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RULE-BASED EXPERT SYSTEM FOR PROJECT DELAY MANAGEMENT: A CASE OF WASH WATER SUPPLY CONSTRUCTION PROJECTS IN ETHIOPIA

BY
EDEN HALEFOM

July, 2021

ADDIS ABABA, ETHIOPIA



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Rule-Based Expert System for Project Delay Management: A Case of WASH Water Supply Construction Projects in Ethiopia

A Thesis Submitted to School of Graduate Studies of Addis Ababa University, Ethiopian Institute of Architecture, Building Construction and City Development (EiABC), in Partial Fulfillment for the Degree of Master of Science in Construction Management.

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This Thesis is submitted to the Ethiopian Institute of Architecture, Building Construction and City Development (EiABC) and to the School of Graduate Studies of Addis Ababa University in the Partial Fulfillment of the Requirements for the Degree of Master of Science in Construction Management.

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Declaration

I, the undersigned, declare that this thesis is my own and original work and has not been presented for a degree in any other university, and that all sources of material used for the thesis have been duly acknowledged, following the scientific guidelines of the Institute.

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Acronyms

AI	Artificial Intelligence
BOQ	Bill of Quantity
CPM	Construction Project Management
EiABC	Ethiopia Institution of Architectural, Building Construction, and City Development
GTP-1	Growth and Transformation Plan-1
GTP-2	Growth and Transformation Plan-11
KBS	Knowledge based expert system
MDG	Millennium Development Goal
PM	Project Management
UN	United Nation
WASH	Water ,sanitation and hygiene
WHO	World Health Organization
WM	Working Memory
WSS	Water Supply and Sanitation

Abstract

In developing countries like Ethiopia, satisfying the access of water supply, sanitation and hygiene to the community is a huge challenge. These challenges are opposed in different sectors by various methods. Among the efforts of United Nations Organization to fulfill this goal includes, setting international plans such as Millennium Development Goal, Supporting countries in financial, human resource, training and infrastructure. Even with all these efforts, access to water supply and sanitation ratio in sub-Saharan Africa is still at its lower rate. Access to water supply and sanitation in Ethiopia is amongst the lowest in Sub-Saharan Africa and the entire world. The major challenge for water supply and hygiene in Ethiopia is to maintain a year-round and adequate supply to meet people's need. The purpose of this research is therefore, to develop rule-based expert system for WASH projects delay management in the case of WASH water supply construction projects in Ethiopia. To achieve the expectations of this system, the methodologies followed in this system were knowledge acquisition using structural interview and workshop as one of primary knowledge source. The required data was gathered from sources such as; first identified the list of causes and effect from the different documents and also through workshop with the group of construction management masters students of Addis Ababa university and also finds the delay causes and effects of 15 towns water supply and sanitation project from their technical audit report arranging in the rule-based form or "if...then" form and in the next phase structured interview was employed with selected experts and come with list of probable solutions and causes of delay. Finally rules for delay management was formulated by the rule-based expert system. Domain experts were selected by using purposive sampling techniques from the experienced experts from construction sector and academicians. After the development of knowledge-based system, verification and validation tests were employed. The study certainly answered the problem of the water sector delay problems because it can identify the cause and solution of the delay regarding the experts view and experiences. As a recommendation additional studies are needed for the rule-based expert system to develop in different soft wares.

Key words: Delay management, Expert, Rule based expert system, WASH project , Water

CHAPTER ONE: INTRODUCTION

1.1. Background

Water is one of the necessities of human being and the attainment of clean water and sanitation is declared as a human right by United Nations in 2010 (UN, the human right to water and sanitation, 2013). Article 44 of the Federal Democratic Republic of Ethiopia's constitution stated that environmental right which said persons have the right to life in a clean and healthy environment. In addition Article 90 of the constitution stated that to the extent the country's resources permit, policies shall aim to provide all Ethiopians access to public health and education, clean water, housing, food, and social security (Constitution of Federal Democratic Republic of Ethiopia, 1995). Ethiopian government outlined driven vision for joining middle income countries by 2025 through designing strategies and programs, among them water sector development strategy, GTP-1 and GTP-2, WASH implementation frame work and WASH national programs are included. The plan includes achieving 100% water supply access coverage as per GTP-1 service level standard and achieve 83 % (85% for rural and 75% for urban) water supply access coverage as per GTP-2 service level standard and Provide water supply access over all to 37 million people (29.3 million for rural and 7.7 million for urban) (Habtamu, 2018).

In 2000 the United Nations launches 8-millennium development goals (MDG) goals for a better world among those goals the seventh goal is about ensure environmental sustainability in this goal there are sub-targets from that 7C which said by 2015, the proportion of the population without sustainable access to safe drinking water and basic improved water source, urban and rural and the other one is Proportion of urban population with access to improved sanitation (UN, 2008).

WASH program is working on water, sanitation, and hygiene and investing on these program means investing in all MDGs. The fact is that without safe water cannot have food, as a result, there is no health and education, if there is no education cannot think about economic activity (Netherlands WASH SDG, 2017).

In Ethiopia WASH project is aimed to increase access to improved water supply and sanitation services for residents in participating woredas/towns and communities. There are three

components to the project those are rural WASH project, urban WASH project in small and medium towns to ensure the long-term viability of low cost and sustainable water supply and sanitation operation to improve the health and productivity of the population in the target towns (Godfrey, 2016).

According to the government in 2017, 70 % of the population had access to safe water; however, according to the World Health Organization (WHO) and local nongovernmental organizations, the figure was closer to 35 %. The WHO estimated that only 13 % of the population had access to sanitation. Ethiopia fulfilled the target of the Millennium Development Goals (MDGs) for improved water and sanitation access which were 70% and 56 % respectively (Netherlands WASH SDG, 2017).

The construction project is becoming increasingly difficult as it involves delay and uncertainty.it requires different type of professional skills to develop a well thought out plan at various phases (Chitakara, 1998). Several studies pointed that most of construction project suffer delays and it is possible to reduce delay through recognition of their real cause (Ashraf and Ghanim , 2016). In Ethiopia only 8.25% projects have been completed according to the target but the remaining 91.75% delayed from its contractual time (Worku &Jah, 2016).

There are different types of delay management systems and rule-based system is software based that uses artificial intelligence or expert system techniques in problem-solving processes. It incorporates a store of expert knowledge with couplings and linkages designed to facilitate its retrieval in response to specific queries or to transfer expertise from one domain of knowledge to another (Darai, 2010). For this purpose Knowledge is represented in the form of rules or other representation techniques and stored in a knowledge base. Testing the knowledge base for validation can be done comparing performance of human experts with system (Calkins, 2000) .

1.2. **Problem statement**

Ethiopia fulfilled the target of the Millennium Development Goals (MDGs) for improved water and sanitation access which were 70 % and 56 % respectively. However, due to rapid urbanization and population growth, the success values are declining significantly (Netherlands

WASH SDG, 2017). Construction projects in Ethiopia, it is very rare that projects were completed on time based on the agreement. There are many water supply and sanitation projects in Ethiopia, which suffered delay or in some cases suffered suspension or abandonment. To alleviate that, the government need to help ensure local water supply and sanitation (WSS) service providers continue to develop their capacity to manage operations. Delay is one of the factors enable projectS to complete at a given time and budget including quality. government construction projects; especially the water supply sector has significant impact on economic activities in the country. Projects are underway around the country, most are experiencing delays at construction zones. To solve the problem in the water supply and sanitation program learn from the past projects is inevitable. Therefore, the research is aimed to answer the following research objectives based on rule based expert system for Water supply and sanitation projects delay management.

1.3.Objective

1.3.1. General Objective

The general objective of this study is to develop a mechanism of rule-based expert system for better delay management in construction project specially on small-town WASH projects in Ethiopia.

1.3.2. Specific objectives

- to identify causes of project delays in Ethiopian small towns water supply projects of WASH
- To investigate the knowledge, attitude and practice of expertise
- to propose a mitigation strategies and solutions for the selected causes of delay based on the rule based expert system by depositing the experts experiences.

1.3. Research questions

- What are the causes of project delay in Ethiopian small towns water supply faced by WASH?
- What is the knowledge, attitude and practice of construction experts in the delay management?
- How to manage delay in WASH projects by applying the rule-based system?

1.4. Significance of the study

This study introduces a rule based expert system for the construction management and this becomes one of the good findings for the use of construction industry. Based on the output of this study, the researcher provide a practical mitigation strategy for controlling the delays in the WASH projects by deeply assessing the current practice in this project and find the causes which create the delay and the mitigations by consulting the experts. Finally, this research give a direction about the application of the rule based system for solving the problems in engineering, in addition with the rule based expert system for WASH projects delay management and to tackle the problems as early as possible.

1.5. Scope of the study

This study was conducted to determine the use of knowledge-based system in the delay management and follow up towards filling the knowledge gap of construction professionals of the sector. There are many techniques for the development of knowledge base system. Rule-based approach is used for this research. The data collection for the knowledge acquisition was also conducted from these groups. The focus area is on a selected small-town water supply construction projects by WASH. This study deals with the rule based expert system on the WASH projects only not the other construction sectors like building and road.

1.6. Limitation of the study

There is only 2018 GC technical audit report data as a document but not having other documents that analyze the projects condition in detail so cannot identify the effect of the delay in every project in detail. Therefore, survey data is also a major limiting factor in this study. Time and money were other limiting factors for this research to collect primary data. As a result, the research used only secondary data.

1.7. Organization of the research

In this thesis, the first chapter introduces the background information about the research and its objectives, and the second chapter discusses about the literature reviewed in relation to the topics. In the third chapter, the research methodology is described incorporating data collection and analysis methods, study approach and study design. The fourth chapter analyses the research findings while in the fifth chapter conclusions and recommendations are given. The last cites all the reference materials used for the study. In addition, relevant data and information about the thesis is given on the appendices.

CHAPTER TWO: LITRATURE REVIEW

2.1. General Description

The literature review discussed issues that are related with expert system particularly rule based expert system and way of knowledge engineering and knowledge representation parts and also delay classification regarding with the impact on the construction projects and finally discussed the research gap.

2.2. Delay and its classification

Definition of delay stated by various scholars in different ways. Delays are defined as events or occurrences that affect the time required to complete a particular task. Al-Hejji, 2006 defined construction delay as the time over run either beyond completion date specified in a contract or beyond the date that parties agree upon for delivery of a project .It is slipping over its planned schedule and is considered as common problem in construction projects. Delay was also defined as an “act event which extends required time to perform or complete works of the contract manifests itself as additional days of work” by Zack (2003).

2.2.1. Classification of delay based on the compensation and exclusion

2.2.1.1.Excusable Delays

An excusable delay is a delay that is due to an unforeseeable event beyond the contractor’s or the subcontractor’s control. If the delay is considered compensable, then the contractor is entitled to additional financial compensation as well as extra project time. Under certain circumstances where non-compensated excusable delays occur, the contractor receives extra time but not compensation money for the additional completed work. Excusable delays are known as “force majeure” delays, and commonly called “acts of God” because they are not the responsibility or fault of any particular party. Most contracts allow for the contractor to obtain an extension of time for excusable delays, but not additional money (Alaghbari, 2007).

Delays resulting from the following events would be considered as excusable:

- i. General labour strikes
- ii. Fire
- iii. Floods
- iv. Acts of God
- v. Owner-directed changes and extra works
- vi. Differing site conditions

- viii. Delayed advance or progressive payment
- ix. Unusually severe weather
- x. Intervention by outside agencies
- xi. Lack of action by government bodies, such as building inspection

b. Excusable Compensable Delay

This type of delay is usually known as Owner-caused delay. If the delay is compensable, then the Contractor is entitled not only to an extension of time but also to adjustment for any increase in costs caused by the delay. Molner (2007) discusses - here, the Owner is responsible for both the time and cost effect of the delay. Moreover, the author states that the Contractor may claim the Owner interfered with the work, did not deliver Owner-purchased equipment or supplies on site as promised, or that the Owner's actions or inactions caused other delays.

c. Excusable Non-compensable

Delay When a delay is caused by factors that are not foreseeable, beyond the Contractor's reasonable control and not attributable to the Contractor's fault or negligence, it may be "excusable". This term has indirect meaning that neither party is at fault under the terms of the contract and has agreed to share the risk and consequences when excusable events occur. Harry (1995) found that examples of excusable, non-compensable delays include; unusually severe weather, fire, acts of God etc. Therefore, it can be revealed that if such types of delays are encountered, the Contractor will not receive compensation for the cost of delay, but he will be entitled for an additional time to complete the work and is relieved from any contractually imposed liquidated damages for the period of delay.

d. Non-Excusable of Delays

Non-excusable delays are events that are within the contractor's control or that are foreseeable. Ahmed et al. (2005) indicated that these delays might be the results of underestimates of productivity, inadequate scheduling or mismanagement, construction mistakes, equipment breakdowns, staffing problems, or bad luck. Such delays are inherently the contractor's responsibility and no relief is allowed

These are some examples of non-excusable delays (Alaghbari M. A., 2007):

- i. Late performance of contractor and/or sub-contractors
- ii. Untimely performance by suppliers
- iii. Faulty workmanship by the contractor or sub-contractors

iv. A project-specific labour strike caused by either the contractor's unwillingness to meet with labour representative or by unfair labour practices

1. Concurrent delays

If only one factor is delaying construction, it is usually fairly easy to calculate both the time and cost resulting from that single issue. A more complicated but also more typical situation is one in which more than one factor delays the project at the same time or in overlapping periods of time. These are called concurrent delays (Alaghbari, 2007).

Concurrent delays arise when one event causes a delay simultaneously with another event. For example, if an owner denies access to a project site for two weeks, and a severe storm prevents contractor from working on the project for one of two weeks as well, there will be a concurrent delay of one week. The contractor will be able to recover for delay damages for one week, as a severe storm is not a cause of delay that is compensable and would have prevented the contractor from performing even if the owner did not deny access to the site.

Harry in his study (1995) show that the concurrent delay is considered an additional delay only to the extent it prolongs the delay to the contract completion time beyond the date that the one it is concurrent with had already delayed that date. Concurrent delays are often more complex. Delays are categorized into 'excusable compensable', 'excusable and non-compensable and non-excusable delays. More often, the excusable and non-excusable delays occur on separate but parallel chains of activities. When there are overlapping causes for the delay, the following principles usually are applied. (Alaghbari, 2007).

When the non-excusable delay is on the critical path and the excusable delay is noncritical, no extension of time is due. When the non-excusable delay is non-critical and the excusable delay is on the critical path, extension of time is due even if the non-excusable delay commenced early in the non-critical chain of activities in so far as the non-excusable delay does not impact the critical activity. When both excusable and non-excusable delays are critical and commenced together and cease at the same time, both the employer and Contractor should bear responsibility for them. The Contractor is entitled to extension and is not entitled to associate costs even if the excusable delay is a compensable delay. When an excusable delay occurs first on a critical path followed by a non-excusable delay on a parallel critical path, the dominant cause of delay should be the deciding factor. For example, if two delays are concurrent, and one is five days long and

the second is seven days long, the second concurrent delay will only extend the contract completion time by two days.

