THEORETICAL ANALYSIS OF CONTRACT CHANGE
IN CONSTRUCTION PROJECTS

by

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A Dissertation Submitted in Partial Fulfillment of the Requirements for the

Doctor of Philosophy

in

Engineering

Graduate School of Engineering

Department of Urban Management

KYOTO UNIVERSITY

August 2014

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ACKNOWLEDGMENTS

The research was carried out in Graduate School of Engineering, Kyoto University, Japan. I am very grateful to Kyoto University. I wish to express my profound gratitude to the members of dissertation committee, namely, Professor Kiyoshi Kobayashi, Professor Hiroyasu Ohtsu, Professor Hirotaka Kawano, Professor Kakuya Matsushima and Professor Masamitsu Onishi for their invaluable comments and suggestions.

Foremost, I would like to convey my heartfelt gratitude to my unique academic advisor, Professor Kiyoshi Kobayashi for accepting me to accomplish my doctoral program in his laboratory and for frequent and helpful guidance and training. He has shown great patience towards my shortcomings and this dissertation might not have been written without his advice and support. Also I would like to thank Professor Masamitsu Onishi who encouraged me during several meetings in my entire doctoral program. My discussion with him have enhanced my understanding on change management and greatly influenced my research work. I thank him very much.

I thank very much Toshihiko Omoto for contributing his knowledge to my understanding about the subject matter.

I am very grateful to Ms. Aya Fujimoto, ex-secretary, and Ms. Chikako Inoue, secretary, for providing me various helps in administrative procedures.

To all those who have helped me in our way or another, I should have better expressed my appreciation. However, due to the limitation in language, I could not have done it earlier. Hereby, I would like to sincerely convey my thankfulness to all members and my fellow students of the Planning and Management Systems Laboratory for their advice and friendship during my time on campus.

I would like to express sincere gratitude to "Global Center for Education and Research on Human Security Engineering for Asian Megacities" (GCOE) in the Graduate School of Engineering for the vital and useful supports.

Last but not least, without the support and the encouragement of my family, especially my dear parents, my study in Japan would not have been so smooth. Not forgetting my beloved husband and my lovely daughter "Mobina", who have prepared a suitable environment for my study and progress. To them, no words of thank is not enough.

ABSTRACT

Almost every project during its lifecycle encounters with evitable or inevitable changes that makes some deviations to the defined scope of work. This consequently makes relevant increase or decrease in cost and time of the project. In fact changes happen due to the uniqueness of each project and limited resources of time and money available for planning.

Contractual provision is required to define the conduct of employer, consultant and contractor to participate in and manage changes. Disputes over change orders and claims are inevitable and the change clauses are often the source of project disputes (Arain and Pheng, 2005; Al-Hams, 2010). If these disputes are not settled peacefully through direct negotiations and arbitration they end up in court and legal procedures may suspend the whole project. The honest negotiation of changes and claims helps mitigate disputes before they damage the relationship and become major problems (Zack, 1995). Successful management of change orders and claims begins even before the start of construction (Ibbs et al., 2001). The employer must accept that no construction method is guaranteed free of changes and claims. Accordingly, the employer must look to a construction method most advantageous to its own goals and limitations rather than theoretical goals or limitations. Decision making is a significant characteristic that occurs in each phase of a project (Arain, 2005). Often, these decisions will, or can affect the other tasks that will take place. To achieve an effective decision making process, project managers and the other personnel of one project need to have a general understanding of change management systems (CII, 1994b). The contents of the initial contract and bargaining power distribution in the renegotiation affects the efficiency of the contract, it was shown that traditional principal-agent model assumed when only one party has the bargaining power at the renegotiation, the optimal contract is socially realizable (when it occupies all surpluses). In this research, contracting parties formulize the incomplete contract model which performs renegotiation involving contract cost and necessary time due to design conditions changes. Moreover, as ADR theory suggested, it will be proved that efficient contract can be designed when employer controls the contract changes by setting initial design conditions and necessary time. As far as the author knows, cases which analyzed the structure of the contract using incomplete contract theory are not found. This research in contrast to ADR theory shows that it is possible to realize socially optimal contract regardless of the bargaining power distribution; socially optimal contract can be realized if initial contract is

designed appropriately when one of the contracting parties takes maximizing behavior for social welfare, this study also leads to incomplete contract theory.

The dissertation is divided into six Chapters. The first half of the thesis presents the research background and literature review. The second half is devoted to achievements of the research objectives and presents its findings.

Namely, Chapter 2 deals with the literature review. The issues of change order, its causes and the effects in construction industry also it deals with controls for change orders and change management system application in construction projects.

Chapter 3 describes in detail disputes causes, dispute resolution methods in construction industry, the adopted methodology for the negotiation decision support systems, and study comparatively dispute resolution mechanism in Japanese public works and International construction projects.

Chapter 4 investigates the incomplete contract model which performs renegotiation involving contract cost and necessary time due to design conditions changes by applying mathematical analysis. The socially optimal contract method is analyzed and the efficiency of the contract is discussed in this chapter.

Chapter 5 formulates asymmetric information and moral hazard and its conquest method and the limits of the contract are then analyzed.

Chapter 6 concludes the study and proposes some potential future research topics.

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1.1 Background

Change orders are frequently encountered in any construction project. Construction projects are complex because they involve many human and non-human factors and variables. They usually have long duration, various uncertainties, and complex relationships among the participants. The need to make changes in a construction project is a matter of practical reality. Even the most thoughtfully planned project may necessitate changes due to various factors (O'Brien, 1998).

Almost every project during its lifecycle encounters with evitable or inevitable changes that makes some deviations to the defined scope of work. This consequently makes relevant increase or decrease in cost and time of the project. In fact changes happen due to the uniqueness of each project and limited resources of time and money available for planning. Change order is a formal change to the contract that authorizes the contractor to execute defined changes and these are often the source of project disputes.

O'Leary (2008) categories some of the changes originated with the employer who finds that the scope of the project must be modified to reflect changes in the project's ultimate use or for important reasons. Also, employers are entitled to change their minds. Other changes are caused by the necessity of correcting errors in the contract documents or to comply with evolving code requirements. Sometimes specified materials or equipment are unavailable at the time of purchase.

Changes during the design and construction processes are to be expected. Changes are inevitable in any construction project (Mokhtar, et al., 2000). Needs of the employer may change in the course of design or construction, market conditions may impose changes to the parameters of the project, and technological developments may alter the design and the choice of the engineer. The engineer's review of the design may bring about changes to improve or optimize the design and hence the operations of the project. Furthermore, errors and omissions in engineering or construction may force a change. All these factors and many others necessitate changes that are costly and generally un-welcomed by all parties.

Consideration must be given from the initial stages of the project until commissioning. Contractual provision is required to define the conduct of employer, consultant and contractor to participate in and manage changes. Systematic and proper procedures must be set in place to process a change from conceptual development until it materializes in the field. The reality is that an adverse environment exists among parties in the construction industry. Changes could be perceived as positive or negative to the preconceived goals of the professionals involved in a project. Therefore, a major change must be managed and handled professionally in order to minimize its cost, schedule and consequential impacts that may divert the project away from its targeted goals.

To identify and analyze potential changes that could happen in a project as early as possible can enhance the management of projects. Learning from these changes is imperative because the professionals can improve and apply their experience in the future.

Most of the research on changes as a separate construction issue is done by or under the guidance of the Construction Industry Institute (CII) an American national organization. There were many significant research contributions in a similar context by many other researchers. In a study done by the Construction Industry Institute (CII publication 5-1, 1986) it was found that change clause is one of the most troublesome contract clauses.

According to Hester (1991) legal disputes over changes often focus on whether or not a compensatory change exists, the appropriate level of compensation, and the relative responsibility for a change. The disputes over change orders and claims are inevitable and the change clauses are often the source of project disputes (CII, 1986). Clear procedures presented in the contract and fair allocation of risks can help in resolving disputes through negotiation rather than litigation (CII, 1986). Frequent communication and strong coordination can assist in eliminating the disputes between professionals. Disputes over change orders and claims are inevitable and the change clauses are often the source of project disputes (Arain and Pheng, 2005; Al-Hams, 2010). If these disputes are not settled peacefully through direct negotiations and arbitration they end up in court and legal procedures may suspend the whole project.

The honest negotiation of changes and claims helps mitigate disputes before they damage the relationship and become major problems (Zack, 1995).

In negotiations, team members often have conflicting goals and values, but when properly performed with cooperative mindsets of decision makers towards one another, negotiation achieves their objectives while maintaining harmony, and reducing time, cost, and hostility.

In a negotiation process, effective negotiation skills are a tremendous asset to any successful executive. They are especially significant for construction executives who are continually involved in managing and administering complex contractual relationships involving substantial amounts of money (Jergeas, 2008). However, many individuals often fail in negotiation not because they are unable to reach an agreement, but because they walk away from the table before they achieve the results they are capable of obtaining. Moreover, in spite of the importance of negotiation, proper training in negotiation skills is not provided within the construction industry. Negotiations are an important activity, but they are the subject of little research or education (Dudziak and Hendrickson, 1988).

Several cases in the literature discuss the application of negotiation support approaches in the construction industry: see, for instance, Aouad and Price (1994), Aouad et al. (1996), Ngee et al. (1997); O'Brien and Al-Soufi (1994), and Shash and Al-Amir (1997). They have found that negotiation support approaches enable construction activities to be programmed and executed in a speedy and cost effective manner.

Aghion, Dewatripont, and Rey (1994) (Hereinafter referred to as ADR theory) pointed out that the contents of the initial contract and bargaining power distribution in the renegotiation affects the efficiency of the contract, it was shown that traditional principal-agent model assumed when only one party has the bargaining power at the renegotiation, the optimal contract is socially realizable (when it occupies all surpluses). In this research, contracting parties formulize the incomplete contract model which performs renegotiation involving contract cost and necessary time due to design conditions changes. Moreover, as ADR theory suggested, it will be proved that efficient contract can be designed when employer controls the contract changes by setting initial design conditions and necessary time. As far as the author knows, cases which analyzed the structure of the contract using incomplete contract theory are not found. This research in contrast to ADR theory shows that it is possible to realize socially optimal contract regardless of the bargaining power distribution; socially optimal contract can be realized if initial contract is designed appropriately when one of the contracting parties takes maximizing behavior for social welfare, this study also leads to incomplete contract theory.

1.2 Objective and Scope of the Study

Successful management of change orders and claims begins even before the start of construction (Ibbs et al., 2001). The employer must accept that no construction method is guaranteed free of changes and claims. Accordingly, the employer must look to a construction method most advantageous to its own goals and limitations rather than theoretical goals or limitations.

Decision making is a significant characteristic that occurs in each phase of a project (Arain, 2005). Often, these decisions will, or can affect the other tasks that will take place. To achieve an effective decision making process, project managers and the other personnel of one project need to have a general understanding of change management systems (CII, 1994b).

This underscores the importance of having a good communication and documentation system for better and prompt decision making during various project phases. If professionals have knowledge about fundamentals of changes and change orders causes and effects and consider conflicts and disputes causes, it would assist the professional team to plan effectively before starting a project, during the design phase as well as during the construction phase to minimize and control changes and their effects (Miresco and Pomerol, 1995).

Contractual provision is required to define the conduct of employer, consultant and contractor to participate in and manage changes. Disputes over change orders and claims are inevitable and the change clauses are often the source of project disputes (Arain and Pheng, 2005; Al-Hams, 2010). If these disputes are not settled peacefully through direct negotiations and arbitration they end up in court and legal procedures may suspend the whole project. The honest negotiation of changes and claims helps mitigate disputes before they damage the relationship and become major problems (Zack, 1995). Successful management of change orders and claims begins even before the start of construction (Ibbs et al., 2001). The employer must accept that no construction method is guaranteed free of changes and claims. Accordingly, the employer must look to a construction method most advantageous to its own goals and limitations rather than theoretical goals or limitations. Decision making is a significant characteristic that occurs in each phase of a project (Arain, 2005). Often, these decisions will, or can affect the other tasks that will take place. To achieve an effective decision making process, project managers and the other personnel of one project need to have a general understanding of change management systems (CII, 1994b). The contents of the initial contract and bargaining power distribution in the renegotiation affects the efficiency of the contract, it was shown that traditional principal-agent model assumed when only one party has the bargaining power at the renegotiation, the optimal contract is socially realizable (when it occupies all surpluses). In this research, contracting parties formulize the incomplete contract model which performs renegotiation involving contract cost and necessary time due to design conditions changes. Moreover, as ADR theory suggested, it will be proved that efficient contract can be designed when employer controls the contract changes by setting initial design conditions and necessary time. As far as the author knows, cases which analyzed the structure of the contract using incomplete contract theory are not found. This research in contrast to ADR theory shows that it is possible to realize socially optimal contract regardless of the bargaining power distribution; socially optimal contract can be realized if initial contract is designed appropriately when one of the contracting parties takes maximizing behavior for social welfare, this study also leads to incomplete contract theory.

The purpose of the following research is to establish the theoretical analysis of contract change in construction projects, to clarify the contract rationality and to improve the efficiency of the contract by defining the key elements to realize socially optimal contracts. Therefore, In order to achieve the aim the following objectives have been set.

1. To review fundamentals of changes and change orders causes and effects in construction under various source related categories (e.g., employer, contractor, designer),
2. To reveal controls for change orders, listing change management systems studies for change control and summarizing characteristics of each system,
3. To consider conflicts and disputes causes, dispute resolution methods (e.g., arbitration, negotiation, mediation) in construction industry,
4. To investigate characteristics of negotiation decision support systems,
5. To study comparatively dispute resolution mechanism between Japanese public works and International construction projects,
6. To address the contractual structure of contract depending employer’s ability to verify the changes.
7. To draw the optimal structure of incomplete contract depending employer’s behavior(e.g. self profit maximizing, social welfare maximizing)

As discussed above, it is therefore important to determine the potential causes, their relevant effects and possible controls for changes orders, and considering nature of construction contracts as incomplete contracts, the following research concentrates on efficiency of socially optimal contract in domestic and international construction projects.

1.3 Methodology of the Study

To achieve the objectives of the study, first the investigation of existing change orders and change management aspects in construction projects is provided along with concepts, techniques, and methodologies related to change orders administration that can be used to develop a negotiation methodology for complex construction disputes. Gathered materials were analyzed and reviewed in chapter two and three. Second, to formulize the incomplete contract model involving contract cost and necessary time due to design conditions changes, mathematical analysis were applied, including theory of Principal-Agent. Third, considering the special nature of the contract as incomplete contract, the socially optimal contract method is analyzed and the efficiency of the contract is considered. Forth, the limits of the contract and moral hazard and its conquest method are then analyzed.

1.4 Structure of the Dissertation

The dissertation is divided into six Chapters. The first half of the thesis presents the research background and literature review. The second half is devoted to achievements of the research objectives and presents its findings.

Namely, Chapter 2 deals with the literature review. The issues of change order, its causes and the effects in construction industry also it deals with controls for change orders and change management system application in construction projects.

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Chapter 6 concludes the study and proposes some potential future research topics.

Appendix A contains proves of several propositions, made in chapter 4 and 5.

CHAPTER 2 - CHANGE ORDERS: CAUSES, EFFECTS AND CONTROLS

2.1 Introduction

This chapter presents a review of the existing body of background knowledge relevant to the research area. It starts with the general review of fundamentals of changes and change orders, and then focuses on the three major aspects of changes: causes, effects and controls for change orders.

There have been numerous articles written on changes, change orders and change management in construction. Most of the articles written discuss the legal aspects of changes such as claims and disputes. Many other articles were devoted to the discussion of the effects of changes on labor productivity. Most of the research on changes as a separate construction issue is done by or under the guidance of the Construction Industry Institute (CII) an American national organization. There were many significant research contributions in a similar context by many other researchers. Most of these significant research works are considered and analyzed in this section.

An overview of change orders and change management aspects in construction projects is provided in this chapter along with concepts, techniques, and methodologies related to change orders administration that can be used to develop a negotiation methodology for complex construction disputes. The fundamentals of changes and change orders, particularly legitimate and management aspects of change orders are reviewed.

Due to source of changes causes and effects of change orders are also explained and suggested categories of the causes and effects are introduced. Finally, controls for change orders and related procedures, particularly in the construction domain, are explained and the relevant literature is reviewed and summarized.

2.2 Fundamentals of Changes

2.2.1 Definitions of Change or Change Order

In construction the term 'change' is often used as a synonym of change order. But strictly speaking, changes and change orders need to be distinguished, with changes being inclusive of change orders. The dictionary defines change as 'the act or an instance of making or becoming different'. Ibbs (1994) defines changes as "additions, deletions, or other revisions within the general scope of a contract that cause an adjustment to the contract price or contract time."

Expanding on that, a change is any action, incidence, or condition that makes differences to an original plan or what the original plan is reasonably based on.

This means that some changes can remain unnoticed by any of parties involved in a project. Furthermore, they may not be properly accommodated through change orders even if they are recognized by any of the parties. Since changes may affect projects, whether recognized or not and accommodated or not, this current study looks at the impacts of changes, not only change orders. The premise behind such a perspective is that claims should not be restricted to impacts of change orders as long as the changes in question are identifiable.

2.2.2 Elements of Change Order

A change order is a written agreement between the employer and the contractor authorizing an addition, deletion, or revision in the work and time of completion within the limits of the terms of the construction contract after it has been executed. It is a specific type of contract modification that does not go beyond the general scope of the existing contract (Clough and Sears, 1994). A change order specifies the agreed-upon change to the contract and should include the following information: Identification of change order; Description of change; Reason for change; Change in contract price; Change in unit prices; Change to contract time; Statement that secondary impact is included; Approvals by employer's and contractor's representatives (Fisk 1997).

2.2.3 Types of Changes

Changes can be classified in many different ways: for example, by features or scopes. (CII publication 6-10(1990), Fisk 1988) Some examples of common classifications of changes are presented as follows:

1) Employer-Acknowledged Changes vs. Constructive Changes

When people talk about change orders, they mostly mean employer-acknowledged changes whether initiated by the employer or the contractor. For an employer-acknowledged change, both parties agree that there is a change. A constructive change is a change that is not acknowledged by the employer when it occurs, but nonetheless a change. In this situation, the employer sometimes takes the position that whatever the contractor is directed to do or is prevented from doing is not a change, but rather is required or prohibited by the original contract (Bartholomew, 2002). As a result, constructive changes are a major source of construction disputes.

2) Cardinal Changes vs. In-Scope Changes

A cardinal change ('change' here is more likely referring to 'change orders') is a change to the contract that, because of its size or the nature of the changed work, is clearly beyond the general scope of the contract (Bartholomew, 2002). Whether a change order is out-of-scope or in-scope is an important question especially for public projects. If the proposed additive modification is outside the scope of the contract, such (cardinal) changes are illegal and the work is essentially new procurement. Even in private contract, a cardinal change cannot be forced and the contractor is not obligated to perform the work.

3) Detrimental Changes vs. Beneficial Changes

Ibbs (1994) classified changes by their total, ultimate impacts on projects and labeled them as "beneficial' and "detrimental" changes, respectively. Beneficial means not only immediate and positive impacts, but also that no long-range negative impacts will occur. Beneficial changes will help reduce cost, schedule or degree of difficulty. They are the necessary changes for improvement. Detrimental changes are those that reduce employer value or have a negative impact on a project as a whole. Ibbs (1994) pointed out that with regard to timing, the later a change occurs on a project, the less efficient is its implementation. So benefits of beneficial changes can be reduced if implemented late.

4) Required Changes vs. Elective Changes

Ibbs (1994) also classified changes by their forcibility. Required changes are the changes that must be implemented. They are necessary; (1) to meet the basic, defined venture business objectives, (2) to meet regulatory or legal requirements, and (3) to meet defined safety and engineering standards. The project team must determine if the project remains viable with these changes. Elective changes are those that are proposed to enhance the project, but are not required to meet the original project objectives. Therefore, they may or may not be implemented. Elective changes are normally considered to be beneficial, but long-range effects should be investigated.

2.2.4 Types of Change Orders

A change order is the formal document that alters some conditions of the contract documents. The change order may alter the contract price, schedule of payments, completion date, or the plans and specifications. Fisk (1997) classified the types of change orders as bilateral change orders and unilateral change orders.

1) Bilateral change orders

The term change order, as normally referred to in most of the contracts, refers to a bilateral agreement between the employer and the contractor to effect a change in the terms of the contract. In US federal contracts, this document is called a contract amendment, as the term change order in federal contracts refers to a unilateral order to effect a change (CII, 1986a).

2) Unilateral change orders

A unilateral contract modification is intended to expedite issuance of a change order to perform emergency work or protested work, and must be replaced by a regular bilateral change order that addresses the effect of the change on contract cost and time before payment can be made to the contractor (CII, 1986a).

2.2.5 Characteristics of Changes

1) Predictability[1]

Some changes are predictable in some degree while others are almost impossible to predict. The changes that are somewhat expected, normal or predictable should be considered at the time of planning. And the change management procedure should provide proper strategies and methods to deal with those changes.

According to Schwartzkopf (1995), there is one study that examined how much of changes can reasonably be expected on construction projects. This study, conducted by Building Research Board National Research Council (1986), analyzed the change order experience on actual projects of the US Army Corps of Engineers (Corps), the Naval Facility Command (NAVFAC), and the Veterans Administration (cited by Schwartzkopf, 1995). The Corps and NAVFAC project data of three year periods (1977, 1980, and 1984) - the overall size of the sample was more than $2.5 billion dollars - showed the range of 5.8 to 11.6% of the average change order increase (See Table 2.1).

Data from Veterans Administration were more extensive. The data were from the year 1974 through June of 1985 and cover 2,200 projects with an original value of $2.26 billion dollars. The modifications averaged 5.3% of the original contract amounts and showed a bit of differences among different types of project ranging from a high of 10% for industrial projects to a low of 2.2% for religious projects (See Table 2.2). According to Schwartzkopf (1995), this

1 *It indicates foreseeability of changes' occurrence, not of changes' impacts.*

Table 2.1 - Average change order increase (Schwartzkopf (1995))

Year	Corps	NAVFAC
1977	8.3 %	7.1 %
1980	9.8%	11.6 %
1984	5.8 %	5.8 %

Table 2.2 - Rate of cost growth - Veterans administration (Schwartzkopf (1995))

Year	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	**Total**
#of Projects	56	128	159	202	197	204	224	259	211	214	257	89	2,200
Rate of Cost Growth	4.87	8.88	5.32	3.55	8.31	4.96	7.32	6.23	5.68	3.90	4.35	4.57	5.38

study concluded that most construction projects would reasonably expect contract modifications which increase contract value by 5 to 10%.

It is also notable that some environments or conditions encourage change occurrences. Unstable labor market or unpredictable economic situations suggest bigger chances to have more changes. Therefore, so-called risky projects may have high possibility of many change occurrences. (Risk can be interpreted as complexity and uncertainty.) It is important to be aware of these change-encouraging environments and prevent the risky environments if possible - if impossible, better get prepared for the more changes.

2) Not Necessarily Agreeable Between Parties

Contractors and employers may have different perspectives and opinions regarding certain changes. One party may consider a situation or what happens as a change while the other party may not. Whether there exists a change and whether a change order is within the general scope of work are common sources of arguments. Usually, employers tend to negate that there is a change because most of changes increase cost of the contract. Even in the case where both parties accept there is a change, agreement on the time and price adjustments isn't easy.

3) Substitution or Addition/Subtraction in Projects Values

A change (especially a change order) can either take the form of substitution or addition/subtraction. If a change doesn't change the price (value) of the final product or the project, such as changes in paint color of doors, that change is a substitution. If a change increases the price of a project, that change is an addition. The opposite case would be a subtraction though deductive change is rare. However, the changes in projects values by a change shouldn't be confused with the cost of a change. Even a deductive change can be costly.

4) Contractual Meanings of Changes

The "changes" clause in a contract provides flexibility to the employer to meet his changing needs after contract execution, and rights to the contractor to be compensated properly for the increase in costs and/or time due to a change order. A change order becomes a part of the contract as soon as it is signed by the employer or by his authorized representative and received by the contractor.

2.2.6 Changes Through Project Phases

Functionally, a change order accomplishes after execution of the agreement what the specifications addenda do prior to bid opening, except that an accompanying price change may be involved in a change order. A price change would not necessarily always be in the contractor’s favor; it could also be in the form of a cash credit to the employer, or it may involve no price change at all (Fisk, 2009). It is the standard practice in construction contracts to allow the employer the right to make changes in the work after the contract has been signed and during the construction period. According to CII's standard six phases of a typical project as follows: Business Planning; Project Planning; Project Scope Definition; Detailed Design; Construction; Start-up and Operation.

This research study considers the phases that start after the “project scope definition” phase. After signing the agreement, all the changes during the design and construction phases are carried out by formal change orders depending on the size of the change.

2.2.7 Sources of Changes

Changes can be originated by all parties in the construction process. All changes, however, must be approved by the employer before implementation. Changes can be classified in many different ways depending on the basis and the purpose. These can also be classified based on their causes. The cause or originator based classification is best suited for the assessment of cost impact or changes. These causes can be numerous (Thomas and Napolitan, 1995).

1) Employer-Originated

The employer frequently needs something not specified in the basic contract. For example, the employer's mission or concepts may have changed since the basic contract was awarded; or, simply the employer may want different designs. The case is called 'preferential engineering', where the client expresses a preference despite the current design fitting for the purpose. Also, the employer may need delivery sooner than initially specified in the basic contract. In these situations, the employer can issue change orders within the general scope of work.

2) consultant-Originated

The designer may have convinced the employer that a change in design would serve more effectively the project purpose.

3) Contractor-Originated

The most common source for field-originated modifications is 'differing site conditions' which are physical conditions at the site, not apparent until construction gets under way. Some other field-originated sources include design deficiencies discovered as construction progresses and ambiguities in the plans and/or specifications that become apparent during construction (Hester et ai., 1991).

4) **Other Changes**

Sometimes modification is necessitated by conditions that are beyond control of both employers and contractors. Third party actions such as public oppositions, strikes and riots, and government actions including changes in regulatory requirements and late approvals/issuance of permits can be the examples. Also damages due to 'Force Majeure' such as floods, tornados, hurricanes, storms and fires can necessitate change orders/modifications.

