Using modern stochastic approaches to schedule Chinese municipal engineering project in Beijing

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DECLARATION

This work is submitted to the University of Central Lancashire in Partial fulfilment of the degree of Master in Project Management. I declare that the work presented here is my own work. The work cited from mass literature is duly references using Harvard Referencing System.

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ABSTRACT

With the development of China's economic, accelerating the progress of urbanization, more and more municipal works appeared in cities. Different with general civil engineering the public works construction site in the city. Due to the special nature of construction sites, the duration of municipal construction were affected by a variety of reasons. Due to municipal engineering are in the city center, its duration are particularly vulnerable to attention from the government, media and nearby residents. This article will be through a case study of planned duration in Beijing to discuss the progress of municipal engineering municipal engineering problems.

Construction scheduling problem belongs to project management. There are three project management constraint which is time, cost and quality. Project management as a science from the 1950s. Project management has evolved from the initial Gantt chart to computer-mediated simulation methods. This article will discuss the most suitable scheduling method now through the development of project management.

By comparing the three methods, the two simulation methods are very suitable for scheduling problems in the municipal engineering. But because the study is relatively simple and not complicated, the results of this study cannot be used in large-scale municipal projects.

CONTENT

ABBREVIATION

AOA	Activity-on-Arrow
ADM	Arrow Diagramming Method
CPM	Critical Path Method
PDM	Precedence Diagramming Method
PERT	Program Evaluation and Review Technique
WBS	Work Breakdown Structure
MC	Monte Carlo

CHAPTER 1-INTRODUCTION

1.1 Background

With the development of economic, the process of urbanisation is also accelerating in the world. This feature is particularly evident in developing countries. However, due to the process of urbanisation driven by a lot of people to the cities, the burden of city is increasingly heavy. The acceleration of urbanisation is became the main challenge in the world (United Nations Human Settlements Programme, 2013).

China, the world's most populous country, plays an important role in the urbanisation of the world. Since the implementation of reform and opening-up policy, China's urbanisation process and urban construction has entered a stage of accelerated development (Fang, 2009). The urban population increased from 172.45 million to 749.16 million between 1978 and 2014. During this period, the proportion of urban population grew from 17.92% to 54.77% (National Bureau of Statistics of China, 2015). The migration of the population not only led to economic growth but also to promote the urban construction. It is clearly to seen the point from the change of built-up area. The Chinese built-up area from 7,438 square kilometers in 1981 expended to 184,099 square kilometers in 2014 (Fang, 2009). In the other words, China has made great achievement in terms of urbanisation during the past thirty years.

Beijing as the capital is the political, economic and cultural centre of China. Absolutely, it plays an important role in the process of reform and opening-up during the past thirty years. Especially, the built-up area of Beijing has significant expansion, form the 19,264 square kilometers in 1995 to 49,773 square kilometers. The built-up area is generally regarded as that consists of developed area, gross building area and illuminated section (Office for National Statistics, 2013). The increase in build-up area will cause an increase in the amount of municipal engineering.

Urbanisation development will inevitably bring about the development of municipal engineering, which as can be seen from the name, are the city-based works. This kind of projects have benefits on improving the living conditions of residents with regard to entertainment (He et al, 2013). Due to the construction sites are mainly in the centre of

city, the construction conditions are more complex than general civil engineering. Especially, the site of municipal engineering is in Beijing. It means that there are more uncertainties and risks in the municipal engineering. All of the risks would possibly extend the project duration. Municipal engineering is closely related to the residents' lives. So a good project management of municipal engineering helps to reduce the impacts of residents' daily lives.

With regard to the Beijing municipal engineering, there are three main types of risks on construction sites. First of all, environment problem is one of the risks. For instance, the construction would be required to cease if it makes pollutions such as create much more dust on the sire. Moreover, the urban policies of traffic in Beijing are special, the engineering trucks are not allow entering city during the day time. Therefore, in some cases, some works such as concrete work might be carried out on night. It is another risk of duration extension. The third type of risks is that sometimes compensation of property owners would be a controversial issue which would also affect the project duration.

There are many activities in a construction project. Scheduling construction activity is a basic method to cut down the duration. Critical Path Method (CPM) and Project Evaluation and Review Technique (PERT) currently are the main methods used in schedule construction activities.

The deterministic and stochastic are two basic models for scheduling. The purely deterministic method for scheduling is CPM. This is because the definition of all activities' duration, relevance and logical destination is the premise CPM is calculated using the longest path of planned activities on the logical end of the project. The critical activities are which on the longest path, their float can change the project duration (Morgan & Kelly, 1959).

There are several stochastic methods of which PERT in one of them. The PERT can be used when the logic relation is known and the duration is unknown. The mothed is through determine the optimistic duration, the pessimistic duration and the most likely duration to calculate the activities duration. The activity duration is always considered to be obey the normal distribution (Malcom, 1959).

In fact, the duration is uncertain, so every path could be the critical path (Elmaghraby, 2000). And in actual project, there are often more than two critical path (Zhoufu, et al.,

2002). So, it is necessary for research the scheduling to use simulation. (Wang, et al., 2004)

The fuzzy mathematics and Monte Carlo simulation are the two approach to estimate the each activity duration.

From the above paragraph, it is apparent that many researchers have carried out studies relating to use PERT to manage construction project. Many of these studies are, however, focus on general civil engineering. For the municipal engineering the emergency and risk is more and complicated.

This research will add the special factor of municipal engineering use the fuzzy mathematics and Monte Carlo simulation to estimate the each activity duration and the project duration.

1.2 Statement of problem

There are more and more municipal engineering will be built in the urban city in China, with the urbanization process. And the municipal engineering the emergency and risk is more and complicated.

For the Chinese municipal engineering, there are three main type risk on the construction site. First of all, the risk is one hot issue Environmental Problem. For instance, the construction must be cease if there are much more fog in the site. Meanwhile, the urban policy of traffic is very special, the engineering car is not allow in city in the day time. It is mean that some work like concrete work must be working on the night. And many times some owner of land required more acquisition to hinder construction work.

1.3 Aim and objective

1.3.1 Aim

The aim is for using the modern stochastic approach of estimation for scheduling construction activities on Chinese municipal engineering projects.

1.3.2 Objectives

a. Give a clear understanding the problems to construction schedule on Chinese municipal project.
b. Analyse all the risk factors affecting the construction time on municipal project.
c. Review all the different methods available for time estimation of activities on construction project.
d. Select the stochastic approaches that will be suitable for implementation in Chinese municipal engineering

1.4 Methodology

The main method is based on the classical the CPM and the PERT to manage the civil engineering. Through the modern stochastic approaches like fuzzy mathematics and Monte Carlo to simulate the duration for reducing the mistake.

1.5 Structure of the dissertation

This dissertation primarily consists of five parts. The main content of each chapter could be present as below:

Chapter one will introduce the whole structure of the article and give a reason of the topic choosing and the social significance of this subject. The aim and objective, methodology and the scope of the study also will be listed. In other word, this chapter is a brief description of the dissertation.

The second chapter is focus on literature review. It is divided in to two parts. First section will introduce some important concept of Critical Path Method and Project Evaluation and Review Technique, and the second section will detail explain the fuzzy mathematics and Monte Carlo simulation.

The next chapter will review the quantitative research methods. It is based on the fuzzy mathematics and Monte Carlo simulation module to analysis the PERT network. And compare the two modern stochastic approaches.

In chapter four, I will choose one Chinese municipal construction project to research the modern stochastic approach apply to actual construction engineering. And compare the traditional research by the duration.

CHAPTER 2-LITERATURE REVIEW

2.1 Introduction

Management is accompanied by human activity has always exist. From the family unit to community units, the management object is increasing. Accompanied by this, the method of management is changing. Among the many management method, the project management is most popular (Sireesha, 2010). And the tool of project management has many kind of, like Critical Path Method (CPM), the Program Evaluation and Review Technique (PERT), Monte Carlo and Fuzzy. All of them will be discuss in this chapter.

2.1.1 Overview of Beijing Municipal Project

According to the General Planning of city of Beijing, the Beijing Municipal Project refer to in accordance with urban and rural planning, provide paid or unpaid public facilities, services, and equipment for residents, and belong to a range of government responsibilities and obligations. So the Beijing municipal project is belong to infrastructure and include building, viaducts, subways, light rail, plumbing, lighting, urban roads and so on (Beijing Municipal People's Government, 2004). For the strategy, Beijing municipal engineering is the city's survival and development of fundamental, is the important basis for the city function orientation and the city's comprehensive competitiveness. With the rapid development of national economy and the gradual acceleration of urbanisation, the region has become the most important city construction by improving the level of people's livelihood and other aspects of the environment (Wang, 2004). Especially the China's 13th five-year plan propose to strengthen the role of the Beijing as the Chinese center. Different with general civil engineering, the Beijing municipal infrastructure itself has a huge investment, long construction duration, the relevant technical specifications imperfect, the margin error between local standards and national standards, the degree of difficulty of construction large construction unstable conditions and other characteristics. All of this characteristics are likely to cause difficulties in construction management and information management, low efficiency, increasing project cost, schedule delays and other issues.

2.1.2 The problems of Beijing Municipal Engineering

Most of Beijing's municipal basic transformation within the built-up area, some still in the downtown. Particular location of Beijing municipal project is easy to cause the civil engineering problems like quality issue, budget issue and schedule delays. As China's most populous city, every Beijing's municipal engineering will affect the residents' daily live. One of the most concerned issues is the schedule delays, it will cause great dissatisfaction of the masses. So this dissertation's object is the construction schedule delay of Beijing municipal engineering.

2.1.3 The factors of Municipal Construction delay

Like most civil engineering, there are many factors which affect municipal engineering schedule delay. Some of them are design factors, demolition factor, the degree of coordination with other construction units, and the problem of the construction company itself (Canadian Home Builder's Association, 2010).

Design factor

On the design stage, there always are some error on the design drawing or the designer is not accurate enough to consider the change of the construction site. It is often leads the construction units to modify the design drawing which often lead to construction delays even shut down.

Demolition factor

Demolition always impact on the duration of municipal engineering. Part of municipal construction will start before the end of the ground attachments demolition, this will result the demolition need to do during construction and lead to municipal engineering's progress is slow. And municipal engineering involve many plumbing engineering which have unforeseen obstacles underground need to deal with by time-consuming.

The degree of coordination with other construction units

Municipal engineering is a systematic project, in addition to the construction unit itself, there are water, electricity, gas, heat, communications and other companies to participate municipal

engineering. Any of the corporation make mistake will result in wasting resources and schedule delays.

The problem of the construction company itself.

Many construction companies do not have the ability to complete the project, such as do not have enough staff, resources and equipment. The management level of construction units is inadequate throughout the construction process.

Due to the municipal engineering is a systematic project and presence of a large number of actual uncertainty problem in construction process, this dissertation choice the project management as the theoretical basis.

2.2 The theoretical basis

2.2.1 The project management

Generally, project management is considered as an independent scientific rather than general management due to the object of project management is project. Project is a kind of economic activity of human society, in order to create a specific product or service for a one-time event. So as long as it is the creation of a particular product or service activities are belongs to the category of the project.

2.2.1.1 The definition of project

Project comes from the differentiation of human organized activities. Stand on a different point of view, the understanding of the concept of the project is not the same, it is generally believed that the project are interconnected one-time tasks under the given constraints of resource and requirements for a particular purpose (Burke, 2001). People's understanding of project is different, so the definition of project is varied.