2. Compensable or non-compensable delays

A compensable delay is a delay where the contractor is entitled to a time extension and to additional financial compensation. Relating back to the excusable and non-excusable delays, only excusable delays can be compensable. Non-compensable delays mean that although an excusable delay may have occurred, the contractor is not entitled to any added compensation resulting from the excusable delay. Thus, the question of whether a delay is compensable must be answered. Additionally, a non-excusable delay warrants neither additional compensation money nor a time extension. In addition to the compensable delays that result from contract changes by change notice, there are compensable delays that can arise in other ways. Such compensable delays are excusable delays, suspensions, or interruptions to all or part of the work caused by an act or failure to act by the owner resulting from owner's breach of an obligation, stated or implied, in the contract. If the delay is compensable, then the contractor is entitled not only to an extension of time but also to an adjustment for any increase in costs caused by the delay (Alaghbari M. A., 2007).

Whether or not a delay is compensable depends primarily on the terms of the contract. In most cases, a contract specifically notes the kinds of delays that are non-compensable, for which the contractor does not receive any additional money but may be allowed a time extension.

2.2.2 Classification Based on Major Actors Involved in Construction Sector

(Emeka, 2016), (Werku, 2016) and others categorized causes of delay based on the major actors (contractors, clients, consultants) involved in in the construction industry and factors external to these parties.

a) Consultant's Related Causes

Causes related to consultants are lack of consultant site engineer, lack of adequate knowledge on the part of the consultant, inexperience on the part of the consultant site staff, delayed in making decisions, insufficient documents, slowness in passing information, contract administration, planning and endorsement of structural drawings and quality control (Emeka, 2016). From consultants/supervisors point of view top 10 construction delay factors are: difficulties in financing project by contractor, infective project planning, scheduling or resource management, low productivity of labour, escalation of materials price, supplying poor quality material by

contractor, lack of skilled professional in construction PM(project management) in the organization, poor coordination and communication with other parties, fluctuating labour availability season to season/seasonal labour availability, price fluctuations, and late delivery of materials (Werku, 2016).

b) Contractors' Related Causes

According to Emeka listed contractors related delays which are, delay in conveying materials to site, materials shortage on site, structural flaw and substandard work, poor skills and inexperience of workers, lack of site labour, poor skills of labour, financial difficulties, supervision problems with labour, lack of subcontractor's skills, lack of site contractor's staff, poor site management, and shortage of construction equipment, poor site management, inappropriate planning of project, contractors incompetency, construction flaw and unsuitable construction techniques. (Werku, 2016), on other hand listed delay in progress payments for completed works, fluctuating labours availability season to season/Seasonal labours availability, late delivery of materials, difficulties in financing project by contractor, type of project bidding and award i.e. negotiation, lowest bidder, bureaucracy (excessively complicated administrative procedure), escalation of materials price, unclear and inadequate details in drawings, poor quality of construction materials, and preparing incomplete/un detailed BOQ as causes of project delay.

c) Clients' Related Causes

According to (Werku, 2016) listed top ten delay causes from clients' point of view. The most frequent and most critical delay factors listed by client/owner organizations are escalation of materials price, difficulties in financing project by contractor, insufficient data collection and survey before design, supplying poor quality material by contractor, lack of skilled professional in construction project management in the organization, ineffective project planning, scheduling or resource management, poor site management and supervision, preparing incomplete/un detailed BOQ, unqualified/inadequate experienced labour, and shortage of equipment in their order.

d) Causes of Delay due to External Factors

Ashraf, 2016, listed seven causes of delay external to clients, consultants and contractors. These factors are: bureaucracy and change in government regulations, other public works on site, effect of local community, changes in the cost of resources, unforeseen site conditions, problems with local community and weather conditions.

2.3. Challenges of Projects in Ethiopia

Regarding to Werku, discussed five most significant factors that cause delays in Ethiopian public building construction according to their finding.

a) Contractor's' Financial Difficulties

Failure to release payments for executed work on time is one of the problems that contractors faced. This problem is leading to financial difficulties to contractors and the pitfalls on the progress of the projects. Therefore the owners should have to release payments on time based on contract agreement and prepare sufficient fund in advance to avoid delay in progress payments for executed work and contractor's financial difficulties.

b) Escalation of Materials

Escalation of material price is another key factor affecting time performance of most construction projects in Ethiopia. Poor cost estimation that failed to predict inflation appropriately is leading to higher cost of construction materials, tools, labors, equipment etc. during construction period. Escalation is causing such negative impacts as delayed projects, lack of firm price quotes, higher project costs, a significant rise in the incidence of jobsite construction materials theft. Some of the more severe impacts can be managed by cooperative efforts to minimize, manage and share risks through proactive changes in project methods and contracts.

c) Ineffective Planning and Scheduling by Contractors

Planning and scheduling is the basic for every construction work. Ineffective planning and scheduling has a significant impact on construction delays. It should be developed from the start of the project until completion of a project. The reasons why contractors are not able to follow the planning and scheduling effectively may be due to inexperience staff and shortage of workers at the site, financial problem, and poor site management. Ineffective planning and scheduling by contractors is the significant causes of delay in construction project.

d) Delay in Progress Payments for Completed Works

Delayed payments of work done by clients on construction projects in the Ethiopian construction industry are considered to be a factor that causes delay. It causes severe cash-flow problems to contractors and this can have a devastating effect down the contractual payment chain Regular monthly payment to contractors for work done removed constraints which otherwise may have impeded project progress to cause delay and cost overruns. Failure to provide adequate funding

resources to contractors for the job done will make it difficult for the contractors to meet project objectives. Delay in progress payments for completed works was found to be one of the major factors that causes schedule overrun.

e) **Lack of Skilled Professional in Construction Project Management in Contractor**

Shortage of talent in the construction sector is a long-term problem and will continue to push up project time and costs. The education and training capacity given through various higher institutions, organizations etc. are clearly inadequate to meet the need of the large percentage of skilled workers in the Ethiopian construction sector. The education system is often not delivering the required number of specialists across project management, engineering, surveying, contract management and the skilled/semi-skilled labour.

2.4. Delay and its Empirical review

The construction industry globally has been faced with the criticisms of delays, which have an extremely negative effect on construction projects. More than 40 per cent of projects globally experienced delay. Governmental organizations, academics and practitioners across the globe are among criticized for poor management of construction projects (KPMG, 2015). According to George and Andrew, 2017, 52 per cent of projects in the UK overrun on time and 70 per cent of the UK public projects exceeded their time estimates. Teixeira.B, 2007, stated that time delay in Portuguese construction industry is 40% on average. Developing countries invest about US\$200 billion a year on new infrastructure, and this constitutes 4% of their national output and a fifth of their total investment (World Bank ,1994).

The two main reasons for the delay in Portuguese construction industry owner and design responsibility, 62% and 61% respectively, followed by project specifics, contractor responsibility and external factors, 45% 39% 36% respectively (Teixeira.B, 2007). Abinayasri, 2017 assessed 40 causes of delay in construction industry in India and categorized them under 9 groups such as design, equipment, personal, manpower, experience, government, material, finance, and owner. The study summarized projects experienced delay in one or more of the above nine categories. Owner related causes, finance related causes and material related causes were the three categories on the top of the list with 69%, 66% and 63% respectively followed by government related causes and experience related causes with 58% and 53% respectively. The sixth and seventh highest causes in the list were personal related causes and Manpower related causes

which accounted for 48% and 42% respectively. Projects that experienced design related causes and Equipment related causes rated as 28% and 39% respectively.

According to (Werku, 2016), outlined the top 10 critical factors that cause construction delays in Ethiopia based on importance index. These factors are: (1) Difficulties in financing project by a contractor with 68.75; (2) Escalation of the materials price with 65.57; (3) Infective project planning with 64.53; (4) Scheduling or resource management with 63.05; (5) Delay in progress payments for completed works with 62.57; (6) Lack of skilled professionals in the field of construction management in the organization 60.59; (7) Fluctuating labor availability season to season /Seasonal labors availability with 58.46, (8) Low productivity of labour with 54.93; (9) Unqualified/inadequate experienced labour with 46.89; and (10) Insufficient data collection and survey before design with 46.85. Ashraf, 2016, listed cost overrun, disputes arbitration, total abandonment and litigation as the six effects of delay causes on project performance construction projects based on the frequency of occurrence of the effects of construction delays on project delivery. According to him, time overrun appeared to be on the top of the list with 94.62 followed by cost overrun with 88.50. Disputes, arbitration and total abandonment were the next three effects with 73.37, 64.33 and 58.21 respectively. Litigation also is ranked from 6th with 55.67 frequency of occurrence.

XXXXXXXXXXXX

2.5. Artificial Intelligence

Artificial Intelligence (AI) is one of the up-to-date sciences; the name artificial intelligence itself was coined in 1956. Majority definitions of artificial intelligence proffered over decades have relied on comparisons to human behaviour. According to different authors define artificial intelligence in different ways such as: the sciences of making machines do things that would require intelligence if done by men and suggested that AI as the mechanization or duplication of the human thought process.” Artificial intelligence is the study of mental process through the use of computational models, “An intelligent program is one that exhibits behaviour similar to that of a human when challenged with a similar problem (Frank, 2007).

From the very beginning, scientists and researchers of AI have been trying to produce systems that can behave like an intelligent being. In course of such developments, they realized the clue of human expertise in a certain field and tried to encode the knowledge and experience of human

experts in computers that led to the idea of developing expert systems in areas of different domains (Frank, 2007).

2.6. Expert System

The term expert system comes from the world of artificial intelligence. Originally, it comprised the idea that computer programs can be devised to solve complex problems of decision making, as well as, or even better than human experts. An Expert System is a computer program that represents and reasons with knowledge of some specialist subject with a view to solving problems or giving advice. To solve expert-level problems, expert systems need efficient access to substantial domain knowledge base, and reasoning mechanism to apply the knowledge to problems they are given. Usually, they also need to be able to explain to the users who rely on them, how they have reached their decisions. An expert system is a so-called knowledge base, a formal model of knowledge that is used to make inferences to arrive at relevant decisions (Jorgen, 2005).

2.6.1. Approaches of expert system

There are different types of expert systems. Such as rule-based, frame based, case-based and model based .Frame-based knowledge is associated with the objects of interest and reasoning consists of confirming expectations for slot values. Such systems often include rules too. Case-based previous examples (cases) of the task and its solution are stored. To solve a new problem the closest matching case is retrieved, and its solution or an adaptation of previous solution and proposed as the solution to the new problem. Model-based: where the entire system models the real world, and this deep knowledge of the design and function of an object is used to diagnose equipment malfunctions, by comparing model predicted outcomes with actual observed outcomes. All the above three are alternatives that used to develop expert systems, but most of expert systems are developed using rule-based and discussed in the next section (Bruce, 1982).

2.6.2. Rule based expert system

Rule-based expert system is an expert system which works as a production system in which much of the knowledge is represented as rules, that is, as conditional sentences relating statements of facts with one another. Rule-based programming is closely related to classical logic usually first order logic and functional programming. First order logic is a symbolized theory in

which each sentence or statement is broken down into subject and predicate. In a typical rule-based expert system, a rule consists of several premises and a conclusion. If all the premises are true, then the conclusion is considered true (Bruce, 1982).

The first rule-based Knowledge Based Systems were tightly integrated with the specific application they were developing for. Thus, new rule based system had been written from the scratch. The EMYCIN, a derivate from MYCIN (ES for diagnosis and therapy selection for bacterial infections of blood) was developed as a generic frame work for rule based systems, without the domain knowledge of the MYCIN. It was the first of its kind. This approach of developing a framework without a domain specific knowledge is followed by most modern rule-based systems (Srinivas, 2010).

2.3.3. Architecture of rule based expert system

Rule-based Knowledge Based System has four main components: working memory, knowledgebase, inference engine and user interface.

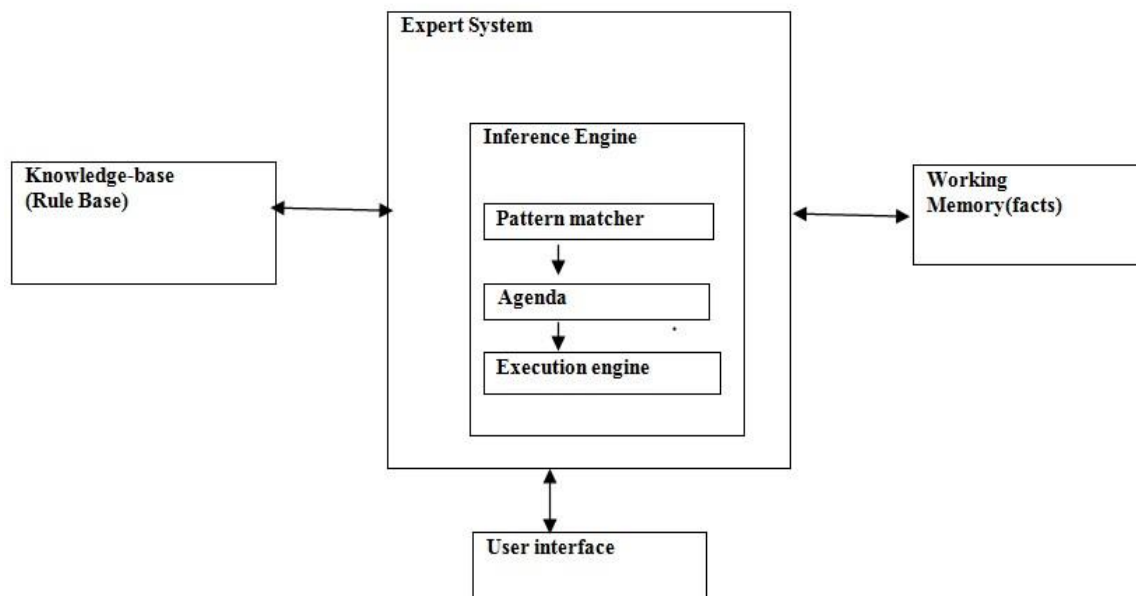


Figure2.1 Architecture of rule-based Knowledge Based System

a. Working memory

The working memory (WM) represents the set of facts known about the domain. The facts are task –specific data for the problem. The contents of WM changes based on problem situation and it is the most dynamic component of Knowledge Based System. WM is used by the inference

engine to get facts and match them against the rules. The facts may be added to the WM by applying some rules.

b. Knowledge Base

The knowledge base is one of the components which consist of problem-solving rules, procedures, and intrinsic data relevant to the problem domain. In rule based Knowledge Based Systems, Knowledge base is also called production memory; rules are in the form of if-then productions.

c. Inference Engine

As the name implies the inference engine makes inferences. It decides which rules are satisfied by the facts, prioritizes them, and executes the rule with the highest priority. It controls the whole process of applying the rules to the working memory to obtain the outputs of the system. According to (Robert, 2003), an inference engine works in discrete cycles as follows:

- All the rules are compared to the working memory (using the pattern matcher) to decide which ones should be activated during this cycle. This unordered list of activated rules, together with any other rules activated in previous cycles, is called the conflict set.
- The conflict set is ordered to form the agenda—the list of rules whose right-hand sides will be executed or fired. The process of ordering the agenda is called conflict resolution.
- To complete the cycle, the first rule on the agenda is fired (possibly changing the working memory) and the entire process is repeated. This repetition implies a large amount of redundant work, but many rule engines use sophisticated techniques to avoid most or all of the redundancy. In particular, results from the pattern matcher and from the agenda 's conflict resolver can be preserved across cycles, so that only the essential, new work needs to be done.

There are two types of inference: forward chaining and backward chaining (Robert, 2003). In forward chaining the initial facts are processed first and keep using rules to draw new conclusions. While in a backward chaining, the hypothesis (or solution/goal) are trying to achieve is processed first, and keep looking for rules that would allow concluding that hypothesis.

2.3.4. The Knowledge engineering process

Figure 2.2 shows, the main components in the development of knowledge-based system includes: Knowledge acquisition, knowledge validation and verification, knowledge representation.

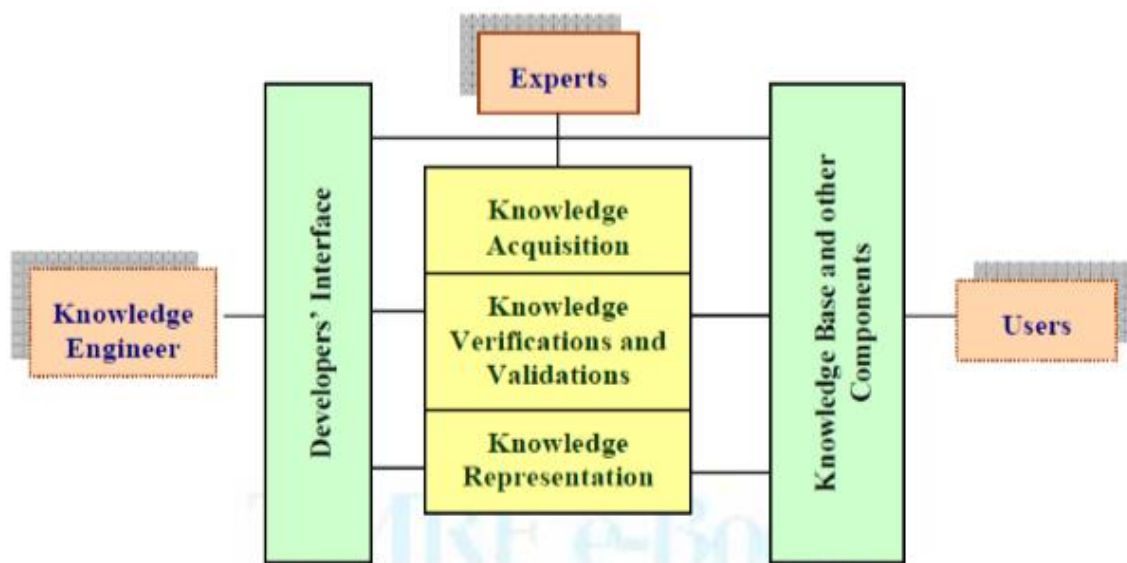


Figure 2.2: Knowledge based system development processes (Srinivas, 2010)

2.3.5. Knowledge Acquisition

Knowledge acquisition is the process of eliciting, structuring and organizing elicited knowledge from domain experts and other sources for knowledge base representation in form of rules or other forms of representation.

It is imperative to the development and implementation of expert systems for it contains the information required to solve problems in expert system domain. As a result of the challenges and difficulties faced in the transfer of expertise knowledge, knowledge acquisition has been described as the bottle neck of expert systems development. The first challenge of knowledge acquisition, the logic or justification behind an expert's thought is not easily revealed and the omission of this tacit knowledge could cause a detrimental gap in knowledge required by an expert system to solve the problem for which it was built. Another major challenge in knowledge

acquisition is expert's lack of willingness to share knowledge. In an academic and research environment, an expert is part of an expert system development team and he/she is acknowledged in the resulting research paper or article. However, expert systems development within a company /organization with the explicit intention of completely or partially replacing the domain expert hinders the co-operation and enthusiasm of domain experts as the threat of losing their jobs or prestige becomes perceptible.

Explicit knowledge is knowledge that the can make explicit by means of verbal statement: some has explicit knowledge of something if a statement of it can be elicited from him by suitable enquiry. Explicit knowledge can be expressed and communicated linguistically.

2.3.5.1. Interviews

An interview between a human expert and a knowledge engineer is probably the most common form of knowledge acquisition. Interviews are usually taped and later transcribed and analysed. Interviews are a widely used tool to access people's experiences and their inner perceptions, attitudes, and feelings of reality. Based on the degree of structuring, interviews can be divided into three categories: structured interviews, semi-structured interviews, and unstructured interviews (Zhang, 2009).

a) Structured interview

A structured interview is an interview that has a set of predefined questions and the questions would be asked in the same order for all respondents. This standardization is intended to minimize the effects of the instrument and the interviewer on the research results. Structured interviews are similar to surveys, except that they are administered orally rather than in writing (Zhang, 2009).

b) Semi-structured interview

Semi-structured interviews are more flexible. An interview guide, usually including both closed ended and open-ended questions, is prepared; but in the course of the interview, the interviewer has a certain amount of room to adjust the sequence of the questions to be asked and to add questions based on the context of the participants' responses (Zhang, 2009).

c) Unstructured interview

This type of interview is non-directed and is a flexible method. There is no need to follow a detailed interview guide. Each interview is different. Interviewees are encouraged to speak openly, frankly and give as much detail as possible. The interviewers ask questions that

respondents would be able to express their opinions, knowledge and share their experience. This can create some problems because the interviewer may not know what to look for or what direction to take the interview. The researcher may not obtain data that is relevant to the question of the study. The interviewer needs to think about what to ask and to ask questions carefully and phrase them properly and know when to probe and prompt (Kajornboon, 2005).

2.3.5.2. Observation

Sometimes it is possible to observe an expert at work. In many ways, this is the most obvious and straightforward approach to knowledge acquisition. However, there are different difficulties that should be considered. For example, most experts advise several people and may work in several domains simultaneously. In this case, the knowledge engineer's observations cover all the other activities as well. Therefore, large quantities of knowledge are being collected, of which only a little is useful. They are generally expensive and time-consuming.

2.3.5.3. Document analysis

The other form of knowledge acquisition method is concerned with a detailed analysis of the existing document. This technique is used to collect relevant knowledge from the existed documents of different format. These documents include professional literature, brochures, manuals, guidelines, employee handbooks, reports, glossaries, course texts, and other relevant materials (Tagel, 2013). For the purpose this study document analysis is chosen because the document prepared by past researchers about delay and its cause.

2.3.5.4. Workshop and focus group discussion

Workshop is also as research methodology focus on the study of domain-related causes using the workshop format as a research methodology. Its aim is to fulfil participant's expectation to achieve something related to their own interests and other one is to design to fulfil a research purpose. (figg, 2015) .

2.3.6. Knowledge Representation

Knowledge representation is important in the expert systems development as it affects the development, efficiency, speed and maintenance of an expert system. The knowledge acquisition process should fit in with knowledge representation paradigm and the knowledge representation should also be adequate for the problem. Knowledge representation can be described in contexts of both the inference and problem solving strategies of a proposed expert system.

2.3.7. Knowledge Verification and Validation

Validation provides evidence upon which users decide whether or not a knowledge-based system (KBS) is reliable. Validation in due course determines the success or failure of a KBS. This can be tested by using test cases, confusion matrix or other techniques and user acceptance (Preece, 2001).

Explanation Facility

Explanation facility is a subsystem that explains the system's actions. The explanation can range from how the final or intermediate solutions were arrived at to justifying the need for additional data.

Methods of Performance Evaluation

The most important problems in developing knowledge-based systems are the lack of methods to verify and validate the Knowledge Base. Unlike most conventional software, rule based systems are rarely validated and verified against an explicit specification of user requirements. Probably the main reason for this is the lack of a complete and common understanding of the task which is intended to perform among end users, human experts and rule based system builders (Meseguer, 1995). Among the components of the knowledge based system, the two major components that compose the intelligent program are a knowledge base and an inference engine. Since the inference engine is algorithmic software i.e., conventional software, software engineering testing techniques can be applied on it. Accordingly, in this system some of the most suitable software engineering testing techniques is used.

Rule based systems evaluation method can be split into verification, validation, assessment of human factors and assessment of clinical effect. Validation and verification are part of a series of techniques and methodologies applied to the evaluation of a system with the purpose of defining whether its construction is correct (verification); and for defining whether the system corresponds to its initial specifications (validation).

Validation process is defined as the process of assuring that a system satisfies user requirements. User requirements are clearly application-dependent but they commonly refer to operation conditions, performance level, user interaction, explanation capabilities and acceptance criteria (Meseguer, 1995). In other terms, validation is the process that evaluates the system capacities to solve problems. Validation provides evidence upon which users decide whether or not a knowledge-based system is reliable. Thus, validation ultimately determines the success or failure

of a knowledge based system project (Preece, 2001). Validation allows assuring that a knowledge based system provides solutions that present a confidence level as high as the ones provided by experts.

Validation is then based on tests, desirably in the real environment and under real circumstances. During these tests, the KBS is considered as a “black box” and only the input and the output are really considered important.

Verification define as the process of checking an ES /KBS against the specifications generated by its requirements. The verification process produces accurate responses about the satisfaction of each specification. Often, specifications establish conditions that should (or should not) hold for all the possible ES/KBS executions. To test these specifications, verification has to be exhaustive; it has to analyse all the possible situations where a specification may be violated (Meseguer, 1995).

Verification is an activity in the validation process which aims to verify whether the system attends formal requirements. In other words, verification process evaluates whether the system is appropriately developed. Verification is widely associated to the question: "are constructing the system correctly?" (Andradei, 2012). Verification allows assuring that a knowledge based system has been correctly conceived and implemented and does not contain technical errors. Verification is intended to examine the interior of the knowledge based system and find any possible errors.

2.3.8. . Knowledge Base System Development Tool

A number of tools that support the development, execution, and maintenance of knowledge-based systems are marketed commercially. In the late 1980s and 1990s, when knowledge based systems was at its peak, approximately 200 knowledge based system tools were commercially available (Kingston, 1989). A knowledge based system tool is a set of software instructions and utilities taken to be a software package designed to assist the development of knowledge-based systems. Knowledge based system can be developed using general purpose programming languages like java and framework like .NET can also be used in knowledge based system development. These programming languages are general purpose and also being used to develop other application than AI applications.

And also knowledge based system can be developed using knowledge based system shell with the readymade utilities of self-learning, explanation and inference etc. like Java Expert System

Shell , Vidwan, which are more specific and useful to develop knowledge based system. Knowledge based system can be developed using programming languages like LISP and Prolog. There are various versions of Lisp available like C Language Integrated Production System (Srinivas, 2010).

Prolog stands for Programming in logic, which was designed in 1972 by Philippe Russel, Alain Colmerauer at the University of Aix-Marseille and Robert Kowalski at the University of Edinburgh. Since 1972, Prolog has been one of the most popular logical programming languages. Prolog programs are often described as declarative, although they also have part of a procedural element.

There are only two components to any prolog program: facts and rules. Prolog works by specifying facts and rules and uses query and prolog interpreter to retrieve solution for users“ queries (Barmer, 2005).

2.7.The Research gap

Many expert systems have been developed in different countries for plant disorder diagnosis for medical purposes and other production aspects. However, while reviewing related works done on expert system in construction sector, no enough expert system work for local context and study on rule based expert system related with delay managements was found. Especially there was no attempt was made in delay management on construction sector. Many researches have been done in the causes of delay for construction projects but none of them included the solution of the delay as observed till now. So this study fills the gap by including the solution by having the expert's solutions.

CHAPTER THREE: METHODOLOGY

3.1.Introduction

This chapter discusses about how to answer research questions and address objectives of the study. The methodology of the study includes study area selection criteria, research approach, data type and source, data collection techniques, data analysis and presentation technique. The study area selection criteria are listed why the study is undertaken in the selected sector and its periphery part. In the research approach what type of research method should be used is discussed. The data type and source method describes the type of data collected from governmental and non-governmental` offices .The data collection technique describes how the data was collected. Data analysis technique stated the type of method used to analyze the collected data.

3.2. Study area selection Criteria

The world vision started its operation in Ethiopia in 1970. Ethiopian Selected Small-Town Water Supply Construction Project is one of the projects of WASH program. WASH is the cooperative term which stands for Water, Sanitation and Hygiene for the universal, affordable, and sustainable access to safe water, adequate sanitation and hygiene to the society. Due to their interdependent nature, these three essential issues are grouped together to represent a growing sector. The concept of WASH groups together water supply, sanitation, and hygiene because the impact of deficiencies in each area overlaps strongly.

The study were focus on 15 secondary small towns those are: Motta, Injibara, Holeta, Fitche , Gebre Guracha , Adigrat, Maychewu ,Sodo ,Bonga , Dembidollo , Shoa Robit , Ataye , Mersa, kemisse and were Ilu in 4 provinces in Ethiopia.

The study was done in Addis Ababa city Minister of Water, Irrigation and Energy of Ethiopia related with WASH projects delay management which emphasized more on small-town water supply construction projects .The reason behind the study area was undertaken in water sector is that Water is basic thing to human being and also written in the constitution as a aright

- The water sector have lower development related with other sectors
- Delay seems usual problem in the water sector

The reason behind the study area was undertaken in WASH projects is that:

- It have variety of projects so, the experts in this project have different work experience

- Those projects have the collective idea of water, sanitation and hygiene not only consider on the water supply projects

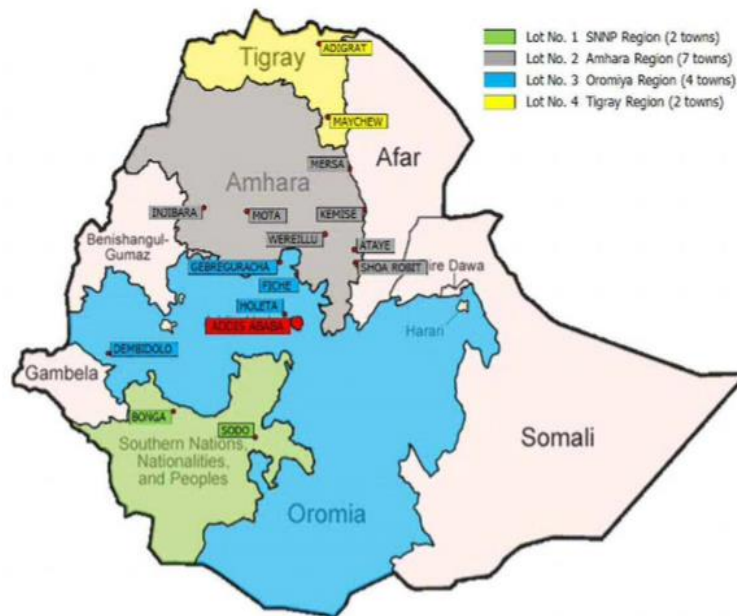


Figure 3.1: Map of the Study Area Addis Ababa city periphery condominium

Source: Technical audit report of the small towns water and sanitation project, 2018

3.3. The Research Design

The outline of the research design has been illustrated in Figure below. The research problem and the objectives stated above are followed by the literature review. Next, identification of data required to deal with and solve the problem was indicated. Secondary data were acquired from different documents available at the government offices. After analysis the result has been discussed and based on the result conclusion and recommendation were formulated. In this study different knowledge acquisition ways were used to attain the objectives. Those are document review to understand about the rule base expert system and to know the tool used to develop the system .The other thing is to collect the causes of delay from different publish papers and

articles. After collecting those cause of delay conducted the workshop and focus group discussion in order to validate and data and to add more knowledge in the course mater. After this journey in order to get the solution the researcher conduct structural interview with purposively selected experts then finally, develop the rule based expert system in the form of if....then with cause and solution of delay.

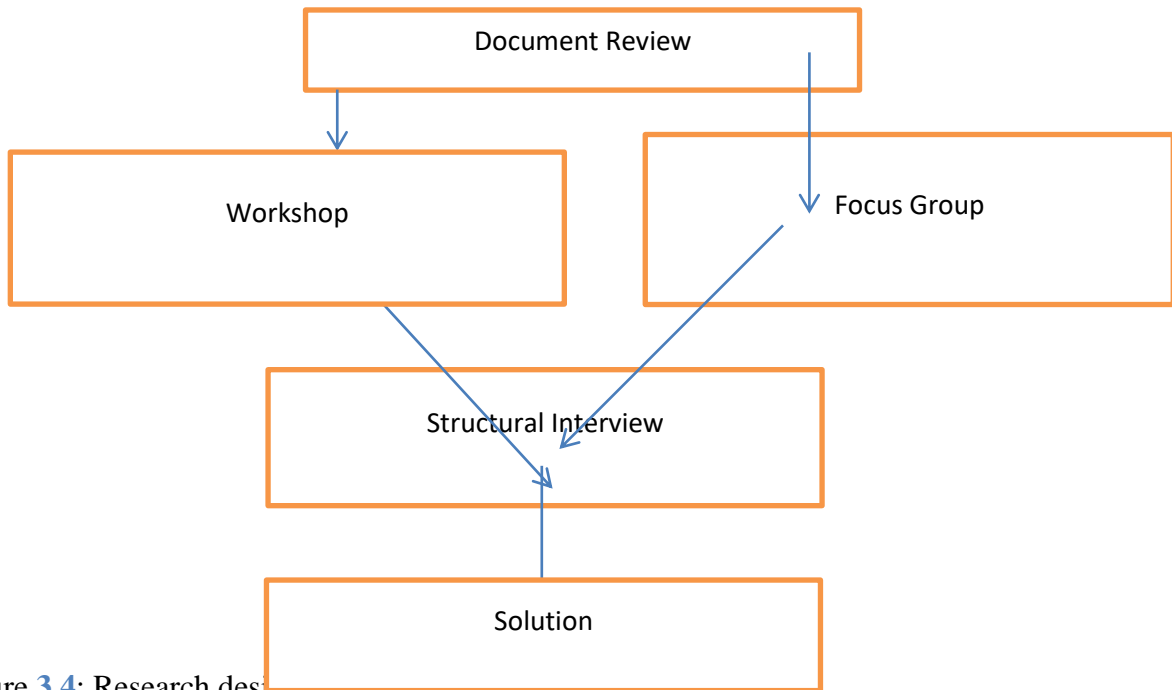


Figure 3.4: Research design

3.4. The Research Approach

Qualitative research method was employed in this study. The qualitative concerned with the understanding of peoples attitude in terms of the study provided of context in which they express their reaction. It takes into account different viewpoints and practices in the field because of the different subjective perspectives and social backgrounds related to them.

The research design of this study was narrative in which data was collected from respondents with structural interview and workshop from domain experts. Major cause of delay identified and also their proper solution was defined from their experience of individuals.

3.5. Data Collection Techniques

To conduct this research and collect required data, both primary and secondary sources of data were used. Secondary data was collected from published books and articles as well as from different documents and manuals from government. The primary sources of data were collected through workshop and interview from those representatives of aforementioned stakeholders.

For the purpose of this study, the researcher employed qualitative data that were obtained through structural interview and workshop for domain expert and also review of related documents.

3.6. Data Type and Source

For the purpose of this research, the process of knowledge acquisition includes some basic activities such as interviewing of domain expert's, review of relevant sources of information and workshop when the expert is troubleshooting. The processes of knowledge acquisition of this thesis are discussed in detail below.

3.6.1. Knowledge Acquisition from Relevant Document

The researcher tries to assess the documents related to delay and gain the causes and effect of the delay with its rank but can't gain the required solutions for each of individual causes of delay. So, this research can be different by accessing the solutions with if....then analysis for delay management. The cause of delay which collected from different literatures was organized in the form of rule based.

The second data was gathered from the technical audit report of the 15 small-town water supply and sanitation construction project.

3.6.2. Knowledge Acquisition from workshop expert's domain

Workshops as research methodology focus on the study of domain-related cases using the workshop format as a research methodology. In these studies, the workshop is, on one hand, authentic, as it aims to participants' expectations to achieve something related to their own interests. On the other hand, the workshop is specifically designed to fulfil a research purpose: to produce reliable and valid data about the domain in question.

Knowledge was collected from the workshop experts in the domain area on the construction management masters students of Addis Ababa University in Ethiopia Institution of Architectural, Building Construction, and City Development (EiABC) compass.

The workshop is started by presenting the objective of the research and the research area in detail. Then after the researcher and my advisor prepare pink and blue colour flashcards the first card which is the pink one distributed to the participants and ask them to write the cause of delay and secondly, in the other flashcard, request to write the solution of the delay. Finally, collect the flashcards and stamp on the wall and collect repeated causes and solutions and compared with literature cause and solution of delay. And also in this workshop diverse idea was rise from different perspective. the researcher observe that there is knowledge gap between the participants in the definition of delay in this fundamental concept some of them are believe that delay is the time where the project is not in work or terminate that means in our case the project is delayed for about 2 years where the project is terminated to change the Italian contractor and consultant only but in the other side argue that delay is extension of time from the schedule one, for example, the project is planned to work by 2 years but it's completed by 10 years so, the project is delayed for 8 years. So, the research observe that there is knowledge gap in between the participants and some of them are also assume that the delay in water sector is such a common thing and validate the causes of delay which collected from the past documents and get ready for the next step. The participant result and the above causes of delay were compared as a result most of them are similar so, decide to continued using the above form. The workshop was used as validation of the cause of delay gathered from different literatures so, the researcher by full confidence go to the next step which is the interview of selected experts.

3.6.3. Knowledge Acquisition from structural interview with experts

The domain experts were selected using purposive sampling technique. structured interviews have been conducted with seven senior experts which have more than 15 years' experience in the construction industry and with different expert categories which are project manager, design professional, claim expert and construction manager by asking questions about the solution of delay methods which are listed from their experience in solving these problems Or the ifthen part.

The final data which give to the experts is prepared with rule-based expert in the form of if.....then analysis to gather the solution of the delay from selected expert and fill in the then part.

3.7.Method of Data Analysis and Presentation

Purposive sampling technique is used to select domain experts for knowledge acquisition. The selection criteria of domain experts for the study are based on the profession or expertise, educational qualification level, year of experience and their immediate position in the construction sectors.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1.Introduction

The data used for this research was secondary data and it was quantitative. The collected quantitative rule of the delay management in the form of if....then were analyzed using excel. Different causes of delay was collected from previous documents and grouping it the eight basic groups and next validate those causes of delay by conducting the work shop with 10 participants from Addis Ababa university MSc students in construction management and also to verify the case matter the focus group is conducted with those 5 workers in minister of water, irrigation and energy staff members and finally select the repeated cause of delay and conduct the structural interview with purposively selected 7 experts. This chapter discusses about data description, result and discussion. It shows the collected data from the workshop participants result from the focused group and from structural interview. The evaluation of total results of each of the combine and create the rules of delay management. The result which gained from this methodology was discussed in this chapter in detail.

4.2. Respondents Data

In the workshop number of participants was 10. Those participants were academicians with different year experience and they are MSc fellows in construction management in Addis Ababa University in Ethiopia Institution of Architectural, Building Construction, and City Development (EiABC) compass.

The focus group was conducted in the Minister of water, irrigation and energy with 5 staff members and team leader of the four district ions which is the North, South, West and East. And the fifth one is coordinator of the four groups. Their centred head office is in Addis Ababa.

Table 4.1 Respondents profile

Sr. No.	Variables	Number		Proportion (%)
1.	Educational level	BA/BSc	7	21.875
		MSc Fellow	10	31.25
		MSc	8	25
		PhD	7	21.875
2.	Experience category	1-5 year	10	31.25
		5-10 years	9	28.125
		10-15 years	6	18.75
		Above 15 years	7	21.875
3.	Expert category	Team leaders	5	15.625
		Coordinator	3	9.375
		Academicians	12	37.5
		Project managers	6	18.75
		Claim experts	2	6.25
		Design professionals	3	9.375
		Construction managers	1	3.125

4.3.Results(knowledge acquisition)

4.3.1. Result from document review

From the last documents 35 cause of delay were analysed and grouped in to eight major categories: Client related, Contractor related, Labor and equipment related, Material related, Consultant related, Community Related, Contractual issues, External issues.

Table 4.2. Causes of delay collected from document review

Causes of delay	
Client related	5. Consultant related

1.1. Insufficient funding	5.1. Inappropriate design
1.2. Interference with project performance	5.2. Poor contract management
1.3. Delay or non-payment for completed works	5.3. Late identification & resolution of drawings & specification errors & omissions
1.4. Wrong choice of consultants & contractors	5.4. Late preparation of drawings and other contract documents
1.5. Slow decision making	5.5. Improper contract packaging/delivery strategy
1.6. Design alterations & change orders	5.6. Over inspection
2. Contractor related	5.7. Long waiting time for testing
2.1. Poor coordination of subcontractors	5.8. Wrong coordination of information and data
2.2. Inappropriate construction methods	6. Community Related
2.3. Inadequate planning	6.1. Lack of project acceptance
2.4. Inadequate experience	6.2. Delay on compensation
2.5. Incompetent site management	6.3. Not providing Right of way timely
3. Labor and equipment related	6.4. Youth unrest
3.1. Unskilled site manpower	7. Contractual issues
3.2. Improper equipment selection & Faulty equipment	7.1. Lack of communication
3.3. Labor disputes	7.2. Regular meetings
4. Material related	7.3. Wrong organizational structure
4.1. Quarry site	7.4. Change of project office
4.2. Poor quality of material	8. External issues
4.3. Material Shortage	8.1. Weather
4.4. Import delay	8.2. Inappropriate Change of leadership
	8.3. Natural disaster

4.3.2. Result from workshop

After analysed those causes of delay this study continue to conduct the workshop as well as the focus group discussion. Final result of the workshop is summarized on the table below.

Table 4.3. Summary of workshop result

No.	Cause of delay from the workshop participants	No. of response repeated
1.	location of the project/remote area	6
2.	payment delay /financial constrain	3
3.	poor performance of the contractor	6
4.	access road	2
5.	awareness on the delay	1
6.	characteristics of the project	1
7.	climatic/ather condition	3
8.	complexity of the project	1
9.	contractual causes	1
10.	contract termination will use time	1
11.	corruption	1
12.	design change	1
13.	design problem	3
14.	disputes beten contractual parties	1
15.	force major	3
16.	foreign currency increment	3
17.	improper documentation of the project	1
18.	inappropriate work methodology	4
19.	incompetence of contractors and supervisors	1
20.	incorrect feasibility study	4
21.	lack of cost estimation /method of financing	1

22.	lack of properly completed design and documents	1
23.	lack of responsible professionals	2
24.	lack of technological advancement	1
25.	local communities cultural/ethical belief	1
26.	market condition /inflation	2
27.	political stability of the area	2
28.	poor communication	2
29.	poor material availability	3
30.	poor planning	5
31.	poor scheduling, project management, and integration	3
32.	poor supervision/monitoring and controlling	5
33.	poor workmanship	1
34.	procurement method	1
35.	project management system	1
36.	risk management way	1
37.	scope of the project	2

4.3.3. Result from focus group review

The other data were collected from the focus group participants who are the team leaders of the four districts and coordinator of those projects. The focus group discussion start by on the collected causes of delay and select the causes which are repeatedly happened in this project and all of them are select that the major causes of delay which are occurred in the project are listed below.

Table 4.4. Summary of Focus group

Delay factors of 15 small town projects	
1.	Problem on right of way
2.	Lack of foreign exchange
3.	The procurement low by itself
4.	Discrepancies in Contract Documents
5.	General Lack of Performance by the Contractor and Sub-Contractors

6.	Non-availability of Materials and Equipment
7.	Poor Quality Assurance and Lack of Co-operation
8.	Access to Sites
9.	Logistical Difficulties
10.	Contractor's Performance
11.	Contractor's Management Capacity
12.	Contractor's possible Liquidity Problem – Low Contract Price

After all this the research conducts the structural interview with the most popular and experienced experts who have more than 15years experience in the construction with different expert category: project manager, claim expert, design professional and construction manager. Preparing the causes of delay in the form of rule based expert system like if.....then analysis. See on appendix. Narratively the respond was discussed below.

4.3.4. Result from experts

a. Expert one

Stakeholder	Expert category	Expert experience	Experience in water project
Consultant	Project manager	+15year	1year

The first question provided to the first interviewee was “started with a question that needs an explanation on the meaning of delay and he said that delay is an event which directly affects the completion of time and indirectly the project cost. And after I started to ask the main questions which are the causes of delay the first is client-related causes of delay and when come to the individual cause that is change order by owner during construction and the expert said that to this problem in the project inception phase need to do the need assessment properly and have to have the qualified designer who can through the design properly manage. For interference with project performance, the expert said that the client has to follow the contract and work with it. And next, on the delay or non-payment for completed works, the solution will be based on the expert have to have better financial planning and have the block payment practices to manage the financial delay problem. I have an inappropriate selection of consultant and contractor the expert suggest that the client have to focus on quality/qualification and have to study the past

history of the professional in detail to have best contractor and consultant. If the client has lack of experience of the owner in this cause the expert idea was it cannot be the case because if the client has less experience he/she can employ qualified owner or adviser representative and the experience cannot be an issue. If the client has poor communication and coordination with other parties the experts suggest that the client should have qualified communication management representative and also as a second solution can change the delivery method as the expert said. If the insufficient funding happens then the expert suggests that have to allocate of funding first and on the last cause of delay as a client related was if unrealistic contract duration and requirements imposed for this cause the suggest that the client have to follow the best practices such as empirical equation development using past practices.

When come to the delay causes related with the contractor which is started by if the stockholder has the poor qualification of the contractor's technical staff the expert suggests that the contractor have to have training which can be built the capacity also the contractor has to partner with other company. If it has the shortage of contractor's materials on-site the expert said that the contractor has to have proper material management or the inventory management and this way can eliminate the material shortage. In order to eliminate the faults during the construction stage, the expert suggests that the contractor have to review the construction or give the value for every construction activity. If the contractor has inadequate experience then as the expert says that the contractor has to partner with other companies to share the experience or done by joint venter. If the contractor has the difficulties in financing the construction project he/she has to increase the number of sources and also have to advance the financing system and as the last solution change the financing regulation in order to have the best financing management as an expert respond. For the inadequate planning and scheduling of work by the contractor the expert suggest number of solutions those are the one has to assign qualified contractor the other one is a project schedule and control and also allowable financial regulation capacity and finally the expert have as the last solution to take the training to improve his/her capacity. If conflicts with sub-contractors occur first of all have to have a proper selection of sub-contractors criteria and have a better way of administration sub-contractors based on the contractual as the expert responds. For the poor managerial skill of the contractor, they have taken the training for the capacity building as an expert said. For the rework due to error during construction, the expert says that has to

improve the design and also have to improve the design and qualified Forman in order to reduce rework at the first instance.

The third cause of delay is related with consultants and the with this category the researcher start the question by if there is poor communication and coordination of the consultant with other parties what is going to be the solution for it and the expert answer me that the consultant has to have the representative communication planning and management. And the second one is if the consultant is delayed in inspection what is going to be the solution for not be delayed on inspection the expert responds that the consultant has to have better staffing and some other thing is that require the proper notification from contractors. When come to the next question if the consultant has an absence of site staffs then the expert suggests that should have to have better staffing and the inspectors have multi-skill and finally, have to assign the human resource allocation and management too. As the expert responds in order to improve the experience of the consultant has to work in partnering and also he/she have to take the training to improve his/her skill. If there is an error and discrepancies in the design document so have to improve the capacity of our design at the first instance and also have to provide adults in the design stage. And regarding the respondent training is important to improve the poor contract management skill of the consultant and also if there is a delay in design documents the consultant should have the better staffing or planning and make it standardized. For the inadequate site investigation, the expert suggests a solution which has to conduct a better geotechnical investigation. For the improper contract packaging/ delivery strategy then the consultant has to work collaborate with the client and decide better delivery strategy which is appropriate for that project.

The fourth cause of delay is related with contractual issues and start by asking the expert about if there is lack of communication then its response was that should have better communication management in order to solve the communication gap among them. The other cause of delay is the wrong organizational structure so the expert respond was that have to the strategical management or prepare the SWOT analysis for the organization structure in detail. The last one is if contract termination will use time then the expert said that have to have better performance management.

The next cause of delay is related to the community that if there is a lack of project acceptance by the community as the expert said the stakeholder engagement is mandatory to convince the community. And if there is delay in compensation to the community which requires then should

have to have better financial planning and also for the right of way cases have to have integrated project plan which is considering the entire beneficiary and also if they don't have the awareness on the delay then the stakeholder engagement is mandatory as the expert said so.

The additional cause of delay is related to material which is like imported delays as an expert say that make fast the procedure of procurement and they have to give special privilege for water projects as a government. In order to improve quality of material have to test the material, quality control and finally have to make quality audit as recommended by the expert one also for the material shortage better inventory and material management is necessary and also there is another issue on the this regard which is foreign currency increment as the expert respond can minimize its effect by using substitution materials and also reducing the exposer .other cause in this category is the absence of technological advancement it can be solved by conducting training or capacity building and also the other solution is put the benchmarking and updating through time.

The next cause of delay is labor and equipment related from this perspective can have different problems like unskilled site manpor for this problem the expert suggest that can improve this by training and also by integration with school graduates for better skill. The second problem is improper equipment selection and faulty equipment the expert respond was in order to solve this problem have to have qualified consultant and for improve the capacity conduct training for capacity building and the last one is the Labour disputes as expert said that have to prepare the duties and responsibility document and everyone have to follow that and also create the awareness.

The last category of the cause of delay is external issues form this category the first problem is climatic or weather condition for this problem the expert suggests that have to have better activity planning list which related with condition or weather. The second problem is a change of leadership if this becomes the problem for the delay can manage it by having better planning and communication regarding the expert respond. The last problem of delay form this category is interference by political leaders for this can engage the as stockholder at the first stage and have created the awareness for the leaders as expert one respond it. From

b. Expert two

Stakeholder	Expert category	Expert experience	Experience in water project

Consultant	Design professional and claim expert	+13 year	No
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This expert was more challenged to accept the interview because the expert believes that if he/she doesn't have the experience on the water projects then the outcome can't be perfect but after some conversations the expert starts to answer the questions and from the beginning the expert defines delay by extension of a project's or actual completion date beyond its intended planned or completion date. When it comes to the main questions from the first category or the client-related delay causes, the first one is if a change order by the owner during construction was the cause of delay, then the expert suggests that we have to conduct thorough investigation and design to reduce change order in the first place to reduce its effect. Delay or non-payment for completed works, then the expert's suggestion was the contractor's stipulated providing for interest and financing too. On the lack of experience of the owner, the expert says that higher a project like by employing construction management consultant to act on behalf of the owner. On this category, the other delay cause is insufficient funding for this cause, the solution will be to confirm funds before contracting, as the expert said. The last cause from this category was unrealistic contract duration and requirements imposed, and the solution for this will be to determine contract duration through critical planning and scheduling before, as the expert proposed it.

The second main category of causes was laid on the contractor-related, and from this category the first cause was if poor qualification of the contractor's technical staff happened, then the solution will be to improve selection criteria to have qualified staff, as recommended. The second cause of delay was if a shortage of contractor material on-site occurs, and the solution will be to stock critical material on-site, as recommended by the expert. If inadequate contractor experience will be the cause of the delay, and again, we have to improve selection criteria for having better-experienced contractors, as the expert said. The other cause of delay was that the difficulties in financing the construction project by the contractor, then the expert's answer was to manage finance properly, and the last cause that the expert gave suggestion was that if inadequate planning and scheduling of work by the contractor is the cause, then the solution is to monitor or review the problem for planning and scheduling in detail.

c. Expert three

Stakeholder	Expert category	Expert experience	Experience in water
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			project
Consultant	Design professional	20 year	No

The expert started by define delay as delay is extension of time from the scheduled one and when come to the main question or the establishment of the delay management rule starting from the first category that is client-related delay causes the first cause was if change order by owner during construction then the expert suggest the solution to complete the design before and also he recommends not to interfere the client with the project performance in order to minimize the delay effect and the client have to pay on time in order to decrease the effect of delay which comes from delay or non-payment from completed works. The other cause of delay was the incorrect choice of consultant and contractors for this cause the expert suggests that the client have to follow the right selection method in order to have experienced consultant as well as the contractor. The next cause of delay from this category will be the lack of experience of the owner the expert clarifies that this cannot be the cause because the owner can have project construction management consultant on behaves of him/here. If the client is poor in communication and coordination with other parties then the expert said that have prepared the communication protocol to solve this problem. If the project has the problem of funding in this cause the expert give two options the first one it didn't start the project if the fund is at hand otherwise have to look for other funding sources and the last cause of delay from this category is if unrealistic contract duration and requirement imposed in this case the contract document have to be clear regarding the expert.

When come to the second category or the contractor related causes of delay the first one is poor qualification of the contractor's technical staff the expert said that technical staff evaluation has to be the technical staff first and if shortage of contractor's material on site is one of cause of delay so have prepared material delivery schedule and also the consultant have to follow.as the expert say that the contractor has to prepare the checklist and follow by the consultant in order minimize the delay because of faults during construction stage. The expert believes that inadequate contractor experience is the basic cause of delay so the solution, for this reason, has to select the experienced contractor and also has to have proper financial management in order to solve the difficulties in financing the construction project by the contractor. If inadequate planning and scheduling of work by contractor cause for a delay to protect this contractor should

have to prepare the realistic schedule and the consultant have to check every step. Should have to have a clear agreement for conflicts with sub-contractors in order to decrease the effect of a delay from the expert view. If there is poor project manager skill then can upgrade by training and also proper quality assurance has to develop to minimizing the delay because of rework due to error during construction.

The third category is the consultant related delay factors and from this category, the first one cause is a delay in inspection and testing by the consultant for this cause the expert suggest that they have to prepare the program and they have to have adequate staff for decrease the absence of consultant's site staff. The other cause from this category was error and discrepancies in the design document and the expert respond as they have to complete the design document. For poor contract management, they have to develop the capacity of the staff and document in order to minimize it delay effect on the project as the expert said. The expert says they have to prepare the timeline to reduce the delay regarding in design documents preparation by the consultant. For the delay which comes from inaccurate site investigation then the expert put as the solution that they should have appropriate site investigation before. The last cause of delay from this category was if improper contract packaging/delivery strategies then the expert say that they have to select a project delivery system has to be selected. The other causes which are the same as the contractor have similar solutions which are listed above in the contractor category.

The other category is on contractual issues and from this category, the first cause was lack of communication then the expert suggests that they have to prepare the communication protocol. And the other one is the expert stand is termination has to be the last resolution because it affects a lot for the project so contract termination can not only the cause of delay but also affects the project but it is the benefit for some construction parties so it's better to put as the last option.

Community-related causes are related each other and the expert give the response as in the community they can have two types of people those are the first one are totally didn't accept the project and the second people are accepting the project and take the compensation but after they don't want to live the place go to the problem of right of way so the only solution that the expert suggest that to work cooperatively with the community and the leaders of that place.

In the material related causes, the expert said that they have to check based on the specification before for materials having poor quality because definitely they can be the cause of delay and for the imported delay they have to order before in order to minimize the problem of during import

process. If there is material shortage the expert said that they should have to detail study on the materials and discuss with agents and the second solution will try to substitute with local material. For the lack of technological advancement for this cause, the expert suggests that they have to give training for the staff to upgrade their knowledge.

The other category is labor and equipment related and the first cause was unskilled site manpower so training will be the solution recommended by the expert. The other cause from this category is improper equipment selection and faulty equipment then they have to warrant for equipment and the last cause from this category was the Labour dispute for this cause they have to have appropriate Labour management based on the expert respond.

The last category is external issues which are the first one is climatic /weather condition for this cause the expert suggest that proper scheduling and risk-minimizing schemes. The other cause from this category was a change of leadership then the expert says that have to establish the system and follow based on the system whenever the leadership is changed can not the problem for delay. The last cause of delay was the interference by political leaders for this problem they have too strengthen their relationship and work with them starting from the beginning.

d. Expert four

Stakeholder	Expert category	Expert experience	Experience in water project
Consultant	Project manager	+28 year	4 year

The interviews started by define delay and he/she says that delay means didn't achieve the targeted date. And when come to the main question or to the establishment of rule the first category is client-related causes of a delay from this category the first cause is change order by the owner during construction the expert solution will be at the first instance they have to clearly define their scope and after if the change is necessary then perform based on the contract administration. And also the expert said that they have to define the responsibility and define the rule in order to decrease the interference with project performance. The other cause of delay was delay or non-payment for completed works as an expert said the only solution for this cause is paying on time. From this category the other cause was an incorrect choice of consultant and contractors then the expert suggests that they have to follow the prequalification not first on the financial. The opinion of the expert on the experience of the owner is if she/he can read and

follow the contract that is enough and cannot be the cause for delay. The other cause of delay was poor communication and coordination of the owner with other parties then the expert solution will be they have to care on the written communication as he said. For insufficient funding, the expert suggests that during the contract the cash flow program preparation have to give great attention. The last cause of delay from this category was unrealistic contract duration and requirement imposed for this cause every constraint like material have to include in the duration from the beginning.

The second category is contractor related causes of a delay from this category poor qualification of the contractor's technical staff was the first one and the expert suggests that they have to have qualified staff and give training for upgrading their skill. If there is a shortage of contractor's material on site this can be solved by planning on the selection of material before the work started as the expert said. For the error during construction stage then solution given by the expert is they have to establish the quality control system and check the quality based on the system. If inadequate contractor experience for this cause the expert suggestion was to select the experienced contractor. If there are difficulties in financing the construction project by the contractor then the expert suggests that they have to have adequate capacity of financing and proper advancing payment management. The other of a delay from this category was inadequate planning and scheduling of works by the contractor then the solution that is given from the expert is that they should have to prepare work breakdown structure for each work. If there is a conflict with sub-contractors then they have to select the nominated subcontractors or select the subcontractors which are known before regarding the expert respond. If the contractor has poor project management skills the expert respond was giving training like human resource and leadership training. The last cause of delay from this category was rework due to error during construction then the expert suggests that they have to have quality assurance system or process follow up system starting from the design up to the end of the work.

The other category was consultant related causes of a delay from this the first one delay in inspection and testing by the consultant and the expert suggests that list out the time of inspection and testing regarding their provided list. If there is a lack of consultant's site staff the expert suggests that they have to have adequate qualification staff this can be by training, provide adequate material and software. If there are error and discrepancies in the design document then the expert said that they have to correct the design and review the design from a different point

of view. If there is inaccurate site investigation then they should have to prepare the comprehensive planning and work with that plan properly regarding the expert. The last one is if there is improper contract packaging/ delivery strategy then the expert suggests that experience is important in here and knowing the delivery strategy properly. The other cause which is similar with contractor and client are left because they have a similar solution.

On the contractual issues, if the wrong organizational structure is the cause of delay then the expert suggest that duties and rules on the contractual document and follow the contract. The other category of delay is community-related and from this category right of way is the critical one and for this cause of delay, the expert suggestion was they have to create community awareness and best planning.

The other category of delay cause is material related causes which are an imported delay is the first one for this problem proper planning will be the solution as the expert said and the second cause of delay is the poor quality of material and the expert suggest that they have to establish proper quality assurance system. The third cause is a material shortage and for this reason, they have to do design review on the material as the expert said and the last one is lack of technological advancement then the expert said they have to improve the ability of bid during contract and time assessment using modern technologies.

Labor and equipment related causes are the other categories and from this category unskilled site manpor is the first cause of delay and for this problem, the expert suggests that they have to select skilled manpower and the also give them training. The other cause is improper equipment selection and faulty equipment then the solution which is given from the expert is that methodology stipulation has to give great attention and the last one is labor disputes and the expert said that they have to list out the right and duty of the labor.

The last category is external issues and from this climatic/weather condition is among this cause of delay from this category and for this cause of delay the expert suggest that they have to have the best scheduling regarding the weather condition and the other cause of delay from this category is change of leadership and the solution will be they have to have staff retention regarding the expert respond. The last but not the list cause of delay from this category is interference by political leaders and the expert suggests that establish stakeholder management. Finally, the expert forwards their idea that if they give time on planning then the delay can be solved.

e. Expert five

Stakeholder	Expert category	Expert experience	Experience in water project
Consultant	claim expert	20 year	2 year

The expert defines delay as going beyond the schedule which is written in the voluntary agreement or the contract administration. When come to the main question started from the client related delay causes among this category change order by owner during construction is the first and this cause of delay the expert respond was that they have prepared detail design in-depth in order to avoid but if the change is very necessary the client has to give extension of time from the schedule unless otherwise not accept the change order. The other cause of delay is interference with project performance they have to contract provision which has the responsible list of each part and the interference condition out of this provision any kind of interference is not allowed and can't be accepted. In order to minimize the delay which comes from delay or non-payment for completed works, the client should have to pay on time as an expert said. For the incorrect choice of consultant and contractors in this cause the expert suggests that they have to proper planning and selection method. The other cause from this category is lack of experience of owner the experts believe that this can't be the cause but if it is necessary they can give training. If there are poor communication and coordination of the owner with other parties then the expert suggests that they have to prepare project coordination assembly for the parties communicate regarding. The other cause of delay from this category is insufficient funding for this cause the expert point of view is they have to have proper budgeting system. The last cause of delay from this category is unrealistic contract duration and requirement imposed, for this cause of delay the expert suggest that they have to prepare time table based on the volume of work and done accordingly.

The second category is contractor related causes of delay among this the first one is the poor qualification of the contractor's technical staff then the expert solution will be they have given training like human resource development. The other cause of delay is shortage of contractors' material on-site in order to avoid this cause they have to provide or arrange sufficient finance as the expert said. The expert suggests that they have to have the proper quality assurance to protecting the mistakes during the construction stage because it becomes the cause for the delay.

Inadequate contractor's experience is the more critical cause of delay as an expert said and the solution is giving training and upgrade his/her knowledge. Difficulties in financing the construction project by the contractor is another cause of delay and its solution operates with financing companies and asks loan or advanced payment as regarding the expert responds. For inadequate planning and scheduling of work by the contractor, the expert suggests that they have to give training to the staff to improve the schedule and planning capacity. They have to be series in selection of subcontractors in order to minimize the conflicts with subcontractors based on the expert respond. For poor project management skills the expert said that giving training. The last cause from this category is reworking due to error during construction and for this cause the solution regarding the expert is establishment of quality assurance system can reduce the rework occurrence.

The third category is consultant related cause of delay, among this poor communication and coordination of the consultant with other parties is the first one for this cause the expert suggests that they have to assign qualified team leader which can coordinate the communication issues. The other one is a delay in inspection and testing by the consultant for this problem the expert recommends establishing quality assurance protocol and they have to have to deploy an adequate number of professionals in staff to minimize the deficiency of consultant's site staff. The other cause is error and discrepancies in design documents then the expert gives the solution to deploy qualified professionals. Quality assurance can solve for the cause which comes from poor contract management as expert said. If there is delay in design documents preparation by consultant the expert advises that to comply with TOR requirements. They have to deploy qualified professionals in order to have accurate site investigation and also minimize delay as expert said. The cause of delay from this category is improper contract packaging/delivery strategy, for this cause the expert response is to pre-planning with the client and selects the appropriate one.

The other category is contractual issues from this the expert address the lack of communication and gives the solution to complain about the contractual time frame. The other group is community-related factors which include lack of project acceptance and for this problem the expert recommendations that they have to discuss with the community in the planning stage and the other one is delay on compensation and for this cause the expert suggest that they have to have sufficient financing and they have to quantify and pay on time because it can be related

with right of way also. The last cause is awareness on the delay, for this cause the expert said they have to give the implication of the delay related with their day to day life. The other classification is material related causes from this the first basic cause of delay is imported delay the expert advice that they have to have advanced planning and also have to comply with a contractor to solve the quality of material. The other issue which related to material is shortage of material for this cause they have to provide sufficient budget for material procurement and best planning. As the expert said that foreign currency increment is the large problem in our construction industry and the solution that is recommended by the expert is forecasting the risk then includes in the price. The last cause of delay from this category is a lack of technological advancement.

When comes to the labor and equipment related cause of delay among that unskilled manpower is the first one and for this problem the expert suggestions to improve the skill they have to give training. And the other cause is improper selection and faulty equipment and this regarding the planning capacity of the contractor as the expert said. And the last one is labor disputes for this problem the expert recommends that they have to provide proper contract arrangement.

The last category of cause of delay are external issues are like climatic/weather condition for this kind of problem the expert suggest to provide proper planning regarding the weather condition of the country. If there is a change of leadership the expert stand is whatever change happens if you maintain Constraint Company pro it can't be the cause of delay at all. The last cause of delay is interference by political leaders then the solution which is provided by the expert includes them in the planning stage but otherwise avoid a direct relationship with them.

f. Expert six

Stakeholder	Expert category	Expert experience	Experience in water project
Consultant	Construction manager	+34 year	Only in arbitration

Expert six is the last expert and defines delay from two perspectives the first one is regarding the employer which is beyond completion of time and it can be justified delay and unjustified delay and the second one is from the contractor point of view which is beyond completion + EOT and it is unjustified.

4.4. Rules(knowledge representation)

Those rules were formulated by investigating the causes of delay parallel with the solution in the form of if.....then analysis or in the form of rule based expert system. The rules indicate that if the causes of delay listed happen then the solution will be recommended in the then parts. Those rules were checked by experts after formulated the if...then format.

RULE001

If

1. change order by owner during construction

Then

- 1) proper need assessment, design phase properly managed, qualified designer
- 2) conduct through(finish) investigation and design to reduce change order in the first place
- 3) complete the design first
- 4) asses the change regarding the contract
- 5) detail design or give extension time
- 6) delay if necessary only refused if it affect the critical activity

ANTECEDENT YES antecedent

RULE002

If

2. Interference with project performance

Then

- 1) follow the contract
- 2) recommend not to interfere
- 3) define the responsibility and the rule
- 4) responsibility list and contract provision
- 5) only contractual interference shall be undertaken

ANTECEDENT YES antecedent

RULE003

If

3. delay on non-payment for completed works

Then

- 1) better financial planning(block payment) preparation
- 2) contract's stipulate provide for interest + financing
- 3) pay on time based on provision
- 4) becarefull during negotiation during expiry of limit for default due to delay /non payment

ANTECEDENT YES antecedent

RULE004

If

4. Incorrect choice of Consultants & contractors

Then

- 1) focus on quality during qualification ,past history
- 2) follow the right selection method
- 3) prequalification(weighted given) not first on the financial
- 4) proper planning selection method
- 5) adhere to adapted world practices selection method

ANTECEDENT YES antecedent

RULE005

If

5. Lack of experience of owner

Then

- 1) employ qualified owner/adviser representative
- 2) higher a project construction management consultant
- 3) provide construction management consultant
- 4) reading/knowing the contract
- 5) training
- 6) use experienced representative professional consultant

ANTECEDENT YES antecedent

RULE006

If

6. Poor communication & coordination of the owner with other parties

Then

- 1) qualified communication management representative
- 2) prepare communication protocol
- 3) be careful in the written communication
- 4) project coordination time group
- 5) identify, plan, monitoring and be project focus

ANTECEDENT YES antecedent

RULE007

If

7. Insufficient funding

Then

- 1) allocation of funding
- 2) conform fund before contracting
- 3) didn't start the project, look for other funding sources
- 4) cash flow program preparation during contract
- 5) proper budgeting system
- 6) payment guaranty

ANTECEDENT YES antecedent

RULE008

If

8. Unrealistic contract duration and requirements imposed

Then

- 1) following best practice such as empirical equation develop using past practical
- 2) determine contract duration through critical planning schedule
- 3) the contract document have to be clear
- 4) include the duration with other constraints like material
- 5) proper time table(volume work)

ANTECEDENT YES antecedent

RULE009

If

9. poor qualification of the contractor's technical staff

Then

- 1) training /capacity building and partnering with other company
- 2) improve selection critical
- 3) technical evaluation has to be the technical staff first
- 4) qualified staff and training
- 5) training, human resource development
- 6) selection criteria, monitoring and replace equivalence

ANTECEDENT YES antecedent

RULE0010

If

10. Shortage of contractors' materials on site

Then

- 1) proper material management(inventory management)
- 2) stock critical material on site
- 3) schedule for material delivery and the consultant have to follow up
- 4) planning on material and selection
- 5) provide(arrange)sufficient finance
- 6) resourced buffer and look I head plan

ANTECEDENT YES antecedent

RULE0011

If

11. Faults during construction stage

Then

- 1) constriction review(value)
- 2) prepare the check list and the consultant follow up
- 3) quality control system
- 4) proper quality assurance

ANTECEDENT YES antecedent

RULE0012

If

12. Inadequate contractor experience

Then

- 1) partnering(joint venter)
- 2) improve selection critical
- 3) select the experienced contractor
- 4) training
- 5) appropriate profession

ANTECEDENT YES antecedent

RULE0013

If

13. Difficulties in financing the construction project by the contractor

Then

- 1) increasing the source and improving the financing system
- 2) manage finance properly
- 3) proper financial management
- 4) adequate capacity of financing and proper advancing payment management
- 5) operate with financing company and loan and advance payment management

ANTECEDENT YES antecedent

RULE0014

If

14. Inadequate planning and scheduling of work by contractor

Then

- 1) create project scheduling and control , assign qualified contractor , training ,allowable financial capacity
- 2) monitor/review problem ,planning and scheduling
- 3) realistic scheduling and the consultant have to check
- 4) work break down structured
- 5) training of staff

ANTECEDENT YES antecedent

RULE0015

If

15. Conflicts with sub-contractors

Then

- 1) proper selection of subcontract and better administration of sub-contractor
- 2) clear agreement
- 3) selected(nominated)subcontractor
- 4) proper selection of subcontractor

ANTECEDENT YES antecedent

RULE0016

If

16. Poor project manager skills

Then

- 1) training (capacity building)
- 2) upgrading by training
- 3) training (human resource, leadership)

ANTECEDENT YES antecedent

RULE0017

If

17. Rework due to error during construction

Then

- 1) improve design and qualified Forman
- 2) proper quality assurance
- 3) Quality assurance system and follow up starting from design
- 4) quality assurance establishment

ANTECEDENT YES antecedent

RULE0018

If

18. Poor communication and coordination of the consultant with other

parties

Then

- 1) communication planning and management
- 2) communication protocol
- 3) the same with contractor
- 4) appoint qualified team leader

ANTECEDENT YES antecedent

RULE0019

If

19. Delay in inspection and testing by the consultant

Then

- 1) better staffing and proper notification from contractor
- 2) prepared the program
- 3) list out the time of inspection and testing
- 4) establish quality assurance program

ANTECEDENT YES antecedent

RULE0020

If

20. Lack of consultant's site staff

Then

- 1) better stuffing , multi skill (inspectors)and assign(human resource allocation)
- 2) adequate staff
- 3) adequate qualification staff, training, material and software
- 4) adequate number of staff

ANTECEDENT YES antecedent

RULE0021

If

21. Inadequate experience of consultant

Then

- 1) partnering(joint venter)

- 2) technical evaluation
- 3) experienced consultant
- 4) training

ANTECEDENT YES antecedent

RULE0022

If

22. Errors and discrepancies in design documents

Then

- 1) improve capacity of design , provide adult
- 2) compline design document
- 3) correct the design and review
- 4) deploy qualified

ANTECEDENT YES antecedent

RULE0023

If

23. Poor contract management

Then

- 1) Training
- 2) develop the capacity staff and document
- 3) experience/ skill capacity or training
- 4) quality assurance

ANTECEDENT YES antecedent

RULE0024

If

24. Delay in design documents preparation by consultant

Then

- 1) better staffing (planning) and standardize
- 2) prepare the time line
- 3) same with contractor
- 4) comply to TOR requirement

ANTECEDENT YES antecedent

RULE0025

If

25. Inaccurate site investigation

Then

- 1) indirect solution(technical)
- 2) appropriate site investigation before
- 3) compensate planning
- 4) deploy qualified professional

ANTECEDENT YES antecedent

RULE0026

If

26. Improper contract packaging/delivery strategy

Then

- 1) working collaboration with the client
- 2) project delivery system has to be selected
- 3) experience and knowing the delivery strategy properly
- 4) pre-planning with client

ANTECEDENT YES antecedent

RULE0027

If

27. Lack of communication

Then

- 1) better communication management
- 2) communication protocol
- 3) comply with contractual time frame

ANTECEDENT YES antecedent

RULE0028

If

28. Wrong organizational structure

Then

- 1) strategically management(SWOT analysis)

2) duties list and rules on the contractual

ANTECEDENT YES antecedent

RULE0029

If

29. contract termination will use time

Then

1) better performance management

2) termination have to be the last resolution

ANTECEDENT YES antecedent

RULE0030

If

30. Lack of project acceptance

Then

1) stakeholder engagement

2) community discussion at planning stage

ANTECEDENT YES antecedent

RULE0031

If

31. Delay on compensation

Then

1) better financial planning

2) sufficient finance

ANTECEDENT YES antecedent

RULE0032

If

32. Right of way

Then

1) integrated project plan

2) community awareness

3) timely qualify and timely payment

ANTECEDENT YES antecedent

RULE0033

If

33. awareness on the delay

Then

- 1) stakeholder engagement
- 2) implication

ANTECEDENT YES antecedent

RULE0034

If

34. Import delay

Then

- 1) imported special privilege for water project
- 2) proper planning
- 3) advance planning

ANTECEDENT YES antecedent

RULE0035

If

35. Poor quality of material

Then

- 1) testing, quality control and audit
- 2) check
- 3) quality assurance system
- 4) comply with contract

ANTECEDENT YES antecedent

RULE0036

If

36. Material Shortage

Then

- 1) better inventory and material management
- 2) design review on the material
- 3) sufficient budget for material procurement

ANTECEDENT YES antecedent

RULE0037

If

37. foreign currency increment

Then

- 1) reducing the exposer , import substitution
- 2) include in contract document
- 3) available
- 4) forecast the risk and include first

ANTECEDENT YES antecedent

RULE0038

If

38. lack of technological advancement

Then

- 1) training , capacity building and benchmarking
- 2) training
- 3) bid ability during the contract time assessment
- 4) well train staff and qualified professional

ANTECEDENT YES antecedent

RULE0039

If

39. Unskilled site manpower

Then

- 1) training , integration with school graduates
- 2) training
- 3) training, skilled manpower

ANTECEDENT YES antecedent

RULE0040

If

40. Improper equipment selection & Faulty equipment

Then

- 1) training , qualified consultant
- 2) warranty/guaranty
- 3) methodology stipulation
- 4) develop the capacity of the contractor

ANTECEDENT YES antecedent

RULE0041

If

41. Labour disputes

Then

- 1) awareness creation ,duties and responsibility
- 2) appropriate Labour management
- 3) list out the right and duty
- 4) provide proper contract arrangement

ANTECEDENT YES antecedent

RULE0042

If

42. climatic/weather condition

Then

- 1) better activity planning
- 2) proper scheduling and risk minimizing schemes
- 3) best scheduling regarding the weather
- 4) provide proper planning

ANTECEDENT YES antecedent

RULE0043

If

43. Change of leadership

Then

- 1) better communication and planning
- 2) establish system
- 3) staff retention
- 4) maintain constraint company procedure

ANTECEDENT YES antecedent

RULE0044

If

44. Interference by political leaders

Then

- 1) awareness creation , stockholder engagement
- 2) relationship development
- 3) stakeholder management
- 4) avoid direct relationship with them but include in planning stage

ANTECEDENT YES antecedent

The formulated rule based expert system or the rules are checked by selected experts to validate the rules and to consider as a rule the experts role have great role. In the antecedent process could analyses that the experts have different stand on the solution the experts select their best solution among the listed delay solution. This was including in appendix.

4.5. Summary

From the research findings it is understood that, for every causes of delay that arises in a construction project could get a solution from the experts experience and could minimized the delay of the construction works specially the water sector with WASH projects indeed.

These rules were formulated stepwise. The first step was identifying the causes of delay from different documents and also from the workshop participants in order to address a numerous

causes of delay and additional with this from the 15 small town projects of WASH add some causes by conducting focus group meeting finally found total 41 causes of delay with main eight group namely Client related, Contractor related, Labor and equipment related, Material related, Consultant related, Community Related, Contractual issues and External issues. The next step was searching the solution of each and every listed causes of delay by conducting the structural interview for the purposively selected experts by their working experience and academic level from those experts can found the solution and then can formulate the if....then or the rule based system by consider the causes as of delay as if clause and the solution as the then clause.

In order to consider the formulated if....then arrangement as a rule the selected experts checked the clause and finally consider as a rule that recommended by this study for the construction sector.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

The research rule based expert system for WASH projects delay management is done based on the problems that are practical observed on the water sector in Ethiopia. It is more of emphasized on the delay that seems as usual practice in the sector especially in the WASH projects.

For the problems identified in the research problem statement three objectives and research questions were formulated. Then after, the methodology is designed to achieve objectives and to answer research questions. The developed to answer research questions so before applying the rule based system on the water sector start to answer the first research question by document review used and whereas objective was answered using simple narrative method .

Rule based system which is developed in this thesis is based on both expert knowledge and a typical case of 15 town's water project data. A rule base developed from knowledge of highly qualified and more experienced construction experts will be used by any construction professionals with more or less qualification and experience in water construction and other sectors.

To formulate the rule based expert system the basic foundation was the causes of delay so, to found these causes different documents where review additionally from the workshop

participants. Second basic knowledge which enters to the system was the solution for the listed causes of delays. To become with the solution conduct the interview and found the solution and ready to formulate the expert system. Finally the result of this study has presented 44 causes of delay and there corresponding solution and the practical causes of delay in 15 town small projects are selected and find out there solution from the experts respond.

From this, system can recognize that the experts knowledge can be put in the system even if the experts passed away and can transfer this knowledge to the next generation and fill the knowledge gap among them not only about the delay but also other things.

5.2.Recommendations

In this study, analysis and discussions have been carried out to develop rule based expert system for delay management in WASH projects. As seen from the evaluation the study achieves its main objectives by proving the applicability of the rule based system for delay management. Based on the findings of the study the following recommendations are suggested for the applicability of rule based system in the domain area. It is clearly identified the causes of delay and its corresponding solution by rule based expert system. Some recommendations were forwarded as below:

- Rule based expert system is found better in delay management in water related constructions. Therefore, it is recommended to use rule based expert system to reduce delay in construction projects.
- The government or private water projects should use Rule based expert system as a mitigation strategies and solutions for delay management.
- Further detail studies are recommended for the rule based expert system to get comprehensive result by other softwares rather than excel.

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Appendix

Appendix 1 Structured Interview Question

Dear Madam and Sir,

Thank you for giving me your precious time for this interview. The purpose of the interview is to collect data for the research work entitled Rule Based Expert System for WASH Projects Delay Management: A Case of an Ethiopian Selected Small-Town Water Supply Construction Project. This MSc thesis aims to assess basically to develop the delay management practice in the 15 small town water and sanitation projects by using the rule based expert from expert's response outlook. In this study the researcher wants to establish the if.....then analysis and provide the if or the Conditions on the table and you are going to fill the then or the actions side by side. The system is worked regarding the experts respond on their past experience this should not happen for the next time in other project so, you are one of experts and your returns are very valuable on my research product.

A. General Information about expert profile

1. Expert Name:(expert company name)

2. Which organization do you represent (stockholder)?

Owner Contractor Consultant

Others _____

3. Expert Category

a. Construction manager e. Claim expert

b. Project manager f. Procurement officer

c. Design professional g. Construction Lawyer

d. Arbitrator h. Professor / Academician

4. Expert Experience

5. Do you have an experience in water project?

6. What is delay?

7. _____

B. Main Interview Questions

Rules for delay management	
1. Client related	
If [Change orders by owner during construction]=	Then []
If [Interference with project performance]	Then []
If [Delay or non-payment for	Then

Completed works]	[]
If [Incorrect choice of Consultants & contractors]	Then []
If [Lack of experience of owner]	Then []
If [Poor communication & coordination of the owner with other parties]	Then []
If [Insufficient funding]	Then []
If [Unrealistic contract duration and requirements imposed]	Then []
2. Contractor related	
If [Poor qualification of the contractor's technical staff]	Then []
If [Shortage of contractors' materials on site]	Then []
If [Faults during construction stage]	Then []
If [Inadequate contractor experience]	Then []
If [Difficulties in financing the construction project by the contractor]	Then []
If [Inadequate planning and scheduling of work by contractor]	Then []
If [Conflicts with sub-contractors]	Then []

If [Poor project manager skills]	Then []
If [Rework due to error during construction]	Then []
3. Consultant related	
If [Poor communication and coordination of the consultant with other parties]	Then []
If [Delay in inspection and testing by the consultant]	Then []
If [Lack of consultant's site staff]	Then []
If [Inadequate experience of consultant]	Then []
If [Errors and discrepancies in design documents]	Then []
If [Poor contract management]	Then []
If [Delay in design documents preparation by consultant]	Then []
If [Inaccurate site investigation]	Then []
If [Improper contract packaging/delivery strategy]	Then []
4. Contractual issues	
If [Lack of communication]	Then []
If [Wrong organizational structure]	Then []

If [contract termination will use time]	Then []
5. Community Related	
If [Lack of project acceptance]	Then []
If [Delay on compensation]	Then []
If [Right of way]	Then []
If [awareness on the delay]	Then []
6. Material related	
If [Import delay]	Then []
If [Poor quality of material]	Then []
If [Material Shortage]	Then []
If [foreign currency increment]	Then []
If [lack of technological advancement]	Then []
7. Labor and equipment related	
If [Unskilled site manpower]	Then []
If [Improper equipment selection & Faulty equipment]	Then []
If [Labour disputes]	Then

	[]
8. External issues	
[climatic/weather condition]	Then []
If [Change of leadership]	Then []
If [Interference by political leaders]	Then []

Thank you very much for your time and response

Appendix 2. Journal Manuscript

Rule-Based Expert System for Wash Project Delay Management: A Case of Small-Town Water Supply Construction Projects in Ethiopia

By: Eden Halefom, Dr. Tilahun Derib,
Tesfaye Hailu (Ph.D. Candidate), Dr.
Binaya Patnaik

Abstract

In developing countries like Ethiopia, satisfying the access of water supply, sanitation and hygiene to the community is a huge challenge. These challenges are opposed in different sectors include governmental and non-governmental organizations. Even with all these efforts, access to water supply and sanitation ratio in sub-Saharan Africa is still at its lower rate in the world. Access to water

supply and sanitation in Ethiopia is between the lowest in Sub-Saharan Africa and the entire world. The major challenge for water supply and hygiene in Ethiopia is to maintain a year-round supply that is adequate to meet people's needs on time because of delay. The drive of this research is therefore to develop rule-based expert system for WASH projects for better delay management in the case of small-town water supply construction projects in Ethiopia. To achieve the expectations of this system, the methodologies followed in this system are knowledge acquisition using structural Interview and workshop is used as one of primary knowledge source which can gather the needed knowledge from knowledge experts such as first identified the list of causes and effect from the different documents and also validates through workshop with the group of construction management masters students of Addis Ababa and also finds the delay causes and effects of 15 small-town water supply and sanitation project from their technical audit report arranging in the rule-based form or if...then form and next conduct structured interview with purposively selected experts and come with list of solution for causes of delay and finally formulate the rule-based expert system. After the development of

knowledge-based system verification and validation tests are conducted. The study certainly answered not only the problem of the water sector but also the other construction sectors delay problems because can identify the cause and solution of the delay regarding the experts view and experience.

Key words: Delay management, Rule based expert system, WASH project

Introduction

Water is one of the necessities of human being and the attainment of clean water and sanitation is declared as a human right by United Nations in 2010 (UN, the human right to water and sanitation, 2013). The 1995 Federal Democratic Republic of Ethiopia's constitution in the article 44 stated that environmental right which said persons have the right to a clean and healthy environment and Article 90 also said that to the extent the country's resources permit, policies shall aim to provide all Ethiopians access to public health and education, clean water, housing, food, and social security (Constitution of Federal Democratic Republic of Ethiopia, 1995).Ethiopian government outlined driven vision for joining middle income countries in 2025 by designing strategies and programs among them water sector development strategy,

GTP-1 and GTP-2, WASH implementation frame work and WASH national programs are include as a main one. The planned includes achieving 100% water supply access coverage as prGTP-1 service level standard and Achieve 83 % (85% for rural and 75% for urban) water supply access coverage as per GTP-2 service level standard and Provide water supply access over all to 37 million people (29.3 million for rural and 7.7 million for urban) (Habtamu, 2018).

In 2000 the United Nations launches 8-millennium development goals (MDG) goals for a better world among those goals the seventh goal is about ensure environmental sustainability in this goal there are sub-targets our concern is target 7C which said by 2015, the proportion of the population without sustainable access to safe drinking water and basic improved water source, urban and rural the second one is Proportion of urban population with access to improved sanitation (UN, 2008).

WASH program is the one which is working on water, sanitation, and hygiene and investing this program means investing in all MDG. Due to their interdependent nature, these three essential issues are grouped together to represent a growing sector. In Netherland Dutch water sectors signs

WASH agreement in 2007 and, its goal was clean water and safe sanitation facility for 50 million people and its approach was public and private working together for the first time. The fact is that without safe water cannot have food, as a result, there is no health and education so, if there is no education cannot think about economic activity (Netherlands WASH SDG, 2017).

According to the government in 2017, 65 % of the population had access to safe water; however, according to the World Health Organization (WHO) and local nongovernmental organizations, the figure was closer to 35 %. The WHO estimated that only 13 % of the population had access to sanitation. Ethiopia fulfilled the target of the Millennium Development Goals (MDGs) for improved water and sanitation access which re 70% and 56 % respectively (Netherlands WASH SDG, 2017).

The construction project is becoming increasingly difficult as it involves delay and uncertainty requires different type of professional skills limitation to develop a well thought out plan at various phases (Chitakara, 1998). Several studies pointed that most of construction project suffer delays and it is possible to reduce delay through recognition of their real cause (Ashraf and Ghanim , 2016). In Ethiopia

only 8.25% projects have been finished to original target completion date but the remaining 91.75% delayed from its contractual time. (Worku & Jah, 2016)

Artificial Intelligence (AI) is one of the up-to-date sciences which mechanized or duplicate the human thought process. An intelligent program is one that exhibits behaviour similar to that of a human when challenged with a similar problem (Frank, 2007).

A rule-based system is software that uses artificial intelligence or expert system techniques in problem-solving processes. It incorporates a store of expert knowledge with couplings and linkages designed to facilitate its retrieval in response to specific queries or to transfer expertise from one domain of knowledge to another (Darai, 2010). Knowledge is represented in the form of rules or other representation techniques and stored in a knowledge base. Testing the knowledge base for validation can be done comparing performance of human experts with system (Calkins, 2000).

Development of an intelligent system by itself is a challenge in terms of knowledge acquisition, knowledge representation, and knowledge inference because there are differences between one individual to other. Expert may be able to communicate the

knowledge needed to knowledge engineer. Knowledge engineer may not be able to structure knowledge for entries into knowledge base are some of challenge during knowledge acquisition process. The size of knowledge base are dealing with is also one challenge in managing knowledge base since representing that knowledge in a computer-readable format is also a challenge. The need of constantly updating knowledge base system because of frequent changes in the real world is also a challenge in the area (Sharma, 2010).

Method

Qualitative research method was employed in this study. The qualitative concerned with the understanding of peoples attitude in terms of the study provided of context in which they express their reaction. It takes into account different viewpoints and practices in the field because of the different subjective perspectives and social backgrounds related to them.

The research design of this study was narrative in which data was collected from respondents with structural interview and workshop from domain experts. Major cause of delay identified and also their proper solution was defined from their experience of individuals.

Results & discussion

From the research findings it is understood that, for every causes of delay that arises in a construction project could get a solution from the experts experience and could minimized the delay of the construction works specially the water sector with WASH projects indeed.

These rules were formulated stepwise. The first step was identifying the causes of delay from different documents and also from the workshop participants in order to address a numerous causes of delay and additional with this from the 15 small town projects of WASH add some causes by conducting focus group meeting finally found total 41 causes of delay with main eight group namely Client related, Contractor related, Labor and equipment related, Material related, Consultant related, Community Related, Contractual issues and External issues. The next step was searching the solution of each and every listed causes of delay by conducting the structural interview for the purposively selected experts by their working experience and academic level from those experts can found the solution and then can formulate the if.....then or the rule based system by consider the causes as of delay as if clause and the solution as the then clause.

In order to consider the formulated if....then arrangement as a rule the selected experts checked the clause and finally consider as a rule that recommended by this study for the construction sector.

Causes of delay		
Client related		6. Consultant related
1.7. Insufficient funding		6.1.Inappropriate 6.2.design
1.8. Interference with project performance		6.3.Poor contract management
1.9. Delay or non-payment for completed works		6.5.Late identification & resolution of drawings & specification errors & omissions
1.12. Wrong choice 1.13. of consultants 1.14. & contractors		6.7.Late preparation of drawings and other contract documents

1.15. Slow decision making	6.8. Improper contract packaging/delivery strategy		2.1. Unskilled site manpower	8. Contractual issues
1.16. Design alterations & change orders	6.9. Over inspection		4.2. Improper equipment selection & Faulty equipment	7.2. Lack of communication
2. Contractor related	6.10. Long waiting time for testing		4.3. Labor disputes	8.2. Regular meetings
1.17. Poor coordination of subcontractors	6.11. Wrong coordination of information and data	5.	Material related	8.3. Wrong organizational structure
1.18. Inappropriate construction methods	7. Community Related		4.7. Poor quality of material	9. External issues
1.19. Inadequate planning	6.2. Lack of project acceptance		4.9. Material Shortage	8.5. Weather
1.20. Inadequate experience	6.4. Delay compensation	on	4.10. Import delay	8.6. Change of leadership
1.21. Incompetent site management	6.5. Right of way			8.7. Natural disaster
2. Labor and equipment related	7.4. Youth unrest			8.8. Interference by political Leaders

RULE001

If

45. change order by owner during construction

Then

- 7) proper need assessment, design phase properly managed, qualified designer
- 8) conduct through(finish) investigation and design to reduce change order in the first place
- 9) complete the design first
- 10) asses the change regarding the contract
- 11) detail design or give extension time
- 12) delay if necessary only refused if it affect the critical activity

ANTECEDENT YES

antecedent

RULE002

If

46. Interference with project performance

Then

- 6) follow the contract
- 7) recommend not to interfere
- 8) define the responsibility and the rule
- 9) responsibility list and contract provision

10) only contractual interference shall be undertaken

ANTECEDENT YES antecedent

RULE003

If

47. delay on non-payment for completed works

Then

- 5) better financial planning(block payment) preparation
- 6) contract's stipulate provide for interest + financing
- 7) pay on time based on provision
- 8) becarefull during negotiation during expiry of limit for default due to delay /non payment

ANTECEDENT YES antecedent

RULE004

If

48. Incorrect choice of Consultants & contractors

Then

- 6) focus on quality during qualification ,past history
- 7) follow the right selection method
- 8) prequalification(weighted given) not first on the financial
- 9) proper planning selection method
- 10) adhere to adapted world practices selection method

ANTECEDENT YES
antecedent

RULE005

If

49. Lack of experience of owner

Then

- 7) employ qualified owner/adviser representative
- 8) higher a project construction management consultant
- 9) provide construction management consultant
- 10) reading/knowing the contract
- 11) training
- 12) use experienced representative professional consultant

ANTECEDENT YES antecedent

RULE006

If

50. Poor communication & coordination of the owner with other parties

Then

- 6) qualified communication management representative
- 7) prepare communication protocol
- 8) be careful in the written communication
- 9) project coordination time group

10) identify, plan, monitoring and be project focus

ANTECEDENT YES

antecedent

RULE007

If

51. Insufficient funding

Then

- 7) allocation of funding
- 8) conform fund before contracting
- 9) didn't start the project, look for other funding sources
- 10) cash flow program preparation during contract
- 11) proper budgeting system
- 12) payment guaranty

ANTECEDENT YES

antecedent

RULE008

If

52. Unrealistic contract duration and requirements imposed

Then

- 6) following best practice such as empirical equation develop using past practical
- 7) determine contract duration thought critical planning schedule
- 8) the contract document have to be clear

9) include the duration with other constraints like material

10) proper time table(volume work)

ANTECEDENT YES

antecedent

RULE009

If

53. poor qualification of the contractor's technical staff

Then

7) training /capacity building and partnering with other company

8) improve selection critical

9) technical evaluation has to be the technical staff first

10) qualified staff and training

11) training, human resource development

12) selection criteria, monitoring and replace equivalence

ANTECEDENT YES

antecedent

RULE0010

If

54. Shortage of contractors' materials on site

Then

7) proper material management(inventory management)

8) stock critical material on site

9) schedule for material delivery and the consultant to follow up

10) planning on material and selection

11) provide(arrange)sufficient finance

12) resourced buffer and look I head plan

ANTECEDENT YES antecedent

RULE0011

If

55. Faults during construction stage

Then

5) constriction review(value)

6) prepare the check list and the consultant follow

7) quality control system

8) proper quality assurance

ANTECEDENT YES antecedent

RULE0012

If

56. Inadequate contractor experience

Then

6) partnering(joint venter)

7) improve selection critical

8) select the experienced contractor

9) training

10) appropriate profession

ANTECEDENT YES antecedent

RULE0013

If

57. Difficulties in financing the construction project by

Then

6) increasing the source and improving the financing s

7) manage finance properly

8) consultant to follow

9) adequate capacity of financing and proper a

management

10) operate with financing company and loan and advance payment management
ANTECEDENT YES antecedent
ANTECEDENT YES antecedent
RULE0014

If 61. Rework due to error during construction
Then 5) improve design and qualified Forman
6) create project scheduling and control , assign qualified quality assurance training ,allowable financial capacity 7) Quality assurance system and follow up starting from 8) quality assurance establishment
ANTECEDENT YES antecedent
RULE0018

10) training of staff
ANTECEDENT YES antecedent
RULE0015

If 59. Conflicts with sub-contractors
Then 5) communication planning and management
6) communication protocol
7) proper selection of subcontract and better administration of subcontractor
8) appoint qualified team leader
ANTECEDENT YES antecedent
RULE0019

8) proper selection of subcontractor
ANTECEDENT YES antecedent
RULE0016

If 60. Poor project manager skills
Then 5) better staffing and proper notification from contractor
6) prepared the program
7) list out the time of inspection and testing
8) establish quality assurance program
ANTECEDENT YES antecedent
RULE0020

4) training (capacity building)
5) upgrading by training
6) training (human resource, leadership)

<p>If</p> <p>64. Lack of consultant's site staff</p> <p>Then</p> <p>5) better staffing , multi skill (inspectors)and assign allocation)</p> <p>6) adequate staff</p> <p>7) adequate qualification staff, training, materials</p> <p>8) adequate number of staff</p> <p>ANTECEDENT YES antecedent</p> <p>RULE0021</p>	<p>5) develop the capacity staff and document</p> <p>6) experience/ skill capacity or training</p> <p>7) quality assurance</p> <p>ANTECEDENT YES antecedent</p> <p>RULE0024</p> <p>If</p> <p>68. Inadequate design documents preparation by consultant</p> <p>Then</p> <p>5) better staffing (planning) and standardize</p> <p>6) prepare the time line</p> <p>7) comply to TOR requirement</p> <p>ANTECEDENT YES antecedent</p> <p>RULE0025</p> <p>If</p> <p>69. Inaccurate site investigation</p> <p>Then</p> <p>5) indirect solution(technical)</p> <p>6) appropriate site investigation before</p> <p>7) compensate planning</p> <p>8) deploy qualified professional</p> <p>ANTECEDENT YES antecedent</p> <p>RULE0026</p> <p>If</p> <p>70. Improper contract packaging/delivery strategy</p> <p>Then</p> <p>5) working collaboration with the client</p> <p>6) project delivery system has to be selected</p> <p>7) experience and knowing the delivery strategy properly</p> <p>8) pre-planning with client</p> <p>ANTECEDENT YES antecedent</p> <p>RULE0027</p>
<p>If</p> <p>65. Inadequate experience of consultant</p> <p>Then</p> <p>5) partnering(joint venter)</p> <p>6) technical evaluation</p> <p>7) experienced consultant</p> <p>8) training</p> <p>ANTECEDENT YES antecedent</p> <p>RULE0022</p>	<p>66. Errors and discrepancies in design documents</p> <p>Then</p> <p>5) improve capacity of design , provide adult</p> <p>6) complete design document</p> <p>7) correct the design and review</p> <p>8) deploy qualified</p> <p>ANTECEDENT YES antecedent</p> <p>RULE0023</p>
<p>If</p> <p>67. Poor contract management</p> <p>Then</p>	<p>66. Errors and discrepancies in design documents</p> <p>Then</p> <p>5) improve capacity of design , provide adult</p> <p>6) complete design document</p> <p>7) correct the design and review</p> <p>8) deploy qualified</p> <p>ANTECEDENT YES antecedent</p> <p>RULE0023</p>

<p>If</p> <p>71. Lack of communication</p> <p>Then</p> <p>4) better communication management</p> <p>5) communication protocol</p> <p>6) comply with contractual time frame</p> <p>ANTECEDENT YES antecedent</p> <p>RULE0028</p> <p>If</p> <p>72. Wrong organizational structure</p> <p>Then</p> <p>3) strategically management(SWOT analysis)</p> <p>4) duties list and rules on the contractual</p> <p>ANTECEDENT YES antecedent</p> <p>RULE0029</p> <p>If</p> <p>73. contract termination will use time</p> <p>Then</p> <p>3) better performance management</p> <p>4) termination have to be the last resolution</p> <p>ANTECEDENT YES antecedent</p> <p>RULE0030</p> <p>If</p> <p>74. Lack of project acceptance</p> <p>Then</p> <p>3) stakeholder engagement</p> <p>4) community discussion at planning stage</p> <p>ANTECEDENT YES antecedent</p> <p>RULE0031</p> <p>If</p> <p>75. Delay on compensation</p>	<p>Then</p> <p>3) better financial planning</p> <p>4) sufficient finance</p> <p>ANTECEDENT YES antecedent</p> <p>RULE0032</p> <p>If</p> <p>76. Right of way</p> <p>Then</p> <p>4) integrated project plan</p> <p>5) community awareness</p> <p>6) timely qualify and timely payment</p> <p>ANTECEDENT YES antecedent</p> <p>RULE0033</p> <p>If</p> <p>77. awareness on the delay</p> <p>Then</p> <p>3) stakeholder engagement</p> <p>4) implication</p> <p>ANTECEDENT YES antecedent</p> <p>RULE0034</p> <p>If</p> <p>78. Import delay</p> <p>Then</p> <p>4) imported special privilege for water project</p> <p>5) proper planning</p> <p>6) advance planning</p> <p>ANTECEDENT YES antecedent</p> <p>RULE0035</p> <p>If</p> <p>79. Poor quality of material</p> <p>Then</p>
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5) testing, quality control and audit		RULE0039
6) check	If	
7) quality assurance system		83. Unskilled site manpower
8) comply with contract	Then	
ANTECEDENT YES antecedent		4) training , integration with school graduates
RULE0036		5) training
If		6) training, skilled manpower
80. Material Shortage		ANTECEDENT YES antecedent
Then		RULE0040
4) better inventory and material management	If	
5) design review on the material		84. Improper equipment selection & Faulty equipment
6) sufficient budget for material procurement	Then	
ANTECEDENT YES antecedent		5) training , qualified consultant
RULE0037		6) warranty/guaranty
If		7) methodology stipulation
81. foreign currency increment		8) develop the capacity of the contractor
Then		ANTECEDENT YES antecedent
5) reducing the exposer , import substitution		RULE0041
6) include in contract document	If	
7) available		85. Labour disputes
8) forecast the risk and include first	Then	
ANTECEDENT YES antecedent		5) awareness creation ,duties and responsibility
RULE0038		6) appropriate Labour management
If		7) list out the right and duty
82. lack of technological advancement		8) provide proper contract arrangement
Then		ANTECEDENT YES antecedent
5) training , capacity building and benchmarking		RULE0042
6) training	If	
7) bid ability during the contract time assessment		86. climatic/weather condition
8) well train staff and qualified professional	Then	
ANTECEDENT YES antecedent		5) better activity planning

<p>6) proper scheduling and risk minimizing schedule</p> <p>7) best scheduling regarding the weather</p> <p>8) provide proper planning</p> <p>ANTECEDENT YES antecedent</p> <p>RULE0043</p> <p>If</p> <p>87. Change of leadership</p> <p>Then</p> <p>5) better communication and planning</p> <p>6) establish system</p> <p>7) staff retention</p> <p>8) maintain constraint company procedure</p> <p>ANTECEDENT YES antecedent</p> <p>RULE0044</p> <p>If</p> <p>88. Interference by political leaders</p> <p>Then</p> <p>5) awareness creation , stockholder engagement</p> <p>6) relationship development</p> <p>7) stakeholder management</p> <p>8) avoid direct relationship with them but include in training stage</p> <p>ANTECEDENT YES antecedent</p>	<p>Conclusion</p> <p>The research rule based expert system for WASH projects delay management is done based on the problems that are practical observed on the water sector in Ethiopia. It is more of emphasized on the delay that seems as usual practice in the sector especially in the WASH projects.</p> <p>For the problems identified in the research problem statement three objectives and research questions were formulated. Then after, the methodology is designed to achieve objectives and to answer research questions. The developed to answer research questions so before applying the rule based system on the water sector start to answer the first research question by document interview used and whereas objective was answered using simple narrative method .</p> <p>Rule based system which is developed in the training stage based on both expert knowledge and a typical case of 15 town's water project checked rule base developed from a knowledge of highly qualified and experienced experts. In the antecedent process could analyze the experts instruction experts will be based by construction professionals with more or less qualification and experience in water construction and other sectors.</p> <p>To formulate the rule based expert system the basic foundation was the causes of delay</p>
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so, to found these causes different documents where review additionally from the workshop participants. Second basic knowledge which enters to the system was the solution for the listed causes of delays. To become with the solution conduct the interview and found the solution and ready to formulate the expert system. Finally the result of this study has presented 44 causes of delay and there corresponding solution and the practical causes of delay in 15 town small projects are selected and find out there solution from the experts respond.

From this, system can recognize that the experts knowledge can be put in the system even if the experts passed away and can transfer this knowledge to the next generation and fill the knowledge gap among them not only about the delay but also other things.

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