2.2.8 Change Orders and Claims

Claims and change orders have often been linked with cost overruns, mismanaged jobs, legal entanglements, and alleged spurious practices on the part of some contractors. Admittedly, claims and change orders suggest to most laymen and employer a costly, nonproductive aspect of the construction process. Claims and change orders are the administrative process required to handle construction events that take place where the contract leaves off changed conditions, design changes, defective specifications, quantity changes, delays, disruptions, and accelerations and the successful resolution of the resulting disputes produced by these events (Levin, 1998).

1) Early Identification

Levin (1998) states prompt identification and notification is imperative in order to comply with contractual requirements. If the contractor does not recognize a situation, or waits too long to take actions, any and all rights to claim can be lost.

2) Signs of Claim Situations

Levin (1998) identifies a list of the general circumstances that typically cause claims and change orders. This list summarizes different types and categories of claims and change orders and can be used as a ready reference. These administrative aids form a foundation for proper claims engineering and serve to keep the contractor out of trouble and free to concentrate on his larger role-construction of the job.

2.2.9 Legitimate Aspects

No one can deny that change orders have a great impact on the performance of projects; therefore, most contracts contain specific clauses that indicate who is authorized to take these decisions. In many construction contracts, the engineer has the authority to order or approve changes to the works as specified in the contract (FIDIC,1999;International Labour Organization, 2006). On the other hand, change orders in some contracts are used when the Employer and Contractor agree on the price and the change in schedule (ECAT, 2003). Regarding to literature discussing legal aspects such as contract change, clause interpretation, substantiation and management of claims, in this approach changes are looked at as a major source of construction claims and disputes. The major legitimate aspects are (CII publication 5-10 (1986), Cox 1997): Selecting the best delivery system (contract format); Drafting and interpreting change clauses; Documenting change orders to be ready in case of litigation.

Sometimes an employer or an engineer may attempt to avoid responsibility of changes by using a disclaimer clause or risk-shifting clause in the contract (CII publication 5-1(1986), Cox 1997). Such a clause may state that ‘subsurface data provided is for information only’ and the employer is not responsible for any change. The employer or the engineer may also place a design responsibility on a contractor, whereas it is the responsibility of the engineer under common law or traditional industry practice. By using such clauses an employer or an engineer is transferring the risk to the contractor. These clauses, if used, become risk items in themselves which affect the contractor bidding strategy. “Some examples are the no damage for delay clause, a site condition disclaimer, a blanket indemnity clause …” (Cox, 1997) and the list is long which requires contractors to allow for these shifted risks in their bids and go into their project with open eyes.

2.2.10 Change Orders and Cost Overruns

As previous studies considered changes in construction from a cost point of view, literature published can be classified as either qualitative or quantitative. Qualitative studies discuss the various attributes of cost and schedule impacts without quantifying them. Quantitative studies on the other hand attempt to quantify the various attributes of cost and schedule impacts. Most of the quantitative studies were done on the productivity factor in change. CII has great contributions to this type of studies. Attempts to quantify change impacts usually confronted two major problems (Zeitoun andOberlender, 1993):Difficulty in collection and accuracy of data, Difficulty in assessing indirect impacts of changes.

The cost impact of a change is greatly affected by the timing of the change (CII publications 5-1(1986) & 6-10 (1990)). A change issued before construction has limited effects as compared to a change issued after construction has already started and materials have been procured. Also successive changes cost more than a single change. Changes after construction or completion of design must provide high cost saving to be justified. Some employers request that a change must provide savings 10 times the direct cost required to implement them. "However if the idea that the cost of change can vary exponentially with time of introduction is accepted, that ratio should probably be 25:1 or higher in the later stage of detail design" (CII publication 6-10,1990). It is clear that the relation between changes and time is an exponential function.

A: Direct Cost Impact

The direct impacts are those limited to the work package in which a change is introduced. The cost impact could be positive (savings) to the employer or negative (more expenditure). The contractor's view of a change being positive or negative will be the opposite. A change may also have a positive cost impact to both employer and contractor.

Further, a change may have zero cost impact to both parties. There are two components to the cost of a change: labor cost and material cost.

a) Productivity Loss

Interruption, delays and redirection of work, associated with change work have a negative impact on labor productivity which in turn translates into labor cost or dollar value. Many studies were conducted to evaluate this aspect of change (CII publication 6- 10 (1990), Thomas et al 1995, Ibbs et al 2006, Serag 2007). Two studies cited in CII publication 6-10 (1990) examined work by single craft crewmen and effects of changes on their productivity. “The setting of the first study was a major chemical facility and the craftsmen involved were union insulators”. “Study 2 was undertaken on a revamp project at a refinery where changes were being generated at a rate that often exceeds 20 per week”. Comparing the productivity index against the frequency of change, the studies concluded:

- Productivity drops rapidly with increased frequency of interruptions.
- As the rate of disturbances to the normal flow of work increases, the extent of productivity loss becomes compounded.
- More than 40% reduction in productivity was noticed with an extreme number of disturbances.

Productivity loss is not the same for all tasks and settings. The following factors are noted:

1. Concentration required performing the task
2. Machine intensive tasks vs. labor intensive tasks
3. Frequency of interruptions and duration of time between them
4. Worker expectation of the change and his opinion about it

We can also expect productivity of workers to be greatly affected in cases where workers were required to work overtime for prolonged periods to compensate for schedule delays. In a study by Thomas and Napolitan (1995) productivity values from three industrial projects constructed between 1989 and 1992 were used in the analysis.

The study concluded that on average there was 30% loss of efficiency due to changes (25- 50% was the actual range). It is worth noting that Thomas and Napolitan concluded that changes do not lead to productivity degradation or efficiency loss in them. Instead, a construction change causes other disruptive influences to be activated.

b. Cost of Delay

To make a change and process takes time. This usually results in placing a hold on the work and waiting for new instructions to come. In addition, equipment, tools and materials may not be the same after the change is introduced. To procure or rent new material, tools and equipment will cause delay and cost of resources may be substantial.

Furthermore, if delays are prolonged demobilization/remobilization may become quite costly. The cost of delay may apply to engineering and procurement activities if impacted by change (CII publication 6-10, 1990).

c. Demolition and Rework

Changes, which are introduced when the construction is underway or even complete involve several direct cost items (CII publication 6-10,1990) which can be summarized as follows:

1. Labor cost to demolish existing facility
2. Equipment cost to demolish existing facility
3. Materials wasted by removal of existing work
4. Associated cost of engineering/shipping and handling of waste materials

B: Direct Schedule Impact

It is easy to document a schedule impact of a change after change work is done, because all data is available regardless of its accuracy. However, it is difficult to predict impact of change on schedule before making a change because of the many uncertainties related to labor productivity, material availability or job interference. The cost of schedule slippage becomes very high if the contract includes a penalty clause.

Most projects are planned using a critical path method, CPM, (CII publication 6- 10, 1990). This method of scheduling shows the activities included and their dependencies. CPM provides the basis against which impact of changes on schedule can be evaluated.

In a study by Ibbs, Lee & Li (2007) on the effects of schedule acceleration on project changes, researchers concluded that “a high level of fast tracking generally does not result in any more changes than non-fast tracking projects”. This study used data from an earlier study (Ibbs & Allen) sponsored by the Construction Industry Institute in which 108 projects were analyzed for change data. The study found that fast track projects, however, tend to generate more changes toward the end of the project, resulting in increased labor intensity and a more hectic finishing and close out operation.

C: Indirect or Consequential Impacts

There are always indirect impacts to changes that are overlooked or underestimated (CII publication 6-10, 1990). Consequential effects can occur later in other work packages and thus on the total project. Therefore it is essential to acknowledge this possibility and establish the mechanism to evaluate its consequences. The contract change clause should fully consider both direct and indirect (consequential) effects.

In summary, changes in construction generate effects that far exceed the working package or activity in which changes occur. This situation is called a “Ripple Effect”. Thomas and Napolitan (1994) indicated that “While much has been said about the ripple effect, there have been no quantitative studies showing the magnitude of these effects”.

An attempt to measure ripple effects quantitatively was done by Zeitoun and Oberlender (1993). The attempt was not successful, because of the relative respondent interpretation of the term ‘ripple effect’. The researchers then proposed a method called ‘ripple tree’. Again results obtained applying the ripple tree method came out to be inconsistent with the actual situation. Zeitoun and Oberlender (1993) attributed the unexpected results to erroneous historical data and suggested the use of the method during construction.

Nevertheless, managers of construction projects must develop the means to evaluate and estimate the consequential impacts of a change. An effective tool in consequential impact evaluation is the use of Work Breakdown Structure (WBS). A contractor should consider using the Work Breakdown Structure (WBS) as an evaluation

2.2.11 Change Management Aspects

The discussion so far has concentrated on the legal and cost aspects of a change. Equally important is the need to have a well developed program for the management of changes. This includes a change control program and change order administration during initiation, evaluation, approval and implementation.

The Changes Impact Task Force of the Construction Industry Institute (CII) prepared a checklist of the most common parameters to consider when considering a change. These parameters were classified under different categories.

1-Promoting a balanced change culture

According to the research team this means allowing ‘beneficial’ changes to proceed while discouraging or preventing changes that do not meet this criterion, or changes the team termed ‘detrimental’. In defining ‘beneficial’ changes, the CII team stressed that long–range negative impacts are also studied. “Sometimes immediate beneficial change means potential long-term problems”. Detrimental changes are defined as “those that reduce employer value or have a negative impact on a project”.

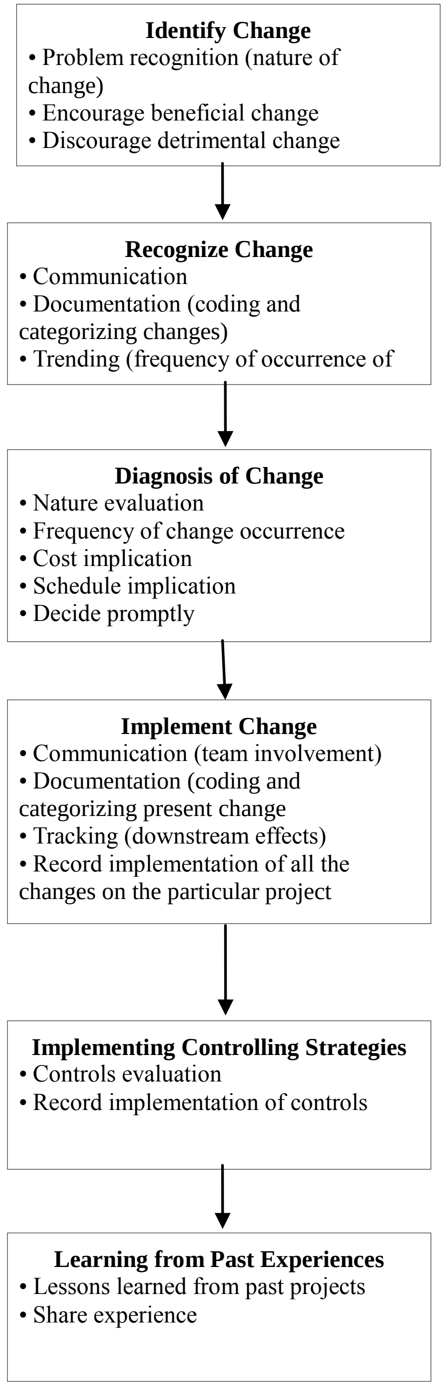


Figure 2.1 Theoretical framework for management of change orders (CII, 1994a)

2-Recognize Change

According to the CII team, there is a common disagreement between parties on what constitutes a change. Consequently, an environment that allows team members to openly communicate is important. The team suggested many ways to enhance change recognition including training team members, flowcharting change management process, devoting specific meetings for change identification, and the regular examination of the total number and value of changes.

3-Evaluate Change

This principle requires a change to be classified as required or elective. Required changes are required to meet original objectives of the project while elective changes are additional features that enhance the project. The team warns against quick judgment in favor of implementing elective changes.

4-Implement Change

This principle requires the flexibility of team members to implement changes at any point on the schedule. Established procedures must be set for authorization and documentation. “Authorization assures that all parties have been communicated with regarding the change” and that the change can be implemented. The research team stressed that the implementation process should contain a documentation system to follow up on the overall impact of the changes.

5-Continuously improve from the lessons learned

The research team emphasized the need to learn from the lessons of past projects executed by an organization. “From the outset, project strategies and philosophies should take advantage of lessons learned from past similar projects”.

The team concluded that “significant savings in total installed costs of construction projects are achievable by improving management of changes”.

There is not much in the literature on change order procedures and administration. Most existing research literature focused on the control part. Ibbs, et al. (1998), in their research about the change impact on fast-track project expressed, that because of the significant economic impact that project change had inflicted upon the industry, many observers within the field recognized the need to avoid change. Yet, the scarcity of reliable quantitative information on changes had forced people in the construction industry to rely on rules of thumb and qualitative anecdotes as guides to minimize project changes.

Successful management of change orders on a project begins before the start of construction and carries through to the last contract close out in the end. An employer’s successful management of change orders goes directly to enhancing the timing and final cost of the construction project (Cox, 1997). If the management process was not included at the inception of construction projects, it may increase the chances of more changes and their adverse effects.

Harrington, et al. (2000) presented a model for the management of change (MOC) in the organizational context. They suggested that the MOC structure can be applied outside the organization to any project change management. The model was based on the following major activity phases:

• Clarify the project: Identify the scope of the project and the level of commitment required for success.

• Announce the project: Develop a tailored change announcement plan.

• Conduct the diagnosis: Following a well-structured announcement, analyze remaining resistance and the organization's capacity to implement the initiative.

• Develop an implementation plan: Specify the precise actions needed for the change project to be successfully implemented on time and within budget.

• Execute the plan: Apply the necessary concepts and/or techniques to fully achieve the human and technical objectives of the project on time and within budget.

• Monitor progress and problems: Periodically prepare a formal report on the implementation status of the project.

• Evaluate the final results: Prepare a final report on the extent to which the human aspects of the project actually achieved its stated objectives on time and within budget.

Harrington, et al. (2000) presented the similar principles that were presented earlier by CII (1994a) for the management of change orders. It was suggested that a systematic and well defined approach would assist in reducing the number of deleterious changes during various project phases.

A theoretical model was proposed by Gray and Hughes (2001) for controlling and managing changes. They expressed that the need for changes could originate from client, architect, engineering consultant, specialists or contractor. The procedure would vary slightly in each case, but it must always be managed and the effect of any change should be understood and accepted by the client. The primary need was to identify the source of the requirement for change and establish its significance, both materially and contractually. Depending on the nature of the project and the problem, there may be a need to obtain input and information from specialists and a formal request for proposal may be issued. This request for proposal would state the scope of the proposed change and request for suggestions as to how it might be resolved and accommodated into the design.

Gray and Hughes (2001) further stated that the evaluation of the options was a complex matter because of the effect, not only on the design, but also on other designers and their work and, if they were already underway, the construction operations. The hidden effects of disrupting the supply and manufacturing processes must also be considered. The complete design team should evaluate the time and cost implications of each option. A formal evaluation and selection process was adopted which lead to the decision whether or not to accept the change. Gray and Hughes (2001) suggested, as the last step of the proposed system, that it was essential to avoid insidious and continuous changes. All changes must be identified and communicated to all those affected, in a clear and unambiguous way, acknowledging the implications on cost and progress. The above mentioned system, if used with a comprehensive knowledge-base of similar past projects, would be helpful in managing and reducing change orders during various project phases (Arain and Low, 2005b).

Ibbs, et al. (2001) proposed a comprehensive project change management system (CMS) that was founded on five principles. These principles were similar to the system proposed earlier by CII (1994a). The CMS was founded on the following five principles:

- Promote a balanced change culture.
- Recognize change.
- Evaluate change.
- Implement change.
- Continuously improve from lessons learned.

These principles work hand-in-hand with others. In fact, it is necessary for each category to interact with others in order to maximize the function of the system. In this system, it is not necessary for the recognition, evaluation, and other principles to be applicable only to one single project. Rather, the actions, results and conclusions from using the system on one project may be similar to another project, given that the scopes of the projects are similar (Ibbs, et al., 2001).

The cost and delay seen in one project can be minimized if there is either a systematic way to change effectively or a systematic way to compare the conflicts in similar projects. The central idea of any change management system is to anticipate, recognize, evaluate, resolve, document, and learn from conflicts in ways that support the overall viability of the project. Learning from the mistakes and conflicts on past similar projects are important, because the team members can enrich and apply their experience in the future (Ibbs, et al., 2001).

Computerized decision systems can be used by project managers to help make more informed decisions regarding changes and delays on projects by providing access to useful and timely information (Yates and Audi, 1998). Not only can computers be used to provide project changes data, but also can provide a consistent, detailed, and systematic analysis of the data; help predict changes; and provide possible causes of changes. In addition, they can suggest ways to prevent further changes and be used to provide a list of corrective measures (Arain and Low, 2005b).

To achieve an effective decision making process, project managers and the other personnel of one project need to have a general understanding of other related or similar past projects (Ibbs, et al., 2001). This underscores the importance of having a good communication and documentation system for better and prompt decision making during various project phases.

Decision support systems are systems under the control of one or more decision makers that assist in the activity of decision making by providing organized sets of tools to impart structure to portions of the decision making situation and to improve the ultimate effectiveness of the decision outcomes (Marakas, 1999). Decision support systems were widely used to solve ill-structured construction problem through formulating an explicit statement of goals for the problem to be solved, identifying the scope and boundaries of feasible solutions, and selecting the optimal solution between a set of alternatives (Li and Love, 1998). Knowledge-based decision support systems increase the likelihood of users making sound decisions. These systems can be used to help reduce costs by trying to minimize the impact of changes through proper management and dispensing timely and accurate information (Arain and Low, 2005b).

Knowledge-based decision support systems for analyzing changes permits project managers to review decisions made under similar circumstances (Skibniewski, et al., 1997). This assists them in learning from past experiences and making more informed decisions (Arain and Low, 2005a). Furthermore, the systems may furnish the project managers with the proper tools for providing clients, top management, project personnel, and others with accurate project information.

2.2.11.1 Change Order Process

A change order as defined by Fisk (1988) is “the formal document that alters some conditions of the contract documents”. The word ‘formal’ implies legal binding and as such all changes should be in writing and verbal changes should be avoided. Although there is no mandatory form, employers usually have their own forms and procedures that must be followed to process a change.

According to W. Bruce Pruitt (1999), the approval of a change order is just the beginning, which must be followed by a course of action "to insure that the change is adequately documented".

As the construction industry is characterized as 'a hectic environment', the procedure to process a change should be precise and 'equally important' fast. "One of the most aggravating conditions is the length of time that elapses between the time that a proposed contract modification is first announced and when the matter is finally rejected or approved as a change order" (Fisk 1988).

The complexity of procedures is a problem in large organizations. Too many control systems and technical department approvals become barriers to an efficient change order procedure. As mentioned earlier, the length of time that elapses between the time that a proposed contract modification is first announced and when the matter is finally rejected or approved as a change order is an influential factor (Fisk, 1997). Through timely notification and documentation of change orders, participants will have kept their rights and thereby their option to pursue a subsequent claim or to defend against a claim (Ibbs, et al., 1997; Cox, 1997; O'Brien, 1998).

In the haste to get the project off the ground, pre-planning and coordination may be compromised, resulting in changes with unpalatable time and cost consequences (Al- Hammad and Assaf, 1992; Sanvido, et al., 1992; Assaf, et al., 1995; Puddicombe, 1997; Reichard and Norwood, 2001). The need for a change can originate from the client, architect, engineering consultants, specialists or contractor (Arain and Low, 2005a). The procedure may vary slightly in each case, but it must always be managed and the effect of any change should be understood and accepted in writing by the client (Krone, 1992; Hester, et al., 1991; Gray and Hughes, 2001). All major changes in construction projects must be claimed in writing by the contractor within the time specified in the contract documents in order to be considered. The employer should evaluate a change order proposal based on such a claim and can use the same reasoning process as any other proposal (Fisk, 1997). Although, there is no universally accepted change order procedure, the important step is to reach an agreement between the parties on the mechanics of the procedure before dilemmas arise (Krone, 1992).

In a study by Krone (1992), two models of change order procedures were proposed: the AIA model and the industry model. Krone (1992) stated that the AIA change order procedure began with the architect preparing the change order. The second step was the signing by all the three parties. The industry model was started with the contractor proposing the change order. The second step was the review by the architect and then after reviewing the proposal, the architect prepared the change order. The last step was the signing by all the three parties.

These two procedures appear to be conflicting. Both assume that change additions, deletions or revisions are necessary, but without a concurrence on the number of nodes and arcs. A review of contractual changes prior to the construction phase fosters understanding between the parties managing the contract (Krone, 1992). When the initial writing of the proposal in the change order procedure is not coordinated between the parties, the proposal can become an isolated event that triggers the ripple effect.

Fisk (1997) presented the conventional change order procedure and stated that change orders were usually initiated by construction personnel at the project site. However, changes were also requested from various other sources. In any case, they must be authorized by the employer before any change order authorizing extra work was valid. A proposed contractual change order was written only after the designers had given consideration as to the necessity, propriety, other methods of accomplishing the work, method of compensation, effect on contract time, estimate of cost, the contractor’s reaction to the proposed change, and the probability of final approval.

Any change in the work that involves a change in the original price must be approved in writing by the employer before a change order can be executed (CII, 1990b; Moselhi, et al., 1991; Hester, et al., 1991; Cox, 1997; Ibbs, et al., 2001; Small and Downey, 2001). If it is not the employer who signs, then the party who does sign for him must have written authorization from the employer to sign on his behalf.

Any change to a contract, once it has been signed, must be avoided unless the full consequences are understood and accepted by all parties before the change order is issued. Contracts must also recognize the inevitable flexibility needed and they must be managed accordingly (Gray and Hughes, 2001).

2.2.11.2 Change Order Administration

It might sound simple, but the procedures and documentation of a change are very vital elements in any change management program. The process starts when the employer, the employer’s representative, or the contractor initiates a change and continues until the change is ready to be implemented. This phase includes a number of important forms and guidelines that must be followed and adhered to in order to bring this change to a successful conclusion. The failure to follow these steps might even jeopardize the right of a contractor to collect fair compensation for a change (Cox 1997). Changes in construction projects can cause substantial adjustment to the contract duration, total direct and indirect cost, or both (Tiong, 1990; Odell, 1995; Ibbs, 1997a; Ibbs, et al., 1998). Therefore, project management teams must have the ability to respond to changes effectively in order to minimize their impact to the project.

Management of changes and claims is the management of risks (Kuprenas, 1998). It begins with the allocation of risk in the project employer's selection of a particular construction method, continues in the prime contract, subcontracts and purchase orders, and culminates in the prevention of and, if necessary, the successful resolution of changes and any claims that occurs during the construction phase (Cox, 1997). The changes may occur at any phase of a project. Therefore, the management process should be comprehensive to encompass the entire project cycle.

Comprehensive guidelines were suggested by Cox (1997) who presented the following guidelines to manage risk:

• Recognize that no construction method or risk-shifting contract clauses would be a panacea for all the risks in construction.

• Know the risks of that construction method or those contract clauses before choosing a particular construction method or risk-shifting clause.

• Plan ahead so as to minimize the allocated risks of the actual construction method or contract clauses.

• Provide a cost effective means of resolving changes and claims that will inevitably arise during a project, regardless of all the risk-shifting, either by the construction method or contract clause.

To manage a change means being able to anticipate its effects and to control, or at least monitor, the associated cost and schedule impact (Hester, et al., 1991). Three management techniques mentioned most frequently in the literature were the Work Breakdown Structure (WBS), Market Factor (MF) and forensic scheduling. WBS and MF techniques are simplistic tools for breaking a project into manageable packages. Forensic scheduling is a technique for assessing the impact of change orders on other parts of a project, principally for the purposes of claims analysis and defense.

2.3 Causes of Change Order

Causes of change are conditions or events that either directly trigger or contribute to a change in construction projects. There have been numerous studies on causes of project change and delays, which can be broadly classified into three groups: questionnaire surveys, reviews of project records, and case studies.

Questionnaire survey is good at gathering views from a large of number of practitioners. However, a response to such a survey represents an accumulative experience over many projects by a respondent (Chan and Kumaraswamy,1997). Similar surveys were carried out by Kaming(1997) in Indonesia, by Frimpong (2003) in Ghana and by Assaf and Al-Hejji(2006) in Saudi Arabia. Hemanta (2012) identified the key factors impacting delay in Indian construction Industry and questionnaire and personal interviews have formed the basis of the research. Odeh and Battaineh (2002), also through a questionnaire survey, identified the most important causes of delays in construction projects with traditional contracts. Al-Khalil and Al-Ghafly(1999) extended the scope of their survey to include both frequency and extent of project delays in addition to causes. Chabota (2008) identified causes and effects of cost escalation and schedule delays in road construction projects in Zambia.

The second research method is review of project records. Hsieh et al. (2004) conducted a statistical analysis in 90 metropolitan public work projects in Taiwan and identified problems in planning and design as main causes of change orders. Yogeswaran et al. (1998) scrutinized 67 civil engineering projects in Hong Kong and suggested that at least a 15–20% time overrun was due to inclement weather. Based on analysis of 46 completed building projects in the UK, Akinsola et al. (1997) identified and quantitatively examined factors influencing the magnitude and frequency of variations in building projects. A total of 6,585 change orders filed in a school district's projects in the 5 1/2 year period from 1999 to 2004 were analyzed by Günhan (2007) in five categories including Employer-directed changes, code compliance issues, errors/omissions in contract documents, discovered or changed conditions, and others.

The third method of investigation is case study, where researchers concentrate on a small number of projects and carry out in-depth analysis. For example, Wu et al. (2004) focused on one large national highway project in Taiwan and identified 34 change order causes. They further proposed a coding system for these change causes.

Table 2.3 Summary of causes of change orders

	Chan and Kumaraswamy (1997)	Hsieh et al. (2004)	Wu et al. (2004)	Günhan (2007)
Employer-related	Employer-initiated variations Unrealistic contract durations imposed by Employer	Requirement changes	Future users or responsible organization request new requirements. Change to prevent casualties and ensure temporary construction safety Employer failure to provide construction sites, equipment, machinery or materials on time Adopting new construction methods to reduce costs or accelerate accomplish	Change of plans or scope by Employer Change of schedule by Employer Employer's financial problems Inadequate project objectives Replacement of materials/procedures Impediment in prompt decision making process Obstinate nature of Employer Change in specifications by Employer
Consultant-related	Necessary variations of works Delay in design information Long waiting time for approval of drawings Mistakes and discrepancies in design documents Inadequate design team experience	Defects in design and planning Errors and omissions in quantity estimations Inconsistency between drawings and site conditions Citation of inadequate specification Design changes	Design changes in respond to site conditions Erroneous or incomplete design information Insufficient site investigation prior to design Changes in construction method	Change in design by consultants Errors and omissions in design Conflicts between contract documents Inadequate scope of work for contractor Lack of contractor's involvement in design
Contractor-related	Poor site management and supervision,Inadequate managerial skills, Improper control over site, Resource allocation, Inadequate	Inadequate planning Lack of contractor experience	Poor workmanship Poor scheduling	Unavailability of equipment Unavailability of Skills
	contractor experience Deficiencies in planning and scheduling at preconstruction stage, Delays in subcontractors' work, Unsuitable management structure			Contractor's financial difficulties

External factors		Change of regulations Change of decision-making authority Unpredictable weather conditions	Political pressure Natural disaster Expected geological conditions Local residents Other organizations	Change in govt. regulations Change in economic conditions Unforeseen problems
Project-related	Project construction complexity Low speed of decision making involving all project teams Lack of communication between Employer, consultant and contractor	Site safety considerations Site security considerations Safety facilities reinforcement	Site restrictions Delays in secure site, equipment or materials	Safety considerations

Table 2.3 summarizes the causes of change orders identified by the existing studies, using one example paper for each of the above discussed three types of studies. The questionnaire survey produced the most comprehensive lists of change causes (Chan, 1997). It also suggested categories for these causes, which are used in the table. On the other hand, documentation reviews and case studies offered a more in-depth analysis of the change causes in a project context.

Causes of change are conditions or events that either directly trigger or contribute to a change in construction projects. There have been numerous studies on causes of project change and delays, which can be broadly classified into three groups: questionnaire surveys, reviews of project records, and case studies.

Changes arise due to many reasons. Some may be genuine which are projects related e.g. to suit unforeseen site conditions and some may be other reason which is designer related for e.g. design error by the designer. Other reasons are contractor related e.g. delay by the contractor supplier to supply material or poor site management by the contractor. Some may be due to Employer requirement in the course of construction. Other may be requirement by external factors such as compliance with local authorities' requirement. All these factors and many others generally are dislike by all parties because it will delay the project completion and in most cases increase in cost. In some cases, it is difficult to establish the reason and quantum of the changes and it will lead to dispute.

Therefore change order shall be controlled to ensure that the initial cost is not exceed excessively or to ensure that the contract sum is within the Employer's original budget. Prior to that, cost control is vital and it aims is to ensure that resources are used to best advantage (Seeley,1984). Apart from that, knowledge on contracts conditions particularly with regards to change is vital to all project participants so as minimize changes.

All possible factors that could lead to change are included in theoretical frameworks are shown in Figure 2.1. The theoretical framework indicates the relationship between dependent and independent variable. Sekaran (2003) referred to the theoretical framework as identify all factors contributing to the problem. The dependent variable is the variable of primary interest while the independent variable is one that influences the dependent variable in either a positive or negative way.

Hsieh et al. (2003) determined major causes of change order appertaining two defined categories of technical changes and administrative changes. In the category of technical changes, there are four types of causes namely: Planning and design; Underground conditions; Safety considerations; and Natural incident. While in the category of administrative changes, it consists of causes as follows: Changes of work rules/regulations; Changes of decision making authority; Special needs for project commissioning and Employership transfer; and Neighborhood pleading.

Hallock (2006) states while an initial reaction to change is often negative, we need to divest ourselves of the concept that change is fundamentally bad. Changes when properly understood can provide us with opportunities to address systemic problems, adopt new techniques, adapt to conditions over which we have little or no control, or bring betterments to the delivery of the project. He categorized the principal cause of changes on projects as the following: Design Revisions; Errors and Omissions; Market conditions; Performance Errors; Differing Conditions; Conscious Decision.

Al-Muhammadi and Al-Harthi (2008) found Seventy-eight significant causes of change orders. Some of these major areas were further divided into eight divisions, as the following: Change of Plans by Employer; Employer's Financial Difficulties; Employer Change of Schedule; Substitution of Materials or Procedures; Conflict between Contract Documents; Change in the design; Lack of Coordination; Environment.

Sekaran (2003) identified all possible factors that could lead to changes including: Design Error; Site Condition; Compliance with Local Authorities or Other Government Agency Requirement; Inadequate Site Inspection; Inadequate Soil Investigation; Employer's requirement; Financial constraint during planning stage; Scope of work not well define during planning; Land acquisition matters; Squatter problem and Compliance with social obligation.

Causes of change orders were identified by many researchers (CII, 1990; Thomas and Napolitan, 1994; Clough and Sears, 1994; Fisk, 1997; Ibbs, et al., 1998; O'Brien, 1998; Gray and Hughes, 2001; Arain, et al., 2004). The causes of changes can be categorized according to the originators (CII, 1990; Thomas and Napolitan, 1994). The 18 causes identified from the literature review are discussed below. These will also form the basis for the survey of the professionals described later.

a. Employer Related Changes

This section discussed the causes of changes that were initiated by the Employer. In some cases, the Employer directly initiates changes or the changes are required because the Employer fails to fulfill certain requirements for carrying out the project.

1- Change of plans or scope by Employer

Change of plans or scope of a project is by far the most significant cause of changes in construction as stated in the literature (CII, 1990a). Change of plans or scope by Employer is usually the result of insufficient planning at the project definition stage or because of the lack of involvement of the Employer in the design phase (Arain, et al., 2004; Ismail et al. 2012; Al-dubaisi, 2000). This cause of changes affects project severely during the later phases. Normally, this source of changes is a result of insufficient planning at the project definition stage or simply because of the lack of involvement of the Employer at the design stage.

2- Employer's financial problems

The Employer of the facility may run into difficult financial situations that force him to make changes in an attempt to reduce cost. Employer's financial problems affect project progress and quality (Clough and Sears, 1994; O'Brien, 1998). The fact that many of the Employers especially in large building construction projects are wealthy individuals who might not have sound and reliable financial sources makes this risk a real one.

3- Inadequate project objectives

This might be a sub-category of change of plans but specifically indicates that the objectives of the project were not well defined. Inadequate project objectives are important causes of change in construction projects (Ibbs, 2007). Due to inadequate project objectives, the designer would

Table 2.4 Causes of change orders grouped under four categories

Employer- related	Change in specifications by Employer Inadequate project objectives Replacement of materials/procedures Obstinate nature of Employer Change of plans or scope by Employer Employer's financial problems
Consultant-related	Change in design by consultants Errors and omissions in design Conflicts between contract documents Inadequate scope of work for contractor
Contractor-related	Unavailability of equipment Unavailability of Skills Lack of contractor's involvement in design Contractor's financial difficulties
Others	Change in govt. regulations Change in economic conditions Unforeseen problems Safety consideration

not be able to develop a comprehensive design, which leads to numerous changes during the project construction phase.

4- Replacement of Materials or Procedures

Substitution of Materials or Procedures may cause major changes during the construction phase. The substitution of procedures includes changes in application methods (Chappell and Willis, 1996). This feature of the market forces people to move away from lump sum contracts that cover supply of material leaving the door open for the Employer to select materials during installation. The substitution of procedures includes changes in application methods of paints or insulation material for example. It is very obvious that different procedures are at a different cost to the contractor and hence adjustment to the original contract value is required in such instances.

5- Obstinate nature of Employer

A building project is the result of the combined efforts of the professionals. They have to work at the various interfaces of a project (Wang, 2000; Arain, et al., 2004). If the Employer is obstinate, he may not accommodate other creative and beneficial ideas. Eventually, this may cause major changes in the later stages and affect the project adversely.

6- Changes in specifications by Employer

Changes in specifications are frequent in construction projects with inadequate project objectives (O'Brien, 1998). In a multi-player environment like any construction project, changes in specifications by the Employer during the construction phase may require major changes and adjustments in project planning and procurement activities.

b. Consultant Related Changes

This section discussed the causes of changes that were initiated by the consultant. In some cases, the consultant directly initiates changes or the changes are required because the consultant fails to fulfill certain requirements for carrying out the project.

1- Change in design by consultant

Change in design for improvement by the consultant is a norm in contemporary professional practice (Arain, et al., 2004). The changes in design are frequent in projects where construction starts before the design is finalized (Fisk, 1997). Design changes can affect a project adversely depending on the timing of the occurrence of the changes.

2- Errors and omissions in design

Errors and omissions in design is an important cause of project delays (Arain, et al., 2004). Design errors and omissions may lead to loss of productivity and delay in project schedule (Assaf, et al., 1995). Hence, errors and omissions in design can affect a project adversely depending on the timing of the occurrence of the errors. It is impossible to create a 100% error free design. Quite often, among the many documents of the project, one will find a note deleted, a detail mis-referenced or an incomplete specification sheet. The contractor's point of view is to escape the extra cost and will look for ways to minimize cost.

3- Conflicts between contract documents

Conflict between contract documents can result in misinterpretation of the actual requirement of a project (CII, 1986). However the Employer may find out that the governing document representation or requirements are not the best and may decide to change. Employer must expend sizable effort to review contract documents for any possible contradictions before award of contract to avoid such changes. Phrases that can be interpreted differently have to be rewritten if confusion is to be avoided. The contractor will normally look for any phrase or note in the contract documents to justifying the cheaper option.

4- Inadequate scope of work for contractor

In a multi-player environment like construction, the scope of work for all the players must be clear and unambiguous for successful project completion (Fisk, 1997; Arain, et al., 2004).

Inadequate scope of work for the contractor can cause major changes that may adversely affect the project, leading to changes in construction planning.

c. Contractor Related Changes

This section discussed the causes of changes that were related to the contractor. In some cases, the contractor may suggest changes to the project or the changes may be required because the contractor fails to fulfill certain requirements for carrying out the project.

1- Lack of contractor's involvement in design

Involvement of the contractor in the design may assist in developing better designs by accommodating his creative and practical ideas (Arain, et al., 2004). Lack of contractor's involvement in design may eventually cause changes. Practical ideas which are not accommodated during the design phase, will eventually affect the project adversely.

2- Unavailability of equipment (lack of equipment)

Unavailability of equipment is a procurement problem that can affect the project completion (O'Brien, 1998). Occasionally, the lack of equipment may cause major design changes or adjustments to project scheduling to accommodate the replacement. The danger in this comes from the fact that some designs are done outside the country by companies not familiar with the resources available locally. Active participation of the Employer during design will minimize this source of changes.

3- Unavailability of skills (shortage of skilled manpower)

Skilled manpower is one of the major resources required for complex technological projects (Arain, et al., 2004). Shortage of skilled manpower is more likely to occur in complex technological projects. This type of change is more likely to happen in construction involving some degree of technological complexity and not in normal building construction.

4- Contractor's financial difficulties

Construction is a labor intensive industry. Whether the contractor has been paid or not, the wages of the worker must still be paid (Thomas and Napolitan, 1994). Contractor's financial difficulties may cause major changes during a project, affecting its quality and progress. Due to the fact that many new contractors in large construction projects face financial difficulties in executing large projects. These difficulties affect their ability to execute and deliver. Therefore, delays in the completion schedule (schedule change) may occur due to the financial problems.

d. Other Changes

This section discussed the causes of changes that were not directly related to the participants.

1- Safety considerations

Safety is an important factor for the successful completion of a building project (Clough and Sears, 1994). Noncompliance with safety requirements may cause major changes in design.Lack of safety considerations may affect the project progress adversely, leading to serious accidents and delays in the project completion. If some safety aspects were overlooked during the design phase, the Employer or consultant may initiate a change to install additional safety features in the facility.

2- Change in government regulations

Local authorities may have specific codes and regulations that need to be accommodated in the design (Arain, et al., 2004). Normally the designer insures that his design is in compliance with these codes. However, new regulations may be issued between design and construction and may force some changes to the original plan. Codes such as environmental or labor codes are revised periodically and the contractor or facility employers are requested to comply.

3- Change in economic conditions

Economic condition is one of the influential factors that may affect a construction project (Fisk, 1997). The economic situation of a country can affect the whole construction industry and its participants. Eventually, this may affect the project adversely, depending on the timing of the occurrence of the changes.

4- Unforeseen problems

Unforeseen conditions are usually faced by professionals in the construction industry (Clough and Sears, 1994; O’Brien, 1998). If these conditions are not solved spontaneously, they may cause major changes in the construction projects. Eventually, this may affect the project adversely, leading to reworks and delays in the project completion.

2.4 Effects of Change Orders

Effects of change refer to direct or indirect impact of a change event on various aspects of a project. Although some projects may benefit from positive changes, most changes interrupt the flow of work, cause cost and time overrun.

According to Woods (2008), in the projects execution change has altered from a positive term to an adverse experience. There is an ongoing debate surrounding the impact changes to a contract have upon the contractor. The perception is that contractors make large profits on change orders. In reality, multiple changes have a detrimental impact on a contractor's ability to complete the project with the planned resources, craft and equipment, and within the planned duration.

Arain and Pheng (2005) conducted study on the effects of change orders on building project and conclude that there are six most frequent effects of change order. The first one is the increase in project cost. Even though construction project is usually allocated with contingency sum major changes according to them, may still leave to cost overrun in the contingency sum. Additional payment was found to be the second most frequent effect of change orders as change are considered as common source of additional works for the contractors. Arain and Pheng (2005) suggested that changes are considered as a common source of additional works and opportunities for contractors to achieve their desired profit margins.

Effects of changes were observed by many researchers as Table 2.5 (CII, 1986; CII, 1990; CII, 1994; Thomas and Napolitan, 1995; Ibbs, et al., 1998, Arain and Low, 2005c). The 10 effects identified, as shown in Table 2.6, from the literature review are discussed below. These will also form the basis for the survey of the professionals described later.

1. Completion schedule delay

Changes often result in time extension. In other instances, the employer may want to compensate the contractor for accelerating the work in order to keep up with the original schedule. In either case, additional time means additional money. Delays in completion can be quite costly. Imagine a facility such as a refinery or a large commercial center that costs millions when it is delayed for weeks or even days. Whoever is signing the change order ought to know the cost of delay before granting a time extension. Delays, disruptions, and accelerations share a reputation with differing site conditions as the most recurring causes of contract problems. Strikes, adverse weather, third parties, contractor errors, change orders, and employer-directed suspensions all can cause delay. These delays can be a few hours, or extend several years, and they almost always cause

Table 2.5 Summary of effects of change orders

	Arain and Pheng (2005)	Hanna(2005)	Bower (2000)
Time-related	Delay in payment Material and equipment procurement delay Logistics delay Rework and demolition Completion delay	Time extension Overtime Rework Re-planning	Time lost in stopping and restarting Rework Standing time for subcontractors
Cost-related	Increase in cost Increase in overhead Additional payments to contractor	Increased costs Adjustment in crew makeup Overtime costs Compensation	Loss of earnings Increased time and material related charges Increased overheads Change in cash flow
Productivity-related	Productivity degradation	Schedule compression Out-of-sequence work Trade stacking Over manning Loss of learning curve Multiple-shift work	Reprogramming Loss of rhythm Unbalanced gangs
Risk-related	Affected progress	Acceleration Interruption Interference Site congestion	Acceleration Loss of float Increased sensitivity to delay
Other effects	Poor professional relations Claims and disputes Poor safety conditions Quality degradation Damage to reputation	Co-ordination problem Less-qualified labour Loss of moral	Revision to project reports and documents Winter working

additional direct and indirect costs. Closely associated with delays are accelerations, for very often contractors must accelerate their work in order to make up for time lost to delays (Levin, 1998).

2. Increase in project cost and overhead expenses

The change in cost was defined as the difference between the cost at the end of the project and the original budget (Ibbs et al, 2003). Serag and Oloufa (2007) built a model to calculate the impact of changes on cost and concluded that only 57% of the changes of the response variable increase the contract price. The increases in cost resulting from any major additions or alterations in the design which may eventually increase the project cost. In every construction project, a contingency sum is usually allocated to cater for possible changes in the project, while keeping the overall project cost intact (Arain and Pheng, 2005).

Table 2.6 Effects of change orders

Change orders effects	
1	Increase in project cost and overhead expenses
2	Delay in payment
3	Adversely affect work quality
4	Lost productivity and efficiency
5	Most contractors incur additional costs due to change orders
6	Rework and demolition
7	Affect firm's reputation
8	Change orders would result in claims and disputes
9	Completion schedule delay
10	Procurement delay

3. Quality

The question is either the quality of works achieves the standard requirement as per contract or not. If there are too many instruction changes by the Architect or S.O, it may lead the contractor feeling unmotivated and afraid for the possibility of changes in completed works and this will result in poor quality of work and low productivity of the contractor (CII, 1995; Ndihokubwayo and Haupt, 2007). According to CII (1995), the quality of work was usually poor because of frequent changes because contractors tended to compensate for the losses by cutting corners.

4. Firm's Reputation

Changes are referred to as a major source of construction claims and disputes (Fisk, 1997; Kumaraswamy et al., 1998). The claims and disputes may affect the firm's reputation adversely, leading to insolvency in severe cases. Changes also increase the possibility of professional disputes. Conventionally, changes present problems to all the parties involved in the construction process(Arain and Pheng, 2005).

5. Decrease in Productivity

Productivity loss was studied by evaluating causes and effects specific to a particular project and, when possible, performing differential analyses between normal and impacted periods of the work. Industry studies alone are of limited use (McEniry, 2007). Interruption, delays, and redirection of work during change orders have a negative impact on labor productivity (Arain and Pheng 2005; Al-Dubaisi, 2000; Al-Jishi and Al-Marzoug, 2008).

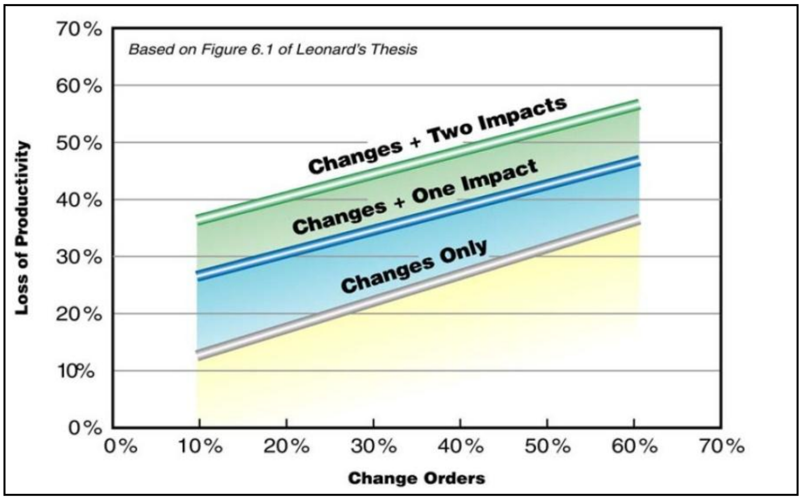


Figure 2.2 Relationship between change orders and productivity loss (Leonard, 1987)

The first trial to measure the productivity losses during change orders was conducted by Leonard (1987), who established the relationship between change orders and the productivity loss illustrated in Figure2.2 below. As we have seen in our review of change literature, the productivity of workers is negatively impacted by change orders especially repetitive changes. Labor cost accordingly increases and so the total project cost. In countries where labor is cheap, this impact is not felt. However this degradation of productivity may cost extra days or weeks of expensive labor.

Many industry professionals believe that changes implemented late in a project cause a greater loss of labor efficiency (Hanna, 1999).

6. Additional Payments for Contractor

No matter how much was said about the negative effects of change orders, there is often additional money gained by the contractor for executing additional scope. The accuracy of this statement depends on the awareness of contractors and employers of direct and indirect impacts of changes and on the willingness to accept this fact in change order pricing. Additional payments for the contractor can be a potential effect of changes in construction projects (Al-Dubaisi, 2000).

7. Demolition and Re-work

Rework and demolition are potential effects of changes in construction, depending on the timing of the occurrence of the changes (Clough and Sears, 1994). These effects are to be expected due to changes during the construction phase (Arain and Pheng, 2005; Al-Dubaisi, 2000; Al-Jishi and

Al-Marzoug, 2008). This is because the changes during the design phase do not require any rework or demolition on construction sites.

8. Disputes among professionals

Frequent communication and strong coordination can assist in eliminating the disputes between professionals. Disputes over change orders and claims are inevitable and the change clauses are often the source of project disputes (Arain and Pheng, 2005; Al-Hams, 2010). If these disputes are not settled peacefully through direct negotiations and arbitration they end up in court and legal procedures may suspend the whole project.

9. Delay in payment

Delay in payment occurred frequently due to changes in construction projects (CII, 1990).Changes may hinder the project progress, leading to delays in achieving the targeted milestones during construction (CII, 1995; Arain and Low, 2005c). Eventually, this may affect payment to the contractors. Occasionally this delay may cause severe problems that end up in delays in payment to the subcontractors; this is because main contractors may not be able to pay the subcontractors unless they get paid by the employer first

10. Procurement Delay

Change orders bring about problems with materials and tools required to carry out a certain activity. Consider for example an order to change the type of doors of a building at a time after the order for doors was issued to the vendor. The new type of doors may not be available from the vendor and may require extra time to order or fabricate. This creates delay for materials which in turn holds up work for finishing subsequent work.

2.5 Controls for Change Orders

Controls for changes and change orders have been suggested by many researchers (Bower, 2000; Ibbs, 2001; Arain and Low, 2005). The common control procedures used to minimize the effects of change orders will be reviewed in this section. Controlling the occurrences of change orders and restraining their bad effect are highly recommended to analyze the controlling stage into three stages. These stages are design stage, construction stage, and design-construction interface stage. Mitigation of detrimental changes requires proactive attention (Motawa;2005); where the earlier this starts, the more likely it is to be successful. The design phase is considered the most important time to initiate action(Arain;2008). The benefits or detriments accrue over time, given that engaging in onsite changes is normally more resource-consuming than conducting changes during design (Arain;2005). The effective management of change orders requires understanding of not only their root causes, but also their potential downstream effects (Ibbs;2001), particularly in project planning and forecasting (Isaac;2009).

2.5.1 Empirical Research Studies of Control for Change Orders

Many studies discuss change phenomena by drawing on empirical evidence from completed or on-going projects (Stasis;2013). Most of these are dedicated to the examination of change causes and effects. Specific methods vary, extending from qualitative analysis to statistical models, yet there is a focus on numerical analysis. Table 2.7 provides a summary of indicative studies of this nature.

Two methods for developing influence curves to numerically evaluate the indirect costs of a variation are compared in Bower's study(2000). Influence curves acknowledge the 'ripple' effects that occur on the event of a variation. The method is tested on 2 variations during the construction. In the first approach, an assessment of direct costs associated with variation introduced, followed by factoring of ripple effect and summed for the project, is conducted at different points in time. In the second approach, an assessment of resourcing level, combined with the lack of available float, is presented at different points in time. By comparing how closely fitted the two curves are the results can be verified or disproved.

Serag, et al. (2010) develop a statistical model based on regression analysis to quantify the contract price increases due to change orders administered during 16 Florida-based heavy road construction projects. Following analysis of 11 relevant variables, those with the most significant impact on change order cost were found to be the timing of change orders and unforeseen conditions in issuance. The authors argue that this statistical model can serve as a template for other heavy construction projects.

2.5.2 Change Management Systems Studies

Toolkits for modeling change management have been developed, as shown in Table 2.8. These studies provided toolkits from simple process models identifying change steps, to more elaborate systems with workflows, databases and subsystems. Systems dynamics, knowledge-based decision-support and stochastic network analysis were used in the studies.

Ibbs, et al. (2001) construct a 'cradle-to-grave', generic process-oriented construction change management system, which they argue is also useful for engineering projects beyond

Table.2.7 : Empirical research studies of control for change orders

Authors	**Objective**	**Data**	**Method**	**Result**
Bower(2000)	Numerical evaluation of indirect costs of a variation using influence curves.	2 variations that occurred during the construction of 2km rural road.	Numerical evaluation &comparison of 2 influence curves.	Widely applicable, as influence curve can be adjusted for acknowledged risk factors on each project.
Ibbs(2005)	Impact of timing changes on construction labour productivity.	Construction projects (N=162); data for cost, labour hour, schedule & change.	Conventional regression analysis.	Late change is found to be more disruptive of project productivity than early change, all other things being equal.
Hanna (2005)	Logistic model to determine probability that a construction project has been impacted by change orders.	Data from questionnaires & documents; 450 electrical& mechanical contractors.	Statistical hypothesis testing and logistical regression techniques.	Main impact factors: per-cent change, type of trade, estimated and actual peak manpower, processing time of change, overtime and over-staffing.
Serag(2010)	Statistical model for quantifying contract price increases due to change orders.	16 Florida Department of Transport projects	Two regression models; 11 variables analysed to test their cost impact.	Timing of change order & unforeseen conditions in issuance are the two variables with maximum impact on cost.

construction. Their high-level process flowchart connects each of their five principles, shown in Table 2.1, which are treated as high-level functional activities, to a set of change management processes. Similar process-oriented theoretical models are presented by later researchers (Motawa;2005, Hao;2008, Arain;2007) with four, five and six stage processes, which differ in the extent to which they seek to prescribe controlled workflows.

Charoenngam (2003) developed an object-oriented web based Change Order Management System (COMS) using change order processes / workflows found within standard forms of contract addressing the issue of control. Motawa(2005) complemented a four stage change implementation model by a database-backed relationship mechanism between 1) project characteristics, 2) change causes, and 3) change effects; illustrated via a relationship diagram.

Sun et al. (2006) sought to address the lack of practical, industrial standards for project change management procedures and methods within construction, conducted a longitudinal study on

Table 2.8: Change management systems studies

Authors	Objective	Basis	Characteristics
Ibbs (2001)	Generic, Process-oriented system.	Built to overcome the various observed inefficiencies of construction change management systems.	1) promote a balanced change culture; 2) recognize change; 3) evaluate change; 4) implement change; 5) Continuously improve.
Charoenngam et al. (2003)	System development and comparison with paper based simulations of a change event.	System analysis of change order processes identified in two standard forms of contract (ICE, FIDIC).	Object-oriented change order management system (COMS) built using standard web technologies and consists of three subsystems.
Motawa (2005)	Change process model, and database backed relationship mechanism.	Builds on process models on projects and monitoring of change events in the author's previous research.	Process-oriented diagram: 1) Pre-change or startup; 2) Identification& evaluation; 3) approval& propagation; 4) Post change.
Sun et al.(2006)	Novel change management toolkit, which assists the application of the generic change process model.	12 month study on change occurrence and management in 2 construction projects through observations, review meetings, and interviews.	2 components: Knowledge includes 4-step change management process, dependency framework, & knowledge management guide. Support a workflow tool & change prediction tool.
Motawa, et al. (2007)	A systems dynamics model allowing for change prediction and dynamic planning.	Synthesis of change process models from literature and case studies. Input data for change prediction and DPM data, are empirically obtained.	Change prediction tool is used to estimate change occurrence likelihood, potential change effects, and project stability. Dynamic Planning Control Methodology (DPM) simulates iterative cycles.
Arain and Pheng (2007)	Novel process oriented model for managing variation orders and reduction of change orders' adverse impacts.	Effective variation management principles were adapted within a framework from previous research. The model is enriched by literature on decision-making and controls.	6 principles of effective variation management were used to sequence the model's process. The framework, groups the principles-turned process steps into 3 high-level phases, and is presented within a systems process flowchart.
Arain (2008)	Develop and use a KB Decision Support System for effective management of variations in educational building projects.	System prototype is based on an existing theoretical model (2007), with further development at the KB and controls level; inputs from 80 completed projects.	The system demonstrates the strength of a practical process model based on decision support, controls, KB, and continuous learning, all of which can be used for effective and efficient management throughout the change cycle.
Hao et al. (2008)	A theoretical improvement to existing change order management systems.	A synthesis of extant change process models, and the characteristics of computational environments.	Process flowchart: 1) identification; 2)evaluation & proposition; 3) Approval; 4) implementation; and 5) analysis.
Isaac and Navon (2009)	Object oriented, graph-based model for proactive change impact identification.	Principles from research to nature & requirements of change identification.	Stochastic network analysis interlinking the client's primary objectives, through the identified elements. It does not require data from past projects, rather available information and relationship types.

change occurrence and management within two on-going construction projects, and extending the previous work with a toolkit with two main components: 1) knowledge and 2) support. Motawa(2006) used fuzzy logic technique to establish inter-dependencies between characteristics, causes and effects, and to effectuate meaningful output using 'whatif' analysis. Sun (2006) forms a holistic construction change management system. It usage can include tool support for change management workflow observation, prediction and anticipation, change documentation, control, decision-making, and learning from past experience. Motawa et al. (2007) also seek to develop an integrated system for proactive construction change management. Their proposal combines a fuzzy logic-based change prediction model with a systems dynamics model based on the Dynamic Planning and control Methodology (DPM). Their guiding four-step change process, illustrated via a low-level processoriented flowchart, is built from a synthesis of prior models sourced from the literature, as well as from the research conducted on past case studies.

Arain and Pheng (2007) present a process-oriented model, grounded in principles of effectiveness, decision-making and controls. Adapted from previous research (Arain;2005), these 6 principles are: 1) identification of variation for promoting a balanced variation culture; 2) recognize variation; 3) diagnose variation; 4) implement variation; 5) implement controlling strategies; and 6) learn from past experience. Arain (2008) then uses this to construct an electronic KB Decision Support System (KBDSS). The pilot system was built within a MS Excel environment and incorporates a graphical user interface. It was deployed to simulate the management of variations in 80 completed Singapore-based educational building projects.

Hence, many of the tools developed use different high-level process models. They are only weakly associated with empirical data from projects discussed in this review. These research efforts are also weakly associated with the development of configuration management principles. The contribution made through this critical examination and review is made in the context of reviews of the literature on change control processes(Stasis;2013).

The research reviewed in this paper also reveals efficiency losses associated with changes during construction, due to schedule and cost overruns. Major causes of these are design revisions and reworks, disputes and resolutions regarding claims, and variations in productivity levels.

This study has identified two streams in the recent research on change order control. The first is a set of empirical studies, explaining what has happened on previous projects; while the second is a set of normative studies, building models of how configuration control should be done on future projects. The review is timely as major construction projects, are implementing configuration management principles to manage change. While the extant model-building work by researchers provides a useful starting point for further research, this study argues that there is important work to do, that is less high-level and more empirically grounded, to examine, test and extend established principles of configuration management.

2.6 Summary and Conclusion

In this chapter, change orders and change management in construction projects were introduced along with concepts, techniques, and methodologies related to change orders administration that can be used to develop a negotiation methodology for complex construction disputes.

The fundamentals of changes and change orders, particularly legitimate and management aspects of change orders were extensively discussed. Change orders causes and effects in construction were explained, and various source related categories (e.g., employer, contractor, designer) were suggested. Controls for change orders and related procedures, were explained, and change management systems studies and empirical studies for change control were listed and the characteristics of each system were summarized.

Considering change orders as one of the critical causes of disputes, the contents of this chapter will be used and addressed to provide an overview of conflict and disputes in construction projects in Japanese public construction works and international construction projects in chapter 3. Considering negotiation as the most preferred method for construction participants due to its low cost and low hostility, negotiation decision support systems and the characteristics of each system will be presented in chapter 3.

CHAPTER 3 – CONFLICTS AND DISPUTES IN THE CONSTRUCTION INDUSTRY

3.1 Introduction

The construction of a project is an integrated process. Every construction project requires detailed planning and involves parties such as the owner, contractor, and subcontractors, who are contractually integrated but who have different responsibilities and knowledge. In such an environment, conflicts and disputes can arise for many reasons, including the complexity and magnitude of the work, lack of coordination among the contracting parties, poorly prepared and/or executed contract documents, inadequate planning, financial issues, and disagreements about solving many of the on-the-spot site-related problems. Any one of these factors can derail a project and lead to complicated litigation or arbitration, increased costs, and a breakdown in the parties' communication and relationship (Harmon, 2003). While changes in the work on construction projects are not unusual, the manner in which these alternatives are addressed; or not, can potentially affect the successful completion of a project by creating additional unresolved and unproductive conflicts. If the construction conflicts are not adequately addressed and managed, they can evolve into serious disputes among the parties involved and, therefore, not only could the working environment be damaged, but the cost and duration of projects may also be significantly increased (Hartman and Jergeas, 1995).

The parties involved in the construction industry are usually bound contractually and thus, the contract is the essential document used in the submission and evaluation of claims. In the early stages of a project, the owner decides on a contract strategy which takes into account the following aspects, as shown in Figure 3.1 (Hegazy, 2002): The project objectives and constraints, a proper project delivery method, a reasonable design/construction interaction scheme, a proper contract form/type, and administration practices.

Different considerations of these factors produce different contractual forms, which shape the process by which conflicts are addressed in construction projects. Considering change orders as one of the critical causes of disputes, an overview of conflict and disputes in construction projects in Japanese public construction works and international construction projects is provided in this chapter.

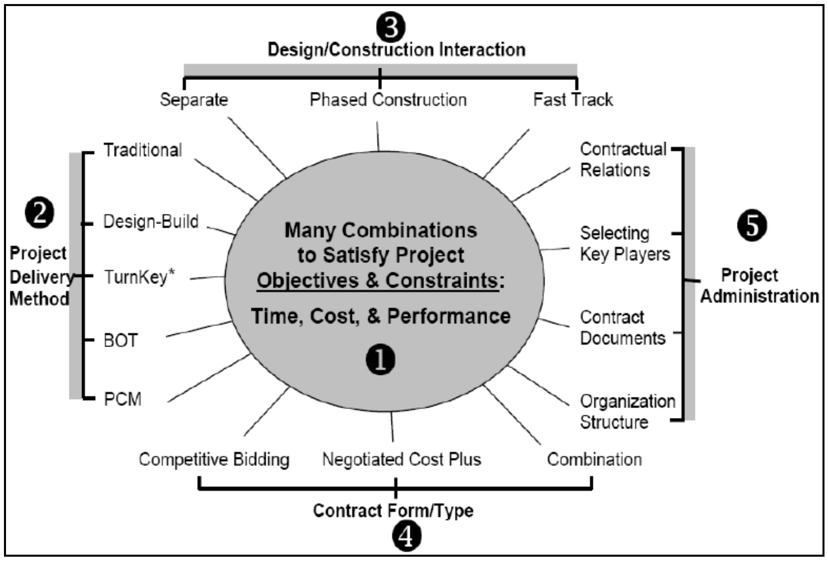


Figure 3.1: Key Considerations in a Contracting Strategy (Hegazy, 2002)

3.2 Causes of Conflicts and Disputes in the Construction industry

Although each construction project is unique, the causes of conflicts are generally similar. They arise from the complexity and magnitude of the work, from multiple parties having different objectives, from unrealistic expectations, from poorly prepared and/or executed contract documents, from financial issues, and from communication problems. A list of the identified causes of disputes in construction is shown in Table 3.1; it represents a compilation from many studies (Ock and Han, 2003; Loosemore, 1999; Harmon, 2003; Fenn et al., 1997; Cheung et al., 2002).

It should be noted that this list is not comprehensive and other causes of disputes in construction projects may exist. The parties involved in construction projects can significantly influence the number and extent of the causes listed in Table 2.1. When a dispute arises on a project, the disputants behave according to different perceptions, needs, objectives, constraints, aspirations, interests, preferences, and/or levels of reservation (Semple et al., 1994; Harmon, 2003).

One of the reasons for these differences is the disputants' varying type of expertise in a construction project. For example, architects have an educational background in aesthetics, whereas engineers have knowledge of the analysis and design of structures and the owner often concentrates on project control and administration. Conflicts and disputes arise when they have

Table 3.1: Compiled causes of disputes in the construction industry

Contractual Causes	Organizational Causes	Technical Causes
1. Varied interpretations 2. Unusual weather 3. Delays 4. Accelerations 5. Contract pressures 6. Contract factors 7. Changes in project 8. Increase in scope	1. Deteriorated relationship 2. Owner's failure to act administratively 3. Improper contractor site management 4. Site availability problems 5. Inadequate contractor organization 6. Change in regulations 7. Problems with neighbors 8. Economic conditions 9. Lack of positive attitudes among the involved parties 10. Lack of proper communication: 10.1. In one organization 10.2. Between two involved organizations, and 10.3. Between the involved and the external organizations.	1. Improper planning 2. Technical mistakes 3. Technical negligence 4. Quality of materials 5. Consultant technical problems 6. Defective specifications: 6.1. Improper workmanship 6.2. Improper design 6.3. Technical misperceptions

to communicate with one another about the project because their background and training are very different and lead to different perspectives on the project (Fenn et al., 1997).

None of the parties usually has an in-depth overall view, which may hamper the finding of a common meeting ground. Any viable means of reducing the incidence of conflicts and disputes (e.g., developing positive attitudes among the parties involved) should have a positive effect on the outcome of the project (Jergeas, 2008). The construction participants are themselves aware that unresolved conflicts and their resulting legal and consulting fees add no value to construction projects.

3.3 Alternative Dispute Resolution

Traditionally, unresolved conflicts and disputes involving large scales, complex construction projects can be resulted in complex construction litigation (Pinnell, 1999). Litigation is a dispute when it has become the subject of a formal court action or law suit. Anyone who has ever been involved litigation knows that it is expensive, time consuming, emotionally draining and unpredictable. With litigation, until a judge or jury decides who is right and who is wrong, the outcome is not certain. Alternative Dispute Resolution tactics, such as mediation, has been gaining popularity as a method to remedy the shortcomings of litigation.

Lengthy and expensive litigation processes have made construction participants less eager to have their day in court, opting instead to resolve their disputes among themselves, as has been done for a long time (Glasner, 2000). In response to the increased cost and duration of litigation, the construction industry has gravitated toward Alternative Dispute Resolution tactics (Mix, 1997; Treacy, 1995). Historically, the construction industry has been seeking innovative and creative ways to resolve conflicts and disputes arising from construction contracts (Henderson, 1996; Mix, 1997). Not only are the costs of court claims avoided, but there are also intangible benefits to avoiding court cases such as maintaining reputation and avoiding emotional stresses (Cheung et al., 2002). For example, arbitration and mediation are similar in that they are alternatives to litigation, or are sometimes used in conjunction with litigation to attempt to avoid litigating a dispute to its conclusion. Both arbitration and mediation employ a neutral third party. Both can be binding; however, it is customary to employ mediation as a non-binding procedure and arbitration as a binding procedure. The characteristics of Alternative Dispute Resolution tactics are summarized in Table 3.2. Alternative Dispute Resolution techniques can include both binding (formal) and nonbinding (informal) procedures (Kellogg, 2001; Honeyman et al., 2004). Binding Alternative Dispute Resolution is predominantly arbitration, and the binding method sometimes used in construction (Di-Donato, 1993). Nonbinding Alternative Dispute Resolution techniques normally include mini-trials, mediation, third-party neutrals, Dispute Review Boards (DRBs), and negotiation.

Because of its low cost and low degree of hostility (Figure 3.2), negotiation is the tactic most preferred by construction participants. In construction conflicts and disputes, negotiation occurs every time the parties communicate directly with one another about disputed issues. Some negotiators seek agreement that offers the opportunity to avoid the "disruptive consequences of non-settlement" (Colosi, 1999). The honest negotiation of changes and claims helps mitigate disputes before they damage the relationship and become major problems (Zack, 1995). In negotiations, team members often have conflicting goals and values, but when properly performed with cooperative mindsets of decision makers towards one another, negotiation achieves their objectives while maintaining harmony, and reducing time, cost, and hostility. Richter (2000) illustrates a continuum of Alternative Dispute Resolution procedures, as shown in Figure 3.2, which clarifies that negotiation not only involves the least cost and degree of hostility but also provides the parties involved with the most control over the outcome of the disputes. In other words, negotiation is the best tactic for participants who would like to make their own choices in a conflict situation. In construction, negotiation is sometimes considered a relief from

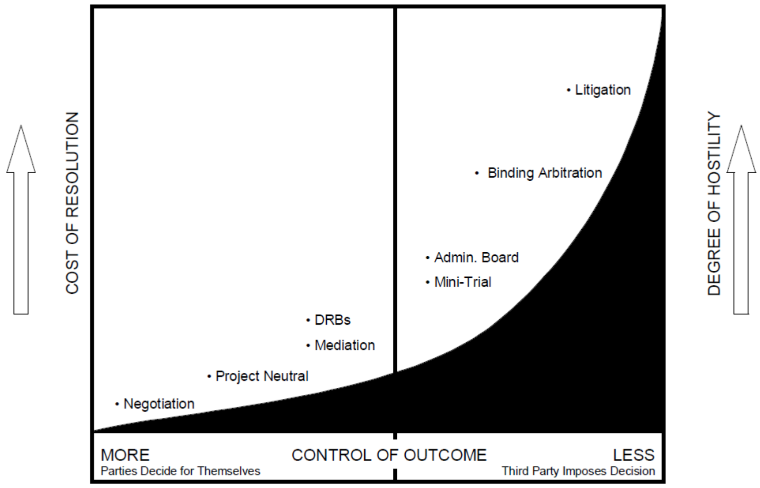


Figure 3.2. Dispute resolution continuum (Richter, 2000)

the normal administration of the contract, for it offers both parties involved the opportunity to break from the daily administrative pressures of the contract and thus provides a better environment in which the conflicting issues are discussed in order to reach mutual agreement (Hartman and Jergeas, 1995).

In a negotiation process, effective negotiation skills are a tremendous asset to any successful executive. They are especially significant for construction executives who are continually involved in managing and administering complex contractual relationships involving substantial amounts of money (Jergeas, 2008). However, many individuals often fail in negotiation not because they are unable to reach an agreement, but because they walk away from the table before they achieve the results they are capable of obtaining. Moreover, in spite of the importance of negotiation, proper training in negotiation skills is not provided within the construction industry.

Negotiations are an important activity, but they are the subject of little research or education (Dudziak and Hendrickson, 1988). Project managers seem to learn negotiating skills only through experience and observation (Smith, 1992). Therefore, negotiation support tools for the construction industry may be useful in enabling the participants in a project to handle negotiation more productively.

Table 3.2 The characteristics of alternative dispute resolution techniques (Harmon, 2003)

Tactics	Application	Advantages	Drawbacks
Litigation	Traditional approach for large complex projects. Last preferred tactic.	Appropriate for large complex disputes, formal win-lose method with assigning damage compensations via a court appeal.	Expensive, time consuming, fraught with flaws, affect parties' reputations.
Arbitration	Alternative to litigation with more preference, incorporated into standard contracts.	Very common usage, acceptance of evidences, maintains the confidentiality of the proceedings, more cost-efficient than litigation, preserved business relationship between parties.	More time preparation, no quick and easy answers to resolving the problem, procedural complexities, adversarial approach, lack of the appeal process.
Mediation	A nonbinding, consensual process, a form of distributive justice, a form of assisted or guided negotiation, better to use before arbitration.	Faster, less expensive, more confidential, and more satisfactory way than litigation, minimizing future disputes by maintaining open communication between the parties, creates a win-win outcome that satisfies both parties, very flexible.	Procedural complexities, leading to a compromise settlement, sometimes resulting in subjective outcomes which may confuse parties.
Med./Arb.	A hybrid of mediation and arbitration, binding mediation, considered as a new and enhances tactic.	Encourages the parties to settle rather than lose control of the outcome if arbitration becomes necessary, includes the capabilities of mediation and arbitration.	Creates some dilemmas for either pursue or hold back from mediation part, not so much used in the construction industry.
Mini-trial	A nonbinding hybrid ADR process, it is not a trial, and is held after other alternative dispute mechanisms have failed, but before an actual trial.	Predicts the results of an actual trial, thereby enabling the parties to come to a decision to resolve their dispute before applying for a full scale trial.	Presentations at a mini-trial are time limited, each party must have a relatively good understanding of its issues and the opposing parties' refutations and issues.
ENE * (third-party neutral)	Used early in the litigation process, a court-ordered process, an informal, nonbinding procedure.	Resolves disputes sooner rather than later, thereby circumventing the need for trial preparation, an alternative to expensive discovery and resolving complex technical issues.	Evaluation can be based on predicting the outcome of a trial or arbitration, the procedure is not very straightforward.
Partnering	Seeks to change attitudes about the relationships between parties, establishing trust and open communication, considers as a preventive dispute resolution.	Reduces exposure to litigation, cost overruns, and delays, promotes mutual rather than bifurcated goals, and restores the spirit of cooperation.	Not a suitable tactic if the root causes of disputes are not addressed, needs a top-down approach, needs a huge amount of communication among parties.
DRB**	A unique, proactive, nonadversarial project management technique, a panel chosen prior to the start of construction.	Facilitates resolving conflicts before escalating to disputes, has familiarity with the ongoing construction and any important developments on the project.	Its focus is on circumventing disputes rather than merely resolving them, only tries to highlight and identify the root causes of disputes.
Negotiation	Applied for both non-binding and binding ADR as well as a preventive tactic.	Fast growing tactic that is very easy to settle between parties. In any stage of a contract, either before or after, is used officially and/or unofficially.	No positive outcome can be anticipated despite long discussion with the opponents, depends mainly on the opponent's attitude which is unpredictable.

*Early Neutral Evaluation, **Dispute Review Board

3.4. Negotiation Support Approaches in the Construction Industry

Several cases in the literature discuss the application of negotiation support approaches in the construction industry: see, for instance, Aouad and Price (1994), Aouad et al. (1996), Ngee et al. (1997); O'Brien and Al-Soufi (1994), and Shash and Al-Amir (1997). They have found that negotiation support approaches enable construction activities to be programmed and executed in a speedy and cost effective manner. Many applications that have been impossible in the past are now feasible, such as a project information management system that can handle tasks like construction programming and information storage and retrieval.

Spreadsheets were among the earliest information management systems that had a profound effect on the widespread use of support systems among construction participants. They have strong features such as their intuitive cell based structure and their simple interface that is easy to use even for a first-time user. Underneath the structure and the interface are a host of powerful and versatile features, from data entry and manipulation to a large number of functions, charts, and word processing capabilities (Hegazy, 2002). In order to increase productivity and versatility, programmability options, a number of add-in programs, and features that allow Internet connectivity and workgroup sharing, have been also added to newer spreadsheet versions. Because of their wide uses particularly among construction professionals and participants, spreadsheets have proven suitable as a decision support system for developing computer models that require ease of use, versatility, and productivity, such as those for decision support methodologies. For example, a decision support system for construction conflict resolution is developed by Kassab et al. (2006) that uses Ms Excel spreadsheet as the system platform. It should be mentioned that Ms Excel spreadsheets have been applied successfully in many infrastructure applications such as planning and cost estimation for highway projects (Hegazy and Ayed, 1998), Critical Path Method and time-cost trade-off analysis (Hegazy and Ayed 1999), construction delay analysis (Mbabazi et al., 2005), infrastructure asset management (Hegazy et al., 2004), and cost estimation for reconstruction of educational buildings (Yousefi et al., 2008). Table 2.4 summarizes the applications of negotiation systems in the construction industry and some of these efforts are briefly explained below. It should be mentioned that the research efforts summarized in Table 3.3 are based on the available reviewed literature and other related studies can be added to the list. Shen et al. (2007) successfully applied bargaining-game theory to obtain detailed concession periods for construction contracts. Game theory principles were used particularly to determine specific time spans between moves. In other words, game theory was employed as a complementary technique for the methodologies that help decision makers with strategic decisions (i.e., to determine a broader range for the concession period). The paper, however, did not consider all the factors (e.g., political, risk attitude, reputation, and contractor's economic condition) that may influence the outcome of bargaining. Nevertheless, with improvements, the technique used in this research has potential benefits for use in the negotiation of construction disputes.

Molenaar et al. (2000) developed a systematic framework for quantifying dispute factors. The purpose of the research was to explain how and why contract-related construction problems occur: logistic regression was used to model the likelihood of construction disputes arising. The study provides a methodology for quantifying contract disputes. In game theory, these issues are considered in terms of cardinal and quantified values.

Cheung et al. (2004) developed a construction negotiation support system, namely CoNegO, which assists parties by providing a suggested solution for a construction dispute. In CoNegO, the communication component is the Internet, and the data accessibility component manages the sharing of information. The negotiators first study the construction dispute case and then formulate the bargaining ranges for each issue using two cardinal values: the pessimistic value represents the baseline of the negotiator with respect to a particular issue (no further concession will be offered beyond this value) and the optimistic value represents the value that produces the highest satisfaction for the negotiator. Negotiators must also determine other parameters for each issue, such as relative importance and satisfaction rating. Although the research provides a valuable approach to a negotiation methodology, it is based on the subjective evaluation of the negotiators. For example, a negotiator may exaggerate his or her position to provide a better negotiation position, or either or both parties may inflate their opening demands, misrepresent their positions or interests, withhold sensitive or potentially damaging information, or use threatening behavior. These issues need to be addressed.

Table 3.3: Negotiation systems studies in the construction industry

Authors	Objective	Method	Factors	Comments
Shen et al. (2007)	Obtaining concession period for BOT-type contracts using game theory.	Bargaining game theory, utility functions.	Players' utility functions, net profit values, time value, bargaining costs and payoffs.	Feasible applications of game theory in construction in which game theory was used to obtain shorter range of concession time period acceptable by both parties.
Molenaar et al. (2000)	Develop a structural equation model framework for quantifying dispute factors between owners and contractors.	Regression analysis as a statistical tool.	Owner management ability, contractor management ability, project complexity, risk, allocation, and project scope definition.	No basic theoretical concepts; only a case study to identify the dispute factors; thus, not a solid work for future research, but good effort to develop a framework for dispute negotiations.
Cheung et al. (2004) (CoNegO)	Assists parties by providing suggested solution for construction disputes.	'Even Swaps' eliminating approach, and tradeoff methodology.	Disputant's issues, Satisfaction graph and rating, the weight of each issue.	Considerable effort to structure negotiation process, but lacks some basic analytical issues for parties such as defining payoff and utility functions for each issue and party.
Ren et al. (2003) (MASCOT)	Develop a multi-agent system for construction claim negotiation (MASCOT).	Probability equations and utility functions.	Rational outcomes, and Risk acceptance to the contractor agent (Pc-max) and engineer agent (Pemax).	Many problems still need to be addressed (the level of empowerment of the MASCOT, the encoding of claim participants' knowledge, and the qualitative claims negotiation), no potential useful research for construction.
Omoto et al. (2002)	Develop bargaining model for construction dispute resolution.	Game theory principles and bargaining model.	Owner's acceptance and/or rejection, and contractor's acceptance and/or rejection.	There are some possible future developments; the basic concept can be used for future applications.
Gibson and Gebken (2006)	Framework for improving project decision making through dispute identification, assessment, and control.	Regression analysis.	Transactional cost, contract amount, original claim, settlement amount.	Transactional costs of dispute resolution efforts are outlined which is a new aspect investigated in the dispute discussion; the concepts can be considered in developing construction negotiation systems.
Yaoyueyong et al. (2005)	Develop an online multiplayer construction negotiation game.	Computer simulation techniques.	Online user database, real time multiplayer system, online votes, scoring system.	Applying negotiation concepts to be added to the negotiation games; no theoretical basis and mostly computer programming.
Li (1996) (MEDIATOR)	Develop a computer model (MEDIATOR) for construction negotiation.	AI techniques (CBR).	Negotiation issues and goals of both parties, case negotiation adoption.	The model cannot 'recognize' the 'thrown-away' issues and goals at the start of a negotiation; further research effort is needed to investigate the feasibility of implementing this ability; potential future development to use hybrid AI techniques.
Ngee et al. (1997)	Develop a mechanism for negotiation of BOT-type contracts.	Multiple regression analysis.	Financial and contractual factors such as tariff, concession period, and rate of return.	A practical and well-developed negotiation mechanism that can be further developed and adapted for reconstruction and brownfield projects.
Shin (2000)	Identify critical dispute characteristics during construction operations.	Content analysis (qualitative data), and statistical analysis (quantitative data).	Personnel, organization, cost, schedule, risk, environment, contract, time, and budget.	Very well-developed research in developing a framework for dispute knowledge management by converting precedence disputes into a source of knowledge for current dispute identification; further research to refine dispute knowledge management can be pursued.

Ren et al. (2003) developed a system specifically for construction claims called MASCOT that utilizes utility theory. Each party is assigned a linear utility function which can be determined by two points: the optimum point and the reservation point. Each party can then estimate the opponent's utility function based on these two critical points. The proposed methodology was developed based on many constraints and idealized assumptions, including quantitative negotiation, rationality, and fixed utility function. These assumptions decrease the accuracy of the outcomes produced by this system. The research also provides some future work to improve the system.

Yaoyueyong et al. (2005) developed an online multiplayer construction negotiation game called Virtual Construction Negotiation Game (VCON), as an innovative tool for negotiation training in the construction industry. In their research, the procedure for developing an Internet-based negotiation system is clearly explained, and the ideas can be used in the development of future computer support systems. Development of the VCON game can be classified into four major phases: the identification of game requirements, system design, software development, and system testing. The drawback of this system, as with many other developed systems, is that the behavioral aspects of decision making (negotiating), particularly the changes in the attitudes of the negotiators during the negotiation, are not taken into account.

Li (1999) designed MEDIATOR a computer system for construction negotiation, which employs a Case-Based Reasoning (CBR) technique to provide intelligent support for construction negotiations. CBR uses previous cases as a basis for addressing new problems. In contrast to conventional expert systems (ESs) that use compiled knowledge in problem solving, the system selects similar cases to help solve a given negotiation problem. The selected cases are then modified and adapted to generate proposals that should move negotiators towards a settlement. The system uses three techniques to modify and transform selected cases in an attempt to generate new proposals: modify the reservation values, introduce new issues and goals, and select additional cases. Although the research tried to use Artificial Intelligence techniques (e.g., CBR) in developing a negotiation methodology, there are significant difficulties in using CBR, for example, in collecting previous negotiation cases. Direct collection is difficult because negotiation history is seldom recorded and documented. Hence, it is very difficult to reconstruct and understand how the results of the negotiation were arrived at. Another difficulty in using CBR lies in capturing the original context of a negotiation. In other words, in special economic and political conditions, negotiators may make concessions at any cost in order to win with respect to specific issues. When a negotiation case for a problem is reused in a different economic climate, it is necessary to know the initial context so that it can be adapted consistently. Therefore, one should be cautious in using CBR or other AI techniques that use historical data as input to the model.

The above studies provide important insights into the application of negotiation support systems in the construction industry. A variety of decision-making techniques have been used, and many studies have been carried out in order to make sure that the decision-making models are as accurate as possible.

As Fisher et al. (1991) emphasize, any negotiation takes place at two levels. The first level involves "negotiation of the substantive issues" (e.g., contract price). The next level of negotiation refers to "the procedure for dealing with the substantive issues". This "upper" level dictates how each side plays the game of negotiation. For instance, one can negotiate by hard positional bargaining, by a cooperative approach, or by another method (Fisher et al., 1991). The objective for the research in this thesis is the development of a systematic, reliable, and sustainable negotiation methodology that is suitable for application to complex construction disputes both in domestic and international construction projects

3.5 Dispute Management Provisions in Japanese Public Construction Works

The Japanese construction business law requires parties involved in a construction contract to make the contract based on equal footing and to fulfill their own duties faithfully and honestly. Thus Japanese contracts are formed on the basis of 'mutual trust' where the contracting parties are expected to perform their duties and fulfill obligations honestly and faithfully. Japanese public construction works have been carried out under the two-party i.e. Owner-Contractor system and the role of the Consultants is not evident for the execution of the projects. The Consultants are being employed for design and making construction documents. However, the Consultants are employed in Japanese official development assistance (ODA) projects for investigation, design and supervision of the construction in the aid recipient countries. Unlike to the Japanese public works construction and grant aid projects, the contracts under the JBIC (Japan Bank for International Cooperation) ODA loan projects have been designed and executed under the 'mutual mistrust' environment. The owner in the Japanese public construction works assumes large authority to determine and to make decision over any issue aroused whereas the Consultants play significant role in the claim/dispute management in ODA construction projects.

a) Standard Form of Contract for Public Construction Works

A construction project is executed under the conditions and scopes stipulated in the contract. The special and general conditions of contract stipulates the roles, responsibility and liabilities of the contracting parties and provides the procedures for whole contract execution including payment, inspection, Change order, claim/dispute settlement. The major provisions included in the Japanese general conditions of contract for public construction works for the consideration and resolution of claims/disputes are: i) claims on action regarding the Superintendent, Engineer and Project Manager (article 12), ii) Differing Site Conditions (article 18), iii) Changes to drawings and specifications (article 19), iv) Suspension of works (article 20), v) Extension of construction period (article 21), vi) Acceleration of construction period (article 22), vii) Procedures for adjustment of construction period (article 23), viii) Procedures for adjustment of contract price (article 24), ix) Adjustment of contract price due to price level change (article 25), ix) General provision for Damages (article 27), x) Damages upon third party (article 28), xi) Damages from force majeure (article 29), xii) Alternative to adjustment to contract price, xiii) Liquidated Damages for arrears (article 45).

b) Change Order

Change order in the Japanese construction industry has been addressed under the articles: Differing Site conditions (article 18) and Changes to Drawings and Specifications (article 19). These articles require the Contractor to promptly inform the Owner about the differing site conditions but do not stipulate any notification deadline beyond which the Contractor is not entitled to be compensated. The contract is not clear about the requirement for the Contractor to submit the Owner sufficient supporting documents to show the changes in the site condition has actually affected or will affect in the schedule and quantity of works, but it provides the provisions for the Project manager to verify and survey to confirm the difference in the site conditions. Similarly, when the Owner changes the original drawings and specifications it is dealt under Changes to drawing and specifications. In both the cases if the Owner confirms the changes, the articles say that ‘the Owner shall adjust the Construction period or the Contract price, if necessary, and shall bear damages incurred by the Contractor, if any.’

3.5.1 Negotiation and Dispute Resolution Procedure

Figure 3.3 shows negotiation and dispute resolution procedure of Japanese public works based on "The Standard Form of Agreement and General Conditions of Government Contract for Works of Building and Civil Engineering Construction: GCW". Summary of the process is stated below.

1- Negotiation between owner and contractor

First phase is negotiation between owner and contractor. Contractor can claim time extension of the construction period and/or additional cost against the owner. After owner receives claim documents from contractor, owner decides and notifies the start day of negotiation. Negotiation period is usually 14 days. If they cannot reach an agreement within negotiation period, owner decides and notifies the adjustment to contractor. If contractor does not agree to this adjustment, they can go to dispute resolution procedure.

2- Dispute resolution procedure

Second phase is dispute resolution procedure. This procedure is called "Alternative Dispute Resolution". Mediation and arbitration are kinds of Alternative Dispute Resolution. Mediation does not bind the owner and contractor. Arbitral award binds the both parties. Mediator/Arbitrator will be member of "The Central/Prefectural Committee for Adjustment of Construction work Disputes (CACD)". These organizations are public third party.

3.5.2 Problem of Negotiation and Dispute Resolution Procedure

Unilateral matters were not existed in the settlement method of negotiation/dispute resolution procedure. However, actually, few contractors make claim against owner in Japanese construction industry. Furthermore, almost contractors give up getting time extension and/or additional cost after receipt of owner's notification of first judgment.

They usually don't think to go to mediation/arbitration procedure. Reasons are thought to be as followings:a) Sense of "Master-servant relationship" b) Contractor afraid of owner's displeasure. They usually think to get future contract with same owner. Owner's displeasure will influence to future business. c) Little knowledge of contract. d) Sue and arbitration is not usual in Japanese business culture. e) Contractors have doubt for neutrality of CACD. Because this organization is public organization. They think "Can public organization make disfavored judgment for public owner?"

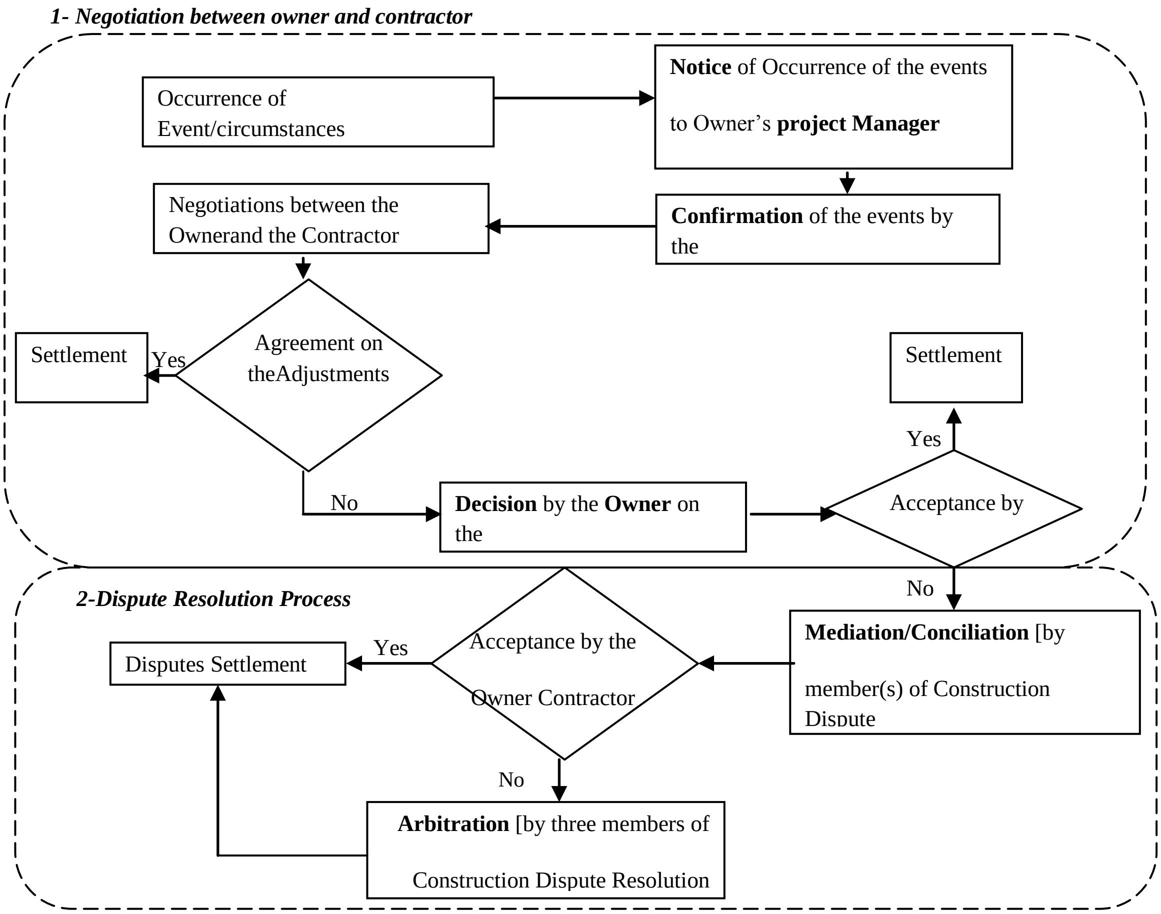


Figure 3.3 Dispute resolution process in Japanese public construction works based on GCW

3.6 Dispute Resolution Mechanism in International Construction Projects

Unlike to Japanese public construction work, international construction projects are executed in the mutual mistrust environment and the conditions of contract are based on the FIDIC conditions of contract. FIDIC (the International Federation of Independent Consulting Engineers) Conditions of Contract for construction Projects also known as the Red Book contains, in addition to clauses governing the claims of the Contractor resp. Employer, a contract clause on variations (Clause 13 Variations and Adjustments).

In a comparative sense, the multi-tier dispute resolution procedure of Clause 67 of FIDIC's well established fourth edition of the Red Book (1987) has been retained in the 1999 FIDIC contracts for construction works, but the role of the Engineer as an adjudicator of disputes has been relegated in favour of allocating the role of adjudication to a board of in dependent professionals, usually three, referred to as Dispute Adjudication Board, "DAB". However, the role of the DAB has been made wider to encompass dispute avoidance as well as dispute resolution. Dispute avoidance can only be used if both parties wish it to take place whereas dispute resolution can be initiated by one party alone once a dispute arises.

The dispute resolution procedure of the 1999 FIDIC contracts for construction works is contained in Sub-Clauses 20.2 to 20.8 of the Contract Conditions. As mentioned above, it is also a multi-tier process. It starts with a dispute adjudication procedure followed by an amicable dispute resolution mechanism and if both of these fail, then arbitration. Once again, due to the fact that the procedure is a difficult and complex one, it is easier explained and better understood by using flow charts. Figure 3.4 shows, essentially, the procedure comprises only five steps that can be summarized as follows:

1. Step 1: A dispute arises.
2. Step 2: The dispute is referred to the DAB in writing for its decision, under Sub-Clause20.4.
3. Step 3: The DAB gives notice of its decision within 84 days or it fails to give a decision within that period.
4. Step 4: The Parties react to the decision of the DAB, which could be one of two possibilities:

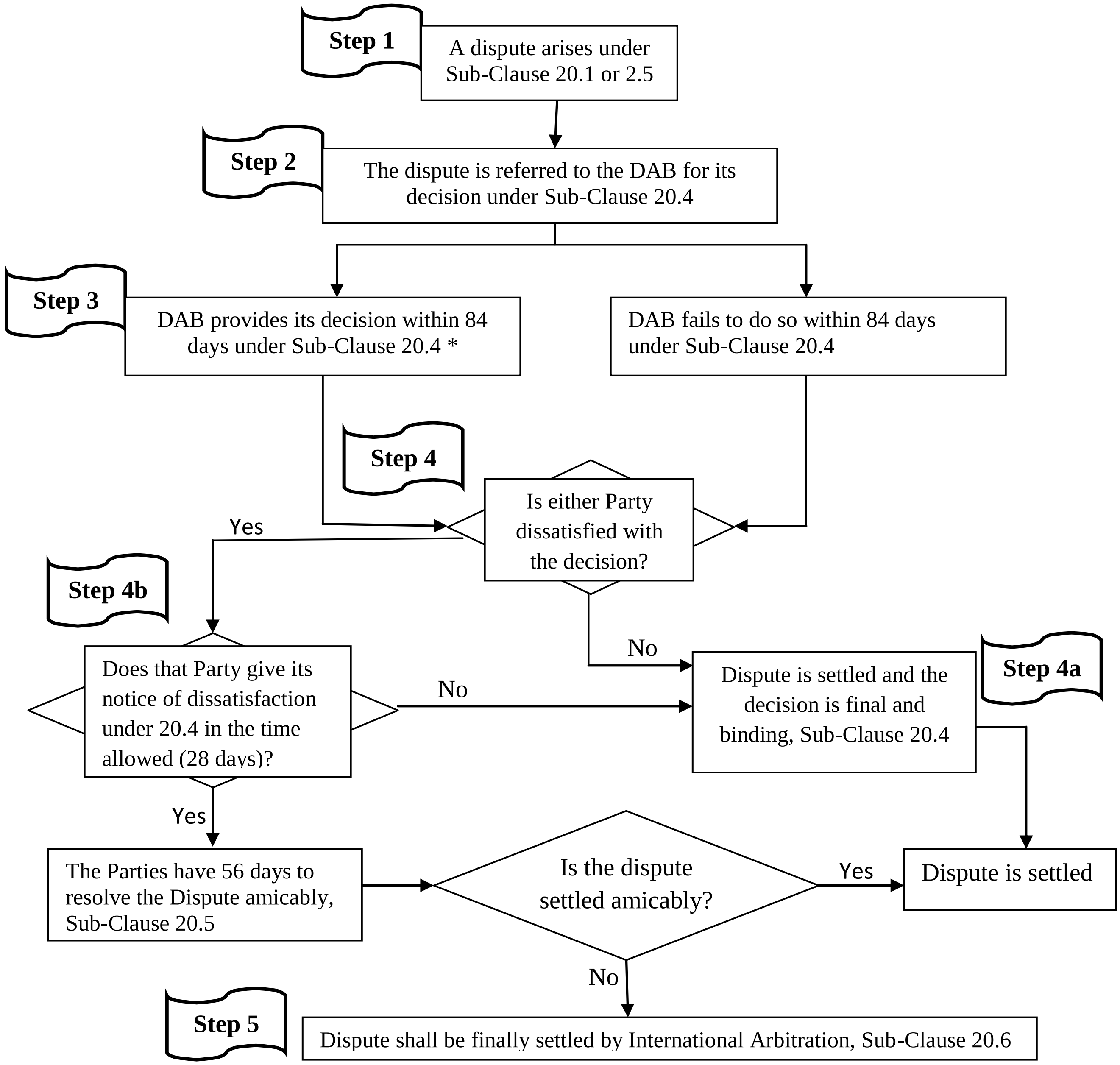
(a) Both Parties are satisfied with that decision, the dispute is resolved and such decision becomes final and binding; or

(b) At least one of the Parties is dissatisfied with the decision of the DAB, or with its lack of decision, and thus notifies the other Party of its dissatisfaction within 28 days. In this case, the Parties are given 56 days to attempt resolving their dispute by amicable settlement, under Sub-Clause 20.5. If the attempt is successful, the dispute is resolved. If not, step 5 applies.

5. Step 5: If the attempt to amicably resolve the dispute fails, such dispute is to be finally settled by international arbitration, under Sub-Clause 20.

It is important to note that irrespective of whether the dispute is resolved through steps 4(a) or 4(b), the decision of the DAB becomes binding on the Parties pursuant to the terms of Sub-Clause 20.4, which provides in its fourth paragraph the following wording: “The decision shall be binding on both Parties, who shall promptly give effect to it unless and until it shall be revised in an amicable settlement or an arbitral award as described below. …”.

The effect of this provision on the decision of the DAB is known technically as a “temporarily final & binding” effect. The decision must be complied with by both parties, which is a characteristic feature of the FIDIC DAB procedure under the 1999 FIDIC contracts for construction works distinguishing it from the DRB procedure under other forms of contract. The



** The decision shall be binding on both Parties, who shall promptly give effect to it unless and until it shall be revised in an amicable settlement or an arbitral award.*

Figure 3.4 Dispute resolution procedure under clause 20 of the 1999 FIDIC contracts for construction works.

decision becomes, in effect, a contractual obligation on both Parties such that non-compliance with it by either of them is a breach of contract and the Party in breach would be liable in damages.

The provisions that describe the situation where one Party is dissatisfied with the DAB's decision are contained in the fifth and sixth paragraphs of Sub-Clause 20.4. They provide that the dissatisfied Party must give a notice to this effect to the other Party within 28 days of the DAB's decision. These two paragraphs also provide that, except as stated elsewhere (Sub-Clauses 20.7 and 20.8), neither Party shall be entitled to proceed to arbitration of the dispute unless such notice of dissatisfaction has been given.

There are three consequences to a properly given decision by the DAB under Sub-Clause 20.4 of the 1999 FIDIC contracts for construction works. These are as follows:

1. The decision of the DAB affects the Parties' rights and obligations and as such it is binding on the Parties who are required to "promptly give effect to it unless and until it shall be revised in an amicable settlement or an arbitral award", as described in Sub-Clauses 20.5 and 20.6 of the contract conditions.

2. Sub-clause 20.4 also stipulates that "If the DAB has given its decision and no notice of dissatisfaction has been given by either Party within 28 days after it received the DAB's decision, then the decision shall become final and binding upon both Parties". (emphasis added.)

3. However, if a notice of dissatisfaction is given by either Party within 28 days after receiving the decision, setting out the matter in dispute and the reason(s) for dissatisfaction, then both Parties are required to attempt to settle their dispute amicably, as stipulated under Sub-Clause 20.5, before commencement of arbitration. Furthermore, as set out in Sub-Clause 20.6, unless settled amicably, any dispute in respect of which the DAB's decision has not become final and binding may be finally settled by international arbitration.

As a result of the first consequence, Sub-Clause 20.7 deals with the possibility of non-compliance with the DAB's decision. However, although the clear intention of Sub-Clause 20.4 is that the DAB's decision should be complied with promptly, unless and until it is revised in a subsequent forum (amicable settlement or arbitration), and irrespective of whether or not one of the Parties is dissatisfied with it, Sub-Clause 20.7 is worded in such a way that it only deals with the event where the Parties are satisfied with the decision. The draftsmen did not deal with circumstances where the parties are dissatisfied with the decision, leaving that situation without any prompt solution or elucidation, hence creating a gap.

It is also worth noting in connection with the amicable dispute resolution requirement in the 1987 Red Book and the 1999 FIDIC contracts for construction works that it is obligatory on the parties, and to correct the erroneous belief that some commentators have that this is intended to be a "cooling off period". There are two reasons for the process being obligatory, the first is to remove any perceived idea that a proposal by one party towards amicable settlement is a sign of weakness in its case and second reason of making the process a mandatory step before reference to arbitration is the avoidance of any possible blame being attached to the decision maker who pursues amicable settlement of a dispute instead of the ultimate forum of arbitration.

Finally, it is worth mentioning that Sub-Clause 20.8 of the 1999 FIDIC contracts for construction works provides that where there is no DAB in place, any dispute arising should proceed directly to arbitration without the benefit of the two intermediate steps of DAB and Amicable Settlement. In this regard, it is in stark contrast with the provisions of the 1987 Red Book, which required an Engineer's decision before either party could proceed to arbitration. That position presented a problem in circumstances where the dispute arises after the works had been completed and the Engineer has departed from the Site. This problem does not exist any longer in the 1999 FIDIC contracts for construction works.

3.7 Comparing Dispute Resolution Mechanism between Japanese Public Works and International Construction Projects

A claim is considered to be a rightful due in the international construction market and the party which assumes, because of for instance change in contract conditions, scopes, etc., the other party should compensate him often file a claim to other party. However, a claim in Japanese domestic construction market is treated as complain and is often filed in the form of petition (Kusayanagi, S, 2007) which indicates that the contractors in the Japanese construction industry do not assumes a claim be a rightful due.

The FIDIC conditions of contract provides clear provisions/conditions for the dispute management with deadline of notification, submission and decision making period, however the Japanese conditions of contract for public works do not usually stipulate the time period for notifying and decision making. Although such provisions may allow flexibility to either party in notifying others but the owner without stipulated time period for giving its decision allow the Owner to make decision according to the owner's convenience, and the contractor do not have base to demand timely decision from the Owner.

Although the Engineer in FIDIC conditions of contract is supposed to act for the Employer, the Engineer's decision if found unfair can be challenged in Dispute Adjudication Board and in

Arbitration which indirectly prevents the Engineer making the decision against the Contractor and in favor of the Employer. However, there is no third party engineer in the Japanese domestic public works and the Employer's (Owner) employee acts as the project manager of the project. There is no any other stakeholders' involvement which can compel the Engineer to make fair and independent decision. Thus, under the prevailing conditions of contract the fairness and independency in decision making solely depends on the integrity of the personnel employed by the employer.

However, construction engineers do not have faith in the fairness of the Engineer's decision. Thus there is little prospect of getting independent and fair decision over any issue in the Japanese domestic construction works.

As such the Japanese conditions of contract give the Employer unilateral authority, if the employer and the contractor could not reach to an agreement, to decide the additional time and cost required for the completion of the project, the contractors do not have other way except accepting the employer's determination. In addition, the Employer has discretionary power in designating the contractors for bidding. If an employer does not like a contractor the employer usually avoid such contractors from participating in the bidding. Thus, such practices and provisions in the conditions of contract for public construction works give the employer huge hidden power to compel the contractor to accept the employer's determination without complaining. The employer's direct/indirect influence to make the contractor accept the employer's determination is also the evidence to the huge hidden power of the employer in the Japanese domestic construction project. This is unlikely to happen in international construction project.

Contractors are not willing to go against the employer's decision/determination and intend for arbitration. It infers that the employers have made (or directly/indirectly forced) the Japanese contractor an obedient follower of the employer's decision, and the contractors also do not want to create any situation which make the employer to lose the trust with them. Contractors usually seek the solution from the employer over any issues. However, the case in the international construction market is not similar to the Japanese. The contractor can go for DAB and arbitration whenever the contractor is dissatisfied with the engineer's determinations. There is no hidden power in the employer which can force the contractor to accept the engineer's determinations.

Thus the international construction market provides the engineers opportunity to use full of their knowledge and skills to recover their rightful lost time and money in the execution of the project. However, the Japanese system in public works construction does not provide such opportunity for the contractors and as a result the construction engineers always sought solution from the employer instead of striving for enhancing their knowledge and skills in negotiation and administration. Because of such cultures of the Japanese construction industry Japanese contractors are prone to lose money in international construction project.

The international construction market has recognized the existence of the mutual mistrust in project management whereas mutual trust is the base of the Japanese contracts. Due to the recognition of the mutual mistrust, the FIDIC conditions of contract provide the position for the third party engineer and stipulate clear provisions for claim/dispute management. However, Japanese public works contract has not envisaged the inclusion of the independent engineer's function and gives huge power to the owner (employer) in determining and deciding over the contractual issues in the name of mutual trust. In effect, the Japanese construction industry has been suffering from the unequal recognition of the construction stakeholders at the cost of so called mutual trust.

3.7.1. Role of Project Manager in Japanese Public Works

The Japanese public construction projects are carried out in 2-actor execution system i.e. the Owner and the Contractor are involved in the execution of the project. The project manager, an employee of the Owner, is the Owner's representative for the execution of the Contract. The duties of the Project Manager, according to the article 9.1, are to exercise the power mentioned in the drawings and specification for instructions, approvals and consultation with the Contractor's representative; preparation and delivery of detailed drawings, etc. or approval of drawings, etc. prepared by the Contractor; and management & observation including inspection of the execution of works and testing/inspection of the construction materials. The project manager does not have the authority to independently decide and give his/her opinion on any contractual matter. The contract assumes that the Owner itself assumes all the authority to decide over the contractual issues and notify the contractor.

3.7.2 Role of the Engineer in the FIDIC (Red Book) Contract

The FIDIC conditions of contract (red book) require the owner to employ the Engineer for the execution of the project and the Engineer shall be deemed to act for the Employer. It clearly describes the roles and responsibility of the Engineer such as to give instructions, to issue drawings, to certify the work, to determine fairly and give decision over the contractual issues, etc. However, the Engineer's decision can be challenged in DAB and in arbitration. The Engineer is required if necessary to give evidences and to act as a witness before the arbitrator(s) of any matter related to the dispute.

The existing claim/dispute management systems prevailing in Japanese public works have made the owner dominated construction industry and the contractor are dependent to the owner for determination over the contractual issues. Such characteristic of the Japanese construction industry has made the contractors to be the obedient follower of the owner. Such contrasting Japanese construction industry culture inhibits the ability of Japanese engineers to be competent in the international construction project management including contract administration, claim/dispute management, etc.

There should not be punishment in claiming for rightful due and unequal recognition at the cost of so called mutual trust. The authority of the employer to decide unilaterally over the contractual issues and discretionary power in selecting the bidders for bidding should be scraped in order to initiate making the Japanese domestic construction environment compatible with the management practices in the international construction. A third party engineer's functions should be integrated in the conditions of contract for interpreting the contractual issues, evaluation of claim and giving independent decision.

By making the claim/dispute management system in Japanese public works compatible with the international construction market would provide domestic construction market opportunity to acquire enough skills and ability to be competent in the international construction market which ultimately enhances the return from the overseas business of Japanese contractors.

FIDIC provide the strict and detailed procedure of claim, and contractor must proceed claims according to the provisions of the contract. FIDIC clearly establishes the contractor's right of claims to changes and his burden of proof. In contrast with FIDIC, GCW form does not contain a claim provision but provides the contractors' right to negotiate with the employer. GCW does not have the provision of the contractor's burden of proof of changes. In reality, we can find the basic idea that the employer decides the changes in GCW form. In Japan, there has been a foundation that the employer has the ability to prove or verify the changes and they do not need the contractor's burden of proof. As far as this foundation exists, efficient changes are achieved without the strict and detailed procedure like FIDIC form. In addition, in the case of a public project, the employer has the burden of proof for justification of a change for the General Accounting Office. But this is not for the contractor but just for accountability for taxpayers.

3.8 Summary and Conclusion

In this chapter, considering change orders as one of the critical causes of disputes, Conflicts and causes of disputes in construction were briefly explained, and various dispute resolution methods (e.g., arbitration, negotiation, and mediation) were presented. Negotiation was presented as the most preferred method for construction participants due to its low cost and low hostility as well as the fact that it provides the parties with more control over their options and outcomes. Negotiation decision support systems were explained and were listed and the characteristics of each system were summarized.

Finally, dispute management provisions in Japanese public construction works and international construction projects, negotiation and dispute resolution procedure, and comparative study on dispute resolution mechanism between Japanese public works and International construction projects were extensively discussed.

A contract is a typical incomplete agreement that cannot describe in detail the possibility of changes in the contract which may happen in the future. "Good faith" in construction contract is regarded as the prohibition rule of the moral hazard and asymmetric information, in order to clarify the contract rationality; the idea is expressed as mathematical contract model in chapter 4. Moreover, it could be theoretically shown that "good faith" established in the market environment, is a certain condition of contract if contract is socially optimal. Also, the problems arise when existing moral hazards are also considered in chapter 5.

CHAPTER 4 - THE CONTRACTUAL STRUCTURE AND SOCIAL EFFICIENCY OF DOMESTIC CONSTRUCTION PROJECTS

4.1 Introduction

Contracts are necessarily limited in length. As a consequence, they may be incomplete in the sense that they fail to address all of the different contingencies that may arise. This incompleteness can lead to inefficiency in the contractual outcome, as evidenced by legal disputes or costly renegotiation. In order to find contract methods which correspond to globalize construction market environment, understanding contract rationality would be essential as the first step. Moreover, it is required to explore why the limit has occurred in the contract in the changing market environment.

Instances of a principal-agent model illustrate the differences among contracting problems with respect to contractual incompleteness. Consider an employer who hires a contractor to operate construction project. The project requires a multitude of decisions and investments in design, material, and construction. Suppose the employer can specify a brief list of features that matter greatly to him. In this case, he is likely to be able to reach a mutually satisfactory agreement with the contractor by writing a contract specifying those features and leaving all other features at the discretion of the contractor. If the employer instead cares greatly about a multitude of details in the construction, then he is unlikely to be satisfied with the outcome of any incomplete contract. This illustrates how the effectiveness of an incomplete contract can depend on the preferences of the contracting parties, specifically with regard to whether or not unspecified contingencies can be regarded as mere “details” that have only a minor effect on utility.

In this study, in order to clarify the contract rationality, the idea is expressed as mathematical contract model. A contract is a typical incomplete agreement that cannot describe in detail the possibility of changes in the contract which may happen in the future. "Good faith" in construction contract is regarded as the prohibition rule of the moral hazard and asymmetric information. Moreover, it could be theoretically shown that "good faith" established in the market environment, is a certain condition of contract if contract is socially optimal. Also, the problems arise when existing moral hazards are also considered in chapter 5. In this chapter, the special nature of the contract as incomplete contract is considered and then the socially optimal contract method is analyzed and the efficiency of the contract is considered whether the employer wants to maximize social welfare or self profit. The limits of the contract and moral hazard and its conquest method are then analyzed in the next chapter.

4.2 The Conventional Research Outline

There are two components of the contracting literature. The first is the incomplete contracting literature, which starts with the assumption that certain contingencies can be contracted upon and others cannot. This is typified by Grossman and Hart (1986), Hart and Moore (1988), Aghion and Bolton (1992), and Aghion, Dewatripont and Rey (1994). This is commonly motivated by the observation that some contingencies may be difficult to characterize unambiguously, even though within the model they may not differ in any mathematical sense from those contingencies that are assumed to be contractible. The standard criticism of this approach is that specifying certain contingencies as uncontractible in this way seems arbitrary.

The second component is the complete contracting literature, which derives contractual incompleteness from primitives of the model such as asymmetric information and limited commitment. Examples include Townsend (1979), Diamond (1984), Gale and Hellwig (1985), Williamson (1986), Allen and Gale (1992), Matthews (1994), and Krasa and Villamil (2000). This study contributes to former literature by considering construction contractual incompleteness.

Traditional contract theory (complete contract theory) has been exploring for a method to solve the problem of adverse selection and moral hazard due to the asymmetry of information in the contract between the parties on the assumption that all the phenomena that may occur in a contract in the future can be described. Optimal contracts are designed on the basis of complete contract theory including very complex contents while the actual contract is not complicated enough to complete contract theory requirements. In particular, if a large uncertainty intervenes construction work, writing a contract which may correspond to all situations that may occur is impossible. Rather, it is often incomplete contract which does not describe contract in detail.

Research on incomplete contract was developed by Grossman and Hart(1986). It is very difficult to show the typical prototype model of incomplete contract reflecting the diversity of actual contract. Initial incomplete contract theory deals with under-investment problems arise when incompleteness exists mainly in contract. The limitations of incomplete contract theory of Grossman and Hart, is that the incompleteness of the contract is given exogenously. In recent years, it was focused on theoretical explanations of contracting parties upon "why incomplete contract is described". Among them, a simple contract method has been found which can be efficient contract even in uncertain environments. For example, it was shown by the case where a simple contract is attainable by existence of law, by adding constraints or some extent of change in advance to a negotiation process that efficiency can be attained on a simple contract.

Aghion, Dewatripont, and Rey(1994)(Hereinafter referred to as ADR theory) pointed out that the contents of the initial contract and bargaining power distribution in the renegotiation affects the efficiency of the contract, it was shown that traditional principal-agent model assumed when only one party has the bargaining power at the renegotiation, the optimal contract is socially realizable (when it occupies all surpluses). In this research, contracting parties formulize the incomplete contract model which performs renegotiation involving contract cost and necessary time due to design conditions changes. Moreover, as ADR theory suggested, it will be proved that efficient contract can be designed when employer controls the contract changes by setting initial design conditions and necessary time. As far as the author knows, cases which analyzed the structure of the contract using incomplete contract theory are not found. This research in contrast to ADR theory shows that it is possible to realize socially optimal contract regardless of the bargaining power distribution; socially optimal contract can be realized if initial contract is designed appropriately when one of the contracting parties takes maximizing behavior for social welfare, this study also leads to incomplete contract theory.

4.3 Incompleteness of Construction Contract

Since the late 1980s (Grossman & Hart, 1986; Hart & Moore 1989), there has been a considerable growth in the literature known as incomplete contract theory (ICT). This literature sets about formalising and extending some of the insights from transaction cost theory (Williamson, 1975, 1985; Klein et al 1978). These include the ideas: that parties to trade fear opportunistic behaviour in the presence of specific investment; that insufficient contractual safeguards can result in inefficient levels of such investment; and that the avoidance of such inefficiencies provides a key element in the theory of the boundaries of the firm. Two assumptions are axiomatic of ICT. The first closely follows transaction cost theory (TCT) in that many important investments are observable ex post by economic agents close to a trade, but they are not verifiable in a court of law. In the jargon, they are not contractible. In particular, a contract cannot condition prices (or anything else) on ex post investments. The second is that parties to a contract cannot prevent themselves from renegotiating the terms if it is mutually beneficial to do so (Hart & Moore, 1988). Anticipating this, the parties use the contract in the context of an effective legal system to frame these renegotiations.

"An incomplete contract has gaps, missing provisions, and ambiguities and has to be completed (by renegotiation or by the courts) with strictly positive probability in some states of the world." (Hart, 1995) According to this definition most real world contracts are incomplete: they are not contingent on all relevant, publicly available information; they are short-term; they are renegotiated frequently; they are interpreted and completed by the courts.

The name, incomplete contract theory suggests that the theory's main concern is to consider the limitations of contracts that fail to specify not only investment levels, but also many of the other contingencies that a complete contract might wish to include in an Arrow-Debreu world. The reason for this failure might be due to bounded rationality such that some contingencies cannot be imagined, or to the cost of writing complex contracts. The theory might then ask, for example: how efficient are simple contracts that can specify, at most, only one price, one product specification and one quantity? An efficient contract is one that gives the optimal incentives for both investment and trade. This characterization of the approach suggests a fairly ad hoc limit on the ability of rational agents to write contracts. However, in practice, much of the literature has avoided this potential criticism (or aspect of reality, depending on your point of view) by adopting one of two directions that finesse the need to specify arbitrary restrictions on the content of contracts.

For the items that have been agreed as a contract, regardless of employer or contractor, complying with the contract is an obligation. The complete contract means contract which states explicitly all actions of the contractor for each situation (state) that may arises in the future. If certain circumstances occur in reality, contractor has to perform in accordance with contract. On the other hand, incomplete contract refers to the contract which has not adequately described the contract items as an action that should be devised to each situation. There are various uncertain factors in construction work, such as geological conditions, natural conditions, and design changes, change of scope of work, and legal revision and abolition. It is impossible to incorporate in a contract all the contents that happen in the future with respect to uncertainties, and it cannot help but become incomplete contract. In incomplete contract, when the type of a situation becomes clear, employer and contractor accept to renegotiate for the change of contract. Instead of describing a detailed contract that corresponds to each situation, rules of renegotiation is described in the contract. As a result, it becomes possible to simplify the contract. In an incomplete contract, it becomes significant challenge to design the rule which improves the efficiency of contract. However, it is not necessarily efficient to allow renegotiation for all of the work issues. In fact, there are some subjects in contracts which do not allow changes to contract items. On the other hand, contract items changes have been recognized as special contract issues. "Which contract item should be set as the object of contract change" is dependent on the character of contract item. From the aspect of economics of contract law, if contractor assesses risk better than employer (depends on risk item) contractor should take risks, however if it is not so, contractor can be the target of contract change. In this study, it focuses only on the contract item which is the target of contract change, and referred to as design condition of contract item which contract changes are accepted to be.

In addition, the design condition means the general item in connection with the design of civil engineering structure, and the contract item which is the target of contract change is also usually included in it. When changes occur, it usually takes form as design changes, so in the study contract item which is subject to change is called as design condition. Therefore, this research refuses to use the word "design conditions", more restrictively than common meaning.

4.3.1 Trade Particularities and Proof Possibility

In order to start construction work, it is necessary to determine construction method in advance to invest for materials procurement and installation of temporary structure. The investment is implemented in order to set the construction work, those kinds of investments which have no value for the other work purposes are called transaction specific investments (hereinafter referred to as easy investment). The cost of transaction specific investment is the sunk cost and it is impossible to correct it thereafter. After investment is completed, even if change of design condition occurs, it is not easy to change the contents of investment determined once. Completed civil engineering construction works, exclusively deal with trading partners and cannot be resell to a third party easily. Therefore, dispute which arises on contract execution must be solved among contracting parties. If it does not reach a settlement between the parties, eventually judicial resolution is planned. Performance of contract parties regarding some items such as construction cost and time which are explicitly specified in a contract can be verified in the court. However, many uncertain factors or contents of investment which accompany construction work are not specified as a concrete contract item in the contract. Even if the contract includes some descriptions regarding uncertainties or uncertain factors, it is often the case; it is difficult to assess realized states by the third party. In this case, it becomes difficult for the court and a third party to arbitrate dispute based on these occurrences. Such factors can be observed, but is said to be unverifiable. When a factor included in a contract cannot be proved, contracting parties use counterpart's investment result strategically, and hold up problem which is going to exploit the surplus which the counterpart brought forth arises. Moreover, there is a risk that moral hazard try to keep confidential information which will causes disadvantages for them. It becomes a subject to overcome the inefficiency due to hold up problems and moral hazard in an incomplete contract.

4.3.2 Japanese Contract as Incomplete Contract

In GCW terms and conditions which is a standard form contract of the domestic construction work before the revision in 1995, and in GCW contract, the specific solutions for changes of the time and costs related to construction, change of construction scope, additional construction work, and change of design conditions (construction) are not shown. For example, in the GCW standard contract terms and conditions, dispute by construction work is described "Contracting parties shall negotiate and settle about the item which is not provided in this contract or agreement as needed basis."

It is assumed that finding the direction in which to convince both parties while respecting the position does not clearly describe how to resolve the dispute or contract change in the construction business in Japan, which is based on the agreement on mutual trust.

Although there is no description of the problem-solving method in construction contracts, it is more possible than many past examples of public projects practices to find out some characteristics of dispute resolution methods. After the revision in 1995, it can be said that substantial feature of construction contract terms and conditions describe below has not changed.

First is a contract with unilateral nature. More contracts are incomplete, so the possibility of contract change is present. Although having equal rights and responsibilities between the parties is a principle of the contract, the employer demonstrates a leading role with respect to contract change in Japan. Secondly is the bilateral nature of the contract, lack of claims terms can be mentioned as one feature which accompanies the contract. Contractor has the rights respect to contract terms, design and additional cost claims (claims) by change of construction conditions. However, additional costs of contract change will not be determined by negotiation between the parties, but it will be calculated based on the prescribed cumulative methods which the employer specified in the contract.

Thirdly, contracting parties mainly implement construction based on good faiths, that does not cause hold up and moral hazard as described. In addition, long-term relationship between contractor and employer has to ensure the effectiveness of the principle of faith and trust. Fourthly, there are some premises that the employer maximizes the social welfare as representative of the public and he does not perform opportunistic behavior to pursue private interests and also the changes in the results when he has opportunistic behavior to pursue private interests. It is assumed that trust relationship is between employer and contractor. Although the above is the typical characteristics of the contract, in this research, the idea of contract with these characteristics is formulized as incomplete contract model.

4.4 Socially Optimal Contract Model

4.4.1 Prerequisites of the Model

In socially optimal contract model, it is assumed that employer is public principal, and contractor's action can be observed completely and can be controlled. In reality, employer cannot necessarily control contractor's action completely. In particular, contractor will act so as to maximize self profits, when a private sector construction company becomes contractor.

In this sense, the contract form which socially optimal contract model is trying to draw is not realistic. The purpose of socially optimal contract model is to obtain the desirable form of contract which maximizes the social welfare defined as the sum of consumer and producer's surplus.Currently, construction work is implemented according to logical order relationship as shown in figure4-1.

The contract related to construction work is concluded between employer (Principal) and contractor (Agent). Contract is described by contract cost p_0, time q_0, and design condition ε_0 and contract change rules of the time and cost due to design change. After employer and contractor agree on a contract, both implement the investment together. Investment level denotes according the investment level of employer by i and contractor by j. Investment is completed in time b. Construction design conditions will be decided by the time c of construction beginning.

Design condition here means the uncertain factor which exceeded the range of employer's control in natural conditions, such as ground conditions, or socioeconomic factor as mentioned above. It is at the time c that contractor and employer have the complete information about the

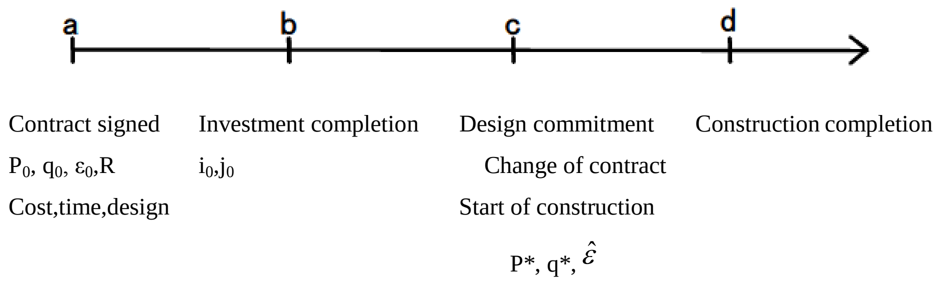


Figure 4.1 Logical order relation of contract

occurrence of design condition, and if change of design occurs, employer will change time which makes social welfare the maximum. Contractor is not allowed to challenge regarding the contents of the change of contract. Construction is completed in time d. The time d is more than time c if there is no change in the original contract when time q_0 having passed, the contract cost p_0 should be paid by employer to contractor.

When contract is changed, new contract cost p* and time q* at the time c. Time c is a time just after construction starting time after the change. Time q* passing at the time d, and contract cost p* is paid to contractor from employer. Employer has the ownership of contract subject simultaneously with the payment of contract cost. In addition, in the following discussion, the essential structure of the discussion does not change even considering the discount rate. In order to avoid description to be too complicated, hereinafter, it is assumed that discount rate is not taken into consideration. Moreover, in the case of many public projects, it is not rare also when employer's investment is completed by the time a. Descriptions of convenient assumptions at the time b when investment is completed are provided. The following discussion is not affected, even if it assumes that investment will be completed by the time a, as mentioned.

On the other hand, the conditions that design condition will be decided by the time c are strict assumptions. In reality, it is not few, when design condition is decided after starting construction. In this case, it will be necessary to change the contents of investment completed before the time b. In order to discuss about change of contract, including changes in investment contents, it is necessary to formulate a more complicated incomplete contract model. It would be considered as future subject on this issue.

4.4.2 Formulation of Social Welfare

Construction work needs transaction specific investment by both parties of employer and contractor, and the input of variable factors, such as labor, materials, etc. by the contract.At the time c when construction work being started, the investment amount i and j by employer and contractor and the value of the design condition ε are already decided . In order to attain the time q, the minimum cost attained by supplying variable factor is expressed using the variable cost function C (q, i, j, ε).In addition, in this research, it is assumed that contractor has to bear all the risks in connection with the contract items which are not qualified for contract change.

To be precise, variable cost function C can be expressed as C (q, i, j, ε)= Eη[C^o (q, i, j, ε ,η)].C^o is a variable cost function, including risk factor η which contractor has to bear, and Eη[C^o (q, i, j, ε ,η)] is expected value operation of η. In actual construction project, "how contractor should control risk factor η" is a very important issue. However, in this research, in order to focus on contract risk, the issue of risk factor η control is not discussed. In the following, discussion is promoted using the variable cost function C for facilitation of description.

$$\frac{\partial C(q,i,j,\varepsilon)}{\partial i} < 0 \quad \frac{\partial^2 C(q,i,j,\varepsilon)}{\partial i^2} > 0$$

$$\frac{\partial C(q,i,j,\varepsilon)}{\partial j} < 0 \quad \frac{\partial^2 C(q,i,j,\varepsilon)}{\partial j^2} > 0$$

$$\frac{\partial^2 C(q,i,j,\varepsilon)}{\partial i \partial j} > 0 \tag{1}$$

It is assumed that variable cost function satisfies characters. Variable cost function is strictly convex decreasing function in which investment level, i and j are mutually substitutable. Furthermore, it is assumed that interval $(0,\bar{q}(i,j,\varepsilon)]$ is satisfied depending on i, j, and ε.

$$\frac{\partial C(q,i,j,\varepsilon)}{\partial q} < 0 \quad \frac{\partial^2 C(q,i,j,\varepsilon)}{\partial q^2} > 0$$

$$\frac{\partial^2 C(q,i,j,\varepsilon)}{\partial q \partial i} > 0 \quad \frac{\partial^2 C(q,i,j,\varepsilon)}{\partial q \partial j} > 0 \tag{2}$$

In other words, in the concerned interval, gradual increase of the variable cost is carried out in relation to shortening time. When the time is greater than $\bar{q}(i,j,\varepsilon)$, construction delay occurs, and variable cost increases by the increase in the time. The marginal cost of time shortening decreases, so that investment increases (the decrement of the marginal cost about time relief increases). In addition, the optimal solution is assumed to be obtained as interior point of interval $(0, \bar{q}(i, j, \varepsilon)]$.

$$\lim_{q \to +0} \frac{\partial C(q, i, j, \varepsilon)}{\partial q} = -\infty$$

$$\frac{\partial C(\bar{q}(i, j, \varepsilon), i, j, \varepsilon)}{\partial q} = 0 \qquad (3)$$

Condition (3) represents variable cost function is a decreasing function with respect to q interval $(0, \bar{q}(i, j, \varepsilon)]$, and if q is asymptotic to 0, it means that marginal variable cost is infinite. ε is a random variable representing design conditions. Although design condition is usually denoted by a multi-dimension vector, even if it expresses by a single random variable, the mathematical structure of contract model does not change. In order to improve the outlook of discussion, design condition is expressed by a single random variable. At the initial contract time, employer provides bidder initial design condition ε0, and bidder estimate cost and bid based on it. But one presenting the cheapest bid is the contractor. The contracting parties form the common belief about the probability distribution of design conditions ε, and express the probability distribution function F (ε) in the interval $[\underline{\varepsilon}, \bar{\varepsilon}]$. Both parties have the common knowledge about variable cost function C (q, i, j, ε). Variable cost function is satisfied to the design condition $\varepsilon \in [\underline{\varepsilon}, \bar{\varepsilon}]$, for any q, I, and j.

$$\frac{\partial C(q, i, j, \varepsilon)}{\partial \varepsilon} > 0 \quad \frac{\partial^2 C(q, i, j, \varepsilon)}{\partial i \partial \varepsilon} < 0$$

$$\frac{\partial^2 C(q, i, j, \varepsilon)}{\partial j \partial \varepsilon} < 0 \quad \frac{\partial^2 C(q, i, j, \varepsilon)}{\partial q \partial \varepsilon} < 0 \qquad (4)$$

Costs have gradual increase by the increase in design condition, and more effects of investment appear (the absolute value of the decrement of a marginal cost increases). Moreover, if design condition increases, the marginal cost by time shortening will increase (the decrement of the marginal cost by time mitigation decreases). Then, the investment cost function of contractor's transaction specific investment j will be denoted by φ (j).

$$\frac{d\varphi(j)}{dj} > 0 \quad \frac{d^2\varphi(j)}{dj^2} > 0 \qquad (5)$$

φ (j) satisfies characters. Now, the contract cost of construction work is expressed as p, and the following equation defines contractor's expected profit.

$$E[\prod] = p - E_{\varepsilon}[C(q,i,j,\varepsilon)] - \varphi(j) \tag{6}$$

However, it is $E_{\varepsilon}[C(q,i,j,\varepsilon)] = \int_{\underline{\varepsilon}}^{\bar{\varepsilon}} C(q,i,j,\varepsilon)dF(\varepsilon)$. On the other hand, contractor obtain the benefit V(q) expressed by the construction project in cost term. If the project is delayed, the benefit at the current time will decrease. It assumes.

$$\frac{dV(q)}{dq} < 0 \quad \frac{d^2V(q)}{dq^2} > 0 \tag{7}$$

Furthermore, it is assumed that for any $q \in (0, \bar{q}(i,j,\varepsilon)]$

$$\frac{d^2V(q)}{dq^2} < \frac{\partial^2 C(q,i,j,\varepsilon)}{\partial q^2} \tag{8}$$

The equation (8) expresses that the increase in marginal cost is larger than the increase in the marginal benefit by time shortening. When the conditions (3) and (8) are satisfied, the optimal time is uniquely determined in the interval $(0, \bar{q}(i,j,\varepsilon)]$. Equation 9 expresses the net benefit B which is attributable to contractor.

$$B = V(q) - p - \psi(i) \tag{9}$$

Here, ψ (i) expresses the investment cost by employer, and is satisfied.

$$\frac{d\psi(i)}{di} > 0 \quad \frac{d^2\psi(i)}{di^2} > 0 \tag{10}$$

Here, social welfare will be defined as total net benefit which is attributable to employer and the profits which contractor gains. Currently, design condition is defined ε. Social welfare was evaluated at the time c and can be expressed.

$$W(q,i,j,\hat{\varepsilon}) = V(q) - C(q,i,j,\hat{\varepsilon}) - \psi(i) - \varphi(j) \tag{11}$$

The contract cost p of construction work is the income transfers to contractor from employer, and it is not included in social welfare.

4.4.3 Structure of Socially Optimal Contract

By backward induction to logical order relation, first consider the problem of changing construction design condition is confirmed to ε at the time c. At the time c, contracting parties investment level are known as i0, and j0 and the true design condition $\hat{\varepsilon}$ .Social welfare becomes $W(q, i_0, j_0, \hat{\varepsilon})$ by changing the time to q at this time.

$$W(q, i_0, j_0, \hat{\varepsilon}) = V(q) - C(q, i_0, j_0, \hat{\varepsilon}) - \psi(i_0) - \varphi(j_0) \tag{12}$$

Social welfare is Pareto improved by changing time based on the true design condition $\hat{\varepsilon}$. It can express the problem to correct the optimal time at the time c.

$$\max_q \{W(q, i_0, j_0, \hat{\varepsilon})\} \tag{13}$$

By considering the optimization conditions of the first step of this problem, q* is expressed to satisfy the optimal change of contract time.

$$\frac{\partial C(q^*, i_0, j_0, \hat{\varepsilon})}{\partial q} = \frac{dV(q^*)}{dq} \tag{14}$$

The second optimization conditions are satisfied from assumption (8). The left side of equation (14) is the effect of reducing the marginal variable cost obtained by the time delayed, and the right-hand side is marginal benefit which decreases when the time is delayed. The optimal change of contract time q* that satisfies equation (14) is the conditional optimal time when investment i0 and j0 is performed and design condition is determined to $\hat{\varepsilon}$.

Then, q* is referred as $q^*(i_0, j_0, \hat{\varepsilon})$.

Change of contract cost is the income transfers between contractor and employer, and it advances discussion, regardless of specifying change mode of contract cost in order not to affect social welfare. Tracing back to b, consider the problem of finding volume of investment of employer who maximizes expected social welfare and contractor, the time of the design condition ε not being decided.

$$\max_{i,j} \{E_\varepsilon[V(q^*(i, j, \varepsilon)) - C(q^*(i, j, \varepsilon), i, j, \varepsilon)] - \psi(i) - \varphi(j)\} \tag{15}$$

It is expressed the optimization conditions of the first step of this problem.

$$E_{\varepsilon}\left[\frac{dV^*}{dq^*}\frac{\partial q^*}{\partial j}-\frac{\partial C^*}{\partial q^*}\frac{\partial q^*}{\partial j}-\frac{\partial C^*}{\partial j}\right]=\frac{d\varphi}{dj} \tag{16a}$$

$$E_{\varepsilon}\left[\frac{dV^*}{dq^*}\frac{\partial q^*}{\partial i}-\frac{\partial C^*}{\partial q^*}\frac{\partial q^*}{\partial i}-\frac{\partial C^*}{\partial i}\right]=\frac{d\psi}{di} \tag{16b}$$

The second optimization conditions are satisfied from assumptions referred to Appendix 1. Moreover, they are $V^*=V(q^*(i,j,\varepsilon)), C^*=C(q^*(i,j,\varepsilon))$.

From equation (14) for any $q^*(i,j,\varepsilon)$, the first and second terms are canceled in the above equation.

$$-E_{\varepsilon}\left[\frac{\partial C(q^*(i_0,j_0,\varepsilon),i_0,j_0,\varepsilon)}{\partial j}\right]=\frac{d\varphi(j_0)}{dj} \tag{17a}$$

$$-E_{\varepsilon}\left[\frac{\partial C(q^*(i_0,j_0,\varepsilon),i_0,j_0,\varepsilon)}{\partial i}\right]=\frac{d\psi(i_0)}{di} \tag{17b}$$

It is obtained as i0, j0 to satisfy at the same time to optimize investment level.

4.5 Formulation of Contract Model

4.5.1 The prerequisites of model

Employer is public entity and contract model also assumes the case where contractor is a private company. Both are risk-neutral. According to the contract, contractor aims at profit maximization. Employer is a public entity and designs contract to maximize social welfare. In the present model, the contract can be performed according to the logical order relation shown in figure4.1. In other words, at the time a, employer and contractor agree to contract as described in the contract change rule R, the contract cost p_0, the time q_0, and design condition ε_0.At time b, employer and contractor shall respectively implement investment i and j. Unlike the socially optimal contract model, the contractor can determine the investment level to maximize self profits. The employer determines the investment level to maximize social welfare. Design conditions will be finalized at the time c, contractor and employer will consult regarding contract change. All the variables are observable and can verify the contract cost p and the time q. In the initial contract, agreement is formed (p_0, q_0, ε_0) with respect to the cost p_0, the time q_0, and the design condition ε_0. If design condition is defined as $\hat{\varepsilon}$ at the time c, the value differs from initial design condition ε_0, possibility to improve social welfare by contract change occurs. In this case, design changes are negotiated between the contractor and employer and the contract is changed.

4.5.2 Formulation of Model

Also in this section, by backward induction to logical order relation, consider the time c as the first point of contract change being performed. If there is change in design conditions, negotiations are performed with respect to change of contract cost and time under the new design condition $\hat{\varepsilon}$.

Negotiations are supposed to be performed in a two-step process of change 1) changing construction time, and 2) changing contract cost. At the first phase, change of the construction time is made to maximize social welfare after the change.

$$\frac{dV(q^*)}{dq} - \frac{\partial C(q^*, i_0, j_0, \hat{\varepsilon})}{\partial q} = 0 \tag{18}$$

q* determined to satisfy the optimal change of contract time. The optimal change of contract time was expressed as $q^*(i_0, j_0, \hat{\varepsilon})$ as a function of the investment i_0, j_0, and the true design condition $\hat{\varepsilon}$. The optimal change of contract time has the following characteristics referred in Appendix 2.

$$\frac{\partial C(q^*, i_0, j_0, \hat{\varepsilon})}{\partial q} > 0 \tag{19}$$

By changing the time to maximize social welfare, it is possible to maximize the benefits redistributed to contract parties (cost is minimized). In this regard, the interest of both parties is consistent. Contract change does not occur at the time c, social welfare $W(q_0, i_0, j_0, \varepsilon_0)$ is defined when the initial construction work is completed as contracted.

$$W(q_0, i_0, j_0, \varepsilon_0) = V(q_0) - C(q_0, i_0, j_0, \varepsilon_0) - \psi(i_0) - \varphi(j_0) \tag{20}$$

If, at the point c, the construction contract time is changed to $q^*(i_0, j_0, \hat{\varepsilon})$, social welfare is expressed as follows.

$$W(q^*, i_0, j_0, \hat{\varepsilon}) = V(q^*(i_0, j_0, \hat{\varepsilon})) - C(q^*(i_0, j_0, \hat{\varepsilon}), i_0, j_0, \hat{\varepsilon}) - \psi(i_0) - \varphi(j_0) \tag{21}$$

Even if changes occur in contract cost by contract changes, the level of p* affects the income transfers between the contractor and the employer but has no effect on social welfare itself.

Change of the social welfare caused by contract change can be expressed.

$$\Delta W(\hat{\varepsilon}) = W(q^*, i_0, j_0, \hat{\varepsilon}) - W(q_0, i_0, j_0, \varepsilon_0)$$
$$= V(q^*(i_0, j_0, \hat{\varepsilon})) - V(q_0) - C(q^*(i_0, j_0, \hat{\varepsilon}), i_0, j_0, \hat{\varepsilon}) + C(q_0, i_0, j_0, \varepsilon_0) \quad (22)$$

Here, change of social welfare due to changes of initial contract is defined, and corresponding to the value of $\hat{\varepsilon}$, ΔW($\hat{\varepsilon}$)can take the values of either positive or negative. By ADR model, parties payoff under realized $\hat{\varepsilon}$ is considered to be status quo in change of contract. However, in an actual changed contract, since it always goes back to an initial contract and renegotiation is performed, it is desirable to consider status quo of renegotiation of the contents of the initial contract. Equation (22) defines change of social welfare here reflecting such reality. In the second stage, negotiation is performed to determine how to allocate the change ΔW ($\hat{\varepsilon}$)of social welfare between both contractor and employer.

Regarding redistribution of the change of social welfare, both parties will be in confrontational situation. It is also possible to describe the agreement point of negotiation using a bargaining game. Alternatively, employer may determine the method of redistribution as an actual contract.

Here, consider $1-\alpha$ is change of social welfare attributable to employer for any surplus sharing rules, the remaining α is attributable to the contractor and is determined in advance. However, $0 \le \alpha \le 1$ is satisfied. At this time, p* is defined satisfying the contract cost determined after change of contract.

$$p_0 - C(q_0, i_0, j_0, \varepsilon_0) - \varphi(j_0) + \alpha \Delta W(\hat{\varepsilon}) = p^* - C(q^*, i_0, j_0, \hat{\varepsilon}) - \varphi(j_0) \quad (23)$$

$$p^* = p_0 + \alpha\{V(q^*(i_0, j_0, \hat{\varepsilon})) - V(q_0)\} + (1-\alpha) \times \{C(q^*(i_0, j_0, \hat{\varepsilon}), i_0, j_0, \hat{\varepsilon}) - C(q_0, i_0, j_0, \varepsilon_0)\} \quad (24)$$

At the time c, change rules can be expressed as R.

$$R = \begin{cases} q_0 \rightarrow q^* & \text{Satisfying eq.(18)} \\ p_0 \rightarrow p^* & \text{Satisfying eq.(24)} \end{cases} \quad (25)$$

4.5.2.1 Employer Without Opportunistic Behavior

There are some premises that the employer maximizes the social welfare as representative of the public and he does not perform opportunistic behavior to pursue private interests. The design condition ε is not defined at the time b. The expected profit of the employer is defined by $E_\varepsilon[\prod]$ at the time b after making investment i_0.

$$E_\varepsilon[\prod] = p_0 - C(q_0, i_0, j_0, \varepsilon_0) - \varphi(j) + E_\varepsilon[\alpha \Delta W(\varepsilon)] \quad (26)$$

If equation (26) is expanded using equation (22), expected profit maximization problem of the contractor at the time and b can be as equation (27).

$$\max_{j}\{p_0-(1-\alpha)C(q_0,i_0,j,\varepsilon_0)-\alpha V(q_0)-\varphi(j)+\alpha E_{\varepsilon}[V(q^*(i_0,j,\varepsilon))-C(q^*,i_0,j,\varepsilon)]\} \qquad (27)$$

Considering optimization conditions of the change of contract time (18), optimization conditions of this problem will be expressed. Moreover, the secondary optimization conditions are automatically satisfied from assumption in Appendix 1.

$$-\alpha E_{\varepsilon}\left[\frac{\partial C(q^*(i_0,j,\varepsilon),i_0,j_0,\varepsilon)}{\partial j}\right]-(1-\alpha)\frac{\partial C(q_0,i_0,j,\varepsilon_0)}{\partial j}=\frac{d\varphi(j)}{dj} \qquad (28)$$

On the other hand, if contractor's behavior is j_0, social welfare maximization problem of employer can be expressed.

$$\max_{i}\{E_{\varepsilon}[V(q^*(i,j_0,\varepsilon))-C(q^*(i,j_0,\varepsilon),i,j_0,\varepsilon)]-\psi(i)-\varphi(j_0) \qquad (29)$$

Similarly, optimization conditions of the first phase of this problem are presented. The secondary optimization conditions are also satisfied as referred to (Appendix 1).

$$-E_{\varepsilon}\left[\frac{\partial C(q^*(i,j_0,\varepsilon),i,j_0,\varepsilon)}{\partial i}\right]=\frac{d\psi(i)}{di} \qquad (30)$$

As mentioned above, Nash equilibrium solution i0 which satisfies simultaneously contractor and employer optimal investment level when the contract change rule R is used; it is given as j_0.

$$-\alpha E_{\varepsilon}\left[\frac{\partial C(q^*(i_0,j_0,\varepsilon),i_0,j_0,\varepsilon)}{\partial j}\right]-(1-\alpha)\frac{\partial C(q_0,i_0,j_0,\varepsilon_0)}{\partial j}=\frac{d\varphi(j_0)}{dj} \qquad (31a)$$

$$-E_{\varepsilon}\left[\frac{\partial C(q^*(i_0,j_0,\varepsilon),i_0,j_0,\varepsilon)}{\partial i}\right]=\frac{d\psi(i_0)}{di} \qquad (31b)$$

4.5.2.2. Employer With Opportunistic Behavior

However, it is assumed that trust relationship is between employer and contractor, the changes in the results will be occurred when the employer has opportunistic behavior to pursue private interests. The design condition ε is not defined at the time b. The expected profit of the employer is defined by $E_{\varepsilon}[\prod]$ at the time b after making investment i_0.

$$E_{\varepsilon}[\prod]=p_0-C(q_0,i_0,j_0,\varepsilon_0)-\varphi(j)+E_{\varepsilon}[\alpha\Delta W(\varepsilon)] \qquad (32)$$

If equation (32) is expanded using equation (22), expected profit maximization problem of the contractor at the time and b can be as equation (33).

$$\max_j \{p_0 - (1-\alpha)C(q_0, i_0, j, \varepsilon_0) - \alpha V(q_0) - \varphi(j) + \alpha E_\varepsilon [V(q^*(i_0, j, \varepsilon)) - C(q^*, i_0, j, \varepsilon)]\} \tag{33}$$

Considering optimization conditions of the change of contract time (18), optimization conditions of this problem will be expressed. Moreover, the secondary optimization conditions are automatically satisfied from assumption in Appendix 1.

$$-\alpha E_\varepsilon \left[\frac{\partial C(q^*(i_0, j, \varepsilon), i_0, j_0, \varepsilon)}{\partial j} \right] - (1-\alpha) \frac{\partial C(q_0, i_0, j, \varepsilon_0)}{\partial j} = \frac{d\varphi(j)}{dj} \tag{34}$$

On the other hand, if employer's behavior is opportunistic, profit maximization problem of employer can be expressed.

$$\max_i \{V(q_0) - p_0 - \psi(i) + E_\varepsilon [(1-\alpha)\Delta W(\varepsilon)]\} \tag{35}$$

Similarly, optimization conditions of the first phase of this problem are presented. The secondary optimization conditions are also satisfied as referred to (Appendix 1).

$$(1-\alpha) E_\varepsilon \left[\frac{\partial C(q^*(i, j_0, \varepsilon), i, j_0, \varepsilon)}{\partial i} \right] + (1-\alpha) \frac{\partial C(q_0, i, j_0, \varepsilon_0)}{\partial i} = \frac{d\psi(i)}{di} \tag{36}$$

As mentioned above, Nash equilibrium solution i_0, j_0 which satisfies simultaneously contractor and employer optimal investment level when the contract change rule R is used are given as.

$$-\alpha E_\varepsilon \left[\frac{\partial C(q^*(i_0, j_0, \varepsilon), i_0, j_0, \varepsilon)}{\partial j} \right] - (1-\alpha) \frac{\partial C(q_0, i_0, j_0, \varepsilon_0)}{\partial j} = \frac{d\varphi(j_0)}{dj} \tag{37a}$$

$$(1-\alpha) E_\varepsilon \left[\frac{\partial C(q^*(i_0, j_0, \varepsilon), i_0, j_0, \varepsilon)}{\partial i} \right] + (1-\alpha) \frac{\partial C(q_0, i_0, j_0, \varepsilon_0)}{\partial i} = \frac{d\psi(i_0)}{di} \tag{37b}$$

4.5.3. Structure of Optimal Contract

Consider the problem of designing initial contract at the time a. In the initial contract, it is necessary that employer sets the construction schedule and design conditions ε0 of construction. Equation (31a) expressing optimal contract conditions and equation (17a) expressing socially optimal contract conditions are compared.

$$E_\varepsilon \left[\frac{\partial C(q^*(i_0, j_0, \varepsilon), i_0, j_0, \varepsilon)}{\partial j} \right] = \frac{\partial C(q_0, i_0, j_0, \varepsilon_0)}{\partial j} \tag{38}$$

It is necessary that contract be in agreement with socially optimal contract, referred to (Appendix 3). Socially optimal contract is realizable by setting initial contract so that marginal cost of investment level of contractor under an initial contract is in agreement with the actual expected marginal cost which arises after the change of contract. Employer sets the design condition ε_0 and the time q_0 in initial contract to satisfy equation (38). Moreover, contract change rule R could be presented due to change of design condition ε_0, the time q_0, and competitive bid which determines the contract cost p_0. Employer presents potential set of design condition ε_0 and time q_0 and contract cost determined by competitive bid of contractors. Suppose, if the perfect competition bid by competitive contractors is realized, the contract cost p0 is determined as the level from which expected profit is zero.

$$p_0 = (1-\alpha)C(q_0, i_0, j_0, \varepsilon_0) + \alpha V(q_0) + \varphi(j_0) - \alpha E_\varepsilon [V(q^*(i_0, j_0, \varepsilon)) - C(q^*(i_0, j_0, \varepsilon), i_0, j_0, \varepsilon)] \quad (39)$$

Expected profit (26), contract cost is considered.

[Proposition 1]:

In the case of mutual trust between employer and contractor, regardless opportunistic behavior of employer as public entity who maximizes social welfare, q_0 and design conditions ε_0 satisfy equation (38), and optimal social contract specifies contract change rule R due to change of design.

In addition, it is assumed that both parties agreed initial contract at the time a and both made investments up to the time b. This is not an essential assumption. It is at the time a, the time the contract is concluded, employer will complete his investment, and the same result is obtained even if it thinks that only contractor invests after concluding contract referred to (Appendix 4).

There are two terms which should be mentioned about the proposition 1. There are two unknown conditions for a single equation (38), the set of q_0, ε_0 satisfy design conditions exist indefinitely at first in the equation. In this model, it is possible to change contract items based on actual design condition by initiating construction. However, it is not desirable to change the contract if the initial design conditions ε_0 match the actual design conditions $\hat{\varepsilon}$ to maintain mutual confidential relation. For that purpose, the initial time q_0 must be the optimal change of contract time under actual design condition ε_0 simultaneously. It can be defined as q_0 and ε_0 which satisfy an initial contract at the same time.

$$\begin{aligned} &E_\varepsilon\left[\frac{\partial C(q^*(i_0, j_0, \varepsilon), i_0, j_0, \varepsilon)}{\partial j}\right] = \frac{\partial C(q_0, i_0, j_0, \varepsilon_0)}{\partial j} \\ &\frac{\partial C(q_0, i_0, j_0, \varepsilon_0)}{\partial q} = \frac{dV(q_0)}{dq} \end{aligned} \quad (40)$$

The initial contract determined as mentioned above(p_0, q_0, ε_0), 1) it is optimal contract under initial design conditions, 2) The role of reference point for determining the amount of income transfers in change of contract, 3) played the role of providing an incentive to implement the optimal investment by contractor . Second point is that proposition 1 is satisfied regardless of the value of surplus sharing rate α in the change of contract. If this specifies clearly surplus sharing rule at the time of change of contract, it means that rule contents do not affect the efficiency of contract. The result depends on the structure of the contract in which change of contract time q* is determined so as to maximize the social welfare $W(q, i_0, j_0, \hat{\varepsilon})$ in change of contract time. Investment is already completed at the change of contract time, and the parties are not able to change the decision. In other words, irreversible relation in contract is concluded among contracting parties; as a result, employer has the incentive to agree on contract changes to maximize the social welfare. This leads to contrasting results with ADR theory. In ADR theory, if the initial contract is set properly, one party bear all the additional costs of change of contract, and efficient contract is realized. On the other hand, socially optimal contract will be realized by setting initial contract appropriately regardless bargaining power distribution, 1)when it is public entity for which employer maximizes social welfare, 2)when status quo of change of contract is defined using initial condition regardless of actual design condition. In addition, in this model, it is assumed contractor is risk-neutral and surplus sharing rules at the change of time does not affect the efficiency of contract.

Furthermore, if initial contract cost is determined by perfect competitive bidding, initial contract cost is determined that expected profit will always be zero. In equation (26), even if change of the expected profit after change of contract arises by change of surplus sharing rules, the value is completely offset by changes of initial contract cost. In other words, surplus sharing rule does not affect the expected profit of contractor to be evaluated at the time a. However, surplus sharing rules affect the risk allocation between contracting parties. For example, in the case $\alpha = 0$, employer bears all contract change risks, but in the case $\alpha = 1$, contractor bears all risks. If contractor is risk aversion, the surplus sharing rules affect contractor's action through risk allocation. In actual contract, employer integrates the additional cost of construction to change of design. Although cumulative cost does not correspond exactly with the actual additional construction cost which caused by design changes, employer has to bear the contract change risk in principle. In particular, if employer bears all contract change risks, initial contract cost is presented by $\tilde{p}_0$.

$$\tilde{p}_0 = C(q_0, i_0, j_0, \varepsilon_0) + \varphi(j_0) \quad (41)$$

Such a risk taking scheme is a risk assignment system efficient in the meaning of guiding contractor's action in the optimal direction, when contractor is risk avert. That is, by entering into a contract by fully competitive bidding, regardless of surplus sharing rules, the efficiency of construction project is attained and it becomes possible to make all expected social surpluses belong to employer. However, from the point of view of risk sharing between the contractor and the employer, be ascribed a contract change risk to employer is desirable.

4.6 Summary and Conclusion

Contract incompleteness can lead to inefficiency in the contractual outcome, as evidenced by legal disputes or costly renegotiation. In order to find contract methods which correspond to globalize construction market environment, understanding contract rationality would be essential as the first step. Instances of a principal-agent model illustrate the differences among contracting problems with respect to contractual incompleteness. In this study, in order to clarify the contract rationality, the idea is expressed as mathematical contract model. "Good faith" in construction contract is regarded as the prohibition rule of the moral hazard and asymmetric information. Moreover, it could be theoretically shown that "good faith" established in the market environment, is a certain condition of contract if contract is socially optimal. Contracting parties mainly implement construction based on good faiths, that does not cause hold up and moral hazard as described. However, long-term relationship between contractor and employer has to ensure the effectiveness of the principle of faith and trust. In this chapter, the special nature of the contract as incomplete contract is considered and then the socially optimal contract method is analyzed and the efficiency of the contract is considered whether the employer maximizes the social welfare as representative of the public and he does not perform opportunistic behavior to pursue private interests and also the changes in the results when he has opportunistic behavior to pursue private interests. The limits of the contract and moral hazard and its conquest method are then analyzed in chapter 5.

CHAPTER 5 – THE CONTRACTUAL STRUCTURE AND SOCIAL EFFICIENCY OF INTERNATIONAL CONSTRUCTION PROJECTS

5.1 Introduction

The traditional contract philosophy aimed in drafting contract clauses assumes that a contract should contain the agreements as to how to deal specifically with all expected incidents which may or may not occur in the future. If the parties to a contract intend to contain all agreements for uncertain situations, a contract document may become extremely complex. In a specific area/field/environment in which Construction Projects are usually executed, have sizeable uncertainties including unforeseeable uncertainties. It is, in fact, impossible to draft a contract envisaging and encompassing all the predictable and measurable uncertainties. Under these limitations, the author of the contract has no choice but to end up with an incomplete contract.

For the reasons brought out above, incomplete contracts do not provide specific responses for all contingencies but the rules to cope with contingencies. There are several clauses which are incorporated with the purpose to resolve amicably all the disputes except defining the risks sharing clause/rule in the contract.

On the other hand, in the case that the principal does not have the ability to verify changes, which situation is assumed in FIDIC form, it is impossible to make the initial contract enforceable any more. Differences of perception between the principal and the contractor of the initial contract are recognized for the first time when the real condition is revealed. Thus, the initial contract is designed to expect the conditions that make costs lowest in feasible conditions. The initial contract plays a role as the status quo of negotiation process. The initial contract is expected to be changed from the beginning and the time or completion and the contract amount are always changed to increase in the case of changes.

Contracts play a crucial role in situations involving important investments in relationship-specific capital. Once such investments have been sunk, each party is to some extent "locked-in," and therefore vulnerable to opportunistic behavior from the other parties. Williamson (1979) and Klein-Crawford-Alchian (1978) have already argued that the risk of ex post breach or renegotiation, when an unspecified event occurs, can lead to underinvestment in transaction-specific capital. Holmstrom (1982) has formalized this argument as a "moral hazard in teams" problem, where the (unobservable and therefore noncon-tractible) investments of several parties contribute to the total surplus. Underinvestment then follows from the fact that at least one party does not capture the full benefits of an increase in his investment. Moreover, Hart-Moore (1988) has obtained a similar underinvestment result, assuming that investments and future contingencies, although ex post observable, are unverifiable by third parties. In this chapter, the special nature of the contract as incomplete contract especially in an international environment is considered and then the socially optimal contract method is analyzed and the efficiency of the contract is considered in FIDIC contracts whether the employer wants to maximize social welfare or self profit. The limits of the contract and moral hazard and its conquest method are then analyzed in this chapter.

5.2 Asymmetric Information and Moral Hazard

One of the implicit assumptions of the fundamental welfare theorems is that the characteristics of all commodities are observable to all parties. However this is not reality. The parties often hold this information asymmetrically (Mas-Colell, 1995). In many instances of asymmetric information, the less-informed side knows that the other side has more information (Katz, 1998). The asymmetric information results in adverse selection problem which is the phenomenon where there is a hidden characteristic problem and people on the informed side self-select in a way that is harmful to the uninformed side (Katz, M.L et all, 1998). The moral hazard problem on the other hand occurs after the transaction. In Moral hazard problem one side of the economic activity engages in activities that are undesirable for the other side in terms of their agreement.

Each party of an economic transaction should have the sufficient knowledge about the other party to be able to make accurate decisions. As briefly defined, the problem of asymmetric information occurs when one party has not got the information. To give an example, when an employer hires a new contractor, that contractor has a much better idea about his/her ability than the employer. Or, a manager of a corporation has better information about how well their business is doing than the stockholders do (Mishkin, F.S and Eakins, S.G. 2000). The pioneering study that introduces and explains the asymmetric information is the famous article by George A.Akerlof (Akerlof, G.A, 1970). The finding of Akerlof is referred to as the ‘lemons problem’ as it resembles the problem that created by lemons in the used-car market. Obviously the potential buyers of used cars cannot assess properly the quality of the used-car, whether a particular car is a good car or the lemon one that will give them grief continually. By contrast, the owner of used car is more likely to know whether the car is lemon or a good one (Akerlof, G.A, 1970).

Basically there are two types of asymmetric information. The hidden characteristic type occurs whenever one side of a transaction knows something about itself that the other side does not. The second type, hidden action, occurs when one side can take an action that affects the other side but which the other side cannot directly observe (Katz, M.L. and Rosen, H.S, 1998). There are two ways which help the uninformed party to infer some information from the informed party. The signaling could be defined as an observable indicator of a hidden characteristic and screening the uninformed party's attempt to sort the informed parties. The adverse selection is a problem of asymmetric information and occurs before the transaction. This problem arises where there is a hidden characteristics problem and people on the informed side of the market self-select in a way that is harmful to the uninformed side (Katz, M.L. and Rosen, H.S, 1998).

In the contract model, the employer and contractor are sharing the "good faith", and the contractor assumes notifying the true design condition ε to employer honestly. In this case, by setting appropriately the construction time in the initial contract , socially optimal contract can be achieved regardless of surplus sharing rules associated with the contract changes. However, in the environment in which the good faith has not been established, contractor does not always notify true design condition honestly.

In particular, if profits decrease by notifying the true design condition $\hat{\varepsilon}$, the contractor will not have the incentive of trying to honestly report the facts of the design changes. Moreover, even if employer gets to know the fact, there is a problem "whether the fact of design condition change can be proved in trial." There is also another problem in the design asymmetric information.

Even if the cost of construction is able to be saved from initial contract, it is difficult for employer to distinguish whether it depends on change of design condition, or due to corporate efforts. If employer seeks partial return of contract cost, he has the responsibility to explain the rationale to contractor and third party. It is not easy for employer with less amount of information than contractor to find such rationale. On the other hand, when the time is delayed by the error of design condition or the cost of construction increases, contractor claims and offers change of contract to employer. The contractor will be accountable and he will ask employer for contract change based on abundant information. Thus, the mechanisms of change of contract completely differ depend on the ability of contractor to expect the increase in profits by change of contract. In the following, there is complete information asymmetry between the contractor and the employer, only if it is expected to increase in profit, we consider the problem of contractor to claim for contract change. When such moral hazard exists, it is considered whether socially optimal contract is achievable by contract.

5.3 The Incentive Conditions of Moral Hazard

The principal-agent model of moral hazard is among the core models of microeconomic theory and central to the economics of information. The problem is conceptually simple; a principal must design a contract to induce the agent to take the desired action. From the agent`s point of view the intended action must be made preferable to all other actions. Thus, a multitude of incentive compatibility constraints must be satisfied. Unfortunately, it is generally difficult to determine which constraints bind and to make robust predictions about the structure of optimal contracts.

If moral hazard is present in the contract, what limits occur in contract will be analyzed. Considering the time c, when change of contract being performed and which the investment i_0 and j_0 has been completed at this time. Let $\prod(p_0, q_0, \varepsilon_0)$ profits that are compensated under the initial contract for any $(p_0, q_0, \varepsilon_0)$.

$$\prod(p_0, q_0, \varepsilon_0) = p_0 - C(q_0, i_0, j_0, \varepsilon_0) - \varphi(j_0) \tag{42}$$

On the other hand, $\prod(p_0, q_0, \hat{\varepsilon})$ is profit that can be acquired when the actual design condition $\hat{\varepsilon}$ occurred, and was not reported.

$$\prod(p_0, q_0, \hat{\varepsilon}) = p_0 - C(q_0, i_0, j_0, \hat{\varepsilon}) - \varphi(j_0) \tag{43}$$

Also, if true $\hat{\varepsilon}$ is declared, the contract change rule R is applied and contractor earns the profits $\prod(p^*, q^*, \hat{\varepsilon})$.

$$\begin{aligned} \prod(p^*, q^*, \hat{\varepsilon}) &= p^* - C(q^*(i_0, j_0, \hat{\varepsilon}), i_0, j_0, \hat{\varepsilon}) - \varphi(j_0) \\ &= p_0 - (1-\alpha)C(q_0, i_0, j_0, \varepsilon_0) - \alpha\{V(q_0) - V(q^*(i_0, j_0, \hat{\varepsilon})) + C(q^*(i_0, j_0, \hat{\varepsilon}), i_0, j_0, \hat{\varepsilon})\} - \varphi(j_0) \end{aligned} \tag{44}$$

When design condition changes, $\prod(p^*, q^*, \hat{\varepsilon}) \geq \prod(p_0, q_0, \hat{\varepsilon})$ is established by applying the contract change rule R. In other words, there is no possibility that the situation-dependent profit has been determined after $\hat{\varepsilon}$ is not deteriorated by the change of contract. However, when the situation dependent profits by not notifying design condition are larger than the situation dependent profits at the time of notifying true design condition, contractor has no incentive to report honestly the design condition. In other words, conditions that contractor has not declared is represented.

$$\prod(p^*, q^*, \hat{\varepsilon}) - \prod(p_0, q_0, \hat{\varepsilon}) \leq C(q_0, i_0, j_0, \hat{\varepsilon}) - C(q_0, i_0, j_0, \varepsilon_0) \tag{45}$$

In the case of $\hat{\varepsilon} > \varepsilon_0$, the right-hand side of equation (45) becomes negative, and equation (45) is not satisfied, but contractor have to always declares design changes. Then, the case of $\hat{\varepsilon} < \varepsilon_0$ is considered. A definition is given as the difference $\Delta\prod$.

$$\begin{aligned}\Delta\prod &= C(q_0,i_0,j_0,\hat{\varepsilon}) - C(q_0,i_0,j_0,\varepsilon_0) - \prod(p^*,q^*,\hat{\varepsilon}) + \prod(p_0,q_0,\hat{\varepsilon}) \\ &= \alpha\{V(q_0) - V(q^*(i_0,j_0,\hat{\varepsilon})) - C(q_0,i_0,j_0,\varepsilon_0) + C(q^*(i_0,j_0,\hat{\varepsilon}),i_0,j_0,\hat{\varepsilon})\}\end{aligned} \tag{46}$$

There is no guarantee that equation (45) always holds expression against any (q_0,ε_0). For example, when the initial contract (q_0, ε_0) which satisfies the equation (18) and (38) is used, $\Delta\prod < 0$ is satisfied, and contractor has no incentive to declare actual design condition referred to Appendix 5.

It is dependent on whether conditions (45) are satisfied whether contractor declares actual design condition. In the case $\alpha = 0$, $\Delta\prod = 0$ is satisfied at all times, "to declare" the design changes or “not to declare" becomes indiscriminate. Since the social welfare is not Pareto improved, when not declaring change of design, in the case of $\alpha = 0$, it is necessary to give the incentive which makes contractor certainly declare change of design.

5.4 Asymmetric Information and Inefficiency

With respect to the initial contract for any (p_0, q0, ε_0), design changes are declared in the case of 1) Design condition $\hat{\varepsilon} > \varepsilon_0$, 2) Design condition $\hat{\varepsilon} < \varepsilon_0$, and when condition (45) is satisfied, change of design is not declared.

Hereinafter, the discussion will be on the assumption that contractor does not declare design changes in $\hat{\varepsilon} < \varepsilon_0$. Now, although both parties have knowledge of the probability distribution function F(ε) of $\hat{\varepsilon}$, but only contractor knows the value. Consider if $\hat{\varepsilon} < \varepsilon_0$ occurs, without contractor claim about contract change, change of design condition is not reported.

In this case, the contractor profits $\prod(p_0,q_0,\hat{\varepsilon})$ can be denoted by equation (43).

On the other hand, in the case of $\hat{\varepsilon} > \varepsilon_0$, contractor claims about contract change. In this case, the contract change rule R is applied and the contractor profits $\prod(p^*,q^*,\hat{\varepsilon})$ can be denoted by equation (44). At this time, the following equation can define the expected profit of the contractor who evaluated by the time b of the design condition ε and not being decided.

$$\int_{\underline{\varepsilon}}^{\varepsilon_0} \Pi(p_0, q_0, \varepsilon) dF(\varepsilon) + \int_{\varepsilon_0}^{\bar{\varepsilon}} \Pi(p^*, q^*, \varepsilon) dF(\varepsilon) = \int_{\underline{\varepsilon}}^{\varepsilon_0} C(q_0, i_0, j_0, \varepsilon) dF(\varepsilon) - (1-\alpha)(1-F(\varepsilon_0))$$
$$\times C(q_0, i, j, \varepsilon_0) - \alpha\{(1-F(\varepsilon_0))V(q_0) - \int_{\varepsilon_0}^{\bar{\varepsilon}} [V(q^*(i,j,\varepsilon)) - C(q^*(i,j,\varepsilon), i, j, \varepsilon)] dF(\varepsilon)\} + p_0 - \varphi(j) \quad (47)$$

If the optimal condition (18) of the change of contract time is taken into consideration, it is expressed the optimal contractor behvior which makes employer's behavior i_0.

$$-\int_{\underline{\varepsilon}}^{\varepsilon_0} \frac{\partial C(q_0, i_0, j, \varepsilon)}{\partial j} dF(\varepsilon) - \alpha \int_{\varepsilon_0}^{\bar{\varepsilon}} \frac{\partial C(q^*(i_0, j, \varepsilon), i_0, j, \varepsilon)}{\partial j} dF(\varepsilon) - (1-\alpha) \times (1-F(\varepsilon_0)) \frac{\partial C(q_0, i_0, j, \varepsilon_0)}{\partial j} = \frac{d\phi(j)}{dj} \quad (48)$$

On the other hand, employer tries to maximize expected social welfare by making contractor's behavior j_0. The expected social welfare EW evaluated at the time b is defined by the following equation.

$$EW = \int_{\underline{\varepsilon}}^{\varepsilon_0} \{V(q_0) - C(q_0, i, j_0, \varepsilon)\} dF(\varepsilon) + \int_{\varepsilon_0}^{\bar{\varepsilon}} \{V(q^*(i, j_0, \varepsilon)) - C(q^*(i, j_0, \varepsilon), i, j_0, \varepsilon\} dF(\varepsilon) - \psi(i) - \phi(j_0) \quad (49)$$

Considering equation (18), optimal conditions are obtained by some equation development.

$$-E_{\varepsilon}\left[\frac{\partial C(q^*(i, j_0, \varepsilon), i, j_0, \varepsilon)}{\partial i}\right] + \int_{\underline{\varepsilon}}^{\varepsilon_0} \left\{\frac{\partial C(q^*(i, j_0, \varepsilon), i, j_0, \varepsilon)}{\partial i} - \frac{\partial C(q_0, i, j_0, \varepsilon)}{\partial i}\right\} dF(\varepsilon) = \frac{d\psi(i)}{di} \quad (50)$$

Optimal investment level can be defined as i_0, j_0 to satisfy the equation (48) and (50) simultaneously, with respect to initial design conditions ε_0 and q_0.

By setting the construction time q0 with respect to the initial design conditions for any $\varepsilon \in (\underline{\varepsilon}, \bar{\varepsilon}]$, socially optimal contract terms (17a), (17b) are unable to match referred to Appendix 6. This shows that execution of socially optimal contract is impossible.

5.5 Asymmetric Information and Optimal Contract Method

5.5.1 Employer Without Opportunistic Behavior

When the asymmetry of information exists, it is not possible to run the socially optimal contract in normal contract. However, it is possible by devising the choice of initial contract to overcome the problem of moral hazard skillfully. Considering the case where employer chooses $\underline{\varepsilon}$ as initial design condition. It is possible to achieve socially optimal contract at this time, by setting optimal conditions (48) to (50).

$$-\alpha E_{\varepsilon}\left[\frac{\partial C(q*(i_0, j_0, \varepsilon), i_0, j_0, \varepsilon)}{\partial j}\right] - (1-\alpha)\times\frac{\partial C(q_0, i_0, j_0, \underline{\varepsilon})}{\partial j} = \frac{d\varphi(j_0)}{dj} \tag{51}$$

$$-E_{\varepsilon}\left[\frac{\partial C(q*(i_0, j_0, \varepsilon), i_0, j_0, \varepsilon)}{\partial i}\right] = \frac{d\psi(i_0)}{di} \tag{52}$$

$$E_{\varepsilon}\left[\frac{\partial C(q*(i_0, j_0, \varepsilon), i_0, j_0, \varepsilon)}{\partial j}\right] = \frac{\partial C(q_0, i_0, j_0, \underline{\varepsilon})}{\partial j} \tag{53}$$

5.5.2 Employer With Opportunistic Behavior

However, it is assumed that mistrust relationship is between employer and contractor, the changes in the results will be occurred when the employer has opportunistic behavior to pursue private interests. To overcome the problem of moral hazard, devising the choice of initial contract is a good solution. When the asymmetry of information exists, it is not possible to run the socially optimal contract in normal contract. However, it is possible considering the case where employer chooses $\underline{\varepsilon}$ as initial design condition. Socially optimal contract is achievable at this time, by setting optimal conditions (48) to (50).

$$-\alpha E_{\varepsilon}\left[\frac{\partial C(q*(i_0, j_0, \varepsilon), i_0, j_0, \varepsilon)}{\partial j}\right] - (1-\alpha)\times\frac{\partial C(q_0, i_0, j_0, \underline{\varepsilon})}{\partial j} = \frac{d\varphi(j_0)}{dj} \tag{54}$$

$$-(1-\alpha)E_{\varepsilon}\left[\frac{\partial C(q*(i_0, j_0, \varepsilon), i_0, j_0, \varepsilon)}{\partial i}\right] + (1-\alpha)\times\frac{\partial C(q_0, i_0, j_0, \underline{\varepsilon})}{\partial i} = \frac{d\psi(i_0)}{di} \tag{55}$$

$$E_{\varepsilon}\left[\frac{\partial C(q*(i_0, j_0, \varepsilon), i_0, j_0, \varepsilon)}{\partial j}\right] = \frac{\partial C(q_0, i_0, j_0, \underline{\varepsilon})}{\partial j} \tag{56}$$

The following proposition is established.

[proposition 2]: If initial design conditions are set as $\underline{\varepsilon}$ when asymmetric information exists, socially optimal contract is realizable by the contract change rule R.

If the moral hazard due to contractor asymmetric information occurs, the lower limit $\underline{\varepsilon}$ of the design condition is specified as the initial design conditions ε0, and if contractor's claim occurs, efficient change of contract can be realized based on the contract change rule R. The initial time q0 set as mentioned above has not satisfied the optimal time conditions (18). $q^*(i_0, j_0, \underline{\varepsilon})$ is expressed as optimal change of contract time which satisfies equation (18) with respect to the initial design condition $\underline{\varepsilon}$. At this time, there is no guarantee the initial contract time q0 will match $q^*(i_0, j_0, \underline{\varepsilon})$.

As long as $q^*(i_0, j_0, \underline{\varepsilon}) < q_0$ is satisfied, contractor would not have incentive to express actual design condition. In order to achieve optimal contract, it will be necessary to supply contractor with the reward which gives the incentive of time shortening. Next, q_0^o will be expressed as the initial contract time of asymmetric information model, and will distinguish from the initial contract time q_0 in contract model. The construction time of the initial contract is satisfied referred to Appendix 7.

$$q_0 \geq q_0^o \tag{57}$$

In other words, in asymmetric information model, the time q_0^o shorter than initial contract time of contract model is considered as initial contract. Since socially optimal contract is realizable even if it uses both models, possibility that the time will be extended by change of design is larger than the contract. Depending on the actual values of the design conditions, the initial agreement in the contract model had expressed the agreement itself is to be realized. However, the initial contract in asymmetric information model is not expressing the contract which should be observed. Rather, the initial contract defines 1) the reference point of change of contract due to design changes, 2) motivated the optimal investment of contractor. However, discussion of the efficiency of the contract shown in Proposition 2 is the result of ignoring the negotiation cost for change of contract. In the situation where the time actually required like many overseas construction and construction cost deviates from initial contract sharply, enormous cost transaction is generated for change of contract. In order to elaborate discussion on the efficiency of the construction contracts in the situation of existing the asymmetry of information, the approach which took negotiation cost into consideration explicitly will be needed.

In addition, the initial contract cost p_0^o in this model if initial contract cost is determined as the level from which an expected profit serves as zero by perfect competition bid is expressed.

$$p_0^o = (1-\alpha)C(q_0^o, i_0, j_0, \underline{\varepsilon}) + \alpha V(q_0^o) + \phi(j_0) - \alpha \times E_\varepsilon[V(q^*(i_0, j_0, \varepsilon)) - C(q^*(i_0, j_0, \varepsilon), i_0, j_0, \varepsilon)] \quad (58)$$

Even if change of the expected profit after change of contract arises by change of surplus sharing rule also in the case of this model, the value is completely offset by change of initial contract cost. In other words, surplus sharing rule does not affect contractor expected profit to be evaluated at the time a. Surplus sharing rule affects the risk allocation between contracting parties. For example, when contractor bears all contract change risks, the initial contract cost p_0 is denoted by the following equation.

$$\tilde{p}_0^o = C(q_0^o, i_0, j_0, \underline{\varepsilon}) + \varphi(j_0) \quad (59)$$

5.6 First Best Results

If the above proposition is synthesized, when it is not concerned with contractor's moral hazard (presence or absence of good faith) but employer chooses appropriately the design condition in initial contract, and the time from the position of social welfare maximization, you can understand that it is possible to carry out the optimally social construction contract. In other words, when employer leads to change of design as contract, also in the method which finds out compromise by negotiation through contractor's claim as overseas construction enterprise, socially optimal contract can be achieved ideally [both]. However, as described above, it should not be forgot that the above conclusion is a conclusion which disregarded the negotiation cost in connection with change of contract. Actually, change of contract does not terminate within the instant and it takes a great deal of time and cost to change contract. Construction contract system in Japan is socially optimal contract method, and there is an advantage that negotiation cost can moreover be saved a lot. However, in order to design the optimal initial contract, it is necessary to perform complicated calculations as discussed. It is not easy to design initial contract based on optimal computation in construction work.

It is possible to seek for a desirable contract system by trial and error through the past construction cases in construction work which has enough construction track records. However, for new type of construction work with no track record in the past, or construction with large contract risk, advanced contract design technique is needed. In addition, the contract is vulnerable to moral hazard problem of the contractor. In order to minimize the risk of moral hazard, it is required to minimize uncertainty of design condition by preliminary survey. When (probability of 0) arisen contractor's moral hazard is sufficiently small, it is possible to obtain desirable result by contract. In order to control disputes by moral hazard,1)contractor bearing risks of change of contract are distinguished clearly (Items, which is defined as covenants) 2)it is necessary to clearly define changes in the design conditions, changes in work period, the surplus sharing rules when change of contract occurs.

In particular, contractor has to describe contract change rule to estimate in advance the profit risks due to contract change by the method that transparency is high. In addition, although the surplus sharing rule in change of contract does not affect the social welfare which construction work brings, in order to affect risk allocation among contracting parties, it is necessary to study many aspects of surplus sharing rules. Finally, it is reaffirmed that above it has been assumed the employer takes social welfare maximization behavior . The contractor is sure of employer not adopting opportunistic strategic action, and the employer is also sure of "the contractor is confident".

In other words, it is common knowledge for the contracting parties that employer adopts social welfare maximization action, and this has made the environment in which good faith is established between both. With regard to moral hazard behavior of the contractor, it can be addressed by appropriate design of the contract. However, when employer not adopt social welfare maximization action (he cannot do), it is impossible to control it by contract.

In this sense , it means the ability or intention to comply with the " good faith " is whether to be provided as part of employer, greatly affects the efficiency of the construction contract . When employer is not public entity, the problem of double moral hazard of acting so that employer may maximize private profits may arise.

In this research, it was shown clearly that the optimal construction work is socially realizable by contract in the market environment to which "good faith" is established between employer and contractor. Employer in the contract1) attempts to maximize expected social welfare, sets initial contract and implements initial investment,2)by changing the time social welfare is maximized at the time of contract change, socially optimal contract is achievable. In this case, although the contents of the initial contract affect the efficiency of contract, the surplus sharing rule of change of contract does not affect efficiency. Furthermore, if moral hazard occurs to contractor, execution of socially optimal construction projects by the normal contract is impossible.

However, if the design condition and the time in initial contract are designed appropriately, it will become possible to deter contractor's moral hazard. These findings were derived by ignoring transaction costs necessary to design cost and feasibility study costs, negotiation costs, etc. to conclude the contract and change of contract .

It is assumed that contracting parties are risk-neutral and it does not address the problem of desirable risk allocation between the parties. In addition, it does not address the issue of performance and quality provision of construction work.

In Principal-Agent models considering asymmetric information, two kinds of asymmetric information eventually are encountered, the first one which is one of the assumptions of the study is when the employer is not capable to observe design conditions unless the contractor claims about the condition and the second which is a crucial assumption is once the contractor claims, there will be no asymmetric information. It means the employer will trust the contractor to state the actual design condition honestly or the employer is able to verify the condition by controlling and monitoring contractor. As in reality, it is somehow impossible to control and monitor contractor, it is supposed that contractor will never hide actions. Otherwise, socially optimal contract is not achievable unless the employer provides incentives for the contractor to tell the truth.

In addition, in Principal-Agent models commonly when asymmetric information exists, the results serve as second best. In other words, contractor (agent) has more information which brings more surplus than symmetric model called as information rent. Regarding the critical assumption of the study, the contractor will always tell the truth leading to social welfare maximization as first-best.

5.7 Summary and Conclusion

In this research, it was shown clearly that the optimal construction work is socially realizable by contract in the market environment to which "good faith" is established between employer and contractor. Employer in the contract1) attempts to maximize expected social welfare, sets initial contract and implements initial investment,2)by changing the time social welfare is maximized at the time of contract change, socially optimal contract is achievable. In this case, although the contents of the initial contract affect the efficiency of contract, the surplus sharing rule of change of contract does not affect efficiency. Furthermore, if moral hazard occurs to contractor, execution of socially optimal construction projects by the normal contract is impossible.

However, if the design condition and the time in initial contract are designed appropriately, it will become possible to deter contractor's moral hazard whether the employer maximizes the social welfare as representative of the public and not performing opportunistic behavior to pursue private interests and also when he has opportunistic behavior to pursue private interests. These findings were derived by ignoring transaction costs necessary to design cost and feasibility study costs, negotiation costs, etc. to conclude the contract and change of contract.

As a research challenge remains in the future ,1)In this research, it assumed that change of design condition would be made by the time construction work is started. However, change of design condition becomes clear in the middle of construction actually in many cases. From now on, it is necessary to approach the problem of the contract change in the construction stage. 2)In this research, the structure of the contract was analyzed only for the construction risk in which change of contract is possible. Finally contractor will take the responsibility of risks not being considered as the object of contract change. Amount of risk attributable to the contractor would also affect the contract .In order to design the contract method that considers the risk allocation, it is necessary to establish a method for the market evaluation and quantification of risk .3) Change of contract cost cannot be ignored in the market environment in which employer and contractor negotiate involving the surplus allocation after change of contract mutually. Not to mention, revised contract clause in the international construction contract (FIDIC) cannot also be compatible to such a situation completely. In the future , it is necessary to accumulate the research on construction optimal contracts by considering change of contract costs , such as transaction costs .4) The efficiency of contract is dependent on the extent of asymmetric information about the uncertainty of design conditions. In order to clarify contract effective ranges and limits, it is necessary to accumulate the empirical measurements for uncertainty for the design conditions . 5)There is a need to discuss the contract system which can ensure the quality and performance of construction work.

CHAPTER 6 – CONCLUSIONS

Changes during the design and construction processes are to be expected and they are inevitable in any construction project. Needs of the employer may change in the course of design or construction, market conditions may impose changes to the parameters of the project, and technological developments may alter the design and the choice of the engineer. The engineer's review of the design may bring about changes to improve or optimize the design and hence the operations of the project. Furthermore, errors and omissions in engineering or construction may force a change. All these factors and many others necessitate changes that are costly and generally un-welcomed by all parties.

The present study reviews change orders and change management in construction projects along with concepts, techniques, and methodologies related to change orders administration that can be used to develop a negotiation methodology for complex construction disputes. The fundamentals of changes and change orders, particularly legitimate and management aspects of change orders were extensively discussed. Change orders causes and effects in construction were explained, and various source related categories (e.g., employer, contractor, designer) were suggested. Controls for change orders and related procedures, were explained, and change management systems studies and empirical studies for change control were listed and the characteristics of each system were summarized.

Considering change orders as one of the critical causes of disputes, Conflicts and causes of disputes in construction were briefly explained, and various dispute resolution methods (e.g., arbitration, negotiation, and mediation) were presented. Negotiation was presented as the most preferred method for construction participants due to its low cost and low hostility as well as the fact that it provides the parties with more control over their options and outcomes. Negotiation decision support systems were explained and were listed and the characteristics of each system were summarized. Finally, dispute management provisions in Japanese public construction works and international construction projects, negotiation and dispute resolution procedure, and comparative study on dispute resolution mechanism between Japanese public works and International construction projects were extensively discussed.

A contract is a typical incomplete agreement that cannot describe in detail the possibility of changes in the contract which may happen in the future. "Good faith" in construction contract was regarded as the prohibition rule of the moral hazard and asymmetric information, in order to clarify the contract rationality; the idea was expressed as mathematical contract model in the study. Moreover, it was theoretically shown that "good faith" established in the market environment, is a certain condition of contract if contract is socially optimal.

Contract incompleteness can lead to inefficiency in the contractual outcome, as evidenced by legal disputes or costly renegotiation. In order to find contract methods which correspond to globalize construction market environment, understanding contract rationality would be essential as the first step. Instances of a principal-agent model illustrate the differences among contracting problems with respect to contractual incompleteness. In this study, contracting parties mainly implement construction based on good faiths, that does not cause hold up and moral hazard as described. However, long-term relationship between contractor and employer has to ensure the effectiveness of the principle of faith and trust. In this research, the special nature of the contract as incomplete contract is considered and then the socially optimal contract method is analyzed and the efficiency of the contract is considered whether the employer maximizes the social welfare as representative of the public and he does not perform opportunistic behavior to pursue private interests and also the changes in the results when he has opportunistic behavior to pursue private interests. Employer in the contract1) attempts to maximize expected social welfare, sets initial contract and implements initial investment,2)by changing the time social welfare is maximized at the time of contract change, socially optimal contract is achievable. In this case, although the contents of the initial contract affect the efficiency of contract, the surplus sharing rule of change of contract does not affect efficiency. Furthermore, if moral hazard occurs to contractor, execution of socially optimal construction projects by the normal contract is impossible. However, if the design condition and the time in initial contract are designed appropriately, it will become possible to deter contractor's moral hazard either the employer maximizes the social welfare as representative of the public and not performing opportunistic behavior to pursue private interests or when he has opportunistic behavior to pursue private interests.

As described above, it should not be forgot that the above conclusion is a conclusion which disregarded the negotiation cost in connection with change of contract. Actually, change of contract does not terminate within the instant and it takes a great deal of time and cost to change contract. Construction contract system in Japan is socially optimal contract method, and there is an advantage that negotiation cost can moreover be saved a lot. However, in order to design the optimal initial contract, it is necessary to perform complicated calculations as discussed. It is not easy to design initial contract based on optimal computation in construction work.

It is possible to seek for a desirable contