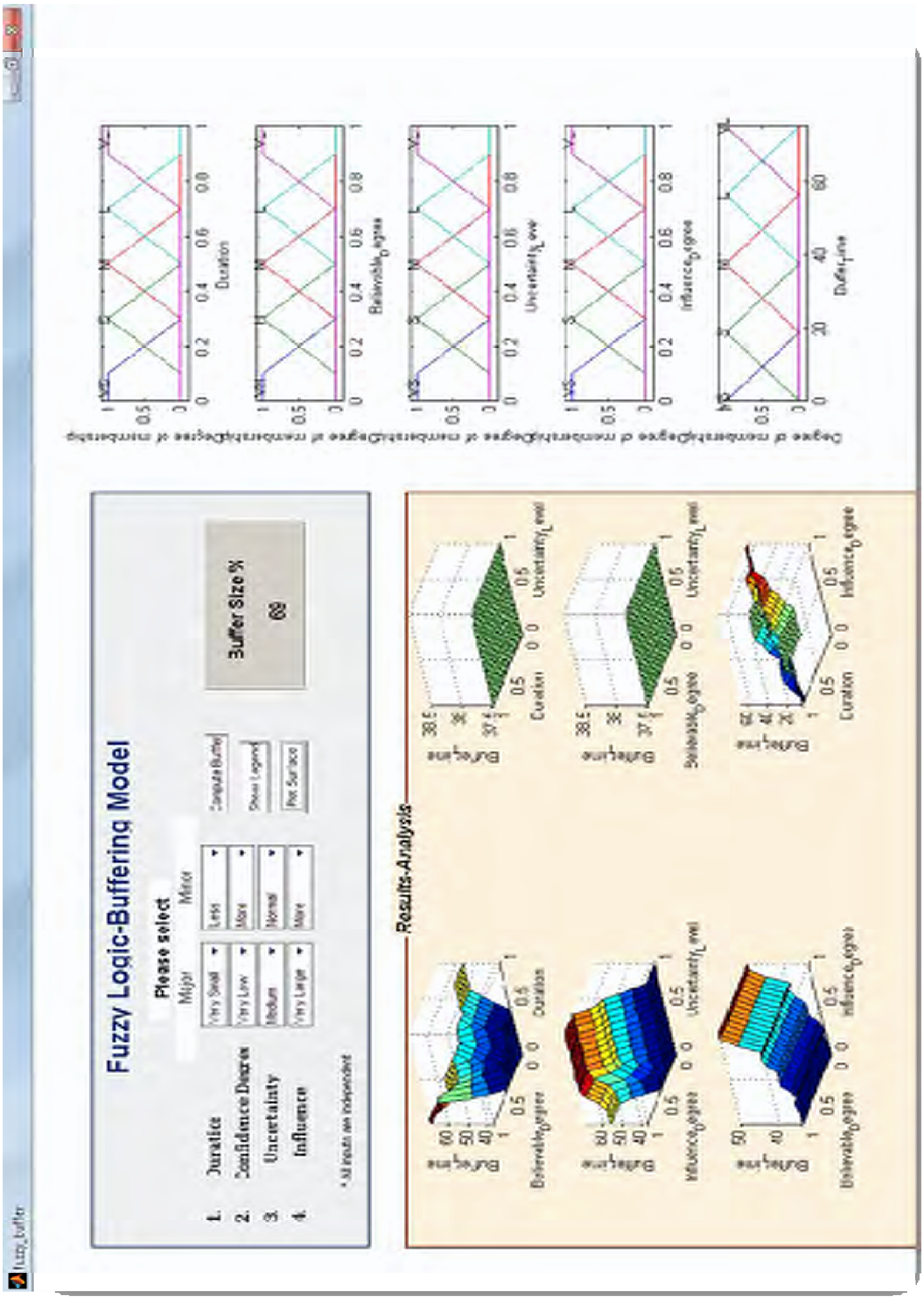


Figure 4-21 Flbm's User Interface

On the basis of the above-developed model for calculating the buffer size some simulations were run for calculating the subsequent buffer size (Table 4-2). For instance, as depicted in (Figure 4-21), a user enters all four input variables independently. Each input is categorized into major and minor intervals to be more accurate. The major intervals for each input are the subsets of each membership function, while the minor describes closely the effect of each input.

For instance, when the input activity was estimated to be of very small duration, of very low degree of confidence, and has very high effect on both uncertainty level and the influence degree, the buffer time calculated was 69% of the activity time. Taking another scenario based on both major and minor choices, even though both scenarios 9 and 10 have the same major inputs, the buffers time is different because of considering the effect of the minor inputs.

4.3.7. [I] Results Analysis

A vital observation from the model developed comes by comparing the scenarios no. 1 and 18. Even though both have the same uncertainty level and the influence degrees, the degree of confidence in the estimate of duration is more in scenario no.1. The buffer times computed by the model show a resounding difference (6 % in scenario 1 and 56.3 % in scenario 18). This clearly shows the fact that the degree of confidence plays a vital role in the estimation of the buffer times. Another significant observation comes by comparing scenarios no. 12 and 13. Both have similar durations and a degree of confidence, the difference arises in the uncertainty level and the influence degree.

In scenario 12 the uncertainty level is medium with a very large influence degree, whereas in scenario 13 the uncertainty level is small with a very small influence degree. This difference in the uncertainty level results in a considerable difference in the computed buffer times (50 % in scenario 11 to 16 % in scenario 12). This goes to show that the uncertainty level and the influence degree of the activity also play a crucial part in the determination of buffer times.

As explained above and also illustrated in both (Figure 4-21 and Table 4-2), buffer sizes are essentially influenced by the characteristics of each activity, and its influence degree under variability. Furthermore, the duration alone does not affect the size of buffers; the degree of confidence also has to be considered while estimating the size. Likewise, uncertainty in general has no effect without the vulnerability of activities to its impact. For example, the late delivery of a certain material may be a certain source of variability, but it should not be considered in an activity, if that activity is not influenced by such uncertainty, and consequently, the buffer should not be provided. (Figure 4-22) emphasized the needs of buffers for the input variables collectively to be more realistic. As shown in the second and fourth surf views, duration alone as well as the degree of uncertainty has no meaning in sizing buffers without the relation to other inputs. The degree of uncertainty should be measured by a certain degree of influence to get a suitable buffer.

The sixth view of (Figure 4-22) could touch the effect of both degree of uncertainty and the influence on the buffer size. Namely, the degree of influence plays more important role in sizing buffers rather than the degree of uncertainty. For instance, we have two examples of activities, first is earthwork and the second is installations work. At a certain degree of uncertainty, i.e. rainy weather, the influence degree of the first activity is rather significant than the second one. Therefore, buffer allotted to the first activity should be quite larger than second.

Similarly, it is not logic to size buffers only by the consideration of the duration of an activity. The degree of confidence is more important to realize the buffers size based on the duration as interpreted previously in (Figure 4-14). The first view of (Figure 4-22) interpreted the larger surface level of buffers at the larger influence to uncertainty and lower degree of confidence. We found that the surface level moved down in the direction of the increase of confidence, and vice versa.

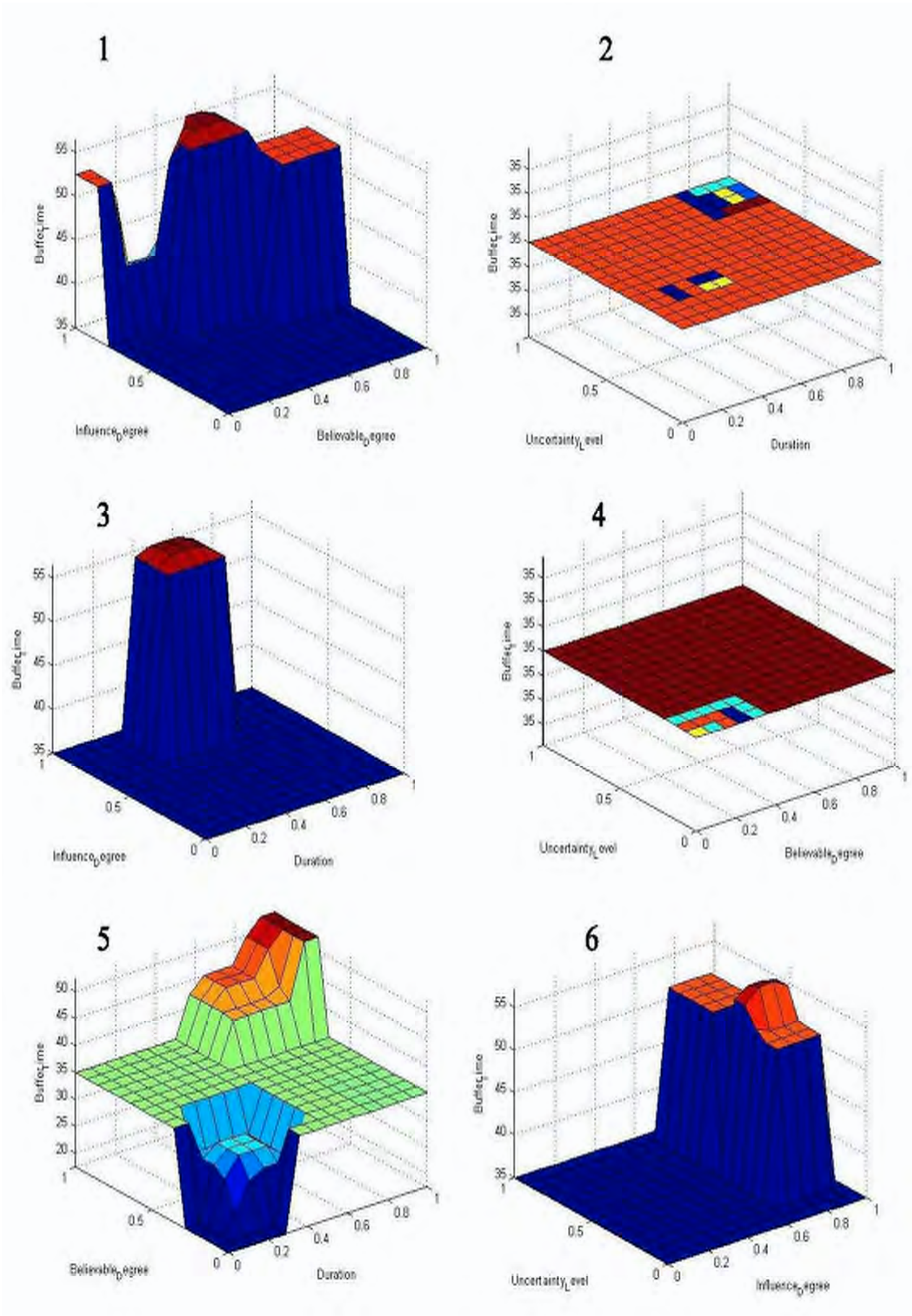


Figure 4-22 Flbm's Surfviews of Whole Relationships Between The Input Variables and The Output Buffer

4.4 BEYOND THE STATISTICS

With statistics and the results analysis of FLBM, the research contributes to setting up the needs of well-dimensioned buffers to increase the reliability of scheduling. Considering the degree of uncertainty, activity characteristics, activity duration, and its associated degree of confidence into sizing buffers improves the desired reliability, realize a well distribution of buffers, and eliminate the waste of either over or under estimates for buffers as well.

Analysis of the outcomes with respect to FLBM, as a proper method to assess buffers, provided a clear understanding for the mechanism that should have been beyond the buffers design process. The process mechanism is not an empirical calculations, but it should be demonstrated through a systematic approach, which its credibility increases when elements using in the calculation process are also increased. In addition, the epistemology associating FLBM was to adapt the most suitable system (Fuzzy Logic) to the imprecise nature that represents the construction process.

4.5 GUIDELINES FOR FLBM

In order to get the maximum benefits from FLBM and optimize its usability as well, a set of guidelines, related to both users and data, is recommended by authors as depicted in (Figure 4-23)

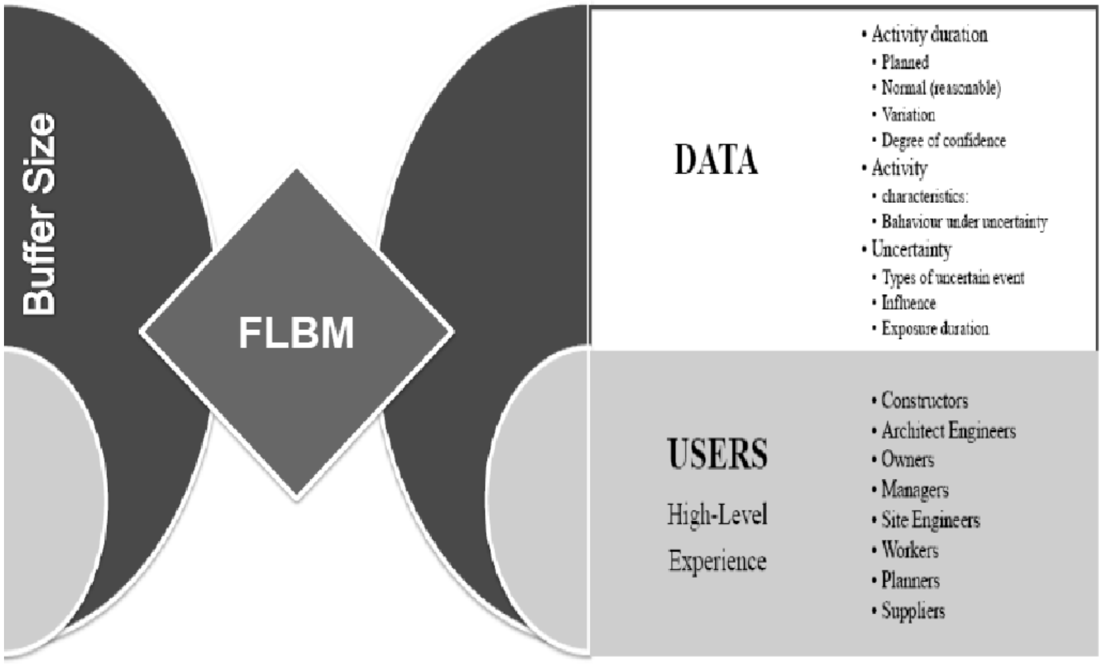


Figure 4-23 Data and users- based guidelines framework for FLBM

4.5.1 Data-related

Data used in the model should be collected through the actual circumstances regarding the activities of a construction process. Users should gather information about uncertain events experiencing the entire process and particularly the studied activity. This information is about the degree of influence of such event on the activity. In addition, users should know the characteristics of this activity to recognize the actual impact level of such uncertainty. Users should further have a high-level expertise in judging the variation between the acceptable duration of an activity and the planned in order to assess the degree of confidence with respect to such estimates. The master planned durations of activities should be available prior to use the model.

4.5.2 Users-related

Users involving FLBM should be with a high level of experience to accommodate realism to the results, and consequently scheduling. Furthermore, to get a significant expertise for the model, it is recommended to exchange different types of experiences. i.e, construction, planning, architect design, worker, supply ……etc.

Obviously, all of those types of experiences are difficult to meet together or work in one system at the first stage of planning. Whereas, most of such different experts may be cooperate together in a system of Last Planner. So, involving Last Planner in FLBM can optimize the high-level experts-based recommendations. With respect to that, the next chapter will move towards integrating the use of FLBM with LPS®.

4.6 SUMMARY

In order to achieve the matching buffers to the actual variability, this chapter developed a fuzzy-based model to predict the appropriate buffer times according to the actual circumstances sharing the execution process. In the traditional approaches, buffer times have often been incorrectly dimensioned leading to a massive loss of money and time. According to a questionnaire-based survey and interviews with construction professionals a model is established to obtain buffer size as a percentage of the activity times. Simulation of the model is conducted in MATLAB using sample data to verify the model. The results of the simulation give positive feedback reflecting the actual conditions. The buffer times are a function of the activity duration and the confidence degree in its estimation as well as the uncertainty degree and the influence degree.

This model can serve as an efficient tool for the planning engineers and the project managers to improve reliability in the planning and avoid the time and cost overruns which have been occurring as a result of improper planning. In addition, FLBM was developed to be internationally applicable in order to move from conventional buffers sizing process to the fuzzy-based approach.

3D-Management System

- **System framework**
- **Understanding of 3D-Management system**

Now join your hands, and with your hands your hearts. *"William Shakespeare"*

CHAPTER 5. 3D-MANAGEMENT SYSTEM: AN INTEGRATION OF LPS® AND FLBM

5.1 PREFACE

Variability in production is one of the largest factors that negatively influence the construction project performance. It can induce dynamic and unexpected conditions, unsteadying project objectives and obscuring the means to achieve them. Many attempts have shown that variability is a well-known problem in construction projects, which leads to a general deterioration of project performance on dimensions of project cost and planning efficiency. A way to deal with variability impacts in production systems is using buffers (Bf), as described in depth in the previous chapters. By using Bf, a production process can be isolated from the environment as well as the processes depending on it.

As mentioned above, one of the effective control tools aims at eliminating the impact of variability in the construction project is the Last Planner System® (see Chapter 2). Last Planner has been in development since 1992 [BALLARD '00] and is associated to the TFV-theory [KOSKELA '00], which Ballard (2000) regard to be synonymies to Lean Construction. The efficiency of LPS® comes from the transparency, and the cooperation associated with its implementation.

At the year of 2009, the Last Planner System® of production control is in wide use throughout the world. Albeit successful applications in both planning and controlling construction phases of projects, there is a lingering question: Do we need something that is somehow different to achieve optimal resistance to variability impacts?

We start from Last Planner because it is currently the production control system in widest use in the construction project management, relying on earlier arguments to the effect that traditional project controls are not production control systems at all.

5.2 3D-MANAGEMENT SYSTEM: Integration/Complementary Action

In order to accommodate the change in management methodology and significantly optimize the control of the construction process, the buffer management approach had to be reconfigured. The Last Planner principles, functions, and methods presented previously in this research appear to apply to the work of designing.

Even though industries have commonly used buffering strategies in their production systems, the way in which they have been applied is clearly different. In manufacturing, buffering strategies have rationally and systematically used methods varying from the application of the Inventory Theory to modern manufacturing techniques such as Material Requirement Planning (MRP), Just-In-Time (JIT), and Constant Work-In-Process (CONWIP). In construction, however, traditional buffering practices have mainly been based on intuition and experience, in a production environment where constructors have no history of accepting and successfully applying analytical tools in decision-making. Therefore, sounder frameworks to deal with buffers are neglected, leading to the use of poor mechanisms to protect construction processes from negative impacts of variability [GONZÁLEZ et al. '09a].

In order to overcome the prior limitations, an integration of buffers design and management methodology, called "*3D-Management System*", is proposed. This methodology provides a sounder and more rational framework based on the FLBM as a buffers design tool and LPS® as a production control tool, enhancing the decision-making process related to the design and management of buffers in construction. The proposed system may moves towards a successful achievement of an improvement cycle, which was discussed by Ballard (2008). FLBM is an element of this system responsible for dimension buffers in match of the degree of uncertainty. Through LPS®, optimization of pre-dimensioned buffers and re-dimensioning them are in iterative accomplished to obtain the optimal lean level of buffering. On the other hand, this methodology proposes some ways to face the interfaces between its levels and procedures to apply it in a reliable and practical way. However, this integrated methodology has not been tested as a whole yet, while their components were satisfactorily tested and validated in an independent way.

5.2.1 The body of 3D- Management System

The proposed 3D-management system framework is outlined in (Figure 5-1). The naming of "3D" comes from the three dimensions involving in the proposed system. These three dimensions are management, scheduling, and uncertainty. Through scheduling, using buffers, enhances the reliability of the planning as one dimension, and mitigates impacts of uncertainty as another dimension. The third dimension regarding management is for controlling and optimizing the use of buffers throughout the construction process to a lower level of the river to reveal the rocks. As shown in the illustration, the framework methodology of the system has relied on a specific vision that advocates the necessity of the transformation from the different levels of thinking, with respect to tackling the problem addressed by this research, to the another level regarding the proposed integration system.

The classical thinking, as represented by triangle one, points out the weakness of methods that focus only on improving the assessment of buffers. With such methods, planning might be fed by a set of proper buffer times that can absorb the impact of uncertainty at occurrence. Further, it may increase the reliability of the plan, but be not able to achieve a significant mitigation of uncertainty without an effective management. Ineffectiveness of management tools may lead to much waste in time. Lean construction, as a modern management philosophy, offers a set of tools able to achieve an increasing effectiveness for the construction process, as represented by triangle two. LPS® is one such tool discussed in depth through Chapter 2. Albeit the successful application of LPS® in planning and controlling construction process, LPS®, as a stand-alone tool, still unable to achieve a complete elimination of variability from the construction process. Hence, the effectiveness of the management tools alone is not capable of moving the process towards the optimum improvement in planning reliability, and dealing with uncertainly.

Therefore, in order to achieve such complete elimination of variability, the research advocates that the integration of LPS® with FLBM may able to provide a complementary action, and a remarkable success in shielding the construction process from uncertainties, and then results in keeping the project goals. Namely, the triangle three, the purpose of the integration of 3D management system, emphasizes the need of the integration of both triangles one and two into a new system.

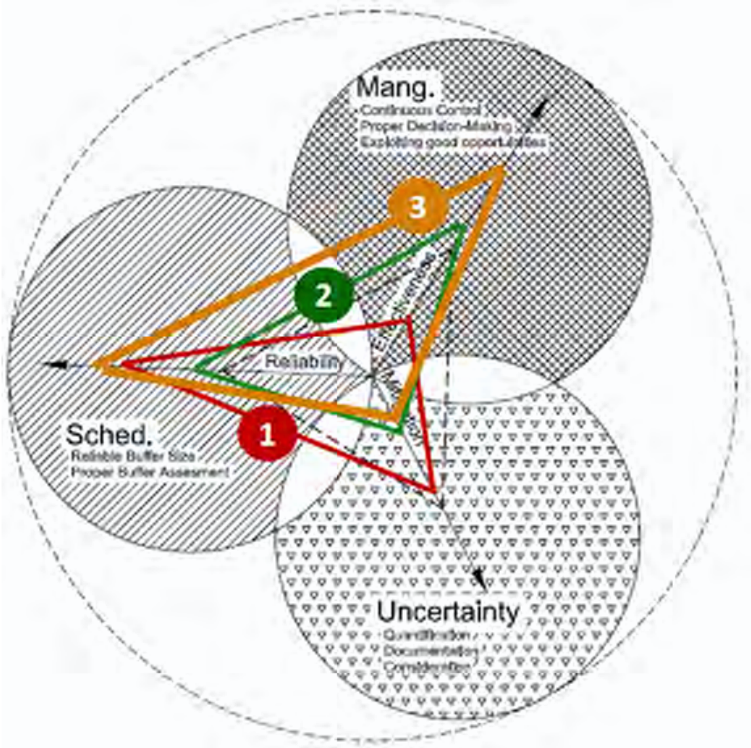


Figure 5-1 The Framework Methodology For The Proposed 3D-Management System

5.2.2 Understanding the 3D-Management-System

In the 3D-Management system, knowledge of the construction environment is the first priority. Hence, in order to acquire sufficient knowledge for making a decision, the observation should be established. This step requires recognition of data, and feedbacks from various other phases, which makes the system framework as a loop. As shown in (Figure 5-2), the overall 3D-Management system framework for the integrated methodology of FLBM and LPS® is employed through three levels of planning. Three levels for construction planning are defined using the planning hierarchy: Master plan or Strategic planning (long-term), Lookahead or Tactical planning (medium-term), and work plan or operational planning (short-term), which are progressively more detailed from top to bottom [GONZÁLEZ et al. '09a]. The following subsections explain the methodology of the proposed system at each scheduling level.

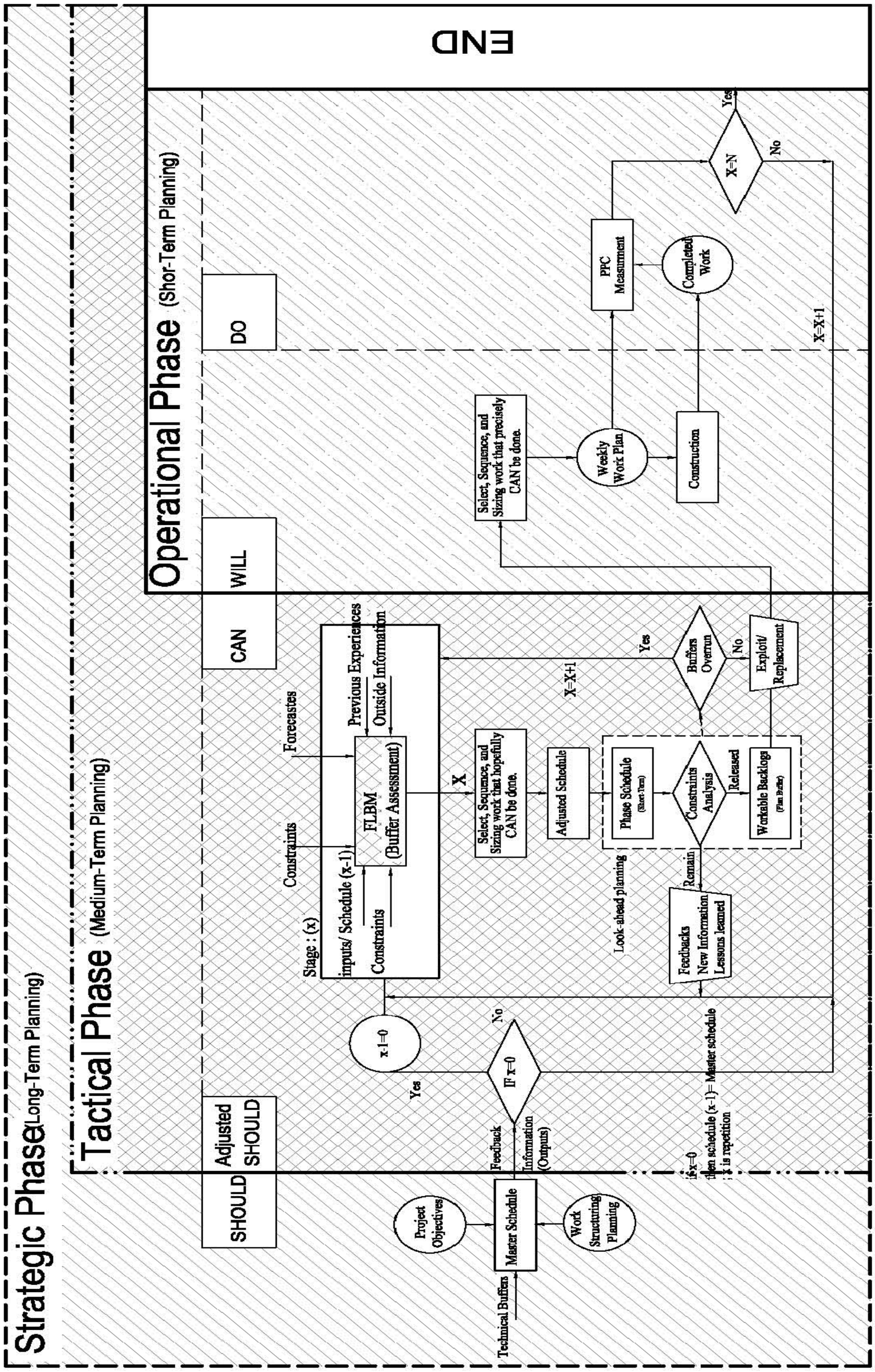


Figure 5-2 The 3D-Management System Framework

5.2.2. [I] Strategic phase

In principle, at this level, the decision-maker must choose the uncertainty level for the project as a whole, and for each activity based on the project information availability, and his experiences. Hence, by using the FLBM and its predefined rules, buffer sizes for the project activities on the control path are calculated. The computed buffer size is subsequently allotted to activities in the *Master Schedule* that be a buffered plan at the strategic level. This buffered master schedule is the initial plan to execute the process is static in nature. The project milestones, completion date can be represented by such planning level, which is fundamentally characterized with a higher probability of keeping the project due date. Eventually, such buffered plan provide what SHOULD be initially done.