According to the Association of Project Management (APM), the definition of project is “A unique, transient endeavour undertaken to achieve planned objectives” (APM, 2006). And for Project Management Institute, the project is described as “It’s a temporary endeavour undertaken to create a unique product, service or result” (PMI, 2008). Both of two definition mentioned the temporary. It is means that every project has a clearly beginning and a clearly

end. So the start and finish time need to define clearly. And a project is unique means it cannot be deal with by rely on conventional manner. It need a particular set of operations designed to accomplish a special goal. So the composition of project team is more complex and specialised than general team and often requires experts in various fields.

2.2.1.2 The basic characteristics of project

Project has the following basic characteristics that can be seen from the definition of project (Bakouros, 2000).

1. One-time

This is the biggest difference between projects and routine tasks. The project will be terminated when reaching a certain goal.

2. Uniqueness

The product, service, or task of the project is not done before, it is unique.

3. Life cycle

Project has life cycle. The project team will be built at the beginning of the project. During the project execution, the project team members and function are constantly changing, and at the end of the project, team will be disbanded.

4. The dependencies and conflict

There are more than one organisation involved in the project, they are combined through contracts, agreements and other social relationship. Meanwhile, the project and other projects of its parent organisation often influence each other.

5. Irreparable consequence

Project unlike anything else you can try to do, or can be repeated after the failure. This determines the projects with greater uncertainty, it is a gradual process, with a variety of risks. Project requires careful design, careful production and careful control in order to achieve the desired goal.

2.2.1.3 The basic theory of project management

Project management is an advanced management methodology which to plan, organise, control and coordinate and so on to make the project successful in order to achieve the desired quality of the project, the project schedule, project budget and other objectives in the whole process and various aspects. This methodology carries out a lot of management activities using a variety of knowledge, skill, methods and tools, in order to meet or exceed the requirements and expectations of the project from related parties (Zhang, 2010). It is the efforts of the project manager and project organisation, using system theories and methods. It is management methodology to plan, organise, coordinate and control the project, in order to achieve specific objectives of the project. To achieve the objectives of the project, the project needs proper investment that the required resources to complete the project, including labor, materials, and equipment. The process that these inputs become output constitutes the whole process of project management (Castells, 2005).

The main feature of project management include:

1. Universality

Project is the redefining of some activities. In essence, the project is some special events in productive activities. Before proposing the project definition, mankind has been completed many projects like The Great wall and Pyramid. Project is universal for the entire world.

2. Purpose

Purpose is the important feature of project management. In order worlds, the project management is a purposeful activity. The role of management is to meet the requirements of project.

3. Uniqueness

The uniqueness is the feature of project management different with the general production management and conventional administration which reflecting from the full range. Each project has its own unique management objects, unique management requirement, unique management activities and unique management methods. It is an independent existence in the management area.

4. Comprehensive

Project management is complex and abundant management activity which depend on a variety of disciplines to solve problems. Due to the project management is uniqueness, there is a lack of experience to use for project management. And the management generally consists of a lot of activities, it is easy to know the project management is a complex task. Coupled with the need to consider the various constraints, the project management is comprehensive.

5. Innovation

Innovation of project management is certain. Due to the uniqueness of project, any management of project is not have rigid models and methods, every specific project needs to innovate to achieve effective management.

6. Temporality

The core of project management is through planning, controlling and allocating resource to reach the goal within the prescribed duration. The progress of project management is over when the goal come true. Therefore, the project management has a predictable life cycle.

2.2.1.4 The Content of Project Management

Modern project management put project management into nine knowledge areas. They are project integration management, project scope management, project time management, and project cost management, project quality management, human resource management, project communication management and procurement management and risk management (Havranek, 1998).

1. Project integration management

Project integration management is the necessary process in order to ensure appropriate coordination of each part of the project. In project development process, various resources or programs will conflict, we must coordinate overall. It is through overall coordination of the various resources and programs, project integration management is to trade-off between the objectives and programs which are conflict with each other, in order to meet or exceed the requirements and expectations of the project stakeholders. Project integration management

includes three aspects: project planning, project planning implementation and integrated change controlling.

2. Project scope management

Project scope management is the process to control the boundaries of related activities. In other words, it is an activity clearing the project content items. It is necessary to identify the project subject, the manner of project management, time requirement of project management, quality requirement of project management and the planning of project management. These will affect the progress of the project management process. Therefore, the definition of the project is priority. It is the foundation of project management.

3. Project time management

Project time management is the activity to make sure that the project is completed on time. It include the definition of the start time, choose time units, sorting by the activity feature, estimating the consume time, project scheduling, time control and other work.

4. Project cost management

The process of project cost management is to ensure that the actual cost to complete the project does not exceed the estimate cost. It usually include resource planning, cost estimate, budget and cost control and so on.

5. Project quality management

Project quality management include quality planning, quality control and quality assurance. It is a series of management processes in order to ensure that projects meet the quality requirement specified by customer.

6. Human resource management

Human resources management refers to the project management of the members, give full play to their ability and subjective initiative to achieve the project objectives. It is include organisation planning, recruitment and project team building.

7. Project communications management

Project communications management is to reduce unnecessary waste of resource in the project management process. The project communications management make the information which generated in the project management process can be delivered timely and handled properly.

8. Project risk management

Risk management of the project is a system procedure since the risk along with the project management from start to finish. In the project risk management, the measure includes risk management planning, risk response planning, and risk monitoring and control.

9. Project procurement management

Project procurement management is a series of management measures in order to ensure the availability of required for the project, especially which need to obtain required goods and services from outside of the project organisation.

These nine aspects formed specifically theory and methodology, and developed modern project management standard.

2.2.1.5 Triple constraint of project management

There are main nine aspect in the project management content and all of them are important part of project management. However, the cost, time and scope are considered to be a significant indicator and mutual restraint among each other (Bichta, 2001). They are named project management triple constraints.

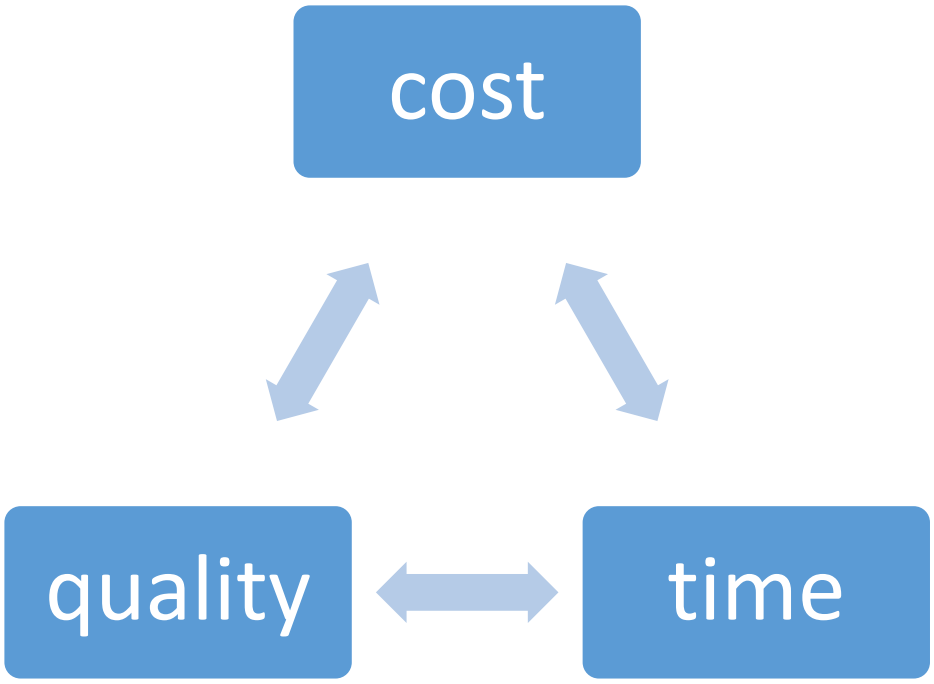
Cost: Any project should have a clear budget, customers will not choose an unidentified price services and products. If the manager reduce the price of the project, it is bound to increase the scope and duration of projects.

Time (Duration): The saying goes, time is money, and the project extension is often happen. All projects have a delivery date. If a project needs to be completed ahead of schedule, it is necessary to increase the cost and reduce the quality.

Scope: The project need to determine the scope at the beginning stage, defining the requirement like the content of the project and the end result should be accomplish. Some individual task is the core of the entire project will determine the overall quality, and some

tasks require a specific time to complete. All of them are the scope of project. Many projects cannot determine the scope at the beginning stage, which is the reason many projects fails. When a project need to increase its scope, the cost or time will increase, too.

Recently, in order to emphasise the importance of project quality, the triple constraint of project management are sub-divided into four core elements. They are time, cost, scope and quality (Burke, 2001). Even more, the quality triangle appears to be more frequently than scope triangle. Sometimes, people even use quality triangle instead of scope triangle like the figure 1 (Jenkins, 2002).



The central of the triangle which composed by cost, time and quality is the customer expectations. No two customer expectations are the same and any project is unique, so the customers' special require is the key point of project.

2.2.1.6 Project management processes

Generally, the processes of project management are organised into five parts. There are initiating, planning, executing, controlling and closing. Every process has their own aim and function (PMI, 2008). Clear tasks for each process to avoid wasting resource and time.

Initiating processes

One idea will be put forward at this stage, and the team will conduct a feasibility analysis of this idea to make sure that this idea can be implemented and beneficial to the team.

Planning processes

Project planning should be recording in writing, which should indicate the important work or critical work. At this stage, a good team should be able to calculate the budget and schedule, and determine what resources are needed.

Executing processes

Executing process is the core process of project management including resource allocation and teams interact.

Controlling processes

On this process, the manager should measure and monitor the project performance periodically, identity the errors which deviate from the project plan, and take corrective measures to achieve the objectives of the project.

Closing processes

Formal project delivery stage, the project team finish the work to complete the project and summarise the successes and lessons of the project.

This essay focuses on the problem of scheduling in project processes.

2.2.1.7 The benefits of project management

Therefore, the project management can ensure the balance between the three constraints of the project, effective project management process. Using a project management approach obviously benefits for requiring of the project. The project manager is responsible for the evolution of this project can effectively control and track projects to ensure that projects achieve the desired objectives (Munns, 1996). To achieve this requires the project manager can always get feedback and update information from the project executing and controlling processes. This information needs a system to deliver the scope of work and indicators performance compared to the initial plan to project manager.

This system which also named approach is the core of the entire project management. Although the system will generate additional costs and consume more time, it should be understood that, if it leads to poor management decisions, the lack of error messages may be more expensive, rework and overflow. So the history of the development of the project management is the history of the main system or method which is the project manager for the project plan arrangements, tracking the progress and making adjusting.

2.2.2 The history of project management

The Egyptian pyramids or the Great Wall of China is considered as the origin of project management. Indeed, these project are large and high construction, complex and sophisticated structures, requiring pre-design and manage a large number of engineering labour. But there no document can be evidenced the project management techniques was used in these project (Burke, 1999).

2.2.2.1 Gantt chart basics

Charts is an intuitive way to express information in the management activities. Milestone charts are early used in modern project management. Milestone charts can intuitive display the events, critical point, checkpoints, current position and the desired goal. It applies to many simple and little management activity. But it cannot display the relationship between the milestones and the requirements of time, cost and resource (Prabhakar, 2009). With the development of modern management, Henty Gantt improve the chart to a new form named Gantt chart early 1900's.

2.2.2.2 Content of Gantt chart

The inherent ideology of Gantt chart is based on a line graph. On the Gantt chart, the horizontal axis represents time, the ordinate represents activities or project and the line indicate planned and actual completion activities on the entire period.

2.2.2.3 The benefits of Gantt chart

The Gantt chart as the most popular method of management is still widely used today. It is composed of multiple causes. For the drawing staff, the Gantt chart is easy to manufacture,

inspect and change. For users like project managers and workers, the Gantt chart is simple to understand and easy to construct.