> ***Step 1*** *(Strategic)*
>
> - Project Objectives
> - Master schedules
> - Work structuring Plan
>
> ***...........What SHOULD be done?***

At this level, a *phase scheduling* is secondly generated in a form of detailed schedule covering each project phase. The phase schedule (or pull schedule as named in the industry) employs the reverse phase scheduling, in a buffered form, and identifies handoffs between the various specialty organizations to meet the milestones stated in the master schedule [HAMZEH et al. '08].

5.2.2. [II] Tactical phase

At a lookahead plan or tactical plan level, the design of buffers is more dynamic where it uses the FLBM in a loop/cycle form. At this level, we refine the buffers and then adjust the master schedule as well as the phase schedule to adjust SHOULD. This scheduling level considers a smaller time window and it is closer to the work front where a higher detail for the construction process is represented. The feedback from site goes directly through the FLBM at x sequence for updating the lookahead plan.

From the buffered master plan resulted at strategic level, a lookahead plan is defined for 3-6 weeks. Based on the updated feedback from the closer view to the construction site, actual resources, and the judgment of expertise, an updated buffers size is calculated by rerunning the FLBM with such new inputs. As a consequence, the decision-makers adjust the schedule by adjusting SHOULD. In this stage the designed buffers, incorporated in a buffered lookahead plan, can be different due to the stochastic nature of the process, with different uncertainty levels. Thus, the buffered lookahead plan is represented with information that is more realistic; therefore, the planning date may be more accurate. That may make up the lack of production information (historical or experts opinion) at the beginning of the project execution.

Step 2: (Tactical)

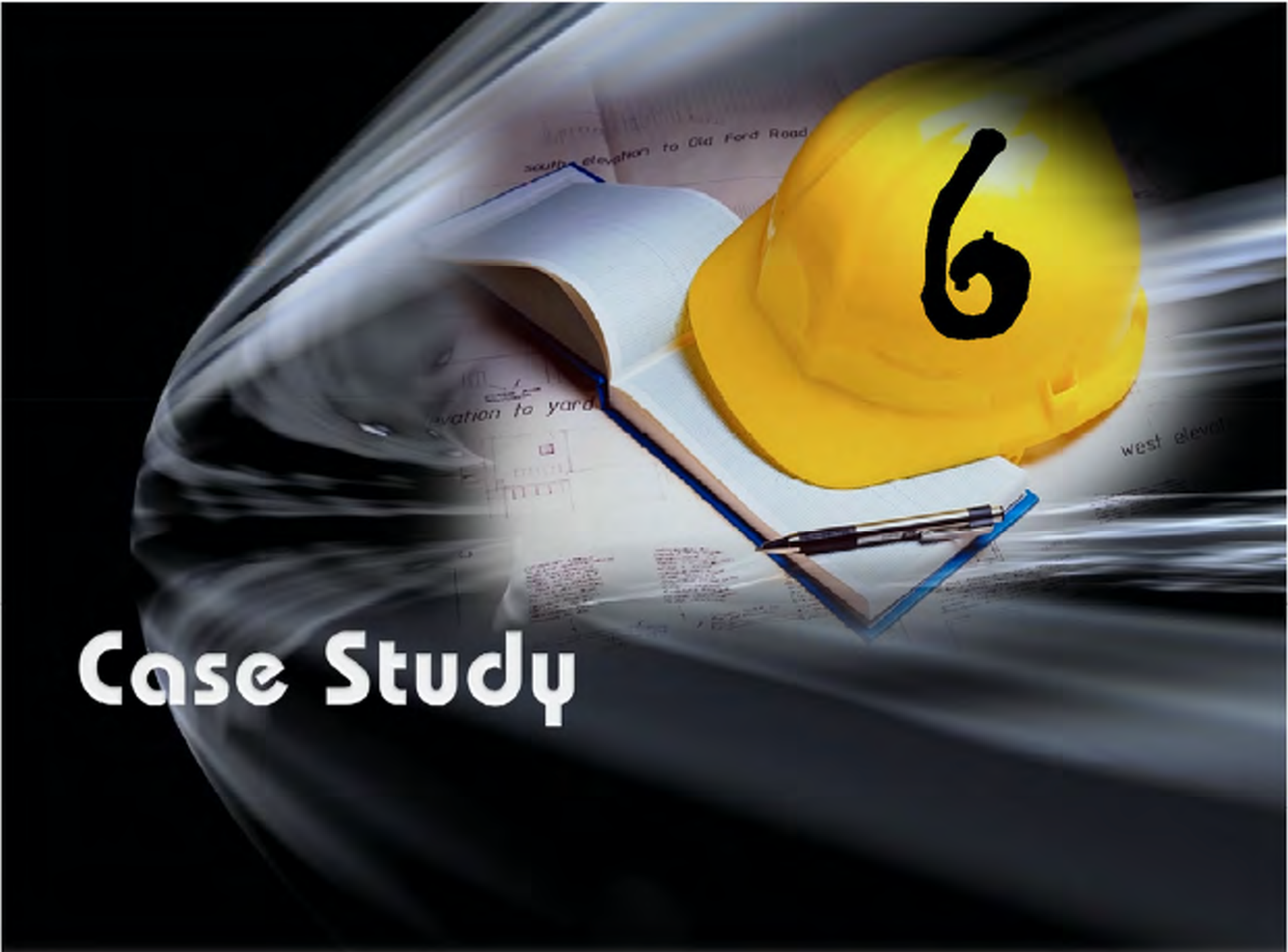
- Feedback from step 1
- FLBM
- Buffered-phase schedule
- Lookahead
- Constraints analysis
- Test buffers overrun
- Workable backlogs
- Buffers refining

...........What CAN be done?

At this level, make ready process should be further established by releasing constraints from the activities and then being in workable backlogs. The status of consuming buffers should be monitored. Buffers that could be taken off, as unused buffers, should be exploited by their replacement with workable backlogs (a plan buffer). Whereas the buffers being overrun are recalculated through the FLBM to refine them in the lookahead plan. Afterwards commitments (free of constraints) are assigned to be performed (CAN). Eventually, feedbacks got though this stage should be considered for the next phase of a lookhead planning.

5.2.2. [III] Operational phase

From the latter level, we get a set of tasks that CAN be done. Promises are the key process to convert what CAN be done into WILL be done. At this phase of operational level, the importance of keeping Will or keeping promises takes place. Furthermore, the work performed involves even more sensitive variability and dynamic conditions. The modeling framework allows the progress of weekly work to be predicted using historical site information. Lastly, performing work execution is further measured in terms of PPC.



6 Case Study

- **Project description**
- **Implementation of FLBM**
- **Findings**
- **Analysis**

The logic of validation allows us to move between the two limits of dogmatism and skepticism. *"Paul Ricoeur"*

CHAPTER 6. CASE STUDY: ASUIT HIGHWAY CONSTRUCTION

6.1 PROJECT DESCRIPTION

ASUIT project is a highway construction project as one of the four sectors highway construction project connecting Upper Egypt to the Red Sea, as depicted in (Figure 6-1). The entire project has a total length of 412 kilometers and width of 32 meters with an approximate budget 117 million US$.

The length of the study project of ASUIT is 112.80 kilometers with the same width. The Egyptian General Authority for Roads & Bridges & Land Transport is the owner of the project as it is public. The project is invested by the ministry of investment. The general contractor is Nasr General Contracting Co. “Hassan Allam”. The general subcontractor is ORASCOM that employs 12 additional subcontractors. The highway construction project of ASUIT sector constructed by 235 machines are categorized as listed in (Table 6-1), and 751 workers. The construction of this sector consisted of a structure of asphaltic pavement of 113,150 m^3 and 10,500,000 m^3 of earthworks, which excluded 2,130,000 m^3 of both soft and rock soil excavations.

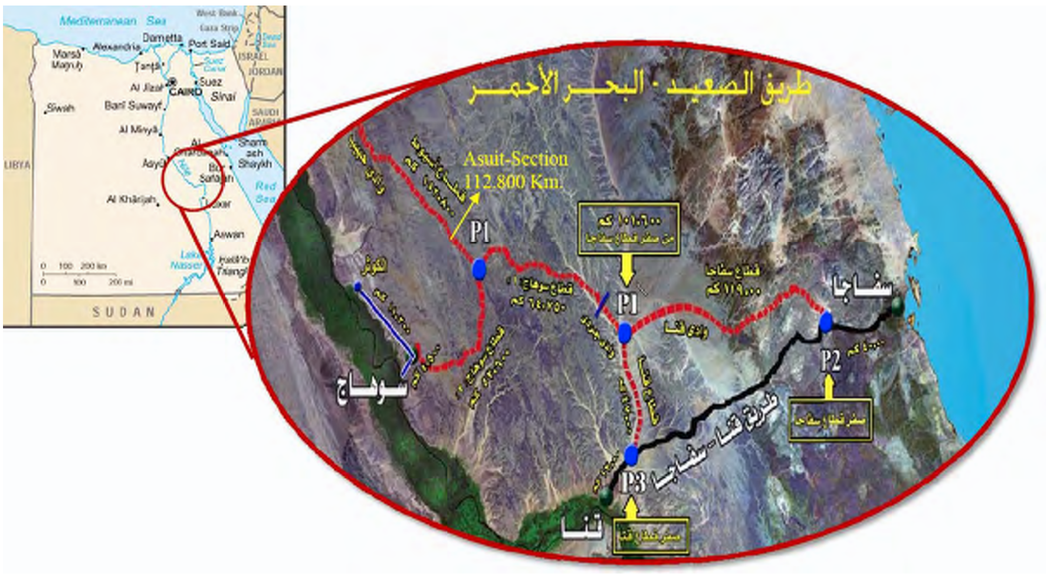


Figure 6-1 Highway Construction Project of Upper Egypt-Red Sea

Table 6-1 List of Equipments For ASUIT Road Construction Project

Equipments	Quantity
Bulldozer	20
Motor Grader	14
Drum Soil Roller	15
Water Tankers	16
Heavy Dump Trucks 18m3	88
Trailer Trucks 45m3	5
Trucks for Pitching	4
Loader	32
Excavator / Back-hoe	9
Transit Asphalt Mixer	2
Crusher	1
Finisher	1
Roller	5
Total	**212**

6.1.1 Project Characteristics

6.1.1. [I] Logistics-related

In fact, ASUIT highway construction project logistics is characterized as follows:

- The nearest water source is placed at the kilo of (00+00) that results in a problem of water transportation.
- Most activities are repetitive.
- More than 50% of the workforce is specialized for pitching works.
- Filling and excavation activities are stochastically performed depending on the nature of the terrain.
- For filling works, the transportation distance of material is approximate 300ms.
- Decision-making is on site and is not from the management office.
- For the base layer, two approved stone pits are only placed at the kilos of (11+00) and (47+00).
- The immense amount of equipment, the more wasted time and non-add value.
- Bad management of the massive numbers of machines results in:

- Waiting and idle times.
- Unnecessary travels.

- Large quantity of excavation.
- Lack of coordination among excavation works subcontractors.

6.1.1. [II] Planning and Execution-related

The construction process of ASUIT road is constituted of 18 activities as shown in (Figure 6-2). These activities are sequenced and related together in a form of a schedule as depicted in (Figure 6-3). As represented in this master schedule, the total duration of the project is 26 months, commenced in May 2007, and should have ended by June 2009.

Activity_ID		Activity Description	Repetitiveness (No / Yes)
S		Mobilization	No
01		Filling works	Yes
02		Excavation in Soft Soil	Yes
03		Excavation in Rock Soil	Yes
04		Base Layer 35cm.	Yes
05		Connecting Layer MC.O	Yes
06		Pavement 7 cm.	Yes
07		Adhesive layer RC3000	Yes
08		Surface Pavement 5cm.	Yes
09		Pitching works	Yes
10		Fencing (New Gercy)	Yes
11		Metal Fencing Erection	Yes
12		R.C Pipes 1m Dia.	No
13		P.C Pipes Foundation	No
14		R.C Pipes Foundation	No
15		Painting works (reflecting colors)	Yes
16		Alert Signs Installation	Yes
17		Traffic Signs Installation	Yes
18		Other Signs Installation	Yes

Figure 6-2 Activities are Involved in The Construction Process of ASUIT Road

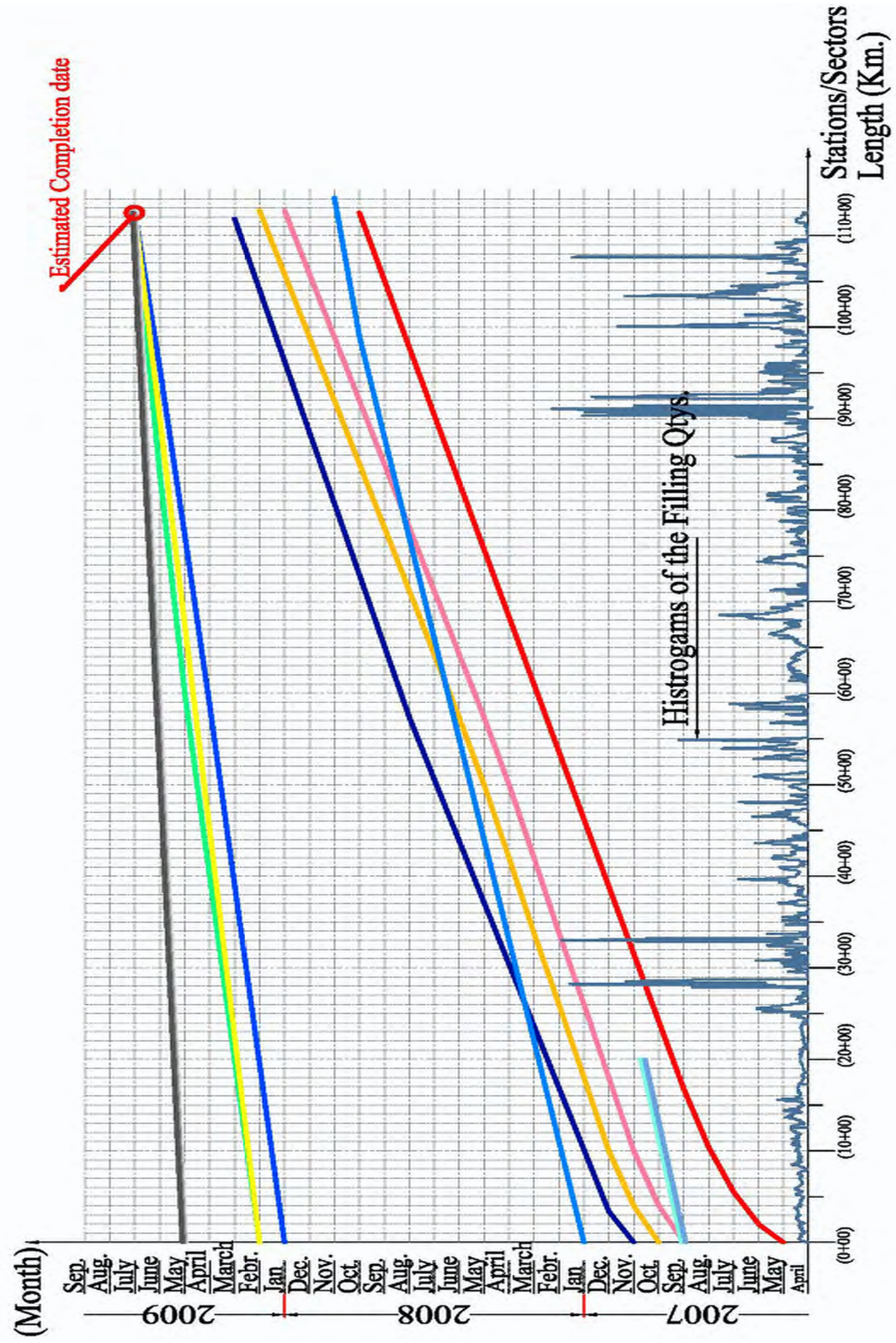


Figure 6-3 Master Schedule of ASUIT Highway Construction Project

6.2 ACTUAL SITUATION

In fact, the actual situation of the project execution was quite different from the planned schedule, which reflects the unreliability of the master schedule. Though the master schedule planned to finish the work by July 2009, the completion date of the construction process will accidentally be extended approximate a year later. By interviewing some of the project personnel, it was observed that master schedule was underestimated. The master schedule was not accomplished considering the uncertainty levels of the project. As a result, the master schedule became unreliable and useless for steering the execution of the project effectively.

The findings of those interviews advocate the benefits of buffers, as a reserved time added to the master schedule, to absorb uncertainty impacts and keep the functionality of the schedule. Thus, (Figure 6-4) represents the changes in the schedule based on the actual execution conditions. It is obvious that the problem is embedded in earthworks activities, which are much vulnerable to the impact of uncertainty. In November 2009, it was observed that activity (01-red line) of filling works, and Activities (02 and 03) of the excavation are quite deviated from the original planned schedule, and consequently affect the successor. The earthwork activities are still at the station of (77+00). The average PPC is approximately 59% of the planned works for the entire process as detailed in (Figure 6-5).

According to the nature of terrain geography, the great variety in the quantities of fill and cut soil takes place as explained in (Figure 6-6). Hence, the nature of ground geography, and additionally the wind, result in many uncertainties that play a tangible role in failing the project to keep the target time and consequently the target cost.

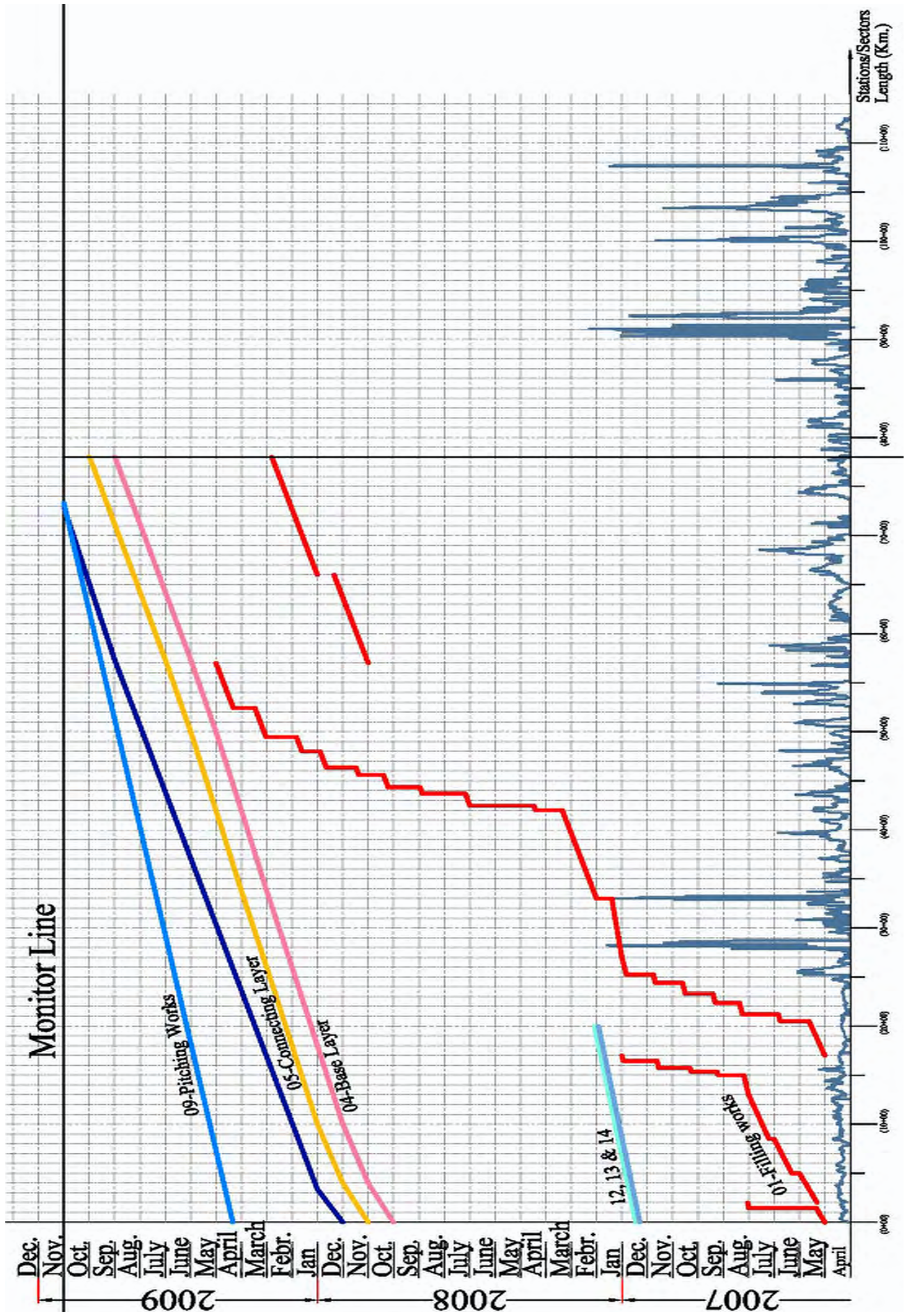


Figure 6-4 The Actual Situation of The Asuit Project Construction

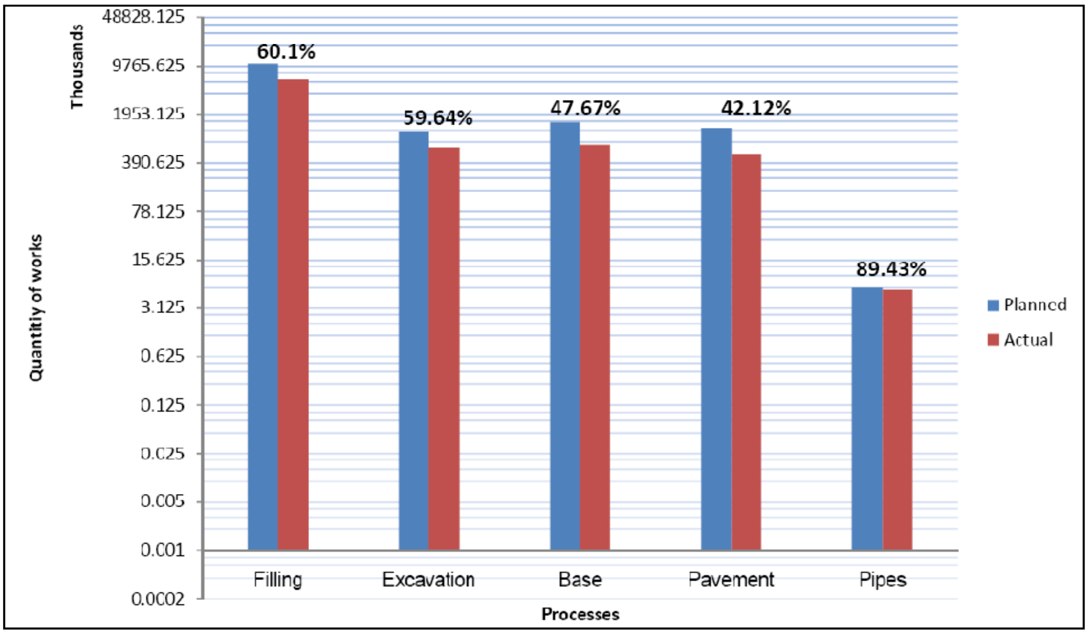


Figure 6-5 Logarithmic Scale Analysis of The PPC For ASUIT Construction Process

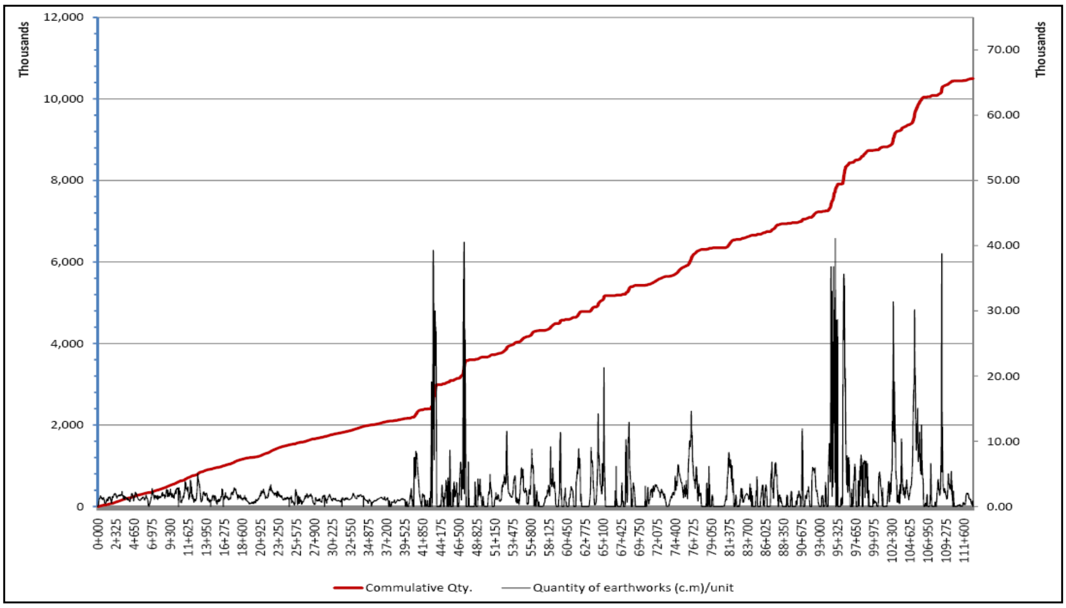


Figure 6-6 Histograms of The Quantities Variation in Earthworks along The Project Stations

6.3 IMPLEMENTATION OF THE 3D-SYSTEM

6.3.1 Implementation of FLBM

In order to validate the role of the proposed FLBM through a real case study of ASUIT highway construction project, implementation of the fuzzy model will be demonstrated to the activities. In principle, the role of the FLBM is to improve the reliability of the master schedule that reduces the deviation between actual and estimated duration. The buffers are only calculated by the model for activities on the control path such as activities 01, 04, 05, and 06.