2.2.2.4 The limitation of Gantt chart

Although there are much benefits of Gantt charts to project management, the limitations cannot be ignored (Frame, 2006). The first limitation Gantt chart is that it cannot show the triple constraints. The focus of Gantt chart is duration of project. The cost and scope are not display on the Gantt chart. So Gantt chart cannot reflect the relationship about cost, time and scope, no matter how detailed the Gantt chart is.

The second limitation of the Gantt chart is that it only works well when used in smaller projects. With the increasing of activities and time, the Gantt chart will be more complex. It will make the Gantt chart lost its benefit and increase the difficulty of reading, especially the chart more than one page.

Meanwhile, the Gantt chart cannot describe the complicated project like some activities has sub-activities. It cannot describe the relationship from each activities. And if there is one worry sequence from two activities, the entire Gantt chart need to changed.

2.2.3 Five management functions

During the same period of the Gantt chart appears five functions of management is created by Fayol who with the Gantt was student of Taylor's theorises of science management. The functions of management are planning, organising, leading, controlling and coordinating. Efficient management and leadership should involve creative, problem solving, motivating employees and making certain the project accomplishes objectives and destinations (Stefan, 2013).

Planning

Management planning function control all planning, enabling project to operate smoothly. The plan includes a goal to define and determine the most effective activities to achieve this goal required curriculum. Under normal conditions, the flexibility of planning involved, as planners and managers at all levels must be coordinated and led organizations. The plan also takes understanding the future objectives of the project resources and operations.

Organising

Project manager function controls the overall construction of the organisation of the project. Organisational structure is the basis of a project; the daily operations of days without such a structure, the business has become difficult and unsuccessful. Organisations involved in the tasks and duties designated to the workers need specific skills to complete the task. The organisation also involved in the project to develop the control structure and chain.

Leading

All recruitment and personnel require to control is the main functions of leading. The main purpose of the leading is to hire the proper people in the right jobs, in order to achieve organisational goals. Staging involves more than just recruitment; leading also includes training and development, performance appraisal, promotion and transfer. If there are no management functions, projects will be delay, the reason is the lack of experienced workers will result in waste project resources and time.

Controlling

The controlling function of management to ensure that all other uses of the organisation are in place, and the successful operation is very useful. Controlling including the formation of performance standards and supervisory personnel output, to ensure the performance of each worker's standard. The controlling process often leads to the situation, it is necessary to identify by creating a new performance standard to work problems. The level of success in all aspects affecting the performance of the organisation.

Coordinating

The coordination function of the project manager to moderate all of the organisation, planning and staffing activities of the project and ensure that the common feature of all the activities for the organisation's benefit. Coordination usually occurs in the progress plan and control, to ensure that all departments have goals and objectives on the same page. Coordination is achieved by involving communication, supervision and guidance.

Therefore, a much better method is required when scheduling project.

2.2.4 Scheduling Networks

Scheduling is the method by which work specified by some means is assigned to resources that completed the work. Scheduling as a management manner has very long history. The scheduling has been applied from ancient Chinese built the Great Wall. The Qin Great Wall had built 120 kilometers by collecting workers, transporting wood and stone, and according to the type of work assigned workers about 2000 years before. Scheduling is a common phenomenon in the development of management (Caro, 2004).

Scheduling network is a graphical model which shaped like network. It is composited by activity, event and path. On the image, they are expressed on nodes, arrows and route. The meaning of the symbol is not the same in different scheduling network.

There are basically two types scheduling network. They are

(a) Activity on Node (AON)
(b) Activity on Arrow (AOA)

The AON is also named Precedence Diagramming Method (PDM). In this method, the node represent the activity and the arrow represent the logic relationship between two adjacent activities. The AON includes four dependency relationship between two activities. They are finish to start, finish to finish, start to finish, and start to start. In this method, the finish to start is the most common logical relationship. The advantage of AON network is there are less nodes and easiness to draw.

The AOA is also named Arrow Diagramming Method (ADM). This method is using arrow represents an activity and node represents the sequence of activity. Generally, the logic relation of AOA is only finish to start. This method is widely used in construction project. Due to the finish to start is the basic logic, there are some virtual activity to describe some other logic.

2.2.5 The Critical Path method and Program Evaluation and Review Technique

The CPM and PERT was started developing a methodology from the scheduling network AOA or ADM about 1950's. There is only one route which is the longest or most time-consuming activity in one project (Leighton, 2012). And the project will finish after all of the

activities from this route finish. This longest route called the Critical Path. The activities which composed of critical path named critical activities.

During the same period, the PERT was developed by the US Navy Special Projects Office. Briefly speaking, the PERT is a technique using network to analysis the plan and evaluate the plan. It can coordinate the entire program of the procedure to reasonably arrange for manpower, resources, time and money to complete the accelerated program.

PERT and CPM are the important part of scheduling network. They are widely used in systems analysis and project management. Both of them use scheduling network and look like similar. The CPM is primarily a kind of based on a single point time estimated and strict order network diagram. It can provide important assistance for the project, in particular to provide a graphical display of the main activities. These quantitative information to identify potential project delays provide an extremely important basis. PERT is built on the basis of the network plan. The working time of the various processes in the project is not certain, so the duration need to estimate. In the engineering practice, due to the people's understanding of things is restricted objective condition, the probability calculation method usually be used in PERT.

2.2.6 The gaps

CPM and PERT usually are used for project management. It can help the manager scheduling the project activities. Actually, the real project network often include thousands of items, it is easy to miss some activities when draw the scheduling network. And the actual relationship between the various activities is not very clear, it is difficult to make plan. The most important issue is the duration for each activity often requires to estimate, there may occur deviation (Pich, 2002).

The ideal conditions of CPM and PERT are the every activities' duration is determined. It can get the best results. But in reality, every project activity is difficult to estimate. It maybe cause risk for project. Especially the project is a complex and huge project. When the determined method is hard to use, the stochastic approaches show be try.

2.3 The stochastic approaches

2.3.1 Monte Carlo

Monte Carlo as the most popular stochastic simulation method using the probability and statistical theory as the basic to calculate. The basic idea of Monte Carlo method had been discovered and utilised long ago. It can be known by the definition of probability, the probability of an event can be estimated with a lot of testing in the frequency of events. When the sample size is large enough, it can consider the frequency of occurrence of the event that is its probability (Grinstead, 2003). So do a large number of random sampling from the random variables, and these sample values of a group of a group substituted into the performance function type, determine whether the failure of the structure. Monte Carlo method is based on this idea.

Although, the theory of Monte Carlo method is simple, it need to large amount of computational expense.

Probabilistic methods usually generate estimates based on Monte Carlo simulation (Moselhi, 1997). These methods may consider correlation among cost items or consider them independent (Sonmez et al., 2007). The application of simulation based methods requires availability of historical data to generate applicable probability density functions needed for accurate simulation. However, the methods use probabilistic approach can yield more accurate contingency estimates than the ones use deterministic approach.

In order to overcome the limitations of simulation based method, fuzzy-based methods were introduced (Idrus et al., 2011; Shaheen et al., 2007). These methods use expert's numeric and linguistic assessment of risks associated with the project. Fuzzy based methods use membership functions bounded by two ranges.

2.3.2 Fuzzy

Fuzzy technology is the core technology in the 21st century, the application of Fuzzy Mathematics has penetrated into almost all areas of natural sciences and social sciences. The PERT network was proposed in 1950, and the usefulness of this method is such obviously. In the project scheduling, the PERT is in common use, it applies to the project which has only

one indeterminate critical path, at the same time the logical relationship and project duration of the project is definite.

Because the construction period of most of the projects is very long, and there are many influence factors of the duration, there are fuzziness between the duration of each working procedure and overlapping relationship between processes. Therefore, how to determine the project duration for a project is so important, in view of the objective fuzziness, on the premise of reasonable assumption. It is not only can help the owners to make investment decisions, but also can provide the foundation for the contractor on the bidding work and contract negotiations.

Many fuzzy things and phenomenon exist in the objective reality, this make people want to build a suitable logical model to describe fuzzy things and phenomena. Fuzzy set theory emerges at a historic moment in this situation (Dorn et al, 1995). Fuzzy set theory is based on fuzzy mathematics, research the inaccurate phenomenon. Fuzzy set theory method regards investigation object and its fuzzy concept as a fuzzy set, set up the appropriate membership functions, through fuzzy set operation and transform, analyse the fuzzy object.

Fuzzy model is the model build to describe the certain features and the internal relations of the objective things with fuzzy mathematics language. Fuzzy model recognition, refers to in the model recognition, the model is fuzzy. That is to say, the model provided by the standard model library is fuzzy. The research of a fuzzy model of resource-constrained project scheduling has been initiated many years ago by three experts. They have developed the priority rule from serial and parallel scheduling schemes to deal with fuzzy parameters.

In 1999 Wang has developed a fuzzy set method, people can use it to arrange the project product development, and the product does not have accurate time information. The project has a fuzzy preparation time and fuzzy deadline, the activities are assumed to have a fuzzy duration, all described by trapezoidal fuzzy number.

In the project construction management, fuzzy set theory is very outstanding. The fuzzy set theory in the management of the project construction period is indispensable for managers. It can provide important management information. The theory combines quantitative and qualitative research, the result is objective and fair, it has high reliability, logicality and universality and other characteristics. It provides a new idea for project construction management.

2.4 Other stochastic approaches

The Bayesian probability

Bayesian probability is a probability of the explanations provided by the Bayesian theory, it is defined as someone using the probability of a proposition trust level concept. Bayesian theory also suggested based on Bayes' theorem can be used to export new information or update existing rules confidence. Bayesian probability is a mathematician Thomas Bayes named. It has been widely used in probability theory.

Generally, there are three steps to Bayesian data analysis (Gelman et al., 2013).

Setting up of a full joint probability distribution for both observable: y, and parameter: θ

$$p(y, \theta) = p(y|\theta)p(\theta)$$

Conditioning on data, $p(\theta|y)$

Model checking

The limitation of Bayesian probability

Some people think Bayesian is sufficient for research on uncertainty, many people consider the Bayesian as a generally applicable rule, because a clear assessment of the conditions and possibilities implied condition is seldom a clear distinction in the relevant discussions open. If there is no such distinction, hallucinations, knowledge of all probability distribution functions can be supported by an explicit condition to represent, and therefore the conditions by using a Bayesian system to learn (Wang, 2003).

When the inference system has sufficient knowledge and resources, we cannot assume that the initial background knowledge does not need to be modified, nor that all editions probability distribution function can be viewed as the update is complete. Therefore, the limitation means that the Bayesian approach is not reasoning in this case of gauge theory, it needs something else (Wang, 2001).

2.5 Software scheduling approaches

There are serval off the shelf software that can be utilised to achieve the same good stochastic scheduling. However only 3 will be discuss at this essay. They are MATLAB, Oracle crystal ball and @RISK.

2.5.1 The Crystal Ball

The Oracle Crystal Ball can predictive modelling, forecasting, simulation and optimization of the leading spreadsheet-based applications. And it is built inside the key factors affecting risk.

There are many tools for risk analysis in the traditional sense, but the establishment of a spreadsheet model will be more intuitive. Crystal Ball is suitable for spreadsheet models, especially Microsoft's Excel spreadsheet models. One of the drawbacks of traditional spreadsheet models is that people can only enter a value in a time cell. This approach is very time-consuming and generates large amounts of data still cannot realize the probability of different outcomes. A good spreadsheet model can identify the possibility of risk, because the formula cell and cell references to identify the causal relationship between variables is very helpful. Due to it can be only changed a value in the calculation process requires changing the value of uncertainty to find the smallest changes, most likely and maximum values. Crystal Ball can define these uncertain variables by defining the cells in a whole new way.

Using the crystal ball for simulation, the forecast results not only show you the different results each prediction value, but also the probability of any value. Some chart can show various aspects of the modern like frequency chart, certainty, sensitivity chart, overlay chart and trend chart. Crystal ball can not only get rid of the restrictions of the spreadsheet, find important factor sensitivity analysis to quantify risk, and very intuitive.

2.5.2 The @RISK

The software @RISK is developed by the company Palisade, which using for risk analysis. @RISK Performed using Monte Carlo simulation of risk analysis, can be possible results are displayed in a spreadsheet model, and shows how likely they are to occur. It is mathematically and objectively calculate and track many different situations that may arise in

the future, and then calculate the probabilities and risks for each different one associated with. It is easy to judge risk, avoid risk and get the best decision decisions under uncertainty.

@RISK Can be optimised by RISKOptimizer, which combines Monte Carlo simulation with the latest technology to solve optimisation and uncertain value of any spreadsheet plan the best risk management strategy, to determine the best allocation of resources, optimise asset allocation, the most efficient schedules, and so on.

2.6 Summary

Scheduling of engineering activities has come a long way from the simple Gantt chart to using a software. From the initial simple Gantt chart is just for clarity of expression workflow, to scheduling networks can develop more accurate and more detailed projects. Development from large projects to the national strategic level civil ordinary project, the factors affecting the duration of the project become more and more, it cannot use the determined project management methods and then use stochastic simulation to the project plan. With the amount of calculation increases, more and more computer software has been developed for the simulation. Today's software is not only more but also very professional subdivision.

CHAPTER 3-RESEARCH METHODOLOGY

3.1 Introduction

The chapter discusses the methodology adopted for the case study. The easy research the scheduling problem in the planning stage of construction project mana gement. It is a critical activity to accurate predict project completion period. However the completion time of all works is often uncertainty as the factors of the natural, social, technological, economic and others. Especially in Beijing. And the project completion time is uncertainty either. So it's very difficult to accurate prediction on project time. If the prediction error of time limit for a project is very big, it will cause great difficulties of project implementation and management. This paper argues that using the Monte Carlo technology can be reliable to control the project schedule, and improve the reliability of the prediction about the period time in the construction project. Monte Carlo simulation is a kind of random statistical simulation test method. This method is based on the theory of probability and mathematical statistics. It is designed as a probability model that by random sampling variables makes the parameters to conform to the actual fact. Using the random number generator to select random variables of all the parameters, this can simulate actual capabilities. Using the trial and error until enough times, it can get the right probability distribution of output variables. This paper uses the MATLAB software to compile the Monte Carlo algorithm, so it can dispense the mathematical reasoning and calculation process that is heavy and complicated. With the aid of computer high-speed operation ability, general engineering and technical management personnel can understand and master this way easy. He can work quickly and simple, instead of laborious calculation process. So he can correctly plan and control construction project time.

3.2 Choice of research methodology

Usually，there are three main methods can be used in social science research, qualitative, quantitative and mixed methods research. They are widely used in social science research.

Quantitative research is the research process that through statistical investigation method and experimental method to make statistical analysis and inspection. Qualitative research tends to use access, observation and literature method in information collection, on the basis of certain

theory and experience, grasp the main features of things, omit the differences on the number of homogeneity temporarily, pay attention to the internal point of view from the researchers to understand what they see in the world, and great attention must be paid to the relationship between the researchers and subjects (Creswell, 2004). Mixed methods research is combined with quantitative research and qualitative research, to use different methods to collect various types of data and emphasize on the solution of the problem (Denzin and Lincoln, 1998).

3.3 Using Monte Carlo simulate project time

3.3.1 Calculation model of time limit for a project

If the time of project tasks is sets to t_i, it is clearly that t_i is independent random variable, the project has n complete paths. A complete path time is $(\sum t_i)j$. So the final time limit for a project is as follow:

$T = Max\{\sum t_i\}$j

It is almost impossible to find the distribution function of project time, because the works time of the project are all kind of distribution functions of random variables. Using the Monte Carlo technique is not necessary to find out the distribution of the project. The basic idea of Monte Carlo method is to use the joint probability density function of basic random variable sampling. The number of sample points occurs as the actual value. Doing enough times, the unbiased estimate of the parameters of project time that obeys normal distribution. Thus we can effectively control over time limit for a construction project at a high reliability level.

The Monte Carlo procedure of simulating time limit for a project

1. Through the data and experts, each work is determined the minimum, the maximum and the most likely time, and is chose a suitable prior distribution model, project time generally obeys normal distribution, triangular distribution, beta distribution and uniform distribution, etc.
2. Generate random numbers. In the practical work, generating random numbers of physical methods are often time-consuming too big or the high cost, so this paper use the Matlab software to produce higher similarity of pseudo-random number instead of the random number. And it does not affect the reliability of the calculation results.

3. Generated random number is used to determine the various works time that may occur actual.
4. Deal with works time occurred in the statistical method. And calculate the time limit date for the project that includes the minimum and maximum data, the mathematical expectation and unit standard deviation.
5. Manage and control the project schedule according to the calculated statistical data. Due to the use of Matlab software, we can calculate that statistical data very fast. And Monte Carol simulation can be used for sensitive analysis simultaneously.

Using Matlab software to simulate actual project time, the computers calculate flow chart is the fig.

Choose the random using Matlab

The main difficulties using Monte Carlo method is 1 how to generate random number; 2 how to determine the size of the sampling number. It is a significant advantage of using Matlab for the Monte Carlo method that Matlab has powerful functions of random number generator.

Usually, using Monte Carlo method to sampling directly must solve the inverse function of the various works time distribution. And we can get corresponding distributed types of random variables. Then we use that function to solve every work time and the whole project time.

Matlab provides a type of random number generator that gives number random of all variable distribution function. It can directly produce variable and calculate with those function. This greatly improves the calculation efficiency.

All variable mean and variation coefficient works time and be got from historical data and technical experts, sampling in Matlab as follows:

Sampling normal distribution random variable:

t=normrnd ($\mu, \sigma, 1, n$)

Sampling beta distribution random variables:

t=betarnd (a,b,1,n)

Triangular distribution can be used beta distribution to instead of. Or use uniformity distribution to generate random number in the open interval (0,1) firstly, and then use the triangle distribution function to change the number into a given variable number.

When using the Monte Carlo method to simulate, we should make sample frequency enough to ensure the accuracy of the predicted results is reliable. Generally, computer output to the mean and variance of the construction project time will come to convergence as the simulation times (n) gradually increasing, and that output is stable as fixed value when the sample frequency is more than a certain number.

In the formula, the S is the standard deviation of time limit for a project. E is the allowed time error.$Z\alpha_{/2}$ is the degree of confidence, when the confidence level is 99%, and $Z\alpha_{/2}$ is 2.58. The simulation times are usually need tens of thousands of times. As the improvement of computer operation ability, modern computer can do it and can fully satisfy the precision requirement.

3.3.2 The benefit of Monte Carlo

But using the Monte Carlo technique can make up for the shortage. All completion paths are calculated their random completion time. And the average completion time, the maximum completion time, the minimum completion time and other related data are calculated according to random completion time. So the fact that the completion time of non-critical path exceeds the time of critical path can be taken in

Using Monte Carlo method to calculate the project all completion paths, we can get accurate comprehensive prediction of project time limit for project. It makes up for PERT and CPM that use the average project completion time. So we can get higher reliability.

Using Monte Carlo simulation operation and improve the reliability and accuracy of the project schedule. And using Matlab software programing can directly get random variable array that subject to the corresponding probability distribution function. So it can overcome the Monte Carlo algorithm difficulty that confirms the generation of random numbers and the size of sampling number. Monte Carlo method based on Matlab makes the calculation of the total project limit for a project simple and highly effective, which make the Monte Carlo method no longer heavy and complicated. The Monte Carlo method can be used easily in the

practical engineering project management. So the project schedule management work is more scientific reasonable and feasible.

3.4 Fuzzy

3.4.1 Fuzzy set

For general set, their basic characteristic is function uniqueness. $X \to \{0,1\}$, this formula means there are only two kinds of degree of membership in the set: the object x belongs to the set or the object does not belong to the set (Moselhi, 2012). Actually, this is not truth in the real life. Zadeh (1965) was the first people who proposed the concept of fuzzy set. The concept make the membership degree which just 0 or 1 of general set expand to any value which belong to $[0,1]$. Therefore, the object's membership with the set is not yes or no, it changed to a gradual process.

Let U is the discourse domain, the map $\mu_A: U \to [0,1], x \to \mu_A(x) \in [0,1]$define the fuzzy set on the U and the map μ_A is the membership of the set A. The membership is a fundamental concept of fuzzy mathematics. When the value of μ_A is approach to 1, it means the membership degree of the object x belong the set A is high. In the other words, When the value of μ_A is approach to 0, it means the membership degree of the object x belong the set A is low.

3.4.2 Membership function

The membership is the basic concept of fuzzy mathematics, because the membership make the fuzzy issue turn to certain. So it is important to build a membership function. Establishing the membership functions always have certain subjectivity but it is the scientific method.

1. Fuzzy statistics

The fuzzy statistics is using fuzzy statistics test to make sure the degree of the x belong the set A. After n times test, the membership of the x belong to the set A is:

$$the\ membership\ of\ x\ to\ A = \frac{the\ times\ of\ x \in A^*}{n}$$

In the formula, the A^*means variable set with associated with the fuzzy set A. With the increase changing, the A^*will be closer to the set A.

2. Subjective experience

The subjective experience is the method which are given the value of membership degree of the object based on subjective knowledge or personal experience. This method is suitable for relatively simple and discrete domain object.

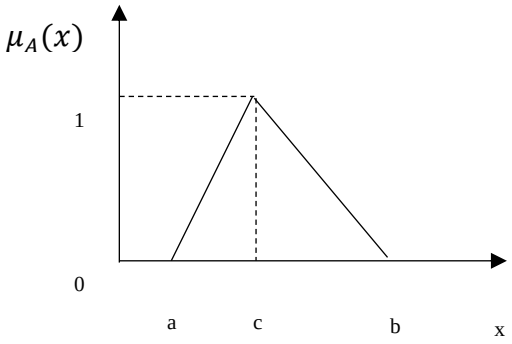
3. Designate

Based on the nature of the specific problems, with the typical function as a membership function, and then use the measured data to determine the distribution parameters contained. Common forms of membership functions are: triangular distribution, distribution ladder, parabolic distribution, normal distribution and so on.

3.4.3 The formula for fuzzy set in construction project

This article uses the triangular distribution, the condition when on set A belong to fuzzy distribution is:

$$\mu_A(x) = \begin{cases} 0 & 0 < a \\ \dfrac{x-a}{c-a} & a \le x \le c \\ \dfrac{b-x}{b-c} & c \le x \le b \\ 0 & c \ge b \end{cases}$$



The probability of fuzzy event

For general event A, if its sample space is continuous, the rate is:

$$P_A(x) = \int_0^A f(x)dx$$

In the formula, the $f(x)dx$ is the characteristic function of the event.

If the sample space is discrete, the rate is:

$$P(x) = \sum_{x_i} p_i$$

The p_i in the formula is the probability rate of the event x_i ($x_i \in A$).

Then making the probability of an ordinary event extend to fuzzy event, for the fuzzy event A, when it's a continuous sample space, the fuzzy rate is:

$$P(A) = \int \mu_A(x) f(x)dx$$

In the formula, the $\mu_A(x)$ is the membership function of the event A, the $f(x)$ is the probability density function.

When the sample space is discrete, the rate is:

$$P(A) = \sum_{i=1}^{n} \mu_A(x_i) p(x_i)$$

In the Formula, the $p(x_i)$ is probability rate of the event A.