Uncertainty levels, the duration length, the influence degree of uncertainty based on the unique characteristics for each activity, and the degree of confidence associated with the estimates of the activity duration are considered in the inputs process for each study activity as explained in (Table 6-2). For the Activity 01 of earthworks, it is commonly known that such tasks are much sensitive to the impact of uncertainty. We divide the activity into three zones according to uncertainty. Performance of this activity from station (00+00) to (55+00) may experience climatic effects as wind, high temperatures, and little rain that do not influence the productivity strongly. Hence, in such interval, the task performance normally is highly vulnerable to uncertainty impact. The duration of Activity 01 in the first section (00+00 to 55+00) is a bit larger than required, which indicated that the degree of confidence was not too high. The consequent buffer is come up with 46.875% or 3.5 months. Likewise, the second interval of activity 01 (55+00 to 90+00) encounters a high level of uncertainty in the sense of the massive quantity of earthworks as expressed in the previous histograms, and unforeseen rough points need for explosions. As shown, the quantity of earthworks at this interval is around 6 million m^3; three times the number for amount of the first section. From the standpoint of experts, the duration of this section was significantly underestimated. That indicates the lower of estimation level or less degree of confidence. In this case, the buffer time is around 56.25% to be able to absorb uncertainty impact enough, and compensate for the shortening in the normal duration that does correspond to reality. Similarly, the third section of the Activity 01 is processed in the FLBM.

On the other hand, Activity 04, 05, and 06 are not divided into sections or intervals because they have equal quantities and conditions throughout the entire project. However, the unique characteristic of such activities is the low influence to the previous uncertain factors encountering the execution of the project such as wind, rain, or temperature increase. It is observed that buffers result from the model is suitable for the nature and characteristics of these activities, which differs from the previous models.

Table 6-2 Inputs Variables and Consequent Buffers For Activities

Activity		Duration		Degree of Confidence		Uncertainty level		Influence Degree		Buffer
ID	Stations	Major	Minor	Major	Minor	Major	Minor	Major	Minor	(%)
1	(00+00) To (55+00)	Large	Normal	Medium	Less	Medium	Slightly more	Very Large	Normal	**46.875%**
	(55+00) To (90+00)	Small	Less	Low	Slightly Less	Very Large	Medium	Very Large	Medium	**56.25%**
	(90+00) To (112+80)	Medium	Normal	Low	More	Very Large	Medium	Very Large	Medium	**56.25%**
4	(00+00) To (112+80)	Very Large	More	Medium	Normal	Medium	Less	Small	Slightly less	**7.09%**
5	(00+00) To (112+80)	Very Large	More	Medium	Normal	Medium	Less	Small	Slightly less	**7.09%**
6	(00+00) To (112+80)	Very Large	More	Medium	Normal	Medium	Less	Small	Slightly less	**7.09%**
8	(00+00) To (112+80)	Very Small	Less	Very High	Medium	Very Small	Less	Very Small	Less	**6%**

6.3.2 The 3D-Management System

Implementation of the proposed integration of LPS® and the results of the FLBM could not indeed be employed through the study project. However, interviews with some of project managers were established. Those interviews were firstly to hand about the resulted buffered schedule from FLBM as depicted in (Figure 6-7) in a comparison with the master schedule, and secondly, to discuss the use of the model through the proposed 3D-Managamenet System framework.

The difficulty of the implementation was essential because of unawareness of lean knowledge and LPS®. That means it should be firstly converting the management thinking existing in mind into lean thinking. However, the vast majority of responses advocate the need of highway construction projects for lean philosophy, and especially for LPS®. They further pointed out the fact of the lack of regular meetings throughout the execution process between all construction partners. They emphasized the tangible reliability for the baseline schedule after implementation of the FLBM in the strategic planning level, which draws an actual image about the construction process. However, to achieve more progress for reducing the total project duration or keeping the planned completion date (based this real view), it is recommended to implement the LPS® collaboratively with FLBM as the framework of the proposed 3D-Management System. The general consensus was that LPS® able to provide a wide view of the entire process, which may control operations effectively towards achieving remarkable success.

Figure (6-7), represents also their expectations of improving the progress of the construction process that may rush the buffered due date of activities 04, 05, and 06 to new due date of activities of 04*, 05*, and 06*. As a consequence, successor activities of (7 to 9, and 15 to 17) may be pulled to the new start buffered dates.

6.4 ANALYSIS AND DISCUSSION

The implementation of FLBM to the study project emphasizes its benefits for the master schedule. These benefits increase the reliability of the schedule. The master schedule under FLBM is neither an optimistic nor a pessimistic schedule. In addition, FLBM does not provide a set of unstudied additional times to activities. It indeed allots a specific buffer time to a specific activity proper to activity characteristics, and uncertainty levels.

At the original master plan, the completion date of the project should have been due at the end of June 2009, whereas in the fact, the construction process is undergoing a delay of approximate 12 months resulting from a lack of study for uncertainty impact in the master plan. The FLBM provided an initial buffered plan nears reality.

Using FLBM through the master plan could rectify the flaws of the master plan that led to be quite optimistic plan and unreliable as well. As concluded from both (Table 6-2) and (Figure 6-4), well quantitative and qualitative study for uncertainties experiencing the execution of the project should have been established. FLBM pointed out that activities of earthworks needed approximate of 50% extra allowance of their original time. That was because of the sensitivity of such activities to uncertainty and the low-level of confidence associated with their duration estimates.

Hence, with FLBM, the master plan was amended to be in needs of approximate 9 months of time buffers. The comparison between the master plan after using FLBM and the actual situation advocated the ability of the model to increase the reliability in the scheduling process. That because of the remarkable reduction of the gap between the actual and planned form approximate 12-13 months in the master schedule to around four months in the schedule with FLBM. By focusing on some facts of the case study;

ES=AS=1/5/2007, EF=1/7/2009 ……….*(Total estimated duration= 26months)*
AF=27/5/2010[4] ……….*(Total Actual duration= 37 months)*

Hence, the reliability of the master plan had been = 1-((37-26)/37) = 70.2 %. However, after using FLBM the reliability of the master plan was = 1-((37-(26+9 buffers)/37) = 94.6 %, which means that FLBM could increase around 24.4% in the reliability of scheduling.

6.4.1 FLBM Vs Goldratt

In order to advocate the benefits of FLBM, a comparison to Goldratt methods was established from sizing and distributing buffers throughout activities on the critical path (CP). As shown in Table (6-3), the outcomes of each method are addressed to emphasize the agreement in their results, which were close to each other only in the total project buffer size. FLBM predicted around 9.5 months extra as a whole project buffer, whereas Goldratt gave around 13 months as an entire project buffers. That means the delay of the project, from the Goldratt and FLBM viewpoints, may approximately be 50% and 40% respectively. The narrowness between each result could give a logic overview.

Nevertheless, the credibility and reliability of each method could be concluded from the distribution of buffers not from the total size of buffer. In Goldratt method, sizing buffers depended mainly on the span of durations regardless the characteristics of the activity, which is the owner of the duration. For instance, activity 6 of pavement needed to 8 months buffer to be allotted, albeit its slightly

[4] Published in the Egyptian official newspaper ALGOMHURIA: "Friday 28th May, 2010, http://www.algomhuria.net.eg/algomhuria/today/fpage/detail00.asp

influence under uncertain event such as wind. On the other side, activity one which is more vulnerable to such example of uncertainty had only 2 months buffers.

With FLBM, as well as focuses on sizing buffers, it focuses also on doing a well distribution of buffers according to the actual circumstances associating each activity individually. The difference between Goldratt and such methods from one side, and FLBM from the other side that the former considers only the duration of activity in sizing buffers, whereas the latter considers many intrinsic factors in sizing buffers.

The well distribution of buffers besides the proper sizing that could be generated by FLBM, eliminated wasted times embedded in either over estimated buffers or the under estimated.

Table 6-3 A comparison between using Goldratt and FLBM for sizing buffers

Activity on CP Time in months			**Goldratt**	**FLBM**	
ID	$t_{0.5}$	$t_{0.9}$	$Bf=\frac{1}{2}\sum_i t_{0.5}^i$	%	Months
1	4	17	2	53	9
4	1	16	0.5	7.09	0.21
5	1	16	0.5	7.09	0.07
6	16	16	8	7.09	0.07
8	4	6	2	6	0.24
Total	26	33	13		9.38

6.4.2 Integration of FLBM with LPS®

Moreover, the implementation of an effective control tool integrated with FLBM may improve the construction process and achieve no waste in both time and cost. As demonstrated in (Figure 6-7), productivity of activities 04, 05, and 06 can be improved (activities 04*, 05* and 06*) to rush their due dates, and as a consequence reduce the total duration of the project. LPS® as a lean control tool can provide an effective surveillance, proactive actions and control throughout the execution of the project. It can exploit the unused buffers in the initial buffered plan by workable backlogs.

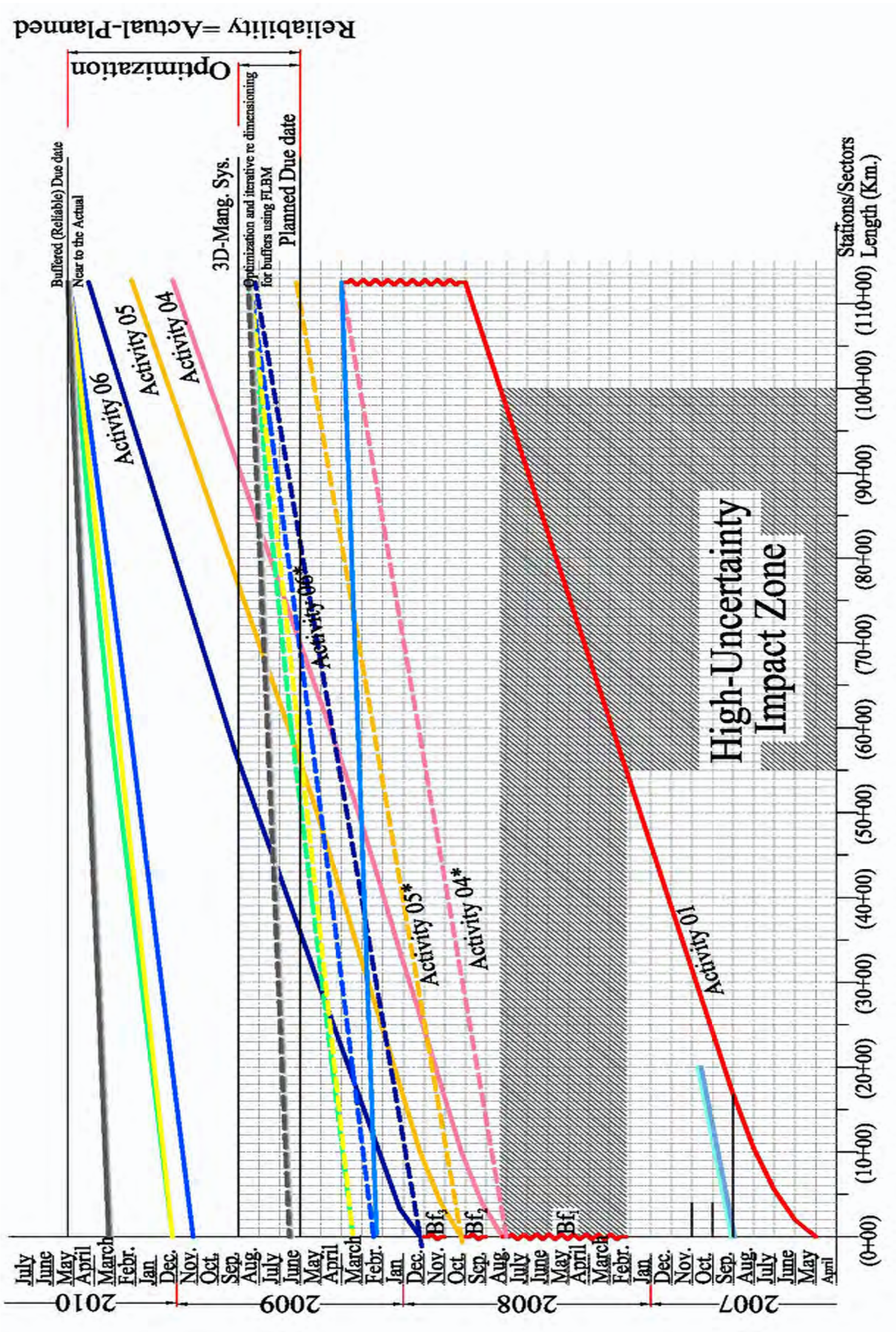


Figure 6-7 Implementation of FLBM to The Study Construction Project of ASUIT Road

6.4.3 Interviewees' Reaction Analysis

In order to get the reactions of practitioners about the reliability of FLBM and the expectation from the proposed integration system, 23 interviews were carried out. Most interviewees were from the staff working in the case study project. The rest of interviewees were from academia and other construction agencies. These interviews reported a synthesis of data collected to provide insight into the following questions as mentioned in section 4.3.2:

1. How is the credibility of the results regarding the use of FLBM?
2. What are the expectation about the improvement of the entire construction process from the integration of FLBM with LPS®?

Table (6-4) shows basic demographic information about the interviewees. Respondents were contacted individually. Most of interviews were in form of telephoning, and notes on discussion were simple taken. 80% of notes were taken in Arabic because it is the native language of the informants.

Table 6-4 demographics of Interviewees

Features	Category	Numbers of respondents
Gender	Male	18
	Female	2
Age	18-25	2
	26-35	5
	36-45	6
	46-55	5
	Older than 56	2
Marital Status	Married	7
	Single	5
	Divorced	-
	Unknown	8
Education	Technical school	2
	College grade	14
	Postgraduate	4
Country	Egypt	15
	Saudi Arabia	1
	Germany	2
	South Africa	2
Work in study project	YES	13
	NO	7
Interview	Meeting	6
	Telephoning	14

Reactions on the first question regarding the credibility of the FLBM were almost positive and impressive. Some examples of reactions were translated into English, and listed as follow:

> "I think it is very nice to make a reliable plan to avoid the disputations between stakeholders. The results of the model was quite reasonable for me."
>
> "What I liked in the model that the way of adding extra time to activities, which vary from one activity to another depending on the actual circumstances."
>
> "….I do not think with the results because the academic efforts are always in form of imagination".
>
> "….The results of FLBM were indeed increase the reliability of the master schedule and they are acceptable and logical for me, however, I think the experts can do the same job without the model".
>
> "Really, the model provides a systematic thinking about buffers design and management, yet it still need to much improvements to be more applicable"
>
> "…Yes the results are believable and credible, but you should believe that we need firstly to qualify managers and engineers to the modern way of management before your model. *YA BASHA,* we have basically no management philosophy, we do schedule just as a document to apply for tendering"

By coding these quotes and reactions, and then analyzing them, a consensus of the reliability and validity of the model results was reached. In addition, there are a number of cultures about management in practice that conflict with thinking of academia. Similarly, after an explanation of the integration system, optimistic expectations, and positive reactions on improving the construction process were established. These reactions advocated that the total project duration may be reduced by using such model with the integration of LPS®.

7

Conclusion and Recommendation

- **Conclusion**
- **Recommendation to future works**

As a result of my study, I came to the conclusion that a common supreme authority was undesirable. *"Fredrik Pager"*

CHAPTER 7. CONCLUSION AND RECOMMENDATION

7.1 SUMMARY

Highway construction projects have unique characteristics, owing to their common execution in an environment characterized by varying degree of uncertainties. In regards to highway construction projects in Egypt, as the focal point of the research, even though almost all of them have tried implementing the traditional management, they have unfortunately created a great deal of waste. The problem that this research is concerned with is dominated through abilities of achievement of a reliable schedule, mitigation of the influence of uncertainty, and establishing appropriate buffers design and management. The research was limited to only the buffers type regarding time.

7.1.1 Current situation of highway construction in Egypt

Managing of highway construction in Egypt was critically discussed through the research to outline the main shortcomings resulting in its ineffectiveness that leads subsequently to various types of waste. Hierarchical organization, lack of the knowledge with respect to Buffer Design and Management, random system of management, push system, inefficient dealing with unforeseen conditions, and bureaucracy were such examples of such deficiencies.

7.1.2 Lean Construction

Lean Production in Construction in essence tries to reduce the wasteful activities in construction to deliver the product to the owner. Lean construction with its tools may have a significant role for eliminating waste experiencing the construction process, particularly highway construction process in Egypt. Last Planner System® is the most important Lean Construction tool for planning and production control as well.

Embracing uncertainty is a major aspect of Lean Construction. Lean construction looks at a construction project as a production system realizing the dependences and variations through supply and assembly chains of construction, and effectively managing process uncertainties. Not only buffers mechanism has been the major concern of Lean Construction to optimize dealing with uncertainty, but also the heart of Lean Construction, in managing buffers, is to reduce the inventories/buffers to reveal the problems and deal with. The management of buffers from the lean viewpoint is like an improvement cycle. Through such cycle, matching buffers to the degree of uncertainty involves sizing the buffer, and then reducing variability and matching buffers to the remaining variation stabilizes a production system.

7.1.3 Buffering in the world of fuzzy logic

In Principe, the Benefits of a fuzzy logic system are to model highly complex business problem, model systems involving multiple experts, and reduce model complexity. The fuzzy logic has been used by several researchers for construction project planning and scheduling. In general, buffers evaluation model (BEM) is an attempt of the buffers sizing using fuzzy logic concepts. It identifies the time buffer for demand variability. Hence, the evaluation of buffers based on fuzzy techniques can improve the performance of project schedule rather than other conventional approaches. Obviously, buffers Management aims mainly to stop the behaviors that waste time in the project. Deficiencies of the previous traditional methods concerning schedule buffers were as follow:

- Lack of activity characteristics.
- Regardless of uncertainty levels.
- Neglect of the degree of confidence of the activity duration assumption.
- Improper distribution of buffers.

The two main elements the research was developed in order to achieve the objectives as well as answer the three questions of 3HOWs, were the model of FLBM and the 3D management system.

7.1.4 Fuzzy Logic-Buffering Model

Fuzzy Logic-Buffering Model (FLBM) was developed to calculate the buffer size of the project. Consequently, that may reduce the entire project buffer time, which finally leads to either reduction in the total project duration or meeting the project completion date. For instance, average activity duration, types and characteristics of each activity, level of uncertainty regarding each factor, and the believable degree associating estimates of the activity duration.

The main sequences of developing FLBM were constructing the membership functions, determining the fuzzy rules, and assessing the model performance. The four inputs variable used for FLBM to get the buffer size, which were expressed linguistically, were:

1. Activity Duration;
2. Degree of confidence ;
3. Uncertainty Level;
4. Degree of Influence.

7.1.5 3D-MANAGEMENT SYSTEM

In order to overcome the prior limitations, an integration of buffers design and management methodology, called "*3D-Management System*", was proposed. FLBM is an element of this system, which is responsible for dimensioning buffers in match of the degree of uncertainty. Through this system, FLBM should used by teams in tandem with Last Planner System® during the levels of planning.

7.2 CONCLUSION

Former traditional approaches concerning schedule buffers have been criticized for their weakness in providing a proper buffers size. Lack of activity characteristics, regardless of uncertainty levels, neglecting the degree of confidence associated with estimates of the activity duration, and improper distribution of buffers are such reasons of this criticisms.

Lean construction with its tools may have a significant role for eliminating waste experiencing highway construction process. Hence, modeling proper approaches for buffers design and management is the fundamental process of managing uncertainty, which has received extensive attention by researchers of various fields of knowledge. In principle, beyond the approach based on fuzzy logic concepts, others explicitly need a massive pile of data to be able to draw initially the probability distribution function. However, in many cases, the distribution of probability of an activity is impossible to be determined because of the lack of historical data.

In order to answer the three questions of 3HOWs forming the problem of the research, a Fuzzy Logic-Buffering Model (FLBM) to estimate the buffer times was developed firstly. Distinctly, in traditional approaches the buffers time has often been incorrectly determined leading to immense loss of money and time. With based on a questionnaire-based survey, the model was fed by data to be established in order to obtain the buffer size as a proportion of the activity times. FLBM focuses upon the reality of buffers according to the degree of uncertainty, by considering factors sharing variability in the execution of a project. Simulation of the model is done in MATLAB using sample data to verify the model. The results of the simulation give positive feedback reflecting the actual conditions. Afterwards, an integration of Bf design and management methodology is proposed. This methodology provides a sounder and more rational framework based on the FLBM as Bf design tool and LPS® as a production control tool, enhancing the decision-making process related to the design and management of Bf in construction.

A set of scenarios were run over the FLBM, and then its employment through a case study of a highway construction project in Egypt was established. Findings from these scenarios advocate the fact that buffer sizes are essentially influenced by the characteristics of each activity, and its influence degree under variability. Furthermore, the duration alone does not affect the size of buffers; the degree of confidence also has to be considered while estimating the size. Likewise, uncertainty in general has no effect without the vulnerability of activities to its impact.

(Figure 7-1) emphasizes the benefits of the implementation of FLBM to the study project through the Master Schedule. As shown, implementation of FLBM through the scheduling phase increase the level of reliability for the Master Schedule from level one up to level number three. It is obvious that use of FLBM could reduce significantly the gap between the estimated and actual plan. This improvement can be observed as the reduction in gap between level 4 and 3 in comparison with the gap between 1 and 4. Hence, FLBM increases the reliability of the schedule. In addition, FLBM does not provide a set of unstudied additional times to activities. It indeed allots a specific buffer time to a specific activity proper to activity characteristics, and uncertainty levels.

In addition, FLBM could be the answer to the second question regarding the enhancement of the schedule reliability. Through the case study of Asuit project, FLBM could proof that the reliability of schedule increased by approximate 24.4% than in the master schedule, which has been done in lack of FLBM. Namely, as illustrated in Figure (7-1), the reliability of the original schedule and FLBM-based schedule improved from 70.2% to 94.6% respectively.

On the other hand, through a comparison of FLBM and Goldratt method, the former could provide another view of evaluating buffers that the more important than predicting of a reasonable buffer size is the well distribution of buffers allotment to activities according to their various characteristics, which make them in varying degrees of influence by uncertainty.

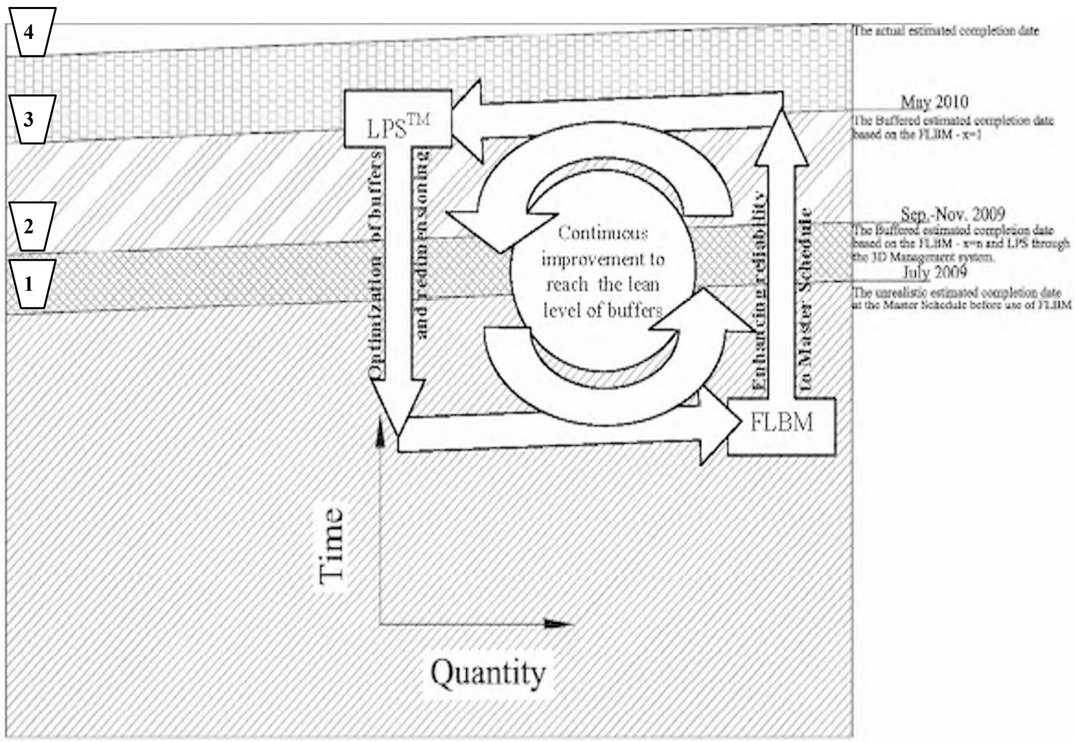


Figure 7-1 Implementation of the 3D-Management System on the case study

For the other two questions regarding lean of buffers and the optimization of managing uncertainty as well, the research developed the integration framework of FLBM and LPS®. Through such framework, LPS® optimizes the size of buffers through all levels of planning to match the actual circumstances associated the construction process. That reduces the buffers size to reveal the 'rocks' to deal with. The optimization of buffers as well as the entire process is performed in a loop or cycle manner through the integration between LPS® and FLBM in one system. Despite the fact that implementation of this system, 3D-Management System as an integration framework of FLBM with LPS®, could not be demonstrated, a general consensus on the ability of the proposed system, and particularly LPS® that provides a wide view of the entire process, which may control operations effectively towards remarkable success, is reached.

The use of the integration system of the 3D management system through the studied project may play an important role in removing wasted time that is hidden in buffers before the refining process, and consequently reducing the project completion time. These benefits of the system are advocated by the highway construction practitioners, who emphasized the optimization of the completion date for the studied project to around seven months and around eleven months front of the buffered schedule at level three and actual schedule at level four respectively.

7.3 RECOMMENDATIONS AND FUTURE WORKS

This thesis opens up a domain of possibilities where future researchers can improve such model, and produce more powerful, user-friendly software that can analyze all the possible factors of demand of variability with all their specific qualities, producing fast and reliable results. In addition, the base of implementation should be widened to more case studies. It is recommended to use the proposed integration system framework for several case studies to enable us to recognize deficiencies need for the remedy, or reveal other missed parameters that should have been considered in the system framework. Hence, future research and opportunities can be directed to the following points:

- Evaluating other design alternative models, by changing the mechanism of the stochastic analysis, i.e., use of Fuzzy-Neural, or by reconfiguring the predefined membership functions, and model variables.
- Optimization of a stand-alone GUI over the World Wide Web.
- Widening of the survey base to be conducted to larger samples as possible, in order to increase the reliability of rules for the proposed model.
- Generating the proposed model's results inside scheduling software.
- Generalize the integrated methodology for any highway construction projects.
- Test and validate the entire methodology.
- Design strategies and actions in order to implement the methodology within the project organization and to obtain commitment from constructors of highway construction projects.

Glossary of Terms[5]

Critical Chain CC The set of tasks that determines the overall duration of the project, taking into account both resource and precedence dependencies.

Possible and Necessary The possible expresses the difficulty associated with the realization of an event, while the necessary refers to the obligation to have an event realized. If an event is necessary, that means its contrary is impossible. One can locate the probable somewhere in between the possible and the necessary.

Master Schedule Schedule produced during front end planning and covering an entire project, with activities to be exploded when creating the lookahead schedule .

Uncertainty and Imprecision *Uncertainty* usually refers to the random nature of a result; this term is of a probabilistic nature. Vicente Gonzalez presents that the notion of uncertainty is as old as the well-known man's history. Already in the year 3500 BC the Egyptians associated the concept of uncertainty to the games of chance. This concept of uncertainty was formalized at the beginning of the renaissance and consolidated with the theory of probabilities during the 17th century.

Imprecision refers to the incompletely defined nature of a result; imprecision has a deterministic nature.

[5] This glossary was produced specifically for this thesis, which are compiled from references, IGLC yahoo group, and LCI at <www.leanconstruction.org>

Plausible and Credible	Everything that comes from a corpus of knowledge is said to be credible. Everything that does not is said to be plausible.
Buffers	Buffers in production systems may be characterized by Location, size, product mix, criticality, etc. They are also influenced by the difficulty of forecasting the available capacity and production demand.
Assignment	A directive or order given to a worker or workers directly producing or contributing to the production of design or construction.
Workable Backlogs	Assignments that have met all quality criteria, except that some must yet satisfy the sequence criterion by prior execution of prerequisite work already scheduled. Other backlog assignments may be performed within a range of time without interfering with other tasks.
Constraint	Something that stands on the way of a task being executable or sound. Typical constraints on design tasks are inputs from others, clarity of criteria for what is to be produced or provided, approvals or releases, and labor or equipment resources. Typical constraints on construction tasks are the completion of design or prerequisite work; availability of materials, information, and directives. Screening tasks for readiness is assessing the status of their constraints. Removing constraints is making a task ready to be assigned.
Work Flow	The movement of information and materials through a network of production units, each of which processes them before releasing to those downstream.

WIP	The inventory between the start and end points of a production process
Shielding	Not releasing work to production units because it does not meet quality criteria; the work is not a quality assignment . It is akin to 'stopping the assembly line.' The purpose of shielding is to make production units less subject to uncertainty and variation, thereby providing them with greater opportunity to be reliable.
Variability	Variability is explained as a random variation, and a consequence of events beyond our immediate control. Therefore, there are two types of variability in flows of production: process-time variability and flow variability. Process-time variability refers to the time required to process a task at one workstation. Process-time variability consists of natural variability (minor fluctuation due to differences in operators, machines and material), random outages, setups, operator availability and rework (due to unacceptable quality). Flow variability means the variability of the arrival of jobs to a single workstation. How - precisely - these concepts should be understood in a construction setting is still a research topic. On the other hand, variability can be viewed as one source of uncertainty rather than a type of uncertainty. Furthermore, variability is very often regarded as the result of not understanding the factors that affect the behavior of a system, i.e. it is considered to be variable because we cannot predict (or control) its behavior.
Batching	Batching means processing products in lots, rather than by the pieces.

Network Defined as multi-sequences of interdependent activities, each having a scope and duration.

Reliability The degree of generic work quality and robustness against uncertainties. A "reliable" activity produces fewer changes, while an "unreliable" activity generates more changes.

Weekly Work Plan A list of assignments to be completed within the specified week; typically produced as near as possible to the beginning of the week.

Lookahead planning The middle level in the planning system hierarchy, below front end planning and above commitment planning, dedicated to controlling the flow of work through the production system.

Plan Reliability The extent to which a plan is an accurate forecast of future events, measured by PPC.

PPC The number of planned completions divided into the number of actual completions, usually referring to activities on a weekly work plan.

$$\frac{\sum_{n=0}^{n=N} n^{o} \text{ of performed activities}}{\sum_{n=0}^{n=N} n^{o} \text{ of planned activities}}$$

SYMBOLS

~	Set not (also complement or inversion)
$\cap$	Set and (also intersection operator)
$\cup$	Set or (also union operator)
$[x,x,x]$	Indicates a fuzzy membership value
$\in$	Member of a set (general membership)
ξ (x)	The expected value of a fuzzy region
μ	Fuzzy membership function
$\mu_A[x]$	Membership or truth function in fuzzy set A of an object x
Ø	Empty or null set
$\wedge$	Logical and
$\vee$	Logical or
Σ	Summation

Abbreviations and Acronyms

AKA	Also Known As
BDM	Buffer design and Management
Bf/Bfs	Buffer/Buffers
CCPM	Critical Chain Path Method
CP	Control Point
CPM	Critical Path Method
DOC	one Day One Cycle
DOF	one Day One Floor/unit
EVA	Earn Value Analysis
FB	Feeding Buffer
FIS	Fuzzy Inference System
FLBM	Fuzzy Logic-Buffering Model
FLS	Fuzzy Logic System
GUI	Graphical User Interface
IMVP	International Motor Vehicle Program
JIT	Just In Time
JITB	Just In Time Purchasing
JITD	Just In Time Distribution
JITP	Just In Time Production
LLB	Lean Level of Buffering
LPS®	Last Planner System®
MAM	Multi-objective Analytical Model
OODA	Orient-Observe-Do-Act loop
PB	Project Buffer
PDF	Probability distribution function
PERT	Project Evaluation and Review Technique
PLC	Project Life Cycle
PMBOK	Project Management Body of Knowledge
PPC	Percent Plan Complete

RB	Resource Buffer
SD	Standard Deviations
SO	Simulation Optimization
SPI	Schedule Performance Index
SSQ	Summations of Squares of standard deviations
TOC	Theory Of Constraints
TPS	Toyota Production System
UD	Universe of Discourse
WB	Workable Backlogs
WIP	Work in Process

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APPENDICES

APPENDIX A: MATLAB CODES AND SUBROUTINES USED FOR FLBM

```
function varargout = fuzzy_buffer(varargin)
% FUZZY_BUFFER M-file for fuzzy_buffer.fig
%      FUZZY_BUFFER, by itself, creates a new FUZZY_BUFFER or raises the existing
%      singleton*.
%
%      H = FUZZY_BUFFER returns the handle to a new FUZZY_BUFFER or the handle to
%      the existing singleton*.
%
%      FUZZY_BUFFER('CALLBACK',hObject,eventData,handles,...) calls the local
%      function named CALLBACK in FUZZY_BUFFER.M with the given input arguments.
%
%      FUZZY_BUFFER('Property','Value',...) creates a new FUZZY_BUFFER or raises the
%      existing singleton*.  Starting from the left, property value pairs are
%      applied to the GUI before fuzzy_buffer_OpeningFcn gets called.  An
%      unrecognized property name or invalid value makes property application
%      stop.  All inputs are passed to fuzzy_buffer_OpeningFcn via varargin.
%
%      *See GUI Options on GUIDE's Tools menu.  Choose "GUI allows only one
%      instance to run (singleton)".
%
% See also: GUIDE, GUIDATA, GUIHANDLES

% Edit the above text to modify the response to help fuzzy_buffer

% Last Modified by GUIDE v2.5 23-Aug-2009 16:08:34

% Begin initialization code - DO NOT EDIT
gui_Singleton = 1;
gui_State = struct('gui_Name',       mfilename, ...
                   'gui_Singleton',  gui_Singleton, ...
                   'gui_OpeningFcn', @fuzzy_buffer_OpeningFcn, ...
                   'gui_OutputFcn',  @fuzzy_buffer_OutputFcn, ...
                   'gui_LayoutFcn',  [] , ...
                   'gui_Callback',   []);
if nargin && ischar(varargin{1})
    gui_State.gui_Callback = str2func(varargin{1});
end

if nargout
    [varargout{1:nargout}] = gui_mainfcn(gui_State, varargin{:});
else
    gui_mainfcn(gui_State, varargin{:});
end
% End initialization code - DO NOT EDIT
% --- Executes just before fuzzy_buffer is made visible.
function fuzzy_buffer_OpeningFcn(hObject, eventdata, handles, varargin)
% This function has no output args, see OutputFcn.
% hObject    handle to figure
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
% varargin   command line arguments to fuzzy_buffer (see VARARGIN)
% Choose default command line output for fuzzy_buffer
handles.output = hObject;
% Update handles structure
guidata(hObject, handles);
% UIWAIT makes fuzzy_buffer wait for user response (see UIRESUME)
% uiwait(handles.figure1);
% --- Outputs from this function are returned to the command line.
function varargout = fuzzy_buffer_OutputFcn(hObject, eventdata, handles)
% varargout  cell array for returning output args (see VARARGOUT);
% hObject    handle to figure
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
% Get default command line output from handles structure
varargout{1} = handles.output;
function input1_editText_Callback(hObject, eventdata, handles)
% hObject    handle to input1_editText (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
% Hints: get(hObject,'String') returns contents of input1_editText as text
%        str2double(get(hObject,'String')) returns contents of input1_editText as a double
%store the contents of input1_editText as a string. if the string
%is not a number then input will be empty
% hObject    handle to MF_pushbutton (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
% duration = get(handles.input1_editText,'String');
% b.degree = get(handles.input2_editText,'String');
% u.level = get(handles.input3_editText,'String');
% i.degree = get(handles.input4_editText,'String');
% % a and b are variables of Strings type, and need to be converted
% % to variables of Number type before they can be added together
```

```
%
% duration = str2num(duration);  %#ok<ST2NM>
% b.degree = str2num(b.degree); %#ok<ST2NM>
% u.level = str2num(u.level); %#ok<ST2NM>
% i.degree = str2num(i.degree); %#ok<ST2NM>
%
% plotmemf = readfis('FLBM5');
% subplot(5,2,2),plotmf(plotmemf,'input',1);
% subplot(5,2,4),plotmf(plotmemf,'input',2);
% subplot(5,2,6),plotmf(plotmemf,'input',3);
% subplot(5,2,8),plotmf(plotmemf,'input',4);
% subplot(5,2,10),plotmf(plotmemf,'output',1);
input = str2num(get(hObject,'String'));
%checks to see if input is empty. if so, default input1_editText to zero
if (isempty(input) || input>1 || input<0 )
     set(hObject,'String','0')
end
guidata(hObject, handles);
% --- Executes during object creation, after setting all properties.
function input1_editText_CreateFcn(hObject, eventdata, handles)
% hObject    handle to input1_editText (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: edit controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
function input2_editText_Callback(hObject, eventdata, handles)
% hObject    handle to input2_editText (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
% Hints: get(hObject,'String') returns contents of input2_editText as text
%        str2double(get(hObject,'String')) returns contents of input2_editText as a double
%store the contents of input1_editText as a string. if the string
%is not a number then input will be empty
input = str2num(get(hObject,'String'));
%checks to see if input is empty. if so, default input1_editText to zero
if (isempty(input) || input>1 || input<0 )
     set(hObject,'String','0')
end
guidata(hObject, handles);
% --- Executes during object creation, after setting all properties.
function input2_editText_CreateFcn(hObject, eventdata, handles)
% hObject    handle to input2_editText (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called
% Hint: edit controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
function edit4_Callback(hObject, eventdata, handles)
% hObject    handle to edit4 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: get(hObject,'String') returns contents of edit4 as text
%        str2double(get(hObject,'String')) returns contents of edit4 as a double
% --- Executes during object creation, after setting all properties.
function edit4_CreateFcn(hObject, eventdata, handles)
% hObject    handle to edit4 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called
% Hint: edit controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
function edit5_Callback(hObject, eventdata, handles)
% hObject    handle to edit5 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: get(hObject,'String') returns contents of edit5 as text
%        str2double(get(hObject,'String')) returns contents of edit5 as a double
% --- Executes during object creation, after setting all properties.
function edit5_CreateFcn(hObject, eventdata, handles)
% hObject    handle to edit5 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called
% Hint: edit controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
function input3_editText_Callback(hObject, eventdata, handles)
% hObject    handle to input3_editText (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
% Hints: get(hObject,'String') returns contents of input3_editText as text
%        str2double(get(hObject,'String')) returns contents of input3_editText as a double
%store the contents of input1_editText as a string. if the string
%is not a number then input will be empty
input = str2num(get(hObject,'String'));

%checks to see if input is empty. if so, default input1_editText to zero
if (isempty(input) || input>1 || input<0 )
     set(hObject,'String','0')
```

```
end
guidata(hObject, handles);


% --- Executes during object creation, after setting all properties.
function input3_editText_CreateFcn(hObject, eventdata, handles)
% hObject    handle to input3_editText (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: edit controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
function input4_editText_Callback(hObject, eventdata, handles)
% hObject    handle to input4_editText (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
% Hints: get(hObject,'String') returns contents of input4_editText as text
%        str2double(get(hObject,'String')) returns contents of input4_editText as a double
%store the contents of input1_editText as a string. if the string
%is not a number then input will be empty
input = str2num(get(hObject,'String'));

%checks to see if input is empty. if so, default input1_editText to zero
if (isempty(input) || input>1 || input<0 )
     set(hObject,'String','0')
end
guidata(hObject, handles);
% --- Executes during object creation, after setting all properties.
function input4_editText_CreateFcn(hObject, eventdata, handles)
% hObject    handle to input4_editText (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: edit controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
% --- Executes on button press in buffer_pushbutton.
function buffer_pushbutton_Callback(hObject, eventdata, handles)
% hObject    handle to buffer_pushbutton (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
% duration = get(handles.input1_editText,'String');
% b.degree = get(handles.input2_editText,'String');
% u.level = get(handles.input3_editText,'String');
% i.degree = get(handles.input4_editText,'String');
% % a and b are variables of Strings type, and need to be converted
% % to variables of Number type before they can be added together
%
% duration = str2num(duration);  %#ok<ST2NM>
% b.degree = str2num(b.degree); %#ok<ST2NM>
% u.level = str2num(u.level); %#ok<ST2NM>
% i.degree = str2num(i.degree); %#ok<ST2NM>
if (get(handles.duration_popupmenu,'Value')==1) && (get(handles.duration1_popupmenu,'Value')==1)
    duration = 0;
elseif (get(handles.duration_popupmenu,'Value')==1) && (get(handles.duration1_popupmenu,'Value')==2)
    duration = 0.1;
elseif (get(handles.duration_popupmenu,'Value')==1) && (get(handles.duration1_popupmenu,'Value')==3)
    duration = 0.15;
elseif (get(handles.duration_popupmenu,'Value')==1) && (get(handles.duration1_popupmenu,'Value')==4)
    duration = 0.2;
elseif (get(handles.duration_popupmenu,'Value')==1) && (get(handles.duration1_popupmenu,'Value')==5)
    duration = 0.3;
elseif (get(handles.duration_popupmenu,'Value')==2) && (get(handles.duration1_popupmenu,'Value')==1)
    duration = 0.1;
elseif (get(handles.duration_popupmenu,'Value')==2) && (get(handles.duration1_popupmenu,'Value')==2)
    duration = 0.2;
elseif (get(handles.duration_popupmenu,'Value')==2) && (get(handles.duration1_popupmenu,'Value')==3)
    duration = 0.3;
elseif (get(handles.duration_popupmenu,'Value')==2) && (get(handles.duration1_popupmenu,'Value')==4)
    duration = 0.4;
elseif (get(handles.duration_popupmenu,'Value')==2) && (get(handles.duration1_popupmenu,'Value')==5)
    duration = 0.5;
elseif (get(handles.duration_popupmenu,'Value')==3) && (get(handles.duration1_popupmenu,'Value')==1)
    duration = 0.3;
elseif (get(handles.duration_popupmenu,'Value')==3) && (get(handles.duration1_popupmenu,'Value')==2)
    duration = 0.4;
elseif (get(handles.duration_popupmenu,'Value')==3) && (get(handles.duration1_popupmenu,'Value')==3)
    duration = 0.5;
elseif (get(handles.duration_popupmenu,'Value')==3) && (get(handles.duration1_popupmenu,'Value')==4)
    duration = 0.6;
elseif (get(handles.duration_popupmenu,'Value')==3) && (get(handles.duration1_popupmenu,'Value')==5)
    duration = 0.7;
elseif (get(handles.duration_popupmenu,'Value')==4) && (get(handles.duration1_popupmenu,'Value')==1)
    duration = 0.5;
elseif (get(handles.duration_popupmenu,'Value')==4) && (get(handles.duration1_popupmenu,'Value')==2)
    duration = 0.6;
elseif (get(handles.duration_popupmenu,'Value')==4) && (get(handles.duration1_popupmenu,'Value')==3)
    duration = 0.7;
elseif (get(handles.duration_popupmenu,'Value')==4) && (get(handles.duration1_popupmenu,'Value')==4)
    duration = 0.8;
elseif (get(handles.duration_popupmenu,'Value')==4) && (get(handles.duration1_popupmenu,'Value')==5)
    duration = 0.9;
elseif (get(handles.duration_popupmenu,'Value')==5) && (get(handles.duration1_popupmenu,'Value')==1)
    duration = 0.7;
elseif (get(handles.duration_popupmenu,'Value')==5) && (get(handles.duration1_popupmenu,'Value')==2)
```

```
    duration = 0.8;
elseif (get(handles.duration_popupmenu,'Value')==5) && (get(handles.duration1_popupmenu,'Value')==3)
    duration = 0.85;
elseif (get(handles.duration_popupmenu,'Value')==5) && (get(handles.duration1_popupmenu,'Value')==4)
    duration = 0.9;
elseif (get(handles.duration_popupmenu,'Value')==5) && (get(handles.duration1_popupmenu,'Value')==5)
    duration = 1;
end

if (get(handles.bdegree_popupmenu,'Value')==1) && (get(handles.bdegree1_popupmenu,'Value')==1)
    b.degree = 0;
elseif (get(handles.bdegree_popupmenu,'Value')==1) && (get(handles.bdegree1_popupmenu,'Value')==2)
    b.degree = 0.1;
elseif (get(handles.bdegree_popupmenu,'Value')==1) && (get(handles.bdegree1_popupmenu,'Value')==3)
    b.degree = 0.15;
elseif (get(handles.bdegree_popupmenu,'Value')==1) && (get(handles.bdegree1_popupmenu,'Value')==4)
    b.degree = 0.2;
elseif (get(handles.bdegree_popupmenu,'Value')==1) && (get(handles.bdegree1_popupmenu,'Value')==5)
    b.degree = 0.3;
elseif (get(handles.bdegree_popupmenu,'Value')==2) && (get(handles.bdegree1_popupmenu,'Value')==1)
    b.degree = 0.1;
elseif (get(handles.bdegree_popupmenu,'Value')==2) && (get(handles.bdegree1_popupmenu,'Value')==2)
    b.degree = 0.2;
elseif (get(handles.bdegree_popupmenu,'Value')==2) && (get(handles.bdegree1_popupmenu,'Value')==3)
    b.degree = 0.3;
elseif (get(handles.bdegree_popupmenu,'Value')==2) && (get(handles.bdegree1_popupmenu,'Value')==4)
    b.degree = 0.4;
elseif (get(handles.bdegree_popupmenu,'Value')==2) && (get(handles.bdegree1_popupmenu,'Value')==5)
    b.degree = 0.5;
elseif (get(handles.bdegree_popupmenu,'Value')==3) && (get(handles.bdegree1_popupmenu,'Value')==1)
    b.degree = 0.3;
elseif (get(handles.bdegree_popupmenu,'Value')==3) && (get(handles.bdegree1_popupmenu,'Value')==2)
    b.degree = 0.4;
elseif (get(handles.bdegree_popupmenu,'Value')==3) && (get(handles.bdegree1_popupmenu,'Value')==3)
    b.degree = 0.5;
elseif (get(handles.bdegree_popupmenu,'Value')==3) && (get(handles.bdegree1_popupmenu,'Value')==4)
    b.degree = 0.6;
elseif (get(handles.bdegree_popupmenu,'Value')==3) && (get(handles.bdegree1_popupmenu,'Value')==5)
    b.degree = 0.7;
elseif (get(handles.bdegree_popupmenu,'Value')==4) && (get(handles.bdegree1_popupmenu,'Value')==1)
    b.degree = 0.5;
elseif (get(handles.bdegree_popupmenu,'Value')==4) && (get(handles.bdegree1_popupmenu,'Value')==2)
    b.degree = 0.6;
elseif (get(handles.bdegree_popupmenu,'Value')==4) && (get(handles.bdegree1_popupmenu,'Value')==3)
    b.degree = 0.7;
elseif (get(handles.bdegree_popupmenu,'Value')==4) && (get(handles.bdegree1_popupmenu,'Value')==4)
    b.degree = 0.8;
elseif (get(handles.bdegree_popupmenu,'Value')==4) && (get(handles.bdegree1_popupmenu,'Value')==5)
    b.degree = 0.9;
elseif (get(handles.bdegree_popupmenu,'Value')==5) && (get(handles.bdegree1_popupmenu,'Value')==1)
    b.degree = 0.7;
elseif (get(handles.bdegree_popupmenu,'Value')==5) && (get(handles.bdegree1_popupmenu,'Value')==2)
    b.degree = 0.8;
elseif (get(handles.bdegree_popupmenu,'Value')==5) && (get(handles.bdegree1_popupmenu,'Value')==3)
    b.degree = 0.85;
elseif (get(handles.bdegree_popupmenu,'Value')==5) && (get(handles.bdegree1_popupmenu,'Value')==4)
    b.degree = 0.9;
elseif (get(handles.bdegree_popupmenu,'Value')==5) && (get(handles.bdegree1_popupmenu,'Value')==5)
    b.degree = 1;
end

if (get(handles.ulevel_popupmenu,'Value')==1) && (get(handles.ulevel1_popupmenu,'Value')==1)
    u.level = 0;
elseif (get(handles.ulevel_popupmenu,'Value')==1) && (get(handles.ulevel1_popupmenu,'Value')==2)
    u.level = 0.1;
elseif (get(handles.ulevel_popupmenu,'Value')==1) && (get(handles.ulevel1_popupmenu,'Value')==3)
    u.level = 0.15;
elseif (get(handles.ulevel_popupmenu,'Value')==1) && (get(handles.ulevel1_popupmenu,'Value')==4)
    u.level = 0.2;
elseif (get(handles.ulevel_popupmenu,'Value')==1) && (get(handles.ulevel1_popupmenu,'Value')==5)
    u.level = 0.3;
elseif (get(handles.ulevel_popupmenu,'Value')==2) && (get(handles.ulevel1_popupmenu,'Value')==1)
    u.level = 0.1;
elseif (get(handles.ulevel_popupmenu,'Value')==2) && (get(handles.ulevel1_popupmenu,'Value')==2)
    u.level = 0.2;
elseif (get(handles.ulevel_popupmenu,'Value')==2) && (get(handles.ulevel1_popupmenu,'Value')==3)
    u.level = 0.3;
elseif (get(handles.ulevel_popupmenu,'Value')==2) && (get(handles.ulevel1_popupmenu,'Value')==4)
    u.level = 0.4;
elseif (get(handles.ulevel_popupmenu,'Value')==2) && (get(handles.ulevel1_popupmenu,'Value')==5)
    u.level = 0.5;
elseif (get(handles.ulevel_popupmenu,'Value')==3) && (get(handles.ulevel1_popupmenu,'Value')==1)
    u.level = 0.3;
elseif (get(handles.ulevel_popupmenu,'Value')==3) && (get(handles.ulevel1_popupmenu,'Value')==2)
    u.level = 0.4;
elseif (get(handles.ulevel_popupmenu,'Value')==3) && (get(handles.ulevel1_popupmenu,'Value')==3)
    u.level = 0.5;
elseif (get(handles.ulevel_popupmenu,'Value')==3) && (get(handles.ulevel1_popupmenu,'Value')==4)
    u.level = 0.6;
elseif (get(handles.ulevel_popupmenu,'Value')==3) && (get(handles.ulevel1_popupmenu,'Value')==5)
    u.level = 0.7;
elseif (get(handles.ulevel_popupmenu,'Value')==4) && (get(handles.ulevel1_popupmenu,'Value')==1)
    u.level = 0.5;
elseif (get(handles.ulevel_popupmenu,'Value')==4) && (get(handles.ulevel1_popupmenu,'Value')==2)
    u.level = 0.6;
elseif (get(handles.ulevel_popupmenu,'Value')==4) && (get(handles.ulevel1_popupmenu,'Value')==3)
    u.level = 0.7;
elseif (get(handles.ulevel_popupmenu,'Value')==4) && (get(handles.ulevel1_popupmenu,'Value')==4)
    u.level = 0.8;
elseif (get(handles.ulevel_popupmenu,'Value')==4) && (get(handles.ulevel1_popupmenu,'Value')==5)
```

```
    u.level = 0.9;
elseif (get(handles.ulevel_popupmenu,'Value')==5) && (get(handles.ulevel1_popupmenu,'Value')==1)
    u.level = 0.7;
elseif (get(handles.ulevel_popupmenu,'Value')==5) && (get(handles.ulevel1_popupmenu,'Value')==2)
    u.level = 0.8;
elseif (get(handles.ulevel_popupmenu,'Value')==5) && (get(handles.ulevel1_popupmenu,'Value')==3)
    u.level = 0.85;
elseif (get(handles.ulevel_popupmenu,'Value')==5) && (get(handles.ulevel1_popupmenu,'Value')==4)
    u.level = 0.9;
elseif (get(handles.ulevel_popupmenu,'Value')==5) && (get(handles.ulevel1_popupmenu,'Value')==5)
    u.level = 1;
end

if (get(handles.idegree_popupmenu,'Value')==1) && (get(handles.idegree1_popupmenu,'Value')==1)
    i.degree = 0;
elseif (get(handles.idegree_popupmenu,'Value')==1) && (get(handles.idegree1_popupmenu,'Value')==2)
    i.degree = 0.1;
elseif (get(handles.idegree_popupmenu,'Value')==1) && (get(handles.idegree1_popupmenu,'Value')==3)
    i.degree = 0.15;
elseif (get(handles.idegree_popupmenu,'Value')==1) && (get(handles.idegree1_popupmenu,'Value')==4)
    i.degree = 0.2;
elseif (get(handles.idegree_popupmenu,'Value')==1) && (get(handles.idegree1_popupmenu,'Value')==5)
    i.degree = 0.3;
elseif (get(handles.idegree_popupmenu,'Value')==2) && (get(handles.idegree1_popupmenu,'Value')==1)
    i.degree = 0.1;
elseif (get(handles.idegree_popupmenu,'Value')==2) && (get(handles.idegree1_popupmenu,'Value')==2)
    i.degree = 0.2;
elseif (get(handles.idegree_popupmenu,'Value')==2) && (get(handles.idegree1_popupmenu,'Value')==3)
    i.degree = 0.3;
elseif (get(handles.idegree_popupmenu,'Value')==2) && (get(handles.idegree1_popupmenu,'Value')==4)
    i.degree = 0.4;
elseif (get(handles.idegree_popupmenu,'Value')==2) && (get(handles.idegree1_popupmenu,'Value')==5)
    i.degree = 0.5;
elseif (get(handles.idegree_popupmenu,'Value')==3) && (get(handles.idegree1_popupmenu,'Value')==1)
    i.degree = 0.3;
elseif (get(handles.idegree_popupmenu,'Value')==3) && (get(handles.idegree1_popupmenu,'Value')==2)
    i.degree = 0.4;
elseif (get(handles.idegree_popupmenu,'Value')==3) && (get(handles.idegree1_popupmenu,'Value')==3)
    i.degree = 0.5;
elseif (get(handles.idegree_popupmenu,'Value')==3) && (get(handles.idegree1_popupmenu,'Value')==4)
    i.degree = 0.6;
elseif (get(handles.idegree_popupmenu,'Value')==3) && (get(handles.idegree1_popupmenu,'Value')==5)
    i.degree = 0.7;
elseif (get(handles.idegree_popupmenu,'Value')==4) && (get(handles.idegree1_popupmenu,'Value')==1)
    i.degree = 0.5;
elseif (get(handles.idegree_popupmenu,'Value')==4) && (get(handles.idegree1_popupmenu,'Value')==2)
    i.degree = 0.6;
elseif (get(handles.idegree_popupmenu,'Value')==4) && (get(handles.idegree1_popupmenu,'Value')==3)
    i.degree = 0.7;
elseif (get(handles.idegree_popupmenu,'Value')==4) && (get(handles.idegree1_popupmenu,'Value')==4)
    i.degree = 0.8;
elseif (get(handles.idegree_popupmenu,'Value')==4) && (get(handles.idegree1_popupmenu,'Value')==5)
    i.degree = 0.9;
elseif (get(handles.idegree_popupmenu,'Value')==5) && (get(handles.idegree1_popupmenu,'Value')==1)
    i.degree = 0.7;
elseif (get(handles.idegree_popupmenu,'Value')==5) && (get(handles.idegree1_popupmenu,'Value')==2)
    i.degree = 0.8;
elseif (get(handles.idegree_popupmenu,'Value')==5) && (get(handles.idegree1_popupmenu,'Value')==3)
    i.degree = 0.85;
elseif (get(handles.idegree_popupmenu,'Value')==5) && (get(handles.idegree1_popupmenu,'Value')==4)
    i.degree = 0.9;
elseif (get(handles.idegree_popupmenu,'Value')==5) && (get(handles.idegree1_popupmenu,'Value')==5)
    i.degree = 1;
end


% duration = get(handles.input1_editText,'String');
% b.degree = get(handles.input2_editText,'String');
% u.level = get(handles.input3_editText,'String');
% i.degree = get(handles.input4_editText,'String');
% % a and b are variables of Strings type, and need to be converted
% % to variables of Number type before they can be added together
%
% duration = str2num(duration);  %#ok<ST2NM>
% b.degree = str2num(b.degree); %#ok<ST2NM>
% u.level = str2num(u.level); %#ok<ST2NM>
% i.degree = str2num(i.degree); %#ok<ST2NM>

readfile = readfis('FLBM5');
buffer1 = evalfis([duration b.degree u.level i.degree], readfile);
buffer = num2str(buffer1);
% print output to buffer, convert it to a string and print using the below
% given code
set(handles.answer_staticText,'String',buffer);
guidata(hObject, handles);


% --- Executes on button press in plot_pushbutton.
% function plot_pushbutton_Callback(hObject, eventdata, handles)
% hObject    handle to plot_pushbutton (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
% hObject    handle to buffer_pushbutton (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
% duration = get(handles.input1_editText,'String');
% b.degree = get(handles.input2_editText,'String');
% u.level = get(handles.input3_editText,'String');
% i.degree = get(handles.input4_editText,'String');
% % a and b are variables of Strings type, and need to be converted
```

```
% % to variables of Number type before they can be added together
%
% duration = str2num(duration);  %#ok<ST2NM>
% b.degree = str2num(b.degree); %#ok<ST2NM>
% u.level = str2num(u.level); %#ok<ST2NM>
% i.degree = str2num(i.degree); %#ok<ST2NM>
%
% plotfile = readfis('FLBM5');
% subplot(5,2,0),plotfis(plotfile);
%
% guidata(hObject, handles);
% --- Executes on button press in MF_pushbutton.
function MF_pushbutton_Callback(hObject, eventdata, handles)
% hObject    handle to MF_pushbutton (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
% duration = get(handles.input1_editText,'String');
% b.degree = get(handles.input2_editText,'String');
% u.level = get(handles.input3_editText,'String');
% i.degree = get(handles.input4_editText,'String');
% % a and b are variables of Strings type, and need to be converted
% % to variables of Number type before they can be added together
%
% duration = str2num(duration);  %#ok<ST2NM>
% b.degree = str2num(b.degree); %#ok<ST2NM>
% u.level = str2num(u.level); %#ok<ST2NM>
% i.degree = str2num(i.degree); %#ok<ST2NM>

plotmemf = readfis('FLBM5');
subplot(5,3,3),plotmf(plotmemf,'input',1);
subplot(5,3,6),plotmf(plotmemf,'input',2);
subplot(5,3,9),plotmf(plotmemf,'input',3);
subplot(5,3,12),plotmf(plotmemf,'input',4);
subplot(5,3,15),plotmf(plotmemf,'output',1);
guidata(hObject, handles);
% --- Executes on button press in surface_pushbutton.
function surface_pushbutton_Callback(hObject, eventdata, handles)
% hObject    handle to surface_pushbutton (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
% duration = get(handles.input1_editText,'String');
% b.degree = get(handles.input2_editText,'String');
% u.level = get(handles.input3_editText,'String');
% i.degree = get(handles.input4_editText,'String');
% % a and b are variables of Strings type, and need to be converted
% % to variables of Number type before they can be added together
%
% duration = str2num(duration);  %#ok<ST2NM>
% b.degree = str2num(b.degree); %#ok<ST2NM>
% u.level = str2num(u.level); %#ok<ST2NM>
% i.degree = str2num(i.degree); %#ok<ST2NM>

if (get(handles.duration_popupmenu,'Value')==1) && (get(handles.duration1_popupmenu,'Value')==1)
    duration = 0;
elseif (get(handles.duration_popupmenu,'Value')==1) && (get(handles.duration1_popupmenu,'Value')==2)
    duration = 0.075;
elseif (get(handles.duration_popupmenu,'Value')==1) && (get(handles.duration1_popupmenu,'Value')==3)
    duration = 0.15;
elseif (get(handles.duration_popupmenu,'Value')==1) && (get(handles.duration1_popupmenu,'Value')==4)
    duration = 0.225;
elseif (get(handles.duration_popupmenu,'Value')==1) && (get(handles.duration1_popupmenu,'Value')==5)
    duration = 0.3;
elseif (get(handles.duration_popupmenu,'Value')==2) && (get(handles.duration1_popupmenu,'Value')==1)
    duration = 0.1;
elseif (get(handles.duration_popupmenu,'Value')==2) && (get(handles.duration1_popupmenu,'Value')==2)
    duration = 0.2;
elseif (get(handles.duration_popupmenu,'Value')==2) && (get(handles.duration1_popupmenu,'Value')==3)
    duration = 0.3;
elseif (get(handles.duration_popupmenu,'Value')==2) && (get(handles.duration1_popupmenu,'Value')==4)
    duration = 0.4;
elseif (get(handles.duration_popupmenu,'Value')==2) && (get(handles.duration1_popupmenu,'Value')==5)
    duration = 0.5;
elseif (get(handles.duration_popupmenu,'Value')==3) && (get(handles.duration1_popupmenu,'Value')==1)
    duration = 0.3;
elseif (get(handles.duration_popupmenu,'Value')==3) && (get(handles.duration1_popupmenu,'Value')==2)
    duration = 0.4;
elseif (get(handles.duration_popupmenu,'Value')==3) && (get(handles.duration1_popupmenu,'Value')==3)
    duration = 0.5;
elseif (get(handles.duration_popupmenu,'Value')==3) && (get(handles.duration1_popupmenu,'Value')==4)
    duration = 0.6;
elseif (get(handles.duration_popupmenu,'Value')==3) && (get(handles.duration1_popupmenu,'Value')==5)
    duration = 0.7;
elseif (get(handles.duration_popupmenu,'Value')==4) && (get(handles.duration1_popupmenu,'Value')==1)
    duration = 0.3;
elseif (get(handles.duration_popupmenu,'Value')==4) && (get(handles.duration1_popupmenu,'Value')==2)
    duration = 0.4;
elseif (get(handles.duration_popupmenu,'Value')==4) && (get(handles.duration1_popupmenu,'Value')==3)
    duration = 0.5;
elseif (get(handles.duration_popupmenu,'Value')==4) && (get(handles.duration1_popupmenu,'Value')==4)
    duration = 0.6;
elseif (get(handles.duration_popupmenu,'Value')==4) && (get(handles.duration1_popupmenu,'Value')==5)
    duration = 0.7;
elseif (get(handles.duration_popupmenu,'Value')==5) && (get(handles.duration1_popupmenu,'Value')==1)
    duration = 0.7;
elseif (get(handles.duration_popupmenu,'Value')==5) && (get(handles.duration1_popupmenu,'Value')==2)
    duration = 0.775;
elseif (get(handles.duration_popupmenu,'Value')==5) && (get(handles.duration1_popupmenu,'Value')==3)
    duration = 0.85;
elseif (get(handles.duration_popupmenu,'Value')==5) && (get(handles.duration1_popupmenu,'Value')==4)
    duration = 0.925;
```

```
elseif (get(handles.duration_popupmenu,'Value')==5) && (get(handles.duration1_popupmenu,'Value')==5)
    duration = 1;
end

if (get(handles.bdegree_popupmenu,'Value')==1) && (get(handles.bdegree1_popupmenu,'Value')==1)
    b.degree = 0;
elseif (get(handles.bdegree_popupmenu,'Value')==1) && (get(handles.bdegree1_popupmenu,'Value')==2)
    b.degree = 0.075;
elseif (get(handles.bdegree_popupmenu,'Value')==1) && (get(handles.bdegree1_popupmenu,'Value')==3)
    b.degree = 0.15;
elseif (get(handles.bdegree_popupmenu,'Value')==1) && (get(handles.bdegree1_popupmenu,'Value')==4)
    b.degree = 0.225;
elseif (get(handles.bdegree_popupmenu,'Value')==1) && (get(handles.bdegree1_popupmenu,'Value')==5)
    b.degree = 0.3;
elseif (get(handles.bdegree_popupmenu,'Value')==2) && (get(handles.bdegree1_popupmenu,'Value')==1)
    b.degree = 0.1;
elseif (get(handles.bdegree_popupmenu,'Value')==2) && (get(handles.bdegree1_popupmenu,'Value')==2)
    b.degree = 0.2;
elseif (get(handles.bdegree_popupmenu,'Value')==2) && (get(handles.bdegree1_popupmenu,'Value')==3)
    b.degree = 0.3;
elseif (get(handles.bdegree_popupmenu,'Value')==2) && (get(handles.bdegree1_popupmenu,'Value')==4)
    b.degree = 0.4;
elseif (get(handles.bdegree_popupmenu,'Value')==2) && (get(handles.bdegree1_popupmenu,'Value')==5)
    b.degree = 0.5;
elseif (get(handles.bdegree_popupmenu,'Value')==3) && (get(handles.bdegree1_popupmenu,'Value')==1)
    b.degree = 0.3;
elseif (get(handles.bdegree_popupmenu,'Value')==3) && (get(handles.bdegree1_popupmenu,'Value')==2)
    b.degree = 0.4;
elseif (get(handles.bdegree_popupmenu,'Value')==3) && (get(handles.bdegree1_popupmenu,'Value')==3)
    b.degree = 0.5;
elseif (get(handles.bdegree_popupmenu,'Value')==3) && (get(handles.bdegree1_popupmenu,'Value')==4)
    b.degree = 0.6;
elseif (get(handles.bdegree_popupmenu,'Value')==3) && (get(handles.bdegree1_popupmenu,'Value')==5)
    b.degree = 0.7;
elseif (get(handles.bdegree_popupmenu,'Value')==4) && (get(handles.bdegree1_popupmenu,'Value')==1)
    b.degree = 0.3;
elseif (get(handles.bdegree_popupmenu,'Value')==4) && (get(handles.bdegree1_popupmenu,'Value')==2)
    b.degree = 0.4;
elseif (get(handles.bdegree_popupmenu,'Value')==4) && (get(handles.bdegree1_popupmenu,'Value')==3)
    b.degree = 0.5;
elseif (get(handles.bdegree_popupmenu,'Value')==4) && (get(handles.bdegree1_popupmenu,'Value')==4)
    b.degree = 0.6;
elseif (get(handles.bdegree_popupmenu,'Value')==4) && (get(handles.bdegree1_popupmenu,'Value')==5)
    b.degree = 0.7;
elseif (get(handles.bdegree_popupmenu,'Value')==5) && (get(handles.bdegree1_popupmenu,'Value')==1)
    b.degree = 0.7;
elseif (get(handles.bdegree_popupmenu,'Value')==5) && (get(handles.bdegree1_popupmenu,'Value')==2)
    b.degree = 0.775;
elseif (get(handles.bdegree_popupmenu,'Value')==5) && (get(handles.bdegree1_popupmenu,'Value')==3)
    b.degree = 0.85;
elseif (get(handles.bdegree_popupmenu,'Value')==5) && (get(handles.bdegree1_popupmenu,'Value')==4)
    b.degree = 0.925;
elseif (get(handles.bdegree_popupmenu,'Value')==5) && (get(handles.bdegree1_popupmenu,'Value')==5)
    b.degree = 1;
end

if (get(handles.ulevel_popupmenu,'Value')==1) && (get(handles.ulevel1_popupmenu,'Value')==1)
    u.level = 0;
elseif (get(handles.ulevel_popupmenu,'Value')==1) && (get(handles.ulevel1_popupmenu,'Value')==2)
    u.level = 0.075;
elseif (get(handles.ulevel_popupmenu,'Value')==1) && (get(handles.ulevel1_popupmenu,'Value')==3)
    u.level = 0.15;
elseif (get(handles.ulevel_popupmenu,'Value')==1) && (get(handles.ulevel1_popupmenu,'Value')==4)
    u.level = 0.225;
elseif (get(handles.ulevel_popupmenu,'Value')==1) && (get(handles.ulevel1_popupmenu,'Value')==5)
    u.level = 0.3;
elseif (get(handles.ulevel_popupmenu,'Value')==2) && (get(handles.ulevel1_popupmenu,'Value')==1)
    u.level = 0.1;
elseif (get(handles.ulevel_popupmenu,'Value')==2) && (get(handles.ulevel1_popupmenu,'Value')==2)
    u.level = 0.2;
elseif (get(handles.ulevel_popupmenu,'Value')==2) && (get(handles.ulevel1_popupmenu,'Value')==3)
    u.level = 0.3;
elseif (get(handles.ulevel_popupmenu,'Value')==2) && (get(handles.ulevel1_popupmenu,'Value')==4)
    u.level = 0.4;
elseif (get(handles.ulevel_popupmenu,'Value')==2) && (get(handles.ulevel1_popupmenu,'Value')==5)
    u.level = 0.5;
elseif (get(handles.ulevel_popupmenu,'Value')==3) && (get(handles.ulevel1_popupmenu,'Value')==1)
    u.level = 0.3;
elseif (get(handles.ulevel_popupmenu,'Value')==3) && (get(handles.ulevel1_popupmenu,'Value')==2)
    u.level = 0.4;
elseif (get(handles.ulevel_popupmenu,'Value')==3) && (get(handles.ulevel1_popupmenu,'Value')==3)
    u.level = 0.5;
elseif (get(handles.ulevel_popupmenu,'Value')==3) && (get(handles.ulevel1_popupmenu,'Value')==4)
    u.level = 0.6;
elseif (get(handles.ulevel_popupmenu,'Value')==3) && (get(handles.ulevel1_popupmenu,'Value')==5)
    u.level = 0.7;
elseif (get(handles.ulevel_popupmenu,'Value')==4) && (get(handles.ulevel1_popupmenu,'Value')==1)
    u.level = 0.3;
elseif (get(handles.ulevel_popupmenu,'Value')==4) && (get(handles.ulevel1_popupmenu,'Value')==2)
    u.level = 0.4;
elseif (get(handles.ulevel_popupmenu,'Value')==4) && (get(handles.ulevel1_popupmenu,'Value')==3)
    u.level = 0.5;
elseif (get(handles.ulevel_popupmenu,'Value')==4) && (get(handles.ulevel1_popupmenu,'Value')==4)
    u.level = 0.6;
elseif (get(handles.ulevel_popupmenu,'Value')==4) && (get(handles.ulevel1_popupmenu,'Value')==5)
    u.level = 0.7;
elseif (get(handles.ulevel_popupmenu,'Value')==5) && (get(handles.ulevel1_popupmenu,'Value')==1)
    u.level = 0.7;
elseif (get(handles.ulevel_popupmenu,'Value')==5) && (get(handles.ulevel1_popupmenu,'Value')==2)
    u.level = 0.775;
```

```
elseif (get(handles.ulevel_popupmenu,'Value')==5) && (get(handles.ulevel1_popupmenu,'Value')==3)
    u.level = 0.85;
elseif (get(handles.ulevel_popupmenu,'Value')==5) && (get(handles.ulevel1_popupmenu,'Value')==4)
    u.level = 0.925;
elseif (get(handles.ulevel_popupmenu,'Value')==5) && (get(handles.ulevel1_popupmenu,'Value')==5)
    u.level = 1;
end

if (get(handles.idegree_popupmenu,'Value')==1) && (get(handles.idegree1_popupmenu,'Value')==1)
    i.degree = 0;
elseif (get(handles.idegree_popupmenu,'Value')==1) && (get(handles.idegree1_popupmenu,'Value')==2)
    i.degree = 0.075;
elseif (get(handles.idegree_popupmenu,'Value')==1) && (get(handles.idegree1_popupmenu,'Value')==3)
    i.degree = 0.15;
elseif (get(handles.idegree_popupmenu,'Value')==1) && (get(handles.idegree1_popupmenu,'Value')==4)
    i.degree = 0.225;
elseif (get(handles.idegree_popupmenu,'Value')==1) && (get(handles.idegree1_popupmenu,'Value')==5)
    i.degree = 0.3;
elseif (get(handles.idegree_popupmenu,'Value')==2) && (get(handles.idegree1_popupmenu,'Value')==1)
    i.degree = 0.1;
elseif (get(handles.idegree_popupmenu,'Value')==2) && (get(handles.idegree1_popupmenu,'Value')==2)
    i.degree = 0.2;
elseif (get(handles.idegree_popupmenu,'Value')==2) && (get(handles.idegree1_popupmenu,'Value')==3)
    i.degree = 0.3;
elseif (get(handles.idegree_popupmenu,'Value')==2) && (get(handles.idegree1_popupmenu,'Value')==4)
    i.degree = 0.4;
elseif (get(handles.idegree_popupmenu,'Value')==2) && (get(handles.idegree1_popupmenu,'Value')==5)
    i.degree = 0.5;
elseif (get(handles.idegree_popupmenu,'Value')==3) && (get(handles.idegree1_popupmenu,'Value')==1)
    i.degree = 0.3;
elseif (get(handles.idegree_popupmenu,'Value')==3) && (get(handles.idegree1_popupmenu,'Value')==2)
    i.degree = 0.4;
elseif (get(handles.idegree_popupmenu,'Value')==3) && (get(handles.idegree1_popupmenu,'Value')==3)
    i.degree = 0.5;
elseif (get(handles.idegree_popupmenu,'Value')==3) && (get(handles.idegree1_popupmenu,'Value')==4)
    i.degree = 0.6;
elseif (get(handles.idegree_popupmenu,'Value')==3) && (get(handles.idegree1_popupmenu,'Value')==5)
    i.degree = 0.7;
elseif (get(handles.idegree_popupmenu,'Value')==4) && (get(handles.idegree1_popupmenu,'Value')==1)
    i.degree = 0.3;
elseif (get(handles.idegree_popupmenu,'Value')==4) && (get(handles.idegree1_popupmenu,'Value')==2)
    i.degree = 0.4;
elseif (get(handles.idegree_popupmenu,'Value')==4) && (get(handles.idegree1_popupmenu,'Value')==3)
    i.degree = 0.5;
elseif (get(handles.idegree_popupmenu,'Value')==4) && (get(handles.idegree1_popupmenu,'Value')==4)
    i.degree = 0.6;
elseif (get(handles.idegree_popupmenu,'Value')==4) && (get(handles.idegree1_popupmenu,'Value')==5)
    i.degree = 0.7;
elseif (get(handles.idegree_popupmenu,'Value')==5) && (get(handles.idegree1_popupmenu,'Value')==1)
    i.degree = 0.7;
elseif (get(handles.idegree_popupmenu,'Value')==5) && (get(handles.idegree1_popupmenu,'Value')==2)
    i.degree = 0.775;
elseif (get(handles.idegree_popupmenu,'Value')==5) && (get(handles.idegree1_popupmenu,'Value')==3)
    i.degree = 0.85;
elseif (get(handles.idegree_popupmenu,'Value')==5) && (get(handles.idegree1_popupmenu,'Value')==4)
    i.degree = 0.925;
elseif (get(handles.idegree_popupmenu,'Value')==5) && (get(handles.idegree1_popupmenu,'Value')==5)
    i.degree = 1;
end

plotsurface = readfis('FLBM5');
subplot(5,5,11),gensurf(plotsurface,[1 2],1,[15 15],[NaN NaN u.level i.degree]);
subplot(5,5,16),gensurf(plotsurface,[3 4],1,[15 15],[duration b.degree NaN NaN]);
subplot(5,5,13),gensurf(plotsurface,[3 1],1,[15 15],[duration NaN u.level NaN]);
subplot(5,5,21),gensurf(plotsurface,[4 2],1,[15 15],[NaN b.degree NaN i.degree]);
subplot(5,5,18),gensurf(plotsurface,[3 2],1,[15 15],[duration NaN u.level NaN]);
subplot(5,5,23),gensurf(plotsurface,[4 1],1,[15 15],[NaN b.degree u.level NaN]);
guidata(hObject, handles);
% --- Executes when figure1 is resized.
function figure1_ResizeFcn(hObject, eventdata, handles)
% hObject    handle to figure1 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
% --- Executes on selection change in duration1_popupmenu.
function duration1_popupmenu_Callback(hObject, eventdata, handles)
% hObject    handle to duration1_popupmenu (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: contents = get(hObject,'String') returns duration1_popupmenu contents as cell array
%        contents{get(hObject,'Value')} returns selected item from duration1_popupmenu
% --- Executes during object creation, after setting all properties.
function duration1_popupmenu_CreateFcn(hObject, eventdata, handles)
% hObject    handle to duration1_popupmenu (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: popupmenu controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end


% --- Executes on selection change in bdegree1_popupmenu.
function bdegree1_popupmenu_Callback(hObject, eventdata, handles)
% hObject    handle to bdegree1_popupmenu (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
```

```
% Hints: contents = get(hObject,'String') returns bdegree1_popupmenu contents as cell array
%        contents{get(hObject,'Value')} returns selected item from bdegree1_popupmenu
% --- Executes during object creation, after setting all properties.
function bdegree1_popupmenu_CreateFcn(hObject, eventdata, handles)
% hObject    handle to bdegree1_popupmenu (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: popupmenu controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end


% --- Executes on selection change in ulevel1_popupmenu.
function ulevel1_popupmenu_Callback(hObject, eventdata, handles)
% hObject    handle to ulevel1_popupmenu (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: contents = get(hObject,'String') returns ulevel1_popupmenu contents as cell array
%        contents{get(hObject,'Value')} returns selected item from ulevel1_popupmenu


% --- Executes during object creation, after setting all properties.
function ulevel1_popupmenu_CreateFcn(hObject, eventdata, handles)
% hObject    handle to ulevel1_popupmenu (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: popupmenu controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
% --- Executes on selection change in idegree1_popupmenu.
function idegree1_popupmenu_Callback(hObject, eventdata, handles)
% hObject    handle to idegree1_popupmenu (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: contents = get(hObject,'String') returns idegree1_popupmenu contents as cell array
%        contents{get(hObject,'Value')} returns selected item from idegree1_popupmenu


% --- Executes during object creation, after setting all properties.
function idegree1_popupmenu_CreateFcn(hObject, eventdata, handles)
% hObject    handle to idegree1_popupmenu (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: popupmenu controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
% --- Executes on selection change in idegree_popupmenu.
function idegree_popupmenu_Callback(hObject, eventdata, handles)
% hObject    handle to idegree_popupmenu (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: contents = get(hObject,'String') returns idegree_popupmenu contents as cell array
%        contents{get(hObject,'Value')} returns selected item from idegree_popupmenu


% --- Executes during object creation, after setting all properties.
function idegree_popupmenu_CreateFcn(hObject, eventdata, handles)
% hObject    handle to idegree_popupmenu (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: popupmenu controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
% --- Executes on selection change in ulevel_popupmenu.
function ulevel_popupmenu_Callback(hObject, eventdata, handles)
% hObject    handle to ulevel_popupmenu (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: contents = get(hObject,'String') returns ulevel_popupmenu contents as cell array
%        contents{get(hObject,'Value')} returns selected item from ulevel_popupmenu
% --- Executes during object creation, after setting all properties.
function ulevel_popupmenu_CreateFcn(hObject, eventdata, handles)
% hObject    handle to ulevel_popupmenu (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: popupmenu controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end


% --- Executes on selection change in bdegree_popupmenu.
```

```
function bdegree_popupmenu_Callback(hObject, eventdata, handles)
% hObject    handle to bdegree_popupmenu (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: contents = get(hObject,'String') returns bdegree_popupmenu contents as cell array
%        contents{get(hObject,'Value')} returns selected item from bdegree_popupmenu
% --- Executes during object creation, after setting all properties.
function bdegree_popupmenu_CreateFcn(hObject, eventdata, handles)
% hObject    handle to bdegree_popupmenu (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: popupmenu controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

% --- Executes on selection change in duration_popupmenu.
function duration_popupmenu_Callback(hObject, eventdata, handles)
% hObject    handle to duration_popupmenu (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: contents = get(hObject,'String') returns duration_popupmenu contents as cell array
%        contents{get(hObject,'Value')} returns selected item from duration_popupmenu
% --- Executes during object creation, after setting all properties.
function duration_popupmenu_CreateFcn(hObject, eventdata, handles)
% hObject    handle to duration_popupmenu (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: popupmenu controls usually have a white background on Windows.
%       See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
% --- Executes on key press with focus on bdegree_popupmenu and none of its controls.
function bdegree_popupmenu_KeyPressFcn(hObject, eventdata, handles)
% hObject    handle to bdegree_popupmenu (see GCBO)
% eventdata  structure with the following fields (see UICONTROL)
%   Key: name of the key that was pressed, in lower case
%   Character: character interpretation of the key(s) that was pressed
%   Modifier: name(s) of the modifier key(s) (i.e., control, shift) pressed
% handles    structure with handles and user data (see GUIDATA)


% --- Executes on slider movement.
function slider3_Callback(hObject, eventdata, handles)
% hObject    handle to slider3 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

% Hints: get(hObject,'Value') returns position of slider
%        get(hObject,'Min') and get(hObject,'Max') to determine range of slider


% --- Executes during object creation, after setting all properties.
function slider3_CreateFcn(hObject, eventdata, handles)
% hObject    handle to slider3 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    empty - handles not created until after all CreateFcns called

% Hint: slider controls usually have a light gray background.
if isequal(get(hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor',[.9 .9 .9]);
end
% --------------------------------------------------------------------
function Untitled_1_Callback(hObject, eventdata, handles)
% hObject    handle to Untitled_1 (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)
```

APPENDIX B: RULES USED FOR FIS OF FLBM

1. If	Duration [VS]	and	Degree of Confidence [VH]	and	Uncertainty Level [VS]	and	Degree of Influence [VS]	THEN	Buffer Time [VS]	1
2. If	Duration [VS]	and	Degree of Confidence [VH]	and	Uncertainty_Level [VS]	and	Degree of Influence [S]	THEN	Buffer_Time [VS]	1
3. If	Duration [VS]	and	Degree of Confidence [VH]	and	Uncertainty_Level [VS]	and	Degree of Influence [M]	THEN	Buffer_Time [VS]	1
4. If	Duration [VS]	and	Degree of Confidence [VH]	and	Uncertainty_Level [VS]	and	Degree of Influence [L]	THEN	Buffer_Time [S]	1
5. If	Duration [VS]	and	Degree of Confidence [VH]	and	Uncertainty_Level [VS]	and	Degree of Influence [VL]	THEN	Buffer_Time [M]	1
6. If	Duration [VS]	and	Degree of Confidence [VH]	and	Uncertainty_Level [S]	and	Degree of Influence [VS]	THEN	Buffer_Time [VS]	1
7. If	Duration [VS]	and	Degree of Confidence [VH]	and	Uncertainty_Level [S]	and	Degree of Influence [S]	THEN	Buffer_Time [VS]	1
8. If	Duration [VS]	and	Degree of Confidence [VH]	and	Uncertainty_Level [S]	and	Degree of Influence [M]	THEN	Buffer_Time [S]	1
9. If	Duration [VS]	and	Degree of Confidence [VH]	and	Uncertainty_Level [S]	and	Degree of Influence [L]	THEN	Buffer_Time [M]	1
10. If	Duration [VS]	and	Degree of Confidence [VH]	and	Uncertainty_Level [S]	and	Degree of Influence [VL]	THEN	Buffer_Time [M]	1
11. If	Duration [VS]	and	Degree of Confidence [VH]	and	Uncertainty_Level [M]	and	Degree of Influence [VS]	THEN	Buffer_Time [S]	1
12. If	Duration [VS]	and	Degree of Confidence [VH]	and	Uncertainty_Level [M]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
13. If	Duration [VS]	and	Degree of Confidence [VH]	and	Uncertainty_Level [M]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
14. If	Duration [VS]	and	Degree of Confidence [VH]	and	Uncertainty_Level [M]	and	Degree of Influence [L]	THEN	Buffer_Time [M]	1
15. If	Duration [VS]	and	Degree of Confidence [VH]	and	Uncertainty_Level [M]	and	Degree of Influence [VL]	THEN	Buffer_Time [M]	1
16. If	Duration [VS]	and	Degree of Confidence [VH]	and	Uncertainty_Level [L]	and	Degree of Influence [VS]	THEN	Buffer_Time [VS]	1
17. If	Duration [VS]	and	Degree of Confidence [VH]	and	Uncertainty_Level [L]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
18. If	Duration [VS]	and	Degree of Confidence [VH]	and	Uncertainty_Level [L]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
19. If	Duration [VS]	and	Degree of Confidence [VH]	and	Uncertainty_Level [L]	and	Degree of Influence [L]	THEN	Buffer_Time [M]	1
20. If	Duration [VS]	and	Degree of Confidence [VH]	and	Uncertainty_Level [L]	and	Degree of Influence [VL]	THEN	Buffer_Time [M]	1
21. If	Duration [VS]	and	Degree of Confidence [VH]	and	Uncertainty_Level [VL]	and	Degree of Influence [VS]	THEN	Buffer_Time [S]	1
22. If	Duration [VS]	and	Degree of Confidence [VH]	and	Uncertainty_Level [VL]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
23. If	Duration [VS]	and	Degree of Confidence [VH]	and	Uncertainty_Level [VL]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
24. If	Duration [VS]	and	Degree of Confidence [VH]	and	Uncertainty_Level [VL]	and	Degree of Influence [L]	THEN	Buffer_Time [M]	1
25. If	Duration [VS]	and	Degree of Confidence [VH]	and	Uncertainty_Level [VL]	and	Degree of Influence [VL]	THEN	Buffer_Time [L]	1
26. If	Duration [VS]	and	Degree of Confidence [H]	and	Uncertainty_Level [VS]	and	Degree of Influence [VS]	THEN	Buffer_Time [VS]	1
27. If	Duration [VS]	and	Degree of Confidence [H]	and	Uncertainty_Level [VS]	and	Degree of Influence [S]	THEN	Buffer_Time [VS]	1
28. If	Duration [VS]	and	Degree of Confidence [H]	and	Uncertainty_Level [VS]	and	Degree of Influence [M]	THEN	Buffer_Time [S]	1
29. If	Duration [VS]	and	Degree of Confidence [H]	and	Uncertainty_Level [VS]	and	Degree of Influence [L]	THEN	Buffer_Time [S]	1
30. If	Duration [VS]	and	Degree of Confidence [H]	and	Uncertainty_Level [VS]	and	Degree of Influence [VL]	THEN	Buffer_Time [M]	1
31. If	Duration [VS]	and	Degree of Confidence [H]	and	Uncertainty_Level [S]	and	Degree of Influence [VS]	THEN	Buffer_Time [VS]	1
32. If	Duration [VS]	and	Degree of Confidence [H]	and	Uncertainty_Level [S]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
33. If	Duration [VS]	and	Degree of Confidence [H]	and	Uncertainty_Level [S]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
34. If	Duration [VS]	and	Degree of Confidence [H]	and	Uncertainty_Level [S]	and	Degree of Influence [L]	THEN	Buffer_Time [M]	1
35. If	Duration [VS]	and	Degree of Confidence [H]	and	Uncertainty_Level [S]	and	Degree of Influence [VL]	THEN	Buffer_Time [M]	1
36. If	Duration [VS]	and	Degree of Confidence [H]	and	Uncertainty_Level [M]	and	Degree of Influence [VS]	THEN	Buffer_Time [S]	1
37. If	Duration [VS]	and	Degree of Confidence [H]	and	Uncertainty_Level [M]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
38. If	Duration [VS]	and	Degree of Confidence [H]	and	Uncertainty_Level [M]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
39. If	Duration [VS]	and	Degree of Confidence [H]	and	Uncertainty_Level [M]	and	Degree of Influence [L]	THEN	Buffer_Time [M]	1
40. If	Duration [VS]	and	Degree of Confidence [H]	and	Uncertainty_Level [M]	and	Degree of Influence [VL]	THEN	Buffer_Time [M]	1
41. If	Duration [VS]	and	Degree of Confidence [H]	and	Uncertainty_Level [L]	and	Degree of Influence [VS]	THEN	Buffer_Time [VS]	1
42. If	Duration [VS]	and	Degree of Confidence [H]	and	Uncertainty_Level [L]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
43. If	Duration [VS]	and	Degree of Confidence [H]	and	Uncertainty_Level [L]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
44. If	Duration [VS]	and	Degree of Confidence [H]	and	Uncertainty_Level [L]	and	Degree of Influence [L]	THEN	Buffer_Time [L]	1
45. If	Duration [VS]	and	Degree of Confidence [H]	and	Uncertainty_Level [L]	and	Degree of Influence [VL]	THEN	Buffer_Time [L]	1
46. If	Duration [VS]	and	Degree of Confidence [H]	and	Uncertainty_Level [VL]	and	Degree of Influence [VS]	THEN	Buffer_Time [S]	1
47. If	Duration [VS]	and	Degree of Confidence [H]	and	Uncertainty_Level [VL]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
48. If	Duration [VS]	and	Degree of Confidence [H]	and	Uncertainty_Level [VL]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
49. If	Duration [VS]	and	Degree of Confidence [H]	and	Uncertainty_Level [VL]	and	Degree of Influence [L]	THEN	Buffer_Time [L]	1
50. If	Duration [VS]	and	Degree of Confidence [H]	and	Uncertainty_Level [VL]	and	Degree of Influence [VL]	THEN	Buffer_Time [L]	1
51. If	Duration [VS]	and	Degree of Confidence [M]	and	Uncertainty_Level [VS]	and	Degree of Influence [VS]	THEN	Buffer_Time [VS]	1

52. If	Duration [VS]	and	Degree of Confidence [M]	and	Uncertainty_Level [VS]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
53. If	Duration [VS]	and	Degree of Confidence [M]	and	Uncertainty_Level [VS]	and	Degree of Influence [M]	THEN	Buffer_Time [S]	1
54. If	Duration [VS]	and	Degree of Confidence [M]	and	Uncertainty_Level [VS]	and	Degree of Influence [L]	THEN	Buffer_Time [M]	1
55. If	Duration [VS]	and	Degree of Confidence [M]	and	Uncertainty_Level [VS]	and	Degree of Influence [VL]	THEN	Buffer_Time [M]	1
56. If	Duration [VS]	and	Degree of Confidence [M]	and	Uncertainty_Level [S]	and	Degree of Influence [VS]	THEN	Buffer_Time [S]	1
57. If	Duration [VS]	and	Degree of Confidence [M]	and	Uncertainty_Level [S]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
58. If	Duration [VS]	and	Degree of Confidence [M]	and	Uncertainty_Level [S]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
59. If	Duration [VS]	and	Degree of Confidence [M]	and	Uncertainty_Level [S]	and	Degree of Influence [L]	THEN	Buffer_Time [M]	1
60. If	Duration [VS]	and	Degree of Confidence [M]	and	Uncertainty_Level [S]	and	Degree of Influence [VL]	THEN	Buffer_Time [M]	1
61. If	Duration [VS]	and	Degree of Confidence [M]	and	Uncertainty_Level [M]	and	Degree of Influence [VS]	THEN	Buffer_Time [S]	1
62. If	Duration [VS]	and	Degree of Confidence [M]	and	Uncertainty_Level [M]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
63. If	Duration [VS]	and	Degree of Confidence [M]	and	Uncertainty_Level [M]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
64. If	Duration [VS]	and	Degree of Confidence [M]	and	Uncertainty_Level [M]	and	Degree of Influence [L]	THEN	Buffer_Time [M]	1
65. If	Duration [VS]	and	Degree of Confidence [M]	and	Uncertainty_Level [M]	and	Degree of Influence [VL]	THEN	Buffer_Time [M]	1
66. If	Duration [VS]	and	Degree of Confidence [M]	and	Uncertainty_Level [L]	and	Degree of Influence [VS]	THEN	Buffer_Time [S]	1
67. If	Duration [VS]	and	Degree of Confidence [M]	and	Uncertainty_Level [L]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
68. If	Duration [VS]	and	Degree of Confidence [M]	and	Uncertainty_Level [L]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
69. If	Duration [VS]	and	Degree of Confidence [M]	and	Uncertainty_Level [L]	and	Degree of Influence [L]	THEN	Buffer_Time [L]	1
70. If	Duration [VS]	and	Degree of Confidence [M]	and	Uncertainty_Level [L]	and	Degree of Influence [VL]	THEN	Buffer_Time [L]	1
71. If	Duration [VS]	and	Degree of Confidence [M]	and	Uncertainty_Level [VL]	and	Degree of Influence [VS]	THEN	Buffer_Time [S]	1
72. If	Duration [VS]	and	Degree of Confidence [M]	and	Uncertainty_Level [VL]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
73. If	Duration [VS]	and	Degree of Confidence [M]	and	Uncertainty_Level [VL]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
74. If	Duration [VS]	and	Degree of Confidence [M]	and	Uncertainty_Level [VL]	and	Degree of Influence [L]	THEN	Buffer_Time [L]	1
75. If	Duration [VS]	and	Degree of Confidence [M]	and	Uncertainty_Level [VL]	and	Degree of Influence [VL]	THEN	Buffer_Time [L]	1
76. If	Duration [VS]	and	Degree of Confidence [L]	and	Uncertainty_Level [VS]	and	Degree of Influence [VS]	THEN	Buffer_Time [M]	1
77. If	Duration [VS]	and	Degree of Confidence [L]	and	Uncertainty_Level [VS]	and	Degree of Influence [S]	THEN	Buffer_Time [M]	1
78. If	Duration [VS]	and	Degree of Confidence [L]	and	Uncertainty_Level [VS]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
79. If	Duration [VS]	and	Degree of Confidence [L]	and	Uncertainty_Level [VS]	and	Degree of Influence [L]	THEN	Buffer_Time [L]	1
80. If	Duration [VS]	and	Degree of Confidence [L]	and	Uncertainty_Level [VS]	and	Degree of Influence [VL]	THEN	Buffer_Time [L]	1
81. If	Duration [VS]	and	Degree of Confidence [L]	and	Uncertainty_Level [S]	and	Degree of Influence [VS]	THEN	Buffer_Time [M]	1
82. If	Duration [VS]	and	Degree of Confidence [L]	and	Uncertainty_Level [S]	and	Degree of Influence [S]	THEN	Buffer_Time [M]	1
83. If	Duration [VS]	and	Degree of Confidence [L]	and	Uncertainty_Level [S]	and	Degree of Influence [M]	THEN	Buffer_Time [L]	1
84. If	Duration [VS]	and	Degree of Confidence [L]	and	Uncertainty_Level [S]	and	Degree of Influence [L]	THEN	Buffer_Time [VL]	1
85. If	Duration [VS]	and	Degree of Confidence [L]	and	Uncertainty_Level [S]	and	Degree of Influence [VL]	THEN	Buffer_Time [VL]	1
86. If	Duration [VS]	and	Degree of Confidence [L]	and	Uncertainty_Level [M]	and	Degree of Influence [VS]	THEN	Buffer_Time [M]	1
87. If	Duration [VS]	and	Degree of Confidence [L]	and	Uncertainty_Level [M]	and	Degree of Influence [S]	THEN	Buffer_Time [M]	1
88. If	Duration [VS]	and	Degree of Confidence [L]	and	Uncertainty_Level [M]	and	Degree of Influence [M]	THEN	Buffer_Time [L]	1
89. If	Duration [VS]	and	Degree of Confidence [L]	and	Uncertainty_Level [M]	and	Degree of Influence [L]	THEN	Buffer_Time [VL]	1
90. If	Duration [VS]	and	Degree of Confidence [L]	and	Uncertainty_Level [M]	and	Degree of Influence [VL]	THEN	Buffer_Time [VL]	1
91. If	Duration [VS]	and	Degree of Confidence [L]	and	Uncertainty_Level [L]	and	Degree of Influence [VS]	THEN	Buffer_Time [M]	1
92. If	Duration [VS]	and	Degree of Confidence [L]	and	Uncertainty_Level [L]	and	Degree of Influence [S]	THEN	Buffer_Time [M]	1
93. If	Duration [VS]	and	Degree of Confidence [L]	and	Uncertainty_Level [L]	and	Degree of Influence [M]	THEN	Buffer_Time [L]	1
94. If	Duration [VS]	and	Degree of Confidence [L]	and	Uncertainty_Level [L]	and	Degree of Influence [L]	THEN	Buffer_Time [VL]	1
95. If	Duration [VS]	and	Degree of Confidence [L]	and	Uncertainty_Level [L]	and	Degree of Influence [VL]	THEN	Buffer_Time [VL]	1
96. If	Duration [VS]	and	Degree of Confidence [L]	and	Uncertainty_Level [VL]	and	Degree of Influence [VS]	THEN	Buffer_Time [M]	1
97. If	Duration [VS]	and	Degree of Confidence [L]	and	Uncertainty_Level [VL]	and	Degree of Influence [S]	THEN	Buffer_Time [M]	1
98. If	Duration [VS]	and	Degree of Confidence [L]	and	Uncertainty_Level [VL]	and	Degree of Influence [M]	THEN	Buffer_Time [L]	1
99. If	Duration [VS]	and	Degree of Confidence [L]	and	Uncertainty_Level [VL]	and	Degree of Influence [L]	THEN	Buffer_Time [VL]	1
100. If	Duration [VS]	and	Degree of Confidence [L]	and	Uncertainty_Level [VL]	and	Degree of Influence [VL]	THEN	Buffer_Time [VL]	1
101. If	Duration [VS]	and	Degree of Confidence [VL]	and	Uncertainty_Level [VS]	and	Degree of Influence [VS]	THEN	Buffer_Time [M]	1
102. If	Duration [VS]	and	Degree of Confidence [VL]	and	Uncertainty_Level [VS]	and	Degree of Influence [S]	THEN	Buffer_Time [M]	1

103. If	Duration [VS]	and	Degree of Confidence [VL]	and	Uncertainty_Level [VS]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
104. If	Duration [VS]	and	Degree of Confidence [VL]	and	Uncertainty_Level [VS]	and	Degree of Influence [L]	THEN	Buffer_Time [L]	1
105. If	Duration [VS]	and	Degree of Confidence [VL]	and	Uncertainty_Level [VS]	and	Degree of Influence [VL]	THEN	Buffer_Time [L]	1
106. If	Duration [VS]	and	Degree of Confidence [VL]	and	Uncertainty_Level [S]	and	Degree of Influence [VS]	THEN	Buffer_Time [M]	1
107. If	Duration [VS]	and	Degree of Confidence [VL]	and	Uncertainty_Level [S]	and	Degree of Influence [S]	THEN	Buffer_Time [M]	1
108. If	Duration [VS]	and	Degree of Confidence [VL]	and	Uncertainty_Level [S]	and	Degree of Influence [M]	THEN	Buffer_Time [L]	1
109. If	Duration [VS]	and	Degree of Confidence [VL]	and	Uncertainty_Level [S]	and	Degree of Influence [L]	THEN	Buffer_Time [VL]	1
110. If	Duration [VS]	and	Degree of Confidence [VL]	and	Uncertainty_Level [S]	and	Degree of Influence [VL]	THEN	Buffer_Time [VL]	1
111. If	Duration [VS]	and	Degree of Confidence [VL]	and	Uncertainty_Level [M]	and	Degree of Influence [VS]	THEN	Buffer_Time [M]	1
112. If	Duration [VS]	and	Degree of Confidence [VL]	and	Uncertainty_Level [M]	and	Degree of Influence [S]	THEN	Buffer_Time [M]	1
113. If	Duration [VS]	and	Degree of Confidence [VL]	and	Uncertainty_Level [M]	and	Degree of Influence [M]	THEN	Buffer_Time [L]	1
114. If	Duration [VS]	and	Degree of Confidence [VL]	and	Uncertainty_Level [M]	and	Degree of Influence [L]	THEN	Buffer_Time [VL]	1
115. If	Duration [VS]	and	Degree of Confidence [VL]	and	Uncertainty_Level [M]	and	Degree of Influence [VL]	THEN	Buffer_Time [VL]	1
116. If	Duration [VS]	and	Degree of Confidence [VL]	and	Uncertainty_Level [L]	and	Degree of Influence [VS]	THEN	Buffer_Time [L]	1
117. If	Duration [VS]	and	Degree of Confidence [VL]	and	Uncertainty_Level [L]	and	Degree of Influence [S]	THEN	Buffer_Time [L]	1
118. If	Duration [VS]	and	Degree of Confidence [VL]	and	Uncertainty_Level [L]	and	Degree of Influence [M]	THEN	Buffer_Time [VL]	1
119. If	Duration [VS]	and	Degree of Confidence [VL]	and	Uncertainty_Level [L]	and	Degree of Influence [L]	THEN	Buffer_Time [VL]	1
120. If	Duration [VS]	and	Degree of Confidence [VL]	and	Uncertainty_Level [L]	and	Degree of Influence [VL]	THEN	Buffer_Time [VL]	1
121. If	Duration [VS]	and	Degree of Confidence [VL]	and	Uncertainty_Level [VL]	and	Degree of Influence [VS]	THEN	Buffer_Time [L]	1
122. If	Duration [VS]	and	Degree of Confidence [VL]	and	Uncertainty_Level [VL]	and	Degree of Influence [S]	THEN	Buffer_Time [L]	1
123. If	Duration [VS]	and	Degree of Confidence [VL]	and	Uncertainty_Level [VL]	and	Degree of Influence [M]	THEN	Buffer_Time [VL]	1
124. If	Duration [VS]	and	Degree of Confidence [VL]	and	Uncertainty_Level [VL]	and	Degree of Influence [L]	THEN	Buffer_Time [VL]	1
125. If	Duration [VS]	and	Degree of Confidence [VL]	and	Uncertainty_Level [VL]	and	Degree of Influence [VL]	THEN	Buffer_Time [VL]	1
126. If	Duration [S]	and	Degree of Confidence [VH]	and	Uncertainty_Level [VS]	and	Degree of Influence [VS]	THEN	Buffer_Time [VS]	1
127. If	Duration [S]	and	Degree of Confidence [VH]	and	Uncertainty_Level [VS]	and	Degree of Influence [S]	THEN	Buffer_Time [VS]	1
128. If	Duration [S]	and	Degree of Confidence [VH]	and	Uncertainty_Level [VS]	and	Degree of Influence [M]	THEN	Buffer_Time [S]	1
129. If	Duration [S]	and	Degree of Confidence [VH]	and	Uncertainty_Level [VS]	and	Degree of Influence [L]	THEN	Buffer_Time [S]	1
130. If	Duration [S]	and	Degree of Confidence [VH]	and	Uncertainty_Level [VS]	and	Degree of Influence [VL]	THEN	Buffer_Time [M]	1
131. If	Duration [S]	and	Degree of Confidence [VH]	and	Uncertainty_Level [S]	and	Degree of Influence [VS]	THEN	Buffer_Time [VS]	1
132. If	Duration [S]	and	Degree of Confidence [VH]	and	Uncertainty_Level [S]	and	Degree of Influence [S]	THEN	Buffer_Time [VS]	1
133. If	Duration [S]	and	Degree of Confidence [VH]	and	Uncertainty_Level [S]	and	Degree of Influence [M]	THEN	Buffer_Time [S]	1
134. If	Duration [S]	and	Degree of Confidence [VH]	and	Uncertainty_Level [S]	and	Degree of Influence [L]	THEN	Buffer_Time [M]	1
135. If	Duration [S]	and	Degree of Confidence [VH]	and	Uncertainty_Level [S]	and	Degree of Influence [VL]	THEN	Buffer_Time [M]	1
136. If	Duration [S]	and	Degree of Confidence [VH]	and	Uncertainty_Level [M]	and	Degree of Influence [VS]	THEN	Buffer_Time [S]	1
137. If	Duration [S]	and	Degree of Confidence [VH]	and	Uncertainty_Level [M]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
138. If	Duration [S]	and	Degree of Confidence [VH]	and	Uncertainty_Level [M]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
139. If	Duration [S]	and	Degree of Confidence [VH]	and	Uncertainty_Level [M]	and	Degree of Influence [L]	THEN	Buffer_Time [M]	1
140. If	Duration [S]	and	Degree of Confidence [VH]	and	Uncertainty_Level [M]	and	Degree of Influence [VL]	THEN	Buffer_Time [M]	1
141. If	Duration [S]	and	Degree of Confidence [VH]	and	Uncertainty_Level [L]	and	Degree of Influence [VS]	THEN	Buffer_Time [VS]	1
142. If	Duration [S]	and	Degree of Confidence [VH]	and	Uncertainty_Level [L]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
143. If	Duration [S]	and	Degree of Confidence [VH]	and	Uncertainty_Level [L]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
144. If	Duration [S]	and	Degree of Confidence [VH]	and	Uncertainty_Level [L]	and	Degree of Influence [L]	THEN	Buffer_Time [M]	1
145. If	Duration [S]	and	Degree of Confidence [VH]	and	Uncertainty_Level [L]	and	Degree of Influence [VL]	THEN	Buffer_Time [M]	1
146. If	Duration [S]	and	Degree of Confidence [VH]	and	Uncertainty_Level [VL]	and	Degree of Influence [VS]	THEN	Buffer_Time [S]	1
147. If	Duration [S]	and	Degree of Confidence [VH]	and	Uncertainty_Level [VL]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
148. If	Duration [S]	and	Degree of Confidence [VH]	and	Uncertainty_Level [VL]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
149. If	Duration [S]	and	Degree of Confidence [VH]	and	Uncertainty_Level [VL]	and	Degree of Influence [L]	THEN	Buffer_Time [M]	1
150. If	Duration [S]	and	Degree of Confidence [VH]	and	Uncertainty_Level [VL]	and	Degree of Influence [VL]	THEN	Buffer_Time [L]	1
151. If	Duration [S]	and	Degree of Confidence [H]	and	Uncertainty_Level [VS]	and	Degree of Influence [VS]	THEN	Buffer_Time [VS]	1
152. If	Duration [S]	and	Degree of Confidence [H]	and	Uncertainty_Level [VS]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
153. If	Duration [S]	and	Degree of Confidence [H]	and	Uncertainty_Level [VS]	and	Degree of Influence [M]	THEN	Buffer_Time [S]	1

154. If	Duration *[S]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[S]*	1
155. If	Duration *[S]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[M]*	1
156. If	Duration *[S]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[VS]*	1
157. If	Duration *[S]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[S]*	1
158. If	Duration *[S]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[M]*	1
159. If	Duration *[S]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[M]*	1
160. If	Duration *[S]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[M]*	1
161. If	Duration *[S]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[S]*	1
162. If	Duration *[S]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[S]*	1
163. If	Duration *[S]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[M]*	1
164. If	Duration *[S]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[M]*	1
165. If	Duration *[S]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[M]*	1
166. If	Duration *[S]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[VS]*	1
167. If	Duration *[S]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[S]*	1
168. If	Duration *[S]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[M]*	1
169. If	Duration *[S]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[L]*	1
170. If	Duration *[S]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[L]*	1
171. If	Duration *[S]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[S]*	1
172. If	Duration *[S]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[S]*	1
173. If	Duration *[S]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[M]*	1
174. If	Duration *[S]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[L]*	1
175. If	Duration *[S]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[L]*	1
176. If	Duration *[S]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[VS]*	1
177. If	Duration *[S]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[S]*	1
178. If	Duration *[S]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[S]*	1
179. If	Duration *[S]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[M]*	1
180. If	Duration *[S]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[M]*	1
181. If	Duration *[S]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[S]*	1
182. If	Duration *[S]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[S]*	1
183. If	Duration *[S]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[M]*	1
184. If	Duration *[S]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[M]*	1
185. If	Duration *[S]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[M]*	1
186. If	Duration *[S]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[S]*	1
187. If	Duration *[S]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[S]*	1
188. If	Duration *[S]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[M]*	1
189. If	Duration *[S]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[M]*	1
190. If	Duration *[S]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[M]*	1
191. If	Duration *[S]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[S]*	1
192. If	Duration *[S]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[S]*	1
193. If	Duration *[S]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[M]*	1
194. If	Duration *[S]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[L]*	1
195. If	Duration *[S]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[L]*	1
196. If	Duration *[S]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[S]*	1
197. If	Duration *[S]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[S]*	1
198. If	Duration *[S]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[M]*	1
199. If	Duration *[S]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[L]*	1
200. If	Duration *[S]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[L]*	1
201. If	Duration *[S]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[S]*	1
202. If	Duration *[S]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[M]*	1
203. If	Duration *[S]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[M]*	1
204. If	Duration *[S]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[L]*	1

205. If	Duration *[S]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[L]*	1
206. If	Duration *[S]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[M]*	1
207. If	Duration *[S]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[M]*	1
208. If	Duration *[S]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[L]*	1
209. If	Duration *[S]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[L]*	1
210. If	Duration *[S]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[L]*	1
211. If	Duration *[S]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[M]*	1
212. If	Duration *[S]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[M]*	1
213. If	Duration *[S]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[L]*	1
214. If	Duration *[S]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[L]*	1
215. If	Duration *[S]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[L]*	1
216. If	Duration *[S]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[M]*	1
217. If	Duration *[S]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[M]*	1
218. If	Duration *[S]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[L]*	1
219. If	Duration *[S]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[L]*	1
220. If	Duration *[S]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[L]*	1
221. If	Duration *[S]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[M]*	1
222. If	Duration *[S]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[M]*	1
223. If	Duration *[S]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[L]*	1
224. If	Duration *[S]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[L]*	1
225. If	Duration *[S]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[L]*	1
226. If	Duration *[S]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[S]*	1
227. If	Duration *[S]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[M]*	1
228. If	Duration *[S]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[M]*	1
229. If	Duration *[S]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[L]*	1
230. If	Duration *[S]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[L]*	1
231. If	Duration *[S]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[S]*	1
232. If	Duration *[S]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[M]*	1
233. If	Duration *[S]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[L]*	1
234. If	Duration *[S]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[L]*	1
235. If	Duration *[S]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[L]*	1
236. If	Duration *[S]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[M]*	1
237. If	Duration *[S]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[M]*	1
238. If	Duration *[S]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[L]*	1
239. If	Duration *[S]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[L]*	1
240. If	Duration *[S]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[L]*	1
241. If	Duration *[S]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[M]*	1
242. If	Duration *[S]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[M]*	1
243. If	Duration *[S]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[L]*	1
244. If	Duration *[S]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[L]*	1
245. If	Duration *[S]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[L]*	1
246. If	Duration *[S]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[M]*	1
247. If	Duration *[S]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[M]*	1
248. If	Duration *[S]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[L]*	1
249. If	Duration *[S]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[L]*	1
250. If	Duration *[S]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[L]*	1
251. If	Duration *[M]*	*and*	Degree of Confidence *[VH]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[VS]*	1
252. If	Duration *[M]*	*and*	Degree of Confidence *[VH]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[VS]*	1
253. If	Duration *[M]*	*and*	Degree of Confidence *[VH]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[S]*	1
254. If	Duration *[M]*	*and*	Degree of Confidence *[VH]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[S]*	1
255. If	Duration *[M]*	*and*	Degree of Confidence *[VH]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[M]*	1

256. If	Duration *[M]*	*and*	Degree of Confidence *[VH]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[VS]*	*THEN*	Buffer_Time *[VS]*	1
257. If	Duration *[M]*	*and*	Degree of Confidence *[VH]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[S]*	*THEN*	Buffer_Time *[S]*	1
258. If	Duration *[M]*	*and*	Degree of Confidence *[VH]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[M]*	*THEN*	Buffer_Time *[S]*	1
259. If	Duration *[M]*	*and*	Degree of Confidence *[VH]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[L]*	*THEN*	Buffer_Time *[M]*	1
260. If	Duration *[M]*	*and*	Degree of Confidence *[VH]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[VL]*	*THEN*	Buffer_Time *[M]*	1
261. If	Duration *[M]*	*and*	Degree of Confidence *[VH]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[VS]*	*THEN*	Buffer_Time *[S]*	1
262. If	Duration *[M]*	*and*	Degree of Confidence *[VH]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[S]*	*THEN*	Buffer_Time *[S]*	1
263. If	Duration *[M]*	*and*	Degree of Confidence *[VH]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[M]*	*THEN*	Buffer_Time *[M]*	1
264. If	Duration *[M]*	*and*	Degree of Confidence *[VH]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[L]*	*THEN*	Buffer_Time *[M]*	1
265. If	Duration *[M]*	*and*	Degree of Confidence *[VH]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[VL]*	*THEN*	Buffer_Time *[M]*	1
266. If	Duration *[M]*	*and*	Degree of Confidence *[VH]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[VS]*	*THEN*	Buffer_Time *[VS]*	1
267. If	Duration *[M]*	*and*	Degree of Confidence *[VH]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[S]*	*THEN*	Buffer_Time *[S]*	1
268. If	Duration *[M]*	*and*	Degree of Confidence *[VH]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[M]*	*THEN*	Buffer_Time *[M]*	1
269. If	Duration *[M]*	*and*	Degree of Confidence *[VH]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[L]*	*THEN*	Buffer_Time *[M]*	1
270. If	Duration *[M]*	*and*	Degree of Confidence *[VH]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[VL]*	*THEN*	Buffer_Time *[M]*	1
271. If	Duration *[M]*	*and*	Degree of Confidence *[VH]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[VS]*	*THEN*	Buffer_Time *[S]*	1
272. If	Duration *[M]*	*and*	Degree of Confidence *[VH]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[S]*	*THEN*	Buffer_Time *[S]*	1
273. If	Duration *[M]*	*and*	Degree of Confidence *[VH]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[M]*	*THEN*	Buffer_Time *[M]*	1
274. If	Duration *[M]*	*and*	Degree of Confidence *[VH]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[L]*	*THEN*	Buffer_Time *[L]*	1
275. If	Duration *[M]*	*and*	Degree of Confidence *[VH]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[VL]*	*THEN*	Buffer_Time *[L]*	1
276. If	Duration *[M]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[VS]*	*THEN*	Buffer_Time *[VS]*	1
277. If	Duration *[M]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[S]*	*THEN*	Buffer_Time *[S]*	1
278. If	Duration *[M]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[M]*	*THEN*	Buffer_Time *[S]*	1
279. If	Duration *[M]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[L]*	*THEN*	Buffer_Time *[S]*	1
280. If	Duration *[M]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[VL]*	*THEN*	Buffer_Time *[M]*	1
281. If	Duration *[M]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[VS]*	*THEN*	Buffer_Time *[VS]*	1
282. If	Duration *[M]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[S]*	*THEN*	Buffer_Time *[S]*	1
283. If	Duration *[M]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[M]*	*THEN*	Buffer_Time *[M]*	1
284. If	Duration *[M]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[L]*	*THEN*	Buffer_Time *[M]*	1
285. If	Duration *[M]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[VL]*	*THEN*	Buffer_Time *[M]*	1
286. If	Duration *[M]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[VS]*	*THEN*	Buffer_Time *[S]*	1
287. If	Duration *[M]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[S]*	*THEN*	Buffer_Time *[S]*	1
288. If	Duration *[M]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[M]*	*THEN*	Buffer_Time *[M]*	1
289. If	Duration *[M]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[L]*	*THEN*	Buffer_Time *[M]*	1
290. If	Duration *[M]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[VL]*	*THEN*	Buffer_Time *[M]*	1
291. If	Duration *[M]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[VS]*	*THEN*	Buffer_Time *[VS]*	1
292. If	Duration *[M]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[S]*	*THEN*	Buffer_Time *[S]*	1
293. If	Duration *[M]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[M]*	*THEN*	Buffer_Time *[M]*	1
294. If	Duration *[M]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[L]*	*THEN*	Buffer_Time *[M]*	1
295. If	Duration *[M]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[VL]*	*THEN*	Buffer_Time *[L]*	1
296. If	Duration *[M]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[VS]*	*THEN*	Buffer_Time *[S]*	1
297. If	Duration *[M]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[S]*	*THEN*	Buffer_Time *[S]*	1
298. If	Duration *[M]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[M]*	*THEN*	Buffer_Time *[M]*	1
299. If	Duration *[M]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[L]*	*THEN*	Buffer_Time *[M]*	1
300. If	Duration *[M]*	*and*	Degree of Confidence *[H]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[VL]*	*THEN*	Buffer_Time *[M]*	1
301. If	Duration *[M]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[VS]*	*THEN*	Buffer_Time *[VS]*	1
302. If	Duration *[M]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[S]*	*THEN*	Buffer_Time *[S]*	1
303. If	Duration *[M]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[M]*	*THEN*	Buffer_Time *[S]*	1
304. If	Duration *[M]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[L]*	*THEN*	Buffer_Time *[M]*	1
305. If	Duration *[M]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[VL]*	*THEN*	Buffer_Time *[M]*	1
306. If	Duration *[M]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[VS]*	*THEN*	Buffer_Time *[S]*	1

307. If	Duration *[M]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[S]*	1
308. If	Duration *[M]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[M]*	1
309. If	Duration *[M]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[M]*	1
310. If	Duration *[M]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[M]*	1
311. If	Duration *[M]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[S]*	1
312. If	Duration *[M]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[S]*	1
313. If	Duration *[M]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[M]*	1
314. If	Duration *[M]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[M]*	1
315. If	Duration *[M]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[L]*	1
316. If	Duration *[M]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[S]*	1
317. If	Duration *[M]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[S]*	1
318. If	Duration *[M]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[M]*	1
319. If	Duration *[M]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[L]*	1
320. If	Duration *[M]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[L]*	1
321. If	Duration *[M]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[S]*	1
322. If	Duration *[M]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[S]*	1
323. If	Duration *[M]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[M]*	1
324. If	Duration *[M]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[L]*	1
325. If	Duration *[M]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[L]*	1
326. If	Duration *[M]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[S]*	1
327. If	Duration *[M]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[M]*	1
328. If	Duration *[M]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[M]*	1
329. If	Duration *[M]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[M]*	1
330. If	Duration *[M]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[L]*	1
331. If	Duration *[M]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[M]*	1
332. If	Duration *[M]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[M]*	1
333. If	Duration *[M]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[M]*	1
334. If	Duration *[M]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[L]*	1
335. If	Duration *[M]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[L]*	1
336. If	Duration *[M]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[M]*	1
337. If	Duration *[M]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[M]*	1
338. If	Duration *[M]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[M]*	1
339. If	Duration *[M]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[M]*	1
340. If	Duration *[M]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[L]*	1
341. If	Duration *[M]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[M]*	1
342. If	Duration *[M]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[M]*	1
343. If	Duration *[M]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[M]*	1
344. If	Duration *[M]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[L]*	1
345. If	Duration *[M]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[L]*	1
346. If	Duration *[M]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[M]*	1
347. If	Duration *[M]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[M]*	1
348. If	Duration *[M]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[L]*	1
349. If	Duration *[M]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[L]*	1
350. If	Duration *[M]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[L]*	1
351. If	Duration *[M]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[S]*	1
352. If	Duration *[M]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[M]*	1
353. If	Duration *[M]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[M]*	THEN	Buffer_Time *[M]*	1
354. If	Duration *[M]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[L]*	THEN	Buffer_Time *[M]*	1
355. If	Duration *[M]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[VL]*	THEN	Buffer_Time *[L]*	1
356. If	Duration *[M]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[VS]*	THEN	Buffer_Time *[S]*	1
357. If	Duration *[M]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[S]*	THEN	Buffer_Time *[M]*	1

358. If	Duration [M]	*and*	Degree of Confidence [VL]	*and*	Uncertainty_Level [S]	*and*	Degree of Influence [M]	*THEN*	Buffer_Time [M]	1
359. If	Duration [M]	*and*	Degree of Confidence [VL]	*and*	Uncertainty_Level [S]	*and*	Degree of Influence [L]	*THEN*	Buffer_Time [M]	1
360. If	Duration [M]	*and*	Degree of Confidence [VL]	*and*	Uncertainty_Level [S]	*and*	Degree of Influence [VL]	*THEN*	Buffer_Time [L]	1
361. If	Duration [M]	*and*	Degree of Confidence [VL]	*and*	Uncertainty_Level [M]	*and*	Degree of Influence [VS]	*THEN*	Buffer_Time [M]	1
362. If	Duration [M]	*and*	Degree of Confidence [VL]	*and*	Uncertainty_Level [M]	*and*	Degree of Influence [S]	*THEN*	Buffer_Time [M]	1
363. If	Duration [M]	*and*	Degree of Confidence [VL]	*and*	Uncertainty_Level [M]	*and*	Degree of Influence [M]	*THEN*	Buffer_Time [M]	1
364. If	Duration [M]	*and*	Degree of Confidence [VL]	*and*	Uncertainty_Level [M]	*and*	Degree of Influence [L]	*THEN*	Buffer_Time [M]	1
365. If	Duration [M]	*and*	Degree of Confidence [VL]	*and*	Uncertainty_Level [M]	*and*	Degree of Influence [VL]	*THEN*	Buffer_Time [L]	1
366. If	Duration [M]	*and*	Degree of Confidence [VL]	*and*	Uncertainty_Level [L]	*and*	Degree of Influence [VS]	*THEN*	Buffer_Time [M]	1
367. If	Duration [M]	*and*	Degree of Confidence [VL]	*and*	Uncertainty_Level [L]	*and*	Degree of Influence [S]	*THEN*	Buffer_Time [M]	1
368. If	Duration [M]	*and*	Degree of Confidence [VL]	*and*	Uncertainty_Level [L]	*and*	Degree of Influence [M]	*THEN*	Buffer_Time [M]	1
369. If	Duration [M]	*and*	Degree of Confidence [VL]	*and*	Uncertainty_Level [L]	*and*	Degree of Influence [L]	*THEN*	Buffer_Time [L]	1
370. If	Duration [M]	*and*	Degree of Confidence [VL]	*and*	Uncertainty_Level [L]	*and*	Degree of Influence [VL]	*THEN*	Buffer_Time [L]	1
371. If	Duration [M]	*and*	Degree of Confidence [VL]	*and*	Uncertainty_Level [VL]	*and*	Degree of Influence [VS]	*THEN*	Buffer_Time [M]	1
372. If	Duration [M]	*and*	Degree of Confidence [VL]	*and*	Uncertainty_Level [VL]	*and*	Degree of Influence [S]	*THEN*	Buffer_Time [M]	1
373. If	Duration [M]	*and*	Degree of Confidence [VL]	*and*	Uncertainty_Level [VL]	*and*	Degree of Influence [M]	*THEN*	Buffer_Time [M]	1
374. If	Duration [M]	*and*	Degree of Confidence [VL]	*and*	Uncertainty_Level [VL]	*and*	Degree of Influence [L]	*THEN*	Buffer_Time [L]	1
375. If	Duration [M]	*and*	Degree of Confidence [VL]	*and*	Uncertainty_Level [VL]	*and*	Degree of Influence [VL]	*THEN*	Buffer_Time [L]	1
376. If	Duration [L]	*and*	Degree of Confidence [VH]	*and*	Uncertainty_Level [VS]	*and*	Degree of Influence [VS]	*THEN*	Buffer_Time [VS]	1
377. If	Duration [L]	*and*	Degree of Confidence [VH]	*and*	Uncertainty_Level [VS]	*and*	Degree of Influence [S]	*THEN*	Buffer_Time [S]	1
378. If	Duration [L]	*and*	Degree of Confidence [VH]	*and*	Uncertainty_Level [VS]	*and*	Degree of Influence [M]	*THEN*	Buffer_Time [S]	1
379. If	Duration [L]	*and*	Degree of Confidence [VH]	*and*	Uncertainty_Level [VS]	*and*	Degree of Influence [L]	*THEN*	Buffer_Time [M]	1
380. If	Duration [L]	*and*	Degree of Confidence [VH]	*and*	Uncertainty_Level [VS]	*and*	Degree of Influence [VL]	*THEN*	Buffer_Time [M]	1
381. If	Duration [L]	*and*	Degree of Confidence [VH]	*and*	Uncertainty_Level [S]	*and*	Degree of Influence [VS]	*THEN*	Buffer_Time [S]	1
382. If	Duration [L]	*and*	Degree of Confidence [VH]	*and*	Uncertainty_Level [S]	*and*	Degree of Influence [S]	*THEN*	Buffer_Time [S]	1
383. If	Duration [L]	*and*	Degree of Confidence [VH]	*and*	Uncertainty_Level [S]	*and*	Degree of Influence [M]	*THEN*	Buffer_Time [M]	1
384. If	Duration [L]	*and*	Degree of Confidence [VH]	*and*	Uncertainty_Level [S]	*and*	Degree of Influence [L]	*THEN*	Buffer_Time [M]	1
385. If	Duration [L]	*and*	Degree of Confidence [VH]	*and*	Uncertainty_Level [S]	*and*	Degree of Influence [VL]	*THEN*	Buffer_Time [L]	1
386. If	Duration [L]	*and*	Degree of Confidence [VH]	*and*	Uncertainty_Level [M]	*and*	Degree of Influence [VS]	*THEN*	Buffer_Time [S]	1
387. If	Duration [L]	*and*	Degree of Confidence [VH]	*and*	Uncertainty_Level [M]	*and*	Degree of Influence [S]	*THEN*	Buffer_Time [S]	1
388. If	Duration [L]	*and*	Degree of Confidence [VH]	*and*	Uncertainty_Level [M]	*and*	Degree of Influence [M]	*THEN*	Buffer_Time [M]	1
389. If	Duration [L]	*and*	Degree of Confidence [VH]	*and*	Uncertainty_Level [M]	*and*	Degree of Influence [L]	*THEN*	Buffer_Time [L]	1
390. If	Duration [L]	*and*	Degree of Confidence [VH]	*and*	Uncertainty_Level [M]	*and*	Degree of Influence [VL]	*THEN*	Buffer_Time [L]	1
391. If	Duration [L]	*and*	Degree of Confidence [VH]	*and*	Uncertainty_Level [L]	*and*	Degree of Influence [VS]	*THEN*	Buffer_Time [S]	1
392. If	Duration [L]	*and*	Degree of Confidence [VH]	*and*	Uncertainty_Level [L]	*and*	Degree of Influence [S]	*THEN*	Buffer_Time [S]	1
393. If	Duration [L]	*and*	Degree of Confidence [VH]	*and*	Uncertainty_Level [L]	*and*	Degree of Influence [M]	*THEN*	Buffer_Time [M]	1
394. If	Duration [L]	*and*	Degree of Confidence [VH]	*and*	Uncertainty_Level [L]	*and*	Degree of Influence [L]	*THEN*	Buffer_Time [L]	1
395. If	Duration [L]	*and*	Degree of Confidence [VH]	*and*	Uncertainty_Level [L]	*and*	Degree of Influence [VL]	*THEN*	Buffer_Time [L]	1
396. If	Duration [L]	*and*	Degree of Confidence [VH]	*and*	Uncertainty_Level [VL]	*and*	Degree of Influence [VS]	*THEN*	Buffer_Time [S]	1
397. If	Duration [L]	*and*	Degree of Confidence [VH]	*and*	Uncertainty_Level [VL]	*and*	Degree of Influence [S]	*THEN*	Buffer_Time [S]	1
398. If	Duration [L]	*and*	Degree of Confidence [VH]	*and*	Uncertainty_Level [VL]	*and*	Degree of Influence [M]	*THEN*	Buffer_Time [M]	1
399. If	Duration [L]	*and*	Degree of Confidence [VH]	*and*	Uncertainty_Level [VL]	*and*	Degree of Influence [L]	*THEN*	Buffer_Time [L]	1
400. If	Duration [L]	*and*	Degree of Confidence [VH]	*and*	Uncertainty_Level [VL]	*and*	Degree of Influence [VL]	*THEN*	Buffer_Time [L]	1
401. If	Duration [L]	*and*	Degree of Confidence [H]	*and*	Uncertainty_Level [VS]	*and*	Degree of Influence [VS]	*THEN*	Buffer_Time [VS]	1
402. If	Duration [L]	*and*	Degree of Confidence [H]	*and*	Uncertainty_Level [VS]	*and*	Degree of Influence [S]	*THEN*	Buffer_Time [S]	1
403. If	Duration [L]	*and*	Degree of Confidence [H]	*and*	Uncertainty_Level [VS]	*and*	Degree of Influence [M]	*THEN*	Buffer_Time [S]	1
404. If	Duration [L]	*and*	Degree of Confidence [H]	*and*	Uncertainty_Level [VS]	*and*	Degree of Influence [L]	*THEN*	Buffer_Time [M]	1
405. If	Duration [L]	*and*	Degree of Confidence [H]	*and*	Uncertainty_Level [VS]	*and*	Degree of Influence [VL]	*THEN*	Buffer_Time [M]	1
406. If	Duration [L]	*and*	Degree of Confidence [H]	*and*	Uncertainty_Level [S]	*and*	Degree of Influence [VS]	*THEN*	Buffer_Time [S]	1
407. If	Duration [L]	*and*	Degree of Confidence [H]	*and*	Uncertainty_Level [S]	*and*	Degree of Influence [S]	*THEN*	Buffer_Time [S]	1
408. If	Duration [L]	*and*	Degree of Confidence [H]	*and*	Uncertainty_Level [S]	*and*	Degree of Influence [M]	*THEN*	Buffer_Time [M]	1

409. If	Duration [L]	and	Degree of Confidence [H]	and	Uncertainty_Level [S]	and	Degree of Influence [L]	THEN	Buffer_Time [M]	1
410. If	Duration [L]	and	Degree of Confidence [H]	and	Uncertainty_Level [S]	and	Degree of Influence [VL]	THEN	Buffer_Time [L]	1
411. If	Duration [L]	and	Degree of Confidence [H]	and	Uncertainty_Level [M]	and	Degree of Influence [VS]	THEN	Buffer_Time [S]	1
412. If	Duration [L]	and	Degree of Confidence [H]	and	Uncertainty_Level [M]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
413. If	Duration [L]	and	Degree of Confidence [H]	and	Uncertainty_Level [M]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
414. If	Duration [L]	and	Degree of Confidence [H]	and	Uncertainty_Level [M]	and	Degree of Influence [L]	THEN	Buffer_Time [L]	1
415. If	Duration [L]	and	Degree of Confidence [H]	and	Uncertainty_Level [M]	and	Degree of Influence [VL]	THEN	Buffer_Time [L]	1
416. If	Duration [L]	and	Degree of Confidence [H]	and	Uncertainty_Level [L]	and	Degree of Influence [VS]	THEN	Buffer_Time [S]	1
417. If	Duration [L]	and	Degree of Confidence [H]	and	Uncertainty_Level [L]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
418. If	Duration [L]	and	Degree of Confidence [H]	and	Uncertainty_Level [L]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
419. If	Duration [L]	and	Degree of Confidence [H]	and	Uncertainty_Level [L]	and	Degree of Influence [L]	THEN	Buffer_Time [L]	1
420. If	Duration [L]	and	Degree of Confidence [H]	and	Uncertainty_Level [L]	and	Degree of Influence [VL]	THEN	Buffer_Time [L]	1
421. If	Duration [L]	and	Degree of Confidence [H]	and	Uncertainty_Level [VL]	and	Degree of Influence [VS]	THEN	Buffer_Time [S]	1
422. If	Duration [L]	and	Degree of Confidence [H]	and	Uncertainty_Level [VL]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
423. If	Duration [L]	and	Degree of Confidence [H]	and	Uncertainty_Level [VL]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
424. If	Duration [L]	and	Degree of Confidence [H]	and	Uncertainty_Level [VL]	and	Degree of Influence [L]	THEN	Buffer_Time [L]	1
425. If	Duration [L]	and	Degree of Confidence [H]	and	Uncertainty_Level [VL]	and	Degree of Influence [VL]	THEN	Buffer_Time [L]	1
426. If	Duration [L]	and	Degree of Confidence [M]	and	Uncertainty_Level [VS]	and	Degree of Influence [VS]	THEN	Buffer_Time [VS]	1
427. If	Duration [L]	and	Degree of Confidence [M]	and	Uncertainty_Level [VS]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
428. If	Duration [L]	and	Degree of Confidence [M]	and	Uncertainty_Level [VS]	and	Degree of Influence [M]	THEN	Buffer_Time [S]	1
429. If	Duration [L]	and	Degree of Confidence [M]	and	Uncertainty_Level [VS]	and	Degree of Influence [L]	THEN	Buffer_Time [M]	1
430. If	Duration [L]	and	Degree of Confidence [M]	and	Uncertainty_Level [VS]	and	Degree of Influence [VL]	THEN	Buffer_Time [M]	1
431. If	Duration [L]	and	Degree of Confidence [M]	and	Uncertainty_Level [S]	and	Degree of Influence [VS]	THEN	Buffer_Time [S]	1
432. If	Duration [L]	and	Degree of Confidence [M]	and	Uncertainty_Level [S]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
433. If	Duration [L]	and	Degree of Confidence [M]	and	Uncertainty_Level [S]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
434. If	Duration [L]	and	Degree of Confidence [M]	and	Uncertainty_Level [S]	and	Degree of Influence [L]	THEN	Buffer_Time [M]	1
435. If	Duration [L]	and	Degree of Confidence [M]	and	Uncertainty_Level [S]	and	Degree of Influence [VL]	THEN	Buffer_Time [L]	1
436. If	Duration [L]	and	Degree of Confidence [M]	and	Uncertainty_Level [M]	and	Degree of Influence [VS]	THEN	Buffer_Time [S]	1
437. If	Duration [L]	and	Degree of Confidence [M]	and	Uncertainty_Level [M]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
438. If	Duration [L]	and	Degree of Confidence [M]	and	Uncertainty_Level [M]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
439. If	Duration [L]	and	Degree of Confidence [M]	and	Uncertainty_Level [M]	and	Degree of Influence [L]	THEN	Buffer_Time [L]	1
440. If	Duration [L]	and	Degree of Confidence [M]	and	Uncertainty_Level [M]	and	Degree of Influence [VL]	THEN	Buffer_Time [L]	1
441. If	Duration [L]	and	Degree of Confidence [M]	and	Uncertainty_Level [L]	and	Degree of Influence [VS]	THEN	Buffer_Time [S]	1
442. If	Duration [L]	and	Degree of Confidence [M]	and	Uncertainty_Level [L]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
443. If	Duration [L]	and	Degree of Confidence [M]	and	Uncertainty_Level [L]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
444. If	Duration [L]	and	Degree of Confidence [M]	and	Uncertainty_Level [L]	and	Degree of Influence [L]	THEN	Buffer_Time [L]	1
445. If	Duration [L]	and	Degree of Confidence [M]	and	Uncertainty_Level [L]	and	Degree of Influence [VL]	THEN	Buffer_Time [L]	1
446. If	Duration [L]	and	Degree of Confidence [M]	and	Uncertainty_Level [VL]	and	Degree of Influence [VS]	THEN	Buffer_Time [S]	1
447. If	Duration [L]	and	Degree of Confidence [M]	and	Uncertainty_Level [VL]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
448. If	Duration [L]	and	Degree of Confidence [M]	and	Uncertainty_Level [VL]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
449. If	Duration [L]	and	Degree of Confidence [M]	and	Uncertainty_Level [VL]	and	Degree of Influence [L]	THEN	Buffer_Time [L]	1
450. If	Duration [L]	and	Degree of Confidence [M]	and	Uncertainty_Level [VL]	and	Degree of Influence [VL]	THEN	Buffer_Time [L]	1
451. If	Duration [L]	and	Degree of Confidence [L]	and	Uncertainty_Level [VS]	and	Degree of Influence [VS]	THEN	Buffer_Time [VS]	1
452. If	Duration [L]	and	Degree of Confidence [L]	and	Uncertainty_Level [VS]	and	Degree of Influence [S]	THEN	Buffer_Time [VS]	1
453. If	Duration [L]	and	Degree of Confidence [L]	and	Uncertainty_Level [VS]	and	Degree of Influence [M]	THEN	Buffer_Time [S]	1
454. If	Duration [L]	and	Degree of Confidence [L]	and	Uncertainty_Level [VS]	and	Degree of Influence [L]	THEN	Buffer_Time [M]	1
455. If	Duration [L]	and	Degree of Confidence [L]	and	Uncertainty_Level [VS]	and	Degree of Influence [VL]	THEN	Buffer_Time [M]	1
456. If	Duration [L]	and	Degree of Confidence [L]	and	Uncertainty_Level [S]	and	Degree of Influence [VS]	THEN	Buffer_Time [VS]	1
457. If	Duration [L]	and	Degree of Confidence [L]	and	Uncertainty_Level [S]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
458. If	Duration [L]	and	Degree of Confidence [L]	and	Uncertainty_Level [S]	and	Degree of Influence [M]	THEN	Buffer_Time [S]	1
459. If	Duration [L]	and	Degree of Confidence [L]	and	Uncertainty_Level [S]	and	Degree of Influence [L]	THEN	Buffer_Time [M]	1

460. If	Duration (L)	and	Degree of Confidence (L)	and	Uncertainty_Level (S)	and	Degree of Influence (VL)	THEN	Buffer_Time (M)	1
461. If	Duration (L)	and	Degree of Confidence (L)	and	Uncertainty_Level (M)	and	Degree of Influence (VS)	THEN	Buffer_Time (S)	1
462. If	Duration (L)	and	Degree of Confidence (L)	and	Uncertainty_Level (M)	and	Degree of Influence (S)	THEN	Buffer_Time (S)	1
463. If	Duration (L)	and	Degree of Confidence (L)	and	Uncertainty_Level (M)	and	Degree of Influence (M)	THEN	Buffer_Time (M)	1
464. If	Duration (L)	and	Degree of Confidence (L)	and	Uncertainty_Level (M)	and	Degree of Influence (L)	THEN	Buffer_Time (M)	1
465. If	Duration (L)	and	Degree of Confidence (L)	and	Uncertainty_Level (M)	and	Degree of Influence (VL)	THEN	Buffer_Time (M)	1
466. If	Duration (L)	and	Degree of Confidence (L)	and	Uncertainty_Level (L)	and	Degree of Influence (VS)	THEN	Buffer_Time (S)	1
467. If	Duration (L)	and	Degree of Confidence (L)	and	Uncertainty_Level (L)	and	Degree of Influence (S)	THEN	Buffer_Time (S)	1
468. If	Duration (L)	and	Degree of Confidence (L)	and	Uncertainty_Level (L)	and	Degree of Influence (M)	THEN	Buffer_Time (M)	1
469. If	Duration (L)	and	Degree of Confidence (L)	and	Uncertainty_Level (L)	and	Degree of Influence (L)	THEN	Buffer_Time (M)	1
470. If	Duration (L)	and	Degree of Confidence (L)	and	Uncertainty_Level (L)	and	Degree of Influence (VL)	THEN	Buffer_Time (L)	1
471. If	Duration (L)	and	Degree of Confidence (L)	and	Uncertainty_Level (VL)	and	Degree of Influence (VS)	THEN	Buffer_Time (S)	1
472. If	Duration (L)	and	Degree of Confidence (L)	and	Uncertainty_Level (VL)	and	Degree of Influence (S)	THEN	Buffer_Time (S)	1
473. If	Duration (L)	and	Degree of Confidence (L)	and	Uncertainty_Level (VL)	and	Degree of Influence (M)	THEN	Buffer_Time (M)	1
474. If	Duration (L)	and	Degree of Confidence (L)	and	Uncertainty_Level (VL)	and	Degree of Influence (L)	THEN	Buffer_Time (L)	1
475. If	Duration (L)	and	Degree of Confidence (L)	and	Uncertainty_Level (VL)	and	Degree of Influence (VL)	THEN	Buffer_Time (L)	1
476. If	Duration (L)	and	Degree of Confidence (VL)	and	Uncertainty_Level (VS)	and	Degree of Influence (VS)	THEN	Buffer_Time (VS)	1
477. If	Duration (L)	and	Degree of Confidence (VL)	and	Uncertainty_Level (VS)	and	Degree of Influence (S)	THEN	Buffer_Time (VS)	1
478. If	Duration (L)	and	Degree of Confidence (VL)	and	Uncertainty_Level (VS)	and	Degree of Influence (M)	THEN	Buffer_Time (S)	1
479. If	Duration (L)	and	Degree of Confidence (VL)	and	Uncertainty_Level (VS)	and	Degree of Influence (L)	THEN	Buffer_Time (S)	1
480. If	Duration (L)	and	Degree of Confidence (VL)	and	Uncertainty_Level (VS)	and	Degree of Influence (VL)	THEN	Buffer_Time (M)	1
481. If	Duration (L)	and	Degree of Confidence (VL)	and	Uncertainty_Level (S)	and	Degree of Influence (VS)	THEN	Buffer_Time (VS)	1
482. If	Duration (L)	and	Degree of Confidence (VL)	and	Uncertainty_Level (S)	and	Degree of Influence (S)	THEN	Buffer_Time (S)	1
483. If	Duration (L)	and	Degree of Confidence (VL)	and	Uncertainty_Level (S)	and	Degree of Influence (M)	THEN	Buffer_Time (S)	1
484. If	Duration (L)	and	Degree of Confidence (VL)	and	Uncertainty_Level (S)	and	Degree of Influence (L)	THEN	Buffer_Time (M)	1
485. If	Duration (L)	and	Degree of Confidence (VL)	and	Uncertainty_Level (S)	and	Degree of Influence (VL)	THEN	Buffer_Time (M)	1
486. If	Duration (L)	and	Degree of Confidence (VL)	and	Uncertainty_Level (M)	and	Degree of Influence (VS)	THEN	Buffer_Time (VS)	1
487. If	Duration (L)	and	Degree of Confidence (VL)	and	Uncertainty_Level (M)	and	Degree of Influence (S)	THEN	Buffer_Time (S)	1
488. If	Duration (L)	and	Degree of Confidence (VL)	and	Uncertainty_Level (M)	and	Degree of Influence (M)	THEN	Buffer_Time (S)	1
489. If	Duration (L)	and	Degree of Confidence (VL)	and	Uncertainty_Level (M)	and	Degree of Influence (L)	THEN	Buffer_Time (M)	1
490. If	Duration (L)	and	Degree of Confidence (VL)	and	Uncertainty_Level (M)	and	Degree of Influence (VL)	THEN	Buffer_Time (M)	1
491. If	Duration (L)	and	Degree of Confidence (VL)	and	Uncertainty_Level (L)	and	Degree of Influence (VS)	THEN	Buffer_Time (VS)	1
492. If	Duration (L)	and	Degree of Confidence (VL)	and	Uncertainty_Level (L)	and	Degree of Influence (S)	THEN	Buffer_Time (S)	1
493. If	Duration (L)	and	Degree of Confidence (VL)	and	Uncertainty_Level (L)	and	Degree of Influence (M)	THEN	Buffer_Time (S)	1
494. If	Duration (L)	and	Degree of Confidence (VL)	and	Uncertainty_Level (L)	and	Degree of Influence (L)	THEN	Buffer_Time (M)	1
495. If	Duration (L)	and	Degree of Confidence (VL)	and	Uncertainty_Level (L)	and	Degree of Influence (VL)	THEN	Buffer_Time (L)	1
496. If	Duration (L)	and	Degree of Confidence (VL)	and	Uncertainty_Level (VL)	and	Degree of Influence (VS)	THEN	Buffer_Time (VS)	1
497. If	Duration (L)	and	Degree of Confidence (VL)	and	Uncertainty_Level (VL)	and	Degree of Influence (S)	THEN	Buffer_Time (S)	1
498. If	Duration (L)	and	Degree of Confidence (VL)	and	Uncertainty_Level (VL)	and	Degree of Influence (M)	THEN	Buffer_Time (S)	1
499. If	Duration (L)	and	Degree of Confidence (VL)	and	Uncertainty_Level (VL)	and	Degree of Influence (L)	THEN	Buffer_Time (M)	1
500. If	Duration (L)	and	Degree of Confidence (VL)	and	Uncertainty_Level (VL)	and	Degree of Influence (VL)	THEN	Buffer_Time (L)	1
501. If	Duration (VL)	and	Degree of Confidence (VH)	and	Uncertainty_Level (VS)	and	Degree of Influence (VS)	THEN	Buffer_Time (VS)	1
502. If	Duration (VL)	and	Degree of Confidence (VH)	and	Uncertainty_Level (VS)	and	Degree of Influence (S)	THEN	Buffer_Time (S)	1
503. If	Duration (VL)	and	Degree of Confidence (VH)	and	Uncertainty_Level (VS)	and	Degree of Influence (M)	THEN	Buffer_Time (S)	1
504. If	Duration (VL)	and	Degree of Confidence (VH)	and	Uncertainty_Level (VS)	and	Degree of Influence (L)	THEN	Buffer_Time (M)	1
505. If	Duration (VL)	and	Degree of Confidence (VH)	and	Uncertainty_Level (VS)	and	Degree of Influence (VL)	THEN	Buffer_Time (M)	1
506. If	Duration (VL)	and	Degree of Confidence (VH)	and	Uncertainty_Level (S)	and	Degree of Influence (VS)	THEN	Buffer_Time (S)	1
507. If	Duration (VL)	and	Degree of Confidence (VH)	and	Uncertainty_Level (S)	and	Degree of Influence (S)	THEN	Buffer_Time (S)	1
508. If	Duration (VL)	and	Degree of Confidence (VH)	and	Uncertainty_Level (S)	and	Degree of Influence (M)	THEN	Buffer_Time (M)	1
509. If	Duration (VL)	and	Degree of Confidence (VH)	and	Uncertainty_Level (S)	and	Degree of Influence (L)	THEN	Buffer_Time (M)	1
510. If	Duration (VL)	and	Degree of Confidence (VH)	and	Uncertainty_Level (S)	and	Degree of Influence (VL)	THEN	Buffer_Time (L)	1

511. If	Duration [VL]	and	Degree of Confidence [VH]	and	Uncertainty_Level [M]	and	Degree of Influence [VS]	THEN	Buffer_Time [S]	1
512. If	Duration [VL]	and	Degree of Confidence [VH]	and	Uncertainty_Level [M]	and	Degree of Influence [S]	THEN	Buffer_Time [M]	1
513. If	Duration [VL]	and	Degree of Confidence [VH]	and	Uncertainty_Level [M]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
514. If	Duration [VL]	and	Degree of Confidence [VH]	and	Uncertainty_Level [M]	and	Degree of Influence [L]	THEN	Buffer_Time [L]	1
515. If	Duration [VL]	and	Degree of Confidence [VH]	and	Uncertainty_Level [M]	and	Degree of Influence [VL]	THEN	Buffer_Time [L]	1
516. If	Duration [VL]	and	Degree of Confidence [VH]	and	Uncertainty_Level [L]	and	Degree of Influence [VS]	THEN	Buffer_Time [S]	1
517. If	Duration [VL]	and	Degree of Confidence [VH]	and	Uncertainty_Level [L]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
518. If	Duration [VL]	and	Degree of Confidence [VH]	and	Uncertainty_Level [L]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
519. If	Duration [VL]	and	Degree of Confidence [VH]	and	Uncertainty_Level [L]	and	Degree of Influence [L]	THEN	Buffer_Time [L]	1
520. If	Duration [VL]	and	Degree of Confidence [VH]	and	Uncertainty_Level [L]	and	Degree of Influence [VL]	THEN	Buffer_Time [VL]	1
521. If	Duration [VL]	and	Degree of Confidence [VH]	and	Uncertainty_Level [VL]	and	Degree of Influence [VS]	THEN	Buffer_Time [S]	1
522. If	Duration [VL]	and	Degree of Confidence [VH]	and	Uncertainty_Level [VL]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
523. If	Duration [VL]	and	Degree of Confidence [VH]	and	Uncertainty_Level [VL]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
524. If	Duration [VL]	and	Degree of Confidence [VH]	and	Uncertainty_Level [VL]	and	Degree of Influence [L]	THEN	Buffer_Time [L]	1
525. If	Duration [VL]	and	Degree of Confidence [VH]	and	Uncertainty_Level [VL]	and	Degree of Influence [VL]	THEN	Buffer_Time [VL]	1
526. If	Duration [VL]	and	Degree of Confidence [H]	and	Uncertainty_Level [VS]	and	Degree of Influence [VS]	THEN	Buffer_Time [VS]	1
527. If	Duration [VL]	and	Degree of Confidence [H]	and	Uncertainty_Level [VS]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
528. If	Duration [VL]	and	Degree of Confidence [H]	and	Uncertainty_Level [VS]	and	Degree of Influence [M]	THEN	Buffer_Time [S]	1
529. If	Duration [VL]	and	Degree of Confidence [H]	and	Uncertainty_Level [VS]	and	Degree of Influence [L]	THEN	Buffer_Time [M]	1
530. If	Duration [VL]	and	Degree of Confidence [H]	and	Uncertainty_Level [VS]	and	Degree of Influence [VL]	THEN	Buffer_Time [M]	1
531. If	Duration [VL]	and	Degree of Confidence [H]	and	Uncertainty_Level [S]	and	Degree of Influence [VS]	THEN	Buffer_Time [S]	1
532. If	Duration [VL]	and	Degree of Confidence [H]	and	Uncertainty_Level [S]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
533. If	Duration [VL]	and	Degree of Confidence [H]	and	Uncertainty_Level [S]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
534. If	Duration [VL]	and	Degree of Confidence [H]	and	Uncertainty_Level [S]	and	Degree of Influence [L]	THEN	Buffer_Time [M]	1
535. If	Duration [VL]	and	Degree of Confidence [H]	and	Uncertainty_Level [S]	and	Degree of Influence [VL]	THEN	Buffer_Time [L]	1
536. If	Duration [VL]	and	Degree of Confidence [H]	and	Uncertainty_Level [M]	and	Degree of Influence [VS]	THEN	Buffer_Time [S]	1
537. If	Duration [VL]	and	Degree of Confidence [H]	and	Uncertainty_Level [M]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
538. If	Duration [VL]	and	Degree of Confidence [H]	and	Uncertainty_Level [M]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
539. If	Duration [VL]	and	Degree of Confidence [H]	and	Uncertainty_Level [M]	and	Degree of Influence [L]	THEN	Buffer_Time [L]	1
540. If	Duration [VL]	and	Degree of Confidence [H]	and	Uncertainty_Level [M]	and	Degree of Influence [VL]	THEN	Buffer_Time [L]	1
541. If	Duration [VL]	and	Degree of Confidence [H]	and	Uncertainty_Level [L]	and	Degree of Influence [VS]	THEN	Buffer_Time [S]	1
542. If	Duration [VL]	and	Degree of Confidence [H]	and	Uncertainty_Level [L]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
543. If	Duration [VL]	and	Degree of Confidence [H]	and	Uncertainty_Level [L]	and	Degree of Influence [M]	THEN	Buffer_Time [M]	1
544. If	Duration [VL]	and	Degree of Confidence [H]	and	Uncertainty_Level [L]	and	Degree of Influence [L]	THEN	Buffer_Time [L]	1
545. If	Duration [VL]	and	Degree of Confidence [H]	and	Uncertainty_Level [L]	and	Degree of Influence [VL]	THEN	Buffer_Time [L]	1
546. If	Duration [VL]	and	Degree of Confidence [H]	and	Uncertainty_Level [VL]	and	Degree of Influence [VS]	THEN	Buffer_Time [S]	1
547. If	Duration [VL]	and	Degree of Confidence [H]	and	Uncertainty_Level [VL]	and	Degree of Influence [S]	THEN	Buffer_Time [S]	1
548. If	Duration [VL]	and	Degree of Confidence [H]	and	Uncertainty_Level [VL]	and	Degree of Influence [M]	THEN	Buffer_Time [L]	1
549. If	Duration [VL]	and	Degree of Confidence [H]	and	Uncertainty_Level [VL]	and	Degree of Influence [L]	THEN	Buffer_Time [L]	1
550. If	Duration [VL]	and	Degree of Confidence [H]	and	Uncertainty_Level [VL]	and	Degree of Influence [VL]	THEN	Buffer_Time [VL]	1
551. If	Duration [VL]	and	Degree of Confidence [M]	and	Uncertainty_Level [VS]	and	Degree of Influence [VS]	THEN	Buffer_Time [VS]	1
552. If	Duration [VL]	and	Degree of Confidence [M]	and	Uncertainty_Level [VS]	and	Degree of Influence [S]	THEN	Buffer_Time [VS]	1
553. If	Duration [VL]	and	Degree of Confidence [M]	and	Uncertainty_Level [VS]	and	Degree of Influence [M]	THEN	Buffer_Time [S]	1
554. If	Duration [VL]	and	Degree of Confidence [M]	and	Uncertainty_Level [VS]	and	Degree of Influence [L]	THEN	Buffer_Time [M]	1
555. If	Duration [VL]	and	Degree of Confidence [M]	and	Uncertainty_Level [VS]	and	Degree of Influence [VL]	THEN	Buffer_Time [M]	1
556. If	Duration [VL]	and	Degree of Confidence [M]	and	Uncertainty_Level [S]	and	Degree of Influence [VS]	THEN	Buffer_Time [VS]	1
557. If	Duration [VL]	and	Degree of Confidence [M]	and	Uncertainty_Level [S]	and	Degree of Influence [S]	THEN	Buffer_Time [VS]	1
558. If	Duration [VL]	and	Degree of Confidence [M]	and	Uncertainty_Level [S]	and	Degree of Influence [M]	THEN	Buffer_Time [S]	1
559. If	Duration [VL]	and	Degree of Confidence [M]	and	Uncertainty_Level [S]	and	Degree of Influence [L]	THEN	Buffer_Time [M]	1
560. If	Duration [VL]	and	Degree of Confidence [M]	and	Uncertainty_Level [S]	and	Degree of Influence [VL]	THEN	Buffer_Time [M]	1
561. If	Duration [VL]	and	Degree of Confidence [M]	and	Uncertainty_Level [M]	and	Degree of Influence [VS]	THEN	Buffer_Time [VS]	1

562. If	Duration *[VL]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[S]*	*THEN*	Buffer_Time *[S]*	1
563. If	Duration *[VL]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[M]*	*THEN*	Buffer_Time *[S]*	1
564. If	Duration *[VL]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[L]*	*THEN*	Buffer_Time *[M]*	1
565. If	Duration *[VL]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[VL]*	*THEN*	Buffer_Time *[M]*	1
566. If	Duration *[VL]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[VS]*	*THEN*	Buffer_Time *[VS]*	1
567. If	Duration *[VL]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[S]*	*THEN*	Buffer_Time *[S]*	1
568. If	Duration *[VL]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[M]*	*THEN*	Buffer_Time *[M]*	1
569. If	Duration *[VL]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[L]*	*THEN*	Buffer_Time *[M]*	1
570. If	Duration *[VL]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[VL]*	*THEN*	Buffer_Time *[M]*	1
571. If	Duration *[VL]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[VS]*	*THEN*	Buffer_Time *[VS]*	1
572. If	Duration *[VL]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[S]*	*THEN*	Buffer_Time *[S]*	1
573. If	Duration *[VL]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[M]*	*THEN*	Buffer_Time *[M]*	1
574. If	Duration *[VL]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[L]*	*THEN*	Buffer_Time *[M]*	1
575. If	Duration *[VL]*	*and*	Degree of Confidence *[M]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[VL]*	*THEN*	Buffer_Time *[M]*	1
576. If	Duration *[VL]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[VS]*	*THEN*	Buffer_Time *[VS]*	1
577. If	Duration *[VL]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[S]*	*THEN*	Buffer_Time *[VS]*	1
578. If	Duration *[VL]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[M]*	*THEN*	Buffer_Time *[S]*	1
579. If	Duration *[VL]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[L]*	*THEN*	Buffer_Time *[M]*	1
580. If	Duration *[VL]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[VL]*	*THEN*	Buffer_Time *[M]*	1
581. If	Duration *[VL]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[VS]*	*THEN*	Buffer_Time *[VS]*	1
582. If	Duration *[VL]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[S]*	*THEN*	Buffer_Time *[S]*	1
583. If	Duration *[VL]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[M]*	*THEN*	Buffer_Time *[S]*	1
584. If	Duration *[VL]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[L]*	*THEN*	Buffer_Time *[M]*	1
585. If	Duration *[VL]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[VL]*	*THEN*	Buffer_Time *[M]*	1
586. If	Duration *[VL]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[VS]*	*THEN*	Buffer_Time *[VS]*	1
587. If	Duration *[VL]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[S]*	*THEN*	Buffer_Time *[S]*	1
588. If	Duration *[VL]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[M]*	*THEN*	Buffer_Time *[S]*	1
589. If	Duration *[VL]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[L]*	*THEN*	Buffer_Time *[M]*	1
590. If	Duration *[VL]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[VL]*	*THEN*	Buffer_Time *[M]*	1
591. If	Duration *[VL]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[VS]*	*THEN*	Buffer_Time *[VS]*	1
592. If	Duration *[VL]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[S]*	*THEN*	Buffer_Time *[S]*	1
593. If	Duration *[VL]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[M]*	*THEN*	Buffer_Time *[M]*	1
594. If	Duration *[VL]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[L]*	*THEN*	Buffer_Time *[M]*	1
595. If	Duration *[VL]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[VL]*	*THEN*	Buffer_Time *[M]*	1
596. If	Duration *[VL]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[VS]*	*THEN*	Buffer_Time *[S]*	1
597. If	Duration *[VL]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[S]*	*THEN*	Buffer_Time *[S]*	1
598. If	Duration *[VL]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[M]*	*THEN*	Buffer_Time *[M]*	1
599. If	Duration *[VL]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[L]*	*THEN*	Buffer_Time *[M]*	1
600. If	Duration *[VL]*	*and*	Degree of Confidence *[L]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[VL]*	*THEN*	Buffer_Time *[M]*	1
601. If	Duration *[VL]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[VS]*	*THEN*	Buffer_Time *[VS]*	1
602. If	Duration *[VL]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[S]*	*THEN*	Buffer_Time *[VS]*	1
603. If	Duration *[VL]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[M]*	*THEN*	Buffer_Time *[S]*	1
604. If	Duration *[VL]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[L]*	*THEN*	Buffer_Time *[S]*	1
605. If	Duration *[VL]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[VS]*	*and*	Degree of Influence *[VL]*	*THEN*	Buffer_Time *[M]*	1
606. If	Duration *[VL]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[VS]*	*THEN*	Buffer_Time *[VS]*	1
607. If	Duration *[VL]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[S]*	*THEN*	Buffer_Time *[VS]*	1
608. If	Duration *[VL]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[M]*	*THEN*	Buffer_Time *[S]*	1
609. If	Duration *[VL]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[L]*	*THEN*	Buffer_Time *[S]*	1
610. If	Duration *[VL]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[S]*	*and*	Degree of Influence *[VL]*	*THEN*	Buffer_Time *[M]*	1
611. If	Duration *[VL]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[VS]*	*THEN*	Buffer_Time *[VS]*	1
612. If	Duration *[VL]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[S]*	*THEN*	Buffer_Time *[VS]*	1

613. If	Duration *[VL]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[M]*	*THEN*	Buffer_Time *[S]*	1
614. If	Duration *[VL]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[L]*	*THEN*	Buffer_Time *[S]*	1
615. If	Duration *[VL]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[M]*	*and*	Degree of Influence *[VL]*	*THEN*	Buffer_Time *[M]*	1
616. If	Duration *[VL]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[VS]*	*THEN*	Buffer_Time *[VS]*	1
617. If	Duration *[VL]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[S]*	*THEN*	Buffer_Time *[S]*	1
618. If	Duration *[VL]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[M]*	*THEN*	Buffer_Time *[S]*	1
619. If	Duration *[VL]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[L]*	*THEN*	Buffer_Time *[M]*	1
620. If	Duration *[VL]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[L]*	*and*	Degree of Influence *[VL]*	*THEN*	Buffer_Time *[M]*	1
621. If	Duration *[VL]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[VS]*	*THEN*	Buffer_Time *[VS]*	1
622. If	Duration *[VL]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[S]*	*THEN*	Buffer_Time *[S]*	1
623. If	Duration *[VL]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[M]*	*THEN*	Buffer_Time *[S]*	1
624. If	Duration *[VL]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[L]*	*THEN*	Buffer_Time *[M]*	1
625. If	Duration *[VL]*	*and*	Degree of Confidence *[VL]*	*and*	Uncertainty_Level *[VL]*	*and*	Degree of Influence *[VL]*	*THEN*	Buffer_Time *[M]*	1

APPENDIX C: CURRICULUM VITA FOR AUTHOR

Professional Experience:

Professional Associations & Activity

- Member of the **American Society of Civil Engineering ASCE**.
- Manager of the Lean Construction group of the Middle East *(Linkedin).*
- Member of the **Egyptian Engineers Society.**
- Member of the **Egyptian Engineer syndicate.**
- Member of the **High Education Quality Assurance Project**, (Minia University).
- Member of the **Higher Studies Rules Development Project, (HEEPF)**. Minia-Tanta Universities.
- Reviewer for the conference of the International Group of Lean Construction (IGLC 18), Haifa, 2010.

Research-related Publications during the period from 2007 to 2010

1. Farag, M. (2008), ***"Egyptian Highway Construction Projects in Need of Lean Management"***, Presentation in the International Conference of European Group of Lean Construction, 28th – 29th May, Karlsruhe, Germany. (http://www.lean-management-Institut.de/fileadmin/downloads/Lean_Construction/E12_EGLC7_Moataz.pdf.)

2. Farag, M., Gehbauer, F. *(2008)*. " ***Scheduling Method with Lean Tools for Highway Construction Project Improvement***." Summer school of IGLC-16: Sixteenth annual conference of the international group for Lean Construction, Manchester, UK.

3. AbdEl-lateef, T., Elsawah, H., Mahmoud, A., and Farag, M. (2008), ***"Using Fuzzy for Assessment Delay in Highway Construction Projects in Egypt"***, Journal of Al-Azhar University Engineering, Vol. 3(10), pp. 432-444

4. Farag, M., Gehbauer, F. (2008), ***"Egyptian Highway Construction Projects in Need of Lean Management"***, Journal of Al-Azhar University Engineering, Vol. 3(10), pp. 483-491

5. Farag, M., Gehbauer, F., and Bhatla, A. *(2010)*. "***An Integration of a Buffering Assessment Model Based on Fuzzy Logic with LPS® for Improving Highway Construction Process***." Proceeding IGLC-18: Seventeenth annual conference of the international group for Lean Construction, Haifa, Israel.

6. Farag, M., Gehbauer, F., Abdelhaleem A., and Bhatla, A. (accepted on 24.02.2010), ***"Use of Fuzzy Logic for Assessment of Schedule Buffers"***, Journal of Management, Procurement and Law (MPL).