3.5 The research project

In this paper, the case is selected Chaoyang District, Beijing Wangjing residential district 3,4. The whole project includes structural engineering body of civil engineering, water supply and drainage, fire protection, heating, ventilation, electrical. In the chapter 4, first determine the critical path of the project with PERT, followed by the construction of fuzzy mathematics and Monte Carlo simulation to calculate the total duration of the project.

3.6 Summary

Through the introduction of this section, the paper will select one particular case of Beijing Municipal Engineering to carry out simulation. Risk analysis performed model simulations complete schedule with PERT and Fuzzy Mathematics. Using Monte Carlo and three-time estimation to calculate the probability of completion.

CHAPTER 4-ANALYSIS AND INVESTIGATION

4.1 Introduction

4.2 Detail of the case studies

4.2.1 Project overview

This construction project was built in the south side of East Lake Road on Chaoyang District of Beijing. This essay chose the Wangjing Garden's 3rd building to do research. The construction area is about 23,964.4 square meter, and the underground part of the construction area is 1,884.98 square meters. This building elevation 38.05 meters, building a total height of 70.5 meters. There are 26 floors to the ground, 2 floors underground. The storey underground section is 3.2 meters, the ground floors of residential is 2.7 meters. The thickness of the external load-bearing walls, the wall underground wall thickness is 300 mm, and the wall out the ground is 200 mm thick.

The structure of foundation is box foundation. Full cast stairs structural form. Building fire rating is one level. The building's seismic rating is two.

4.2.2 Project features

Because of the tight schedule of the project, high quality requirements, it is necessary to use advanced construction methods and advanced technology and quality assurance, safety measures, reasonable arrangements for construction work, in order to achieve the contract duration, quality, and security objectives.

The project is located on the south side of East Lake Road, construction site is relatively small. According to the construction schedule, basic part needs to be done by the end of May. Backfill work carried out during the rainy season. The need to control the moisture content of the soil, to guarantee the normal backfill work. The project's main structure will be completed before winter construction, so there no winter construction.

To avoid wasting staff and resources to ensure the project is completed according to plan, the project need a body and installation, body and decoration, installation and decoration of the

interchange construction program. To make installation, renovation started early, it will be divided into four structural engineering inspection, which is a fundamental part of the acceptance, 1-8 layer structure of acceptance, 9-16 layer structure of acceptance, acceptance of part of the structure above the 16th floor.

4.2.3 The configuration of engineering resources

The main quantity

Item	Unit	Quantity
Waterproof of foundation	m^2	2180
Roof reinforcement/Layer	t	26
Roof template/Layer	m^2	650
Concrete roof/Layer	m^3	136
Wall reinforcement/Layer	t	46
Wall template/Layer	m^2	2200
Concrete wall/Layer	m^3	185

The main material

Material name	Unit	Quantity	Material name	Unit	Quantity
Reinforced	t	2245	Waterproofing	m^2	8635

			membrane		
Cement	t	11000	Red brick machine	Piece	50000
Sand	t	17620	Ceramic blocks	m^3	543
Pebble	t	23000	Paint	t	75

Main equipment

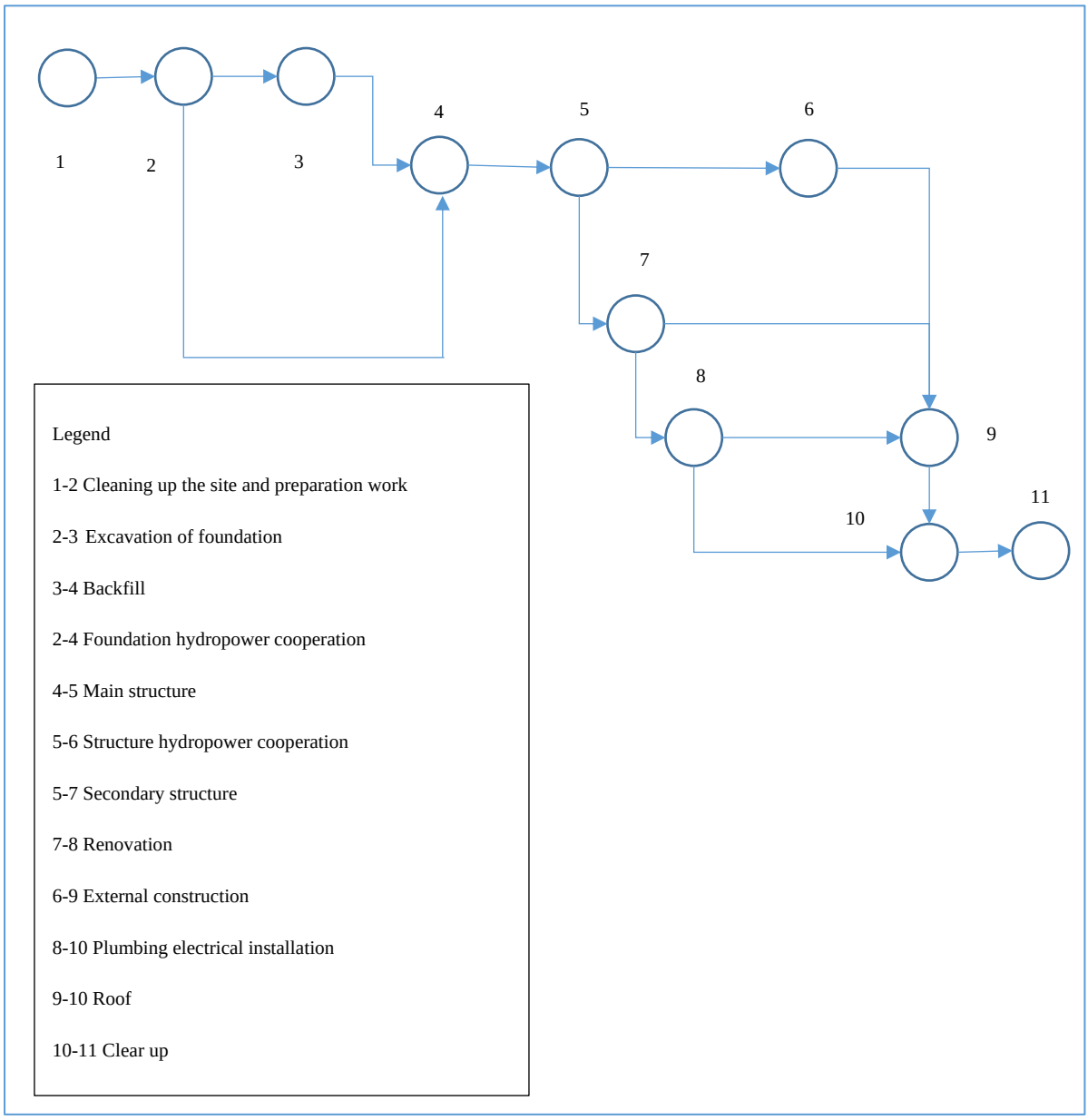
	Equipment name	Model	Quantity(units)
1	Concrete pump	HBT80	2
2	Crane	6516	2
3	Welder		4
4	Electroslag welding		2
5	Vibrator	HZ-50	8
6	External staircase		2
7	Breaststroke ramming machine		8
8	Mixer		4

9	Concrete placing machine		2

The labour

	Carpenter	Reinforcing steel workers	Concrete workers	Waterproof workers	Plastering workers	Bricklayer	Welder	Worker of heating and plumbing	Painter	Electrician	mechanic	Total
Foundation	90	70	20	10		15	8	10		15	10	264
Structure	70	50	20				8	4		20	10	198
Decorative	25	5		10	100		2	50	100	30	10	

4.2.4 The scheduling



Duration risk analysis

Step	Name	a	b	c	μ	σ
A(1,2)	Cleaning up the site and preparation	4	5	6	5	0.3333

	work					
B(2,3)	Excavation of foundation	71	73	75	73	0.6667
C(3,4)	Backfill	26	30	34	30	1.3333
D(2,4)	Foundation hydropower cooperation	38	46	54	46	2.6667
E(4,5)	Main structure	160	172	184	172	4
F(5,6)	Structure hydropower cooperation	145	149	153	149	1.3333
G(5,7)	Secondary structure	157	165	173	165	2.6667
H(7,8)	Renovation	251	258	265	258	2.3333
I(6,9)	External construction	43	47	50	47	1.1667
J(8,10)	Plumbing electrical installation	223	229	235	229	2

K(9,10)	Roof	26	30	34	30	1.3333
L(10,11)	Clear up	8	9	10	9	0.3333

4.3 The simulation

4.3.1 The PERT

According the figure, the critical path is

1-2-3-4-5-7-8-10-11

The total estimated duration and the overall standard deviation is:

$$\mu = \sum_{(i,j)\in A} \mu_{ij} = \sum_{(i,j)\in A} \frac{a_{ij} + 4c_{ij} + b_{ij}}{6} = 1213$$

$$\sigma = \sqrt{\sum_{(i,j)\in A} \sigma_{ij}^2} = \sqrt{\sum_{(i,j)\in A} \frac{(b_{ij} - a_{ij})^2}{36}} = 6.8556$$

So the completion probability is:

$$P(T \le T_p) = \Phi\left(\frac{T_p - \mu}{\sigma}\right) = \Phi\left(\frac{1220 - 1213}{6.8556}\right) = 0.8531$$

4.3.2 The Fuzzy

Using Fuzzy to analysis the completion probability, the critical path is same with using PERT. So the optimistic duration, the most likely duration and the pessimistic duration is:

$$a = 1152 \qquad b = 1213 \qquad c = 1273$$

$$\mu = 1213 \qquad \sigma = 6.8556$$

The degree of membership function

$$\mu(T) = \begin{cases} 0 & T < 1152 \\ \dfrac{T - 1152}{121} & 1152 \le T < 1213 \\ 1 & T = 1213 \\ \dfrac{1273 - T}{121} & 1213 < T \le 1273 \end{cases}$$

The standardized regression coefficient is

$$\gamma = \left[\int_0^b \mu(T) f(T) dT\right]^{-1} = 0.2224$$

The planning duration is 1213, $1213 \le 1220 \le 1273$, so the probability is:

$$P(T) = \gamma P(T)' = 0.2224 \times 4.3976 = 0.9780$$

4.3.3 The Monte Carlo

Activity	Duration				
	Min	Max	Variance	Standard deviation	Average
A(1,2)	4.223892	5.622364	0.095935	0.380513	4.982792
B(2,3)	71.7917	74.2543	0.438384	0.697867	73.07114
C(3,4)	27.18513	32.86367	1.622955	1.162713	29.92629
D(2,4)	41.55993	50.59803	9.636825	2.320668	45.76209
E(4,5)	166.8572	179.3728	24.21334	3.676284	172.3372
F(5,6)	146.6505	150.6419	2.017504	1.491886	149.0888

G(5,7)	160.4422	172.1792	8.244814	2.680254	165.8223
H(7,8)	253.6799	262.1542	5.237477	1.864468	258.425
I(6,9)	44.41386	49.01167	1.676727	1.238875	46.59225
J(8,10)	224.4359	233.0091	4.200988	1.828877	228.8978
K(9,10)	27.26406	33.44369	1.327861	1.374915	29.67627
L(10,11)	8.297353	9.67652	0.135308	0.327973	9.010647

4.4 The summary of this chapter

This chapter uses the project of are Wangjing district, that is completed in this paper fuzzy probability model and the time limit for a project risk analysis model based on the MC method on them , and will be completed the fuzzy probability model of the calculated results compared with PERT model, with the time limit for a project risk analysis model based on the MC method with the traditional MC method, comparing the calculated results illustrate the feasibility and applicability of this method.

CHAPTER 5-CONCLUSION

5.1 Overall summary

This paper proposes the duration limit for a municipal project scheduling analysis model based on PERT and fuzzy mathematics and the duration limit for a municipal project scheduling analysis model based on MC, and its application to the instance of the analysis, in this paper, the main conclusions are as follows:

In this paper, considering the fuzziness of time limit for a project is put forward based on PERT and time limit for a project risk analysis model of fuzzy mathematics, the introduction of fuzzy triangular number. And combining with PERT method of probability distribution and fuzzy theory, calculating the total duration prescribed period network planning under fuzzy completion probability. Through analysis, fuzzy completion probability calculation, due to join the membership functions, narrowed the variance, improves the precision, and under the same regulation time limit for a project in this paper, fuzzy completion probability than PERT model to calculate the value of a slightly smaller, with the previous research in PERT method due to its too ideal by computing the completion probability of large consistent conclusions.

In this paper, on the basis of the traditional MC method, based on the simulation results in line become a key line of the statistics, the number of considering the non-critical lines may become a key line, determine the key index line, again with the total duration distribution parameters of probability distribution and statistical data, calculate the completion probability under the prescribed time limit for a project. Example shows, due to consider the possibility of the non-critical line become a key line, this model is compared with the traditional MC model calculation results is small, and the time limit for a project is considered the scope of the increase, The calculation results are closer to the actual traditional MC method.

As the capital of China, Beijing has been developing at a high speed. In the city construction and expansion, we need to perfect the municipal engineering. There are a lot of new constructions and repair projects. Both the project owner and construction unit want low cost, high quality and short construction period of the project, so most of the projects, the duration is often very nervous, this requires that the construction units quicken the pace of the

construction reasonably, shorten construction period and meet the owner's request, at the same time, improve the economic benefit and social influence of the construction units. We need to use modern management methods to shorten the construction period through the scientific theory and technology, should arrange the construction schedule reasonably, and strengthen management effectively. On the basis of the conventional measures, and according to the specific circumstances, Construction units should collect and process information scientifically, and make decisions, target management. To combine quantitative analysis with qualitative analysis, use the fuzzy network technology, realize the optimal allocation of resources and dynamic management, in order to achieve the purpose that speed up the construction schedule and shorten the construction period. I believe that, the research method introduced in this paper is very useful in Beijing municipal engineering management, it can improve the work efficiency and work quality, and make project management more scientific and accurate.

5.2 Limitation

Although the duration limit for a project scheduling analysis two kinds of model is put forward, and applied to the analysis of examples, but there are still many to be further discussed:

The research is based on fuzzy completion probability discussed, assuming that only a key link, therefore, how to consider the effect of non-critical circuit of key circuit also need further research.

For fuzzy network plan, the membership functions of the total duration of the option to consider, there is no an objective method of membership functions are given, thus the determination of membership function is needed to solve the problem.

using the MC method used in the simulation of the construction period is a function of MATLAB software in operation, not the general program, so the calculation process, work a bit complicated, the compilation of general procedure is the next step of work to do.

5.3 Feature recommendations

There are only completed the calculation of probability on the basis of the proposed model, and no analysis of how to be completed in know the probability of network planning under the condition of control, and the time limit for a project is the ultimate goal of risk analysis in the actual process of constant adjustment of network plan, therefore, how the completion probability of network planning on the basis of control is another research direction.

REFERENCE

AACE (2012), Risk Analysis and Contingency Determination Using Expected Value, AACE, Morgantown, WV, pp. 1-14.

Ahuja, I.P.S. and Khamba, J.S. (2008), "An evaluation of TPM initiatives in Indian industry for enhanced manufacturing performance", International Journal of Quality & Reliability Management, Vol. 25 No. 2, pp. 147 - 72.

Alan, A. and Pritsker, B., 1977, "Modelling and analysis using Q-GERT network", A Halsted Press Book, New York

Association for Project Management, 2006. "Body of knowledge. 5th edition.

Atherton, E., French, N. and Gabrielli, L. (2008), "Decision theory and real estate development: a note on uncertainty", Journal of European Real Estate Research, Vol. 1 No. 2, pp. 162 - 82.

Bakouros, Y. and Kelessidis, V., (2000), "Project management", Dissemination of innovation and knowledge management techniques.

Beijing municipal commission of house and urban-rural development, 2014, "Check and accept standard for construction of municipal engineering in Beijing", Beijing municipal administration of Quality and Technology Supervision.

Beijing Municipal People's Government, (2004), "General Planning of City of Beijing (2004-2020)".

Burke, R. (2001), "Project management planning and control techniques", Wiley, 3rd edition.

Byrne, P. (1995), "Fuzzy analysis: a vague way of dealing with uncertainty in real estate analysis", Journal of Property Valuation and Investment, Vol. 13 No. 3, pp. 22 - 41.

Canadian Home Builders' Association, (2010), "A Guide to Residential Renovation Contracts", 2nd edition.

Carlsson, C., Fedrizzi, M. and Fuller, R. (2004), Fuzzy Logic in Management, Kluwer Academic Publishers, Norwel, MA.

Chen, C.T. and Cheng, H.L. (2009), "A comprehensive model for selecting information system project under fuzzy environment", International Journal of Project Management, Vol. 27 No. 4, pp. 389-399.

Cheng, E.W.L. and Li, H. (2005), "Analytic network process applied to project selection", Journal of Construction Engineering and Management, Vol. 131 No. 4, pp. 459-466.

Fang, C.L., (2009), "The Urbanization and Urban Development in China after the Reform and Opening - up", Economic Geography, Vol. 29 No. 1, pp. 19-25.

Formoso, C., Dos Santos, A. and Powell, J. (2002), "An explanatory study on the applicability of process transparency in construction sites", Journal of Construction Research, Vol. 3 No. 1, pp. 35–54.

Gelman, A., Carlin J.B., Stern, H.S., Dunson, D.B., Vehtari, A. and Rubin, D.B., 2013, "Bayesian Data Analysis", CHAPMAN&HALL/CRC, 3rd edition.

He, X., Liu, Y., Li, T., and Chen. J., (2013), "Does the rapid development of China's urban residential buildings matter for the environment?", Building and Environment, No. 64, pp. 130-137.

Hertz, D.B. (1964), "Risk analysis in capital investment", Harvard Business Review, January/February, p. 64.

Idrus, A., Nuruddin, M. and Rohman, M. (2011), "Development of project contingency estimation model using risk analysis and fuzzy expert system", Expert Systems with Applications, Vol. 38 No. 3, pp. 1501-1508.

Kelliher, C.F. and Mahoney, L.S. (2000), "Using Monte Carlo Simulation to improve long–term investments decisions", The Appraisal Journal, January, pp. 44–56.

Lee, J.W. and Kim, S.H. (2000), "Using analytic network process and goal programming for interdependent information system project selection", Computers & Operations Research, Vol. 27 No. 4, pp. 367-382.

Lei, S.Q., 1996, “International Project Risk Management and Insurance”, China Building Industry Press.

Li, J.R., 2003, “Construction progress of major projects Analysis Theory Methods and Applications”, Tianjin University, Tianjin.

Liang, T.F. (2010), “Applying fuzzy goal programming to project management decisions with multiple goals in uncertain environment”, Expert Syst. Appl., Vol. 37 No. 12, pp. 8499-8507.

Lifson, M. and Shaifer, E. (1982), Decision and Risk Analysis for Construction Management, Wiley, New York, NY.

Loterapong, P. and Moselhi, O. (1996), “Project-network analysis using fuzzy set theory”, Journal of Construction Engineering and Management , Vol. 122 No. 4, pp. 308-318.

Mak, S. and Picken, D. (2000), “Using risk analysis to determine construction project contingencies”, Journal of Construction Engineering and Management, Vol. 126 No. 2, pp. 130-136.

Malcolm, D.G., Roseboom, J.H., Clark, C.E. and Fazar, W., 1959, “Application of a Technique for Research and Development Evaluation”, Special Projects Office, US Navy, pp. 646-669.

Marquez, A.C. and Iung, B. (2007), “A structured approach for the assessment of system availability and reliability using Monte Carlo simulation”, Journal of Quality in Maintenance Engineering, Vol. 13 No. 2, pp. 125 - 36.

Mohamed, D., Srour, F., Tabra, W. and Zayed, T. (2009), A Prediction Model for Construction Project Time Contingency , Construction Research Congress, Seattle, WA, pp. 736-745.

Moselhi, O. (1997), “Risk assessment and contingency estimating”, AACE Trasactions, Vol. 41, pp. A.06, 1-6.

Nagarajan, K. (2004). “Project management”, new age international publishers, 2nd edition.

National Audit Office (2000), Modernising Construction, National Audit Office, London.

National Bureau of Statistics of China, (2015), 2015 China Statistical Yearbook.

Office for national statistics, (2013), 2011 Built-up Area Methodology and Guidance.

Project Management Institute, (2008). "A Guide to the Project Management Body of Knowledge", 4th edition.

Prospect Industrial Research Institute, (2015), "Report of Market Prospective and Investment Strategy Planning on China Municipal Engineering Industry (2016-2021)".

Robert, C., and Casella, G. (2004), "Monte Carlo Statistical Methods", Springer Texts in statistics, 2nd Edition.

Shaheen, A., Robinson, A.F. and Aburizk, S.M. (2007), "Fuzzy numbers in cost range estimating", Construction Engineering and Management, Vol. 133 No. 4, pp. 325-334.

Sireesha, V., and Shankar, N. R., 2010, "A New Approach to find Total Float time and Critical Path in a fuzzy Project Network", International Journal of Engineering Science and Technology, Vol. 2 No. 4, pp. 600-608.

Sonmez, R., Ergin, A. and Birgonul, T.M. (2007), "Quantitative methodology for determination of cost contingency in international projects", Journal of Management and Engineering. Vol. 23 No. 1, pp. 35-39.

Sowlati, T., Paradi, J.C. and Suld, C. (2005), "Information systems project prioritization using data envelopment analysis", Mathematical and Computer Modelling, Vol. 41 Nos 11/12, pp. 1279-1298.

United Nations Human Settlements Program. (2015), "Global report on human settlements 2013".

Wang J.X., (2004). "China's urban development problems and countermeasures", Zhongnan University of Economics and Law. Vol. 2 No. 3, pp. 67-72.

Wang, G. T. (2010), "Better City Better Life: State of China Cities 2010/2011", Beijing, Foreign Language Press, 1st edition.

Wang, J., 2002. "A fuzzy project scheduling approach to minimize schedule risk for product development". Fuzzy Sets and Systems Vol. 127 No.2, pp99–116.

Wang, J., 2004. “A fuzzy robust scheduling approach for product development projects. European Journal of Operational Research” No.152, pp180–194.

Wang, J.R., 1999. “A fuzzy set approach to activity scheduling for product development”. Journal of the Operational Research Society No.50, pp.1217–1228.

Wang, P., 2001, “Confidence as higher-order uncertainty”, Proceedings of the Second International Symposium on Imprecise Probabilities and Their Applications, Ithaca, New York, pp. 352–361.

Wang, P., 2003, “The limitation of Bayesianism”, Elsevier science.

Wang, S.D., 2012, “Discuss the controlling of municipal construction period”, Management & Technology of SME, pp. 102-103.

Wu, S.D., Storer, R.H., Chang, P.C., 1993. “One machine rescheduling heuristics with efficiency and stability as criteria”. Computers and Operations Research No.20, pp1–14.

Yan, C.J., Chen, Y. and Pan, G.J., 2002, “Construction Project Risk Review”, Shenyang Institute of Architectural Engineering, Vol. 01, pp. 78-80.

Zhang, C.M., and Wang, Y., 2014, “Using Monte Carlo Method to Analyze project time”, International conference on Computer Science and Software Engineering, pp. 320-325.

Zhang, S., 2006, “Tunnel engineering risk analysis and risk of loss study period”, Tongji University

Zimmermann, H.J., (1978), “Fuzzy programming and linear programming with several objective functions”, Fuzzy Set Syst., Vol. 1 No. 1, pp. 45-55.

APPENDIX

The part of simulation data

ACTIVITY	A(1-2)	B(2-3)	C(3-4)	D(2-4)	E(4-5)	F(5-6)	G(5-7)	H(7-8)	I(6-9)	J(8-10)	K(9-10)	L(10,11)
OPTIMUM value	4	71	26	38	160	145	157	251	43	223	26	8
nomal value	5	73	30	46	172	149	165	258	47	229	30	9
pessimistic value	6	75	34	54	184	153	173	265	50	235	34	10
alpha	4	4	4	4	4	4	4	4	4	4	4	4
beta	4	4	4	4	4	4	4	4	4	4	4	4
	5.112079	72.799969	30.48447	42.91046	170.6795	151.0047	168.2835	258.7588	46.32796	232.4835	30.36235	8.970315
	4.582075	73.10386	30.19605	47.32073	173.374	151.155	168.5674	258.4302	46.09031	228.6718	29.88266	8.615916
	5.45	72.8	32.3	46.8	178.	149.	169.	257.	47.8	226.	27.7	8.31

	5883	518	1364	6362	5644	8869	3737	1931	6889	948	7727	7367
	5.111998 2	72.09631	29.18098	43.58952	168.8084	151.7718	162.9323	261.9953	45.55773	231.7255	29.97901	8.648282
	4.682774	74.23332	30.5027	47.39622	167.4961	148.391	168.7501	254.8002	46.61399	229.6105	27.29439	8.834259
	4.691224	73.85352	30.18517	46.22715	176.7298	149.468	167.8594	258.1299	47.27096	230.9468	30.04271	9.299758
	4.745469	72.71119	27.52847	46.52578	171.7194	147.483	165.172	254.8788	46.07563	224.5105	29.20972	9.217584
	5.559133	73.15283	31.92539	47.03778	166.4576	148.3314	165.4497	257.6676	45.56913	225.5648	28.17962	9.407205
	4.419592	73.3477	30.51204	44.20902	172.1544	148.2811	168.3188	257.5985	44.56964	231.5518	30.76328	9.162023
	5.153597	71.44619	30.9641	45.76699	176.2253	145.9772	160.2544	256.719	45.21054	232.4115	30.5258	9.173105

	5.10465 4	74.33043	27.57664	43.57826	174.4264	150.0262	165.6959	258.9565	47.75128	225.1457	29.95529	8.561716
	5.27252 4	72.15635	30.53781	46.97418	180.3383	148.6242	167.8947	255.1384	47.92924	225.5008	28.07819	9.04966
	4.84672 4	73.78113	29.60938	45.3237	170.6425	146.7264	164.4776	254.2603	46.03041	231.0546	29.45786	8.449964
	5.70312 1	71.91845	32.85738	43.17406	175.4535	147.1032	164.2128	257.2877	47.83546	231.9065	29.60668	8.945797
	5.39547	72.3987	28.89616	41.35656	174.726	149.3438	165.9675	257.0957	44.91591	227.0776	29.99221	8.966571
	5.03499 8	72.73432	32.9524	45.66464	179.7715	147.8947	163.3238	258.7313	47.34354	227.5085	29.87299	8.98304
	4.54322 6	74.23972	30.76779	46.25675	171.9098	148.5997	167.8103	260.322	46.74659	225.6925	30.73297	8.93016
	5.09137 2	74.2471	31.48071	47.43468	179.3109	147.7916	167.0169	255.9726	44.7464	229.2447	30.51954	8.823067

	4.85433 9	73.1249 7	29.8375 5	45.5521 7	177.081 3	148.189 7	161.914 5	259.890 9	44.8455 8	229.342 8	31.7510 2	8.86969 5
	5.2029	72.3128 4	32.8321	44.4066 3	170.067 1	149.146 5	164.385	259.426 4	47.3200 8	229.317 7	31.9782 7	9.26150 6
	4.90560 3	73.3976 2	28.2533 2	46.2893 4	171.732 3	148.506 5	164.591 8	258.922 4	46.6614 6	230.086 4	30.0993 6	8.21175 2
	4.61153 3	72.6113	31.8119 9	46.0728 5	169.016 7	149.342 3	168.579 1	258.941 2	45.6914 7	233.258 3	30.3182 4	8.85474 9
	5.54328 9	72.9113	28.4607	46.2543 1	162.894 8	149.858 4	165.504 2	257.415 7	46.5166 4	231.178	29.2172 9	8.31464 5
	5.61637 9	72.0270 3	32.9176 5	45.4935 7	176.327 6	147.309 9	168.142 7	256.319	48.4123 6	232.424	29.2716 3	9.19652 7
	5.34356 3	72.3836 3	29.6633	48.4714	174.585	151.458 3	166.224 9	260.075 1	46.1219 7	229.598 7	30.5901 5	9.62008 2
	5.39154 3	72.4014 7	29.0091 8	42.8689 2	178.425 4	148.304 4	161.586 1	252.134 3	47.0205	228.530 4	31.1317 6	8.77320 2

	4.56034	73.83452	28.90767	46.48324	168.8175	149.2625	166.1091	258.1238	48.68255	227.6254	31.69772	8.933064
	4.80758	73.9595	27.17759	42.39188	166.2675	149.1289	165.2337	253.553	46.44896	225.2378	32.49742	9.436767
	4.898122	74.21683	31.35434	46.23256	169.9845	146.7693	162.5712	256.9793	45.63627	225.3511	30.60693	8.727105
	5.250377	72.98431	31.1442	49.90362	174.9623	148.6923	163.1937	256.9191	47.91778	225.1709	30.16422	8.394517
	5.097048	72.85662	31.3738	46.20324	176.8295	148.4335	161.8014	256.2054	45.68016	230.4815	28.85471	9.014667
	5.366877	73.65292	28.77914	43.21315	172.256	150.4996	163.4231	257.6052	47.63876	226.8865	29.31746	8.841362
	5.749191	73.45125	28.34744	48.87987	173.5031	148.9533	166.3658	257.3523	46.30099	229.4616	30.14638	9.508827
	5.492884	73.17541	30.00919	47.75641	173.1305	150.6052	164.3725	260.609	45.91027	229.5375	29.70074	8.985498

	5.04295	72.9337	30.2831	46.6983	171.2197	149.1561	169.6785	261.5344	44.8392	229.4028	31.3291	9.359099
	5.589873	73.46745	30.63866	44.18084	169.332	148.7744	162.5073	258.0772	46.71177	228.3832	32.02836	9.298966
	5.244915	73.42313	29.354	43.79205	174.5341	150.3727	163.9913	258.8673	46.11364	228.1649	30.53935	9.312316
	4.291447	72.00972	30.46218	48.74361	172.4469	148.1736	158.0112	258.2871	45.08324	232.4239	32.07208	8.703804
	5.495939	72.07941	28.53173	51.22351	164.1668	148.7565	163.2139	261.3821	45.65884	226.9041	27.63902	9.537105
	5.080153	72.03597	30.76052	52.60171	174.85	147.4825	167.212	259.4712	46.24527	230.2267	29.96631	9.512943
	4.501731	73.81572	29.84007	47.2629	176.5399	150.0516	166.0783	259.2199	45.89635	230.3409	31.84857	8.63105
	4.672722	72.80087	29.40044	53.59004	177.9437	151.0627	166.1393	257.1174	48.14487	229.1842	30.92859	9.010432

	5.13003 5	72.0531 2	31.4406 9	40.2345 7	166.347 6	148.906	163.566 7	255.003 7	48.5308	230.833 9	31.4101 8	8.86305 9
	4.96533 3	73.9049 6	29.3576 1	46.5172 1	170.522 3	150.499 9	165.813 5	261.144 1	48.0444 9	233.276 7	32.7610 1	9.22933 5
	5.25953 6	71.6928 2	30.2663 6	48.6730 8	166.851 4	147.227 5	164.835 2	258.033 1	48.0594 7	229.828	32.2395 8	9.18622 4
	4.89812 4	72.4120 9	28.3690 5	45.0883 2	166.903 3	146.318 9	166.893 8	256.810 9	47.0640 8	229.023	31.8497	8.92735 6
	4.64712 1	73.0559 1	28.5174 1	45.9889 9	175.335 6	148.025	165.944 7	260.772 3	46.5753 6	232.255 8	30.9702 2	8.74958 1
	5.41702 8	71.5458 1	29.4292 1	46.1552 6	176.628 6	149.242 1	164.860 3	260.884 5	46.3491 6	227.840 5	31.4277 4	9.05030 8
	5.41942 7	73.7423 8	28.5861 9	42.5783 6	177.210 2	149.637 9	170.031 9	259.776 8	48.5370 2	232.292 2	31.2963 9	8.61322 4
	5.26411 3	74.3456 3	27.8109 7	43.7099 7	175.736 9	147.775 5	166.956 4	257.879 4	46.1483 2	227.918 2	30.2111 4	8.58375 2

	5.06479 7	72.6726 7	31.6304 3	44.6307 4	171.332 6	149.251 3	166.602 5	256.057 7	47.0255	226.318 6	28.0258 1	9.42612 6
	4.45777 9	71.8496 7	30.6390 1	42.1733 9	170.119 9	150.986 2	168.347 2	254.931 4	45.5934 9	227.771 8	29.3038 8	8.76620 5
	5.19721 2	73.8666 3	29.0989 8	43.3172 7	168.121 8	149.579 2	166.918 8	257.065 5	44.1223 8	229.957 6	31.7724 5	8.35294 9
	4.67586 9	73.7562 7	30.6568	46.0790 3	169.550 2	148.878 1	168.288 1	254.956 7	48.2193 9	231.082 2	30.4079 7	9.11449 2
	4.90827 9	71.9855 3	32.6163 7	42.8361 5	170.684 8	148.600 7	164.414 4	254.976 7	47.9813 8	232.008 1	29.7599 3	8.37595 3
	5.12884 5	72.2881 9	27.4962 4	44.2815 4	172.040 9	147.726 1	165.823 1	254.769 4	46.4693 5	225.290 6	27.2005	9.00463 6
	4.62050 2	73.2474	30.2727 8	44.7462 5	172.792 7	147.072 6	169.108 1	256.017 4	45.4790 7	233.400 2	31.9606 7	9.09169 6
	5.02711 7	72.8479 7	30.1422 6	41.4410 8	168.840 8	148.476	161.166 8	256.390 3	46.0878	227.686 4	28.7867 1	9.36347 4

	4.978187	73.20006	29.75468	43.72789	166.5269	147.7324	164.3997	256.114	48.09148	228.1326	32.92583	9.592729
	4.490193	74.10209	29.30401	45.9112	175.4513	147.4983	164.7932	255.4132	45.96977	227.9371	30.87294	8.728587
	5.181582	72.63325	31.75016	43.64665	166.7551	147.9297	167.1812	260.1031	47.12062	230.3209	27.41451	9.11283
	5.357201	71.9562	29.15859	45.07911	169.2836	147.6012	159.086	257.4889	44.84395	228.7768	29.84437	9.375074
	5.405336	73.32926	28.82528	50.39093	171.3273	150.5816	167.0783	258.403	47.00562	225.8337	31.17407	8.283914
	5.128201	73.02038	29.84558	43.05477	175.9191	149.8383	162.2663	259.8115	47.10485	229.1377	30.64074	9.415336
	5.407511	72.81376	31.97993	44.53878	173.5758	149.8757	164.4907	259.7812	44.55942	227.2611	29.88964	9.057467
	4.280898	73.30179	31.70647	42.56978	166.8768	145.8473	163.7824	258.2218	47.7706	224.7644	31.42554	9.364249

	4.93823 4	72.922	30.3844 1	49.2507 5	163.4654	149.4079	169.8641	257.8766	44.4547 6	227.8672	28.3891 8	8.73468 8
	4.76240 8	72.3587 2	29.8826	45.7185 3	171.2444	149.0014	165.1153	256.3741	46.4976 7	228.7048	31.5794 5	8.79911 8
	4.27356 2	73.2129	30.423	49.0606 6	167.7022	149.3494	164.8894	258.9692	46.4948 8	231.5045	28.5184	8.90805 9
	5.32657 8	72.8605 4	30.2864 1	42.7023 8	172.7976	151.8228	169.3629	254.1398	45.2801 6	230.3092	29.3733 8	8.56077 9
	4.62108 1	71.8820 2	30.2586 4	47.493	162.1948	149.344	168.3828	260.4292	47.3626 3	225.649	30.8802 7	9.59293 7
	4.95096 3	72.7685 7	29.7896 8	48.2489 7	169.5581	148.2032	165.9189	260.5722	47.2570 7	225.0929	31.1420 8	9.14138 2
	4.71009	72.9152 3	28.2108 6	49.5188 6	172.4937	148.8388	162.1681	256.9946	45.6474 1	229.6578	30.6843 2	8.62876 2
	4.46240 1	72.1668 6	33.2096 9	45.4778 9	166.445	149.0256	162.492	259.12	47.2671 3	231.4725	31.6729 5	8.55584 5

	5.197647	73.15089	30.9393	43.04998	168.971	149.003	165.9848	260.9417	46.855	227.6818	31.41508	9.421793
	5.136923	71.73839	31.36342	45.46563	173.9843	146.9826	166.0304	258.2264	46.68819	231.0709	28.94	8.607901
	4.830836	73.85403	31.0837	48.4902	178.1442	148.5457	161.3146	258.2285	44.49142	226.8123	26.81726	9.365159
	5.372743	74.15694	29.56008	44.92747	169.9626	148.6087	166.596	255.0586	46.25685	228.6519	29.78493	8.891048
	5.399413	71.91527	30.72493	46.35052	171.2158	148.9575	168.5683	257.1897	46.94064	227.5251	30.67241	9.331841
	4.801575	72.83372	31.27642	48.0915	171.022	147.7832	165.0631	256.0411	44.80203	228.6849	31.02863	9.047072
	5.699561	73.0097	30.15865	46.17338	176.9082	148.561	168.4147	259.5115	45.60292	231.8466	29.86629	9.351788
	4.832342	72.2396	30.02416	43.60883	175.1768	149.7998	167.3843	257.3133	46.15137	230.6866	32.44023	9.077444

	5.06794 3	71.3977 5	29.0166	43.3874 1	164.2875	151.3445	161.8803	253.6558	46.9459 1	226.6953	30.2271	9.34943 5
	5.01731 7	72.4705 1	28.8233 5	43.7094 4	169.4524	147.8645	163.6091	255.7286	46.5561 2	227.737	30.4933 2	9.60286 8
	5.60058 2	73.1908 3	30.6096 9	43.5712 5	166.4468	149.1823	169.4983	255.5931	44.8512 7	228.7258	30.8124 9	8.90830 8
	4.77545 2	74.4681 9	28.5811 4	45.6900 2	171.2237	148.0152	165.0448	254.8263	46.7805 7	231.5448	28.8469 9	9.28889 8
	4.6783	72.1917 9	31.8067 6	47.3893 7	171.7898	148.5778	168.3526	260.5725	44.5553 9	227.9736	29.5365 3	8.99555
	4.74333 4	73.5980 9	31.5970 1	44.4596 9	170.3194	151.3047	165.7901	257.0246	47.1837 1	227.5452	29.8468 3	8.83061 2
	5.04464	73.4349 2	29.9611 1	44.4271 1	175.479	151.5807	168.1931	257.8654	44.0648 4	232.4545	29.1831 7	8.59681 5
	4.59594 5	72.6024 3	28.3509 9	51.9324 8	166.5804	151.4794	163.8695	260.5011	47.0932 2	230.191	31.7545 8	8.88733 8

	4.874665	71.9622	30.9691	48.41198	171.8496	149.8629	163.3381	259.7404	45.53551	231.0372	30.8231	8.821026
	5.744331	72.90956	32.27827	47.18327	168.4452	146.9514	166.1038	259.5328	48.32962	229.9249	29.81288	9.157993
	4.962547	73.79332	31.3101	46.40117	165.6229	147.5546	167.133	261.1422	45.88657	231.8875	30.78741	8.901209
	5.172609	72.56526	29.23626	49.57201	176.386	148.9601	161.2103	257.3246	47.80371	230.258	30.12853	8.761132
	4.642261	73.08346	28.45006	44.67562	168.8897	149.4446	168.381	263.137	48.44628	230.1271	29.60922	9.050492
	4.321256	73.78015	29.9182	45.16655	172.461	149.0195	163.8425	260.9774	48.85046	228.3105	28.43908	9.141033
	4.798229	72.47814	29.63179	45.20557	175.5945	146.9723	166.5388	256.8117	46.72861	225.8577	28.82988	9.324804
	4.473798	73.79368	27.55261	44.93058	171.7043	149.0854	167.7989	252.9233	46.26631	229.6017	30.42488	9.411529

	4.42091 8	72.2726 7	31.0061 7	43.2781 9	170.971 8	146.270 3	168.670 3	257.519 1	46.5423 6	227.453 4	30.5647 6	8.79914 2
	5.19912 4	74.1884 1	29.0817 7	41.4483 5	171.005 3	149.844 3	167.084 3	258.053 5	47.5205 2	231.719 4	29.2767 5	8.93658 3
	5.43103 6	71.9866 1	29.6061 2	51.8738 1	175.150 3	150.394 3	161.735 7	261.979 2	47.9729 2	231.376 1	31.4740 5	8.927
	5.51166 9	72.8142 4	29.9554 1	45.7375 2	176.055	145.690 6	161.753 8	259.967 9	46.1192 9	231.197 5	30.9833 5	8.86506 7
	4.67305 4	73.1073 3	31.0828 6	46.1092 7	171.328 3	147.935 1	163.785 5	257.505 8	46.6381	226.891 2	29.3832 2	8.73823 2
	4.85950 4	71.3970 6	32.4973 4	48.2445 4	172.094 5	149.363 3	165.053 5	257.180 8	46.6341 2	228.253 2	29.2492 4	8.90964
	4.48081 9	74.1785 5	31.4158 4	48.1605 7	169.122 7	150.407 1	163.588 6	259.664 2	45.5129 1	231.338 2	29.5041 6	8.57570 3
	5.08465 5	73.0827 1	29.5439 1	46.8285 9	171.610 9	149.593	166.770 9	253.510 5	47.5382 3	229.010 6	31.2241 8	8.98928 2

	4.71760 5	72.2768 4	29.5485 9	47.5391 4	169.363 8	148.536 4	164.423 8	256.305 4	44.7007 5	226.165 3	32.0783 7	9.23898 1
	5.10840 1	73.7339 7	29.9596 6	49.3885 5	174.336 4	148.845 9	164.773 6	258.334 3	46.0126 6	225.864 7	31.9969 8	9.45726 9
	4.98145	73.1986 8	32.0781 6	48.3552 8	166.500 8	150.044 7	165.996 8	258.039 7	45.4406 5	229.334 5	30.2289 7	9.36979 1
	4.29393 9	72.8797 5	28.4342 6	43.0190 8	168.602 1	149.399 4	168.817 8	260.720 2	47.3818 6	227.623 6	28.0069 8	9.21302 7
	5.22159 1	73.4318 2	30.0138 9	51.5345 6	169.606 2	149.338 5	164.635 6	261.912 2	45.6868 1	230.850 8	30.7317 8	9.14623 8
	5.05611 4	74.3497 5	30.0757	50.5930 9	177.598 5	149.328 2	167.022 8	258.097 3	47.4727 3	226.473 6	29.2597 5	8.78810 1
	5.23011 7	73.2833 9	29.0877 7	46.0216 7	178.948 2	148.752 1	164.9	257.921	46.0773 4	227.707 1	29.8875 7	8.93178 1
	5.20373	73.3352	30.1699 3	42.9188 7	168.655 6	148.591 2	165.506 7	256.519 9	45.8797 1	228.417 6	30.4394 9	9.11206 1

	5.180417	73.33563	28.47321	46.79921	164.6372	148.5328	164.8105	261.1059	45.9421	231.3769	28.79626	8.576019
	5.186497	72.80379	29.60219	50.46679	169.1726	150.4073	165.5864	256.4234	45.62853	232.9192	28.19708	9.410277
	4.491625	73.15433	29.49783	49.63888	174.7463	147.1331	168.3621	259.3626	46.96451	230.6785	29.90286	9.277639
	5.011131	73.14672	31.52714	49.26975	165.5833	149.3699	162.2761	260.6626	46.06683	228.3423	31.62457	8.912653
	5.094743	72.43443	30.30139	53.32939	174.4389	151.5384	166.7776	255.0849	47.38113	230.411	31.02077	8.835995
	5.113645	72.06498	29.72001	44.74213	175.3815	147.6752	168.8863	261.884	45.12739	225.6277	28.71411	9.19608
	4.712977	73.10013	30.66538	51.78484	174.3492	149.984	165.942	255.0567	46.90566	230.3059	32.26595	9.371839
	4.860305	72.70037	28.95673	46.81981	172.4013	151.2947	165.7353	262.3281	46.6973	225.6478	28.28007	8.565659

	4.79599 8	73.9923 9	32.6680 5	44.5435 2	174.082	149.0794	164.5599	260.094	46.05448	226.4746	30.0803	8.260483
	4.96138	74.2380 2	29.5738 5	42.6468 9	165.8319	150.4534	163.007	259.9462	44.8740 5	226.0485	29.0568 9	9.517084
	5.56659 8	72.2981 3	30.0091 9	49.6051	170.8802	149.7852	169.0636	260.4176	46.2842 7	227.4363	30.8453 6	9.467019
	4.75470 5	73.9264 3	28.7608 5	48.6873	166.9127	150.6672	160.9598	256.3655	46.1344 3	229.5499	30.8492 6	9.732464
	4.96227 1	73.1519 2	29.3331 4	48.2813 9	170.872	149.4796	160.3258	257.7219	46.4788	231.1462	30.8392 8	9.235689
	4.81239 2	72.5381 5	32.5087 5	40.3441 7	174.8073	149.5565	163.9401	262.0461	47.6454 8	231.0989	29.0886 9	8.56392
	4.49789 1	73.7728 4	29.6747 8	48.8168 5	177.4534	148.3433	163.3664	257.2233	46.9031 3	226.2029	29.7360 6	8.702587
	5.13662 1	73.5735 2	31.4785 5	50.7672 7	165.4711	148.8276	167.2134	258.0296	44.8446 2	229.372	31.5116 6	8.401474

	4.94146 3	73.1755 3	27.3099 6	43.4676 6	177.832 4	147.679	161.992 7	258.297	48.8145 8	226.460 6	30.1019 9	8.84785 8
	5.14122 8	72.8778 8	30.7626 2	43.6600 6	165.057 6	150.841 7	163.329 7	253.875	45.5987 8	228.186 2	31.0603 4	8.63701 6
	4.69326 8	74.0459 5	31.0521 7	46.2423 4	173.211 6	150.014 5	167.151 8	255.759 1	46.9303	229.917 8	30.5163 6	9.05450 1
	5.55474 7	73.4675 3	31.4209 2	49.0950 7	164.617 1	147.473	165.364 4	255.004 4	44.5610 9	229.027 2	30.6354 9	9.45795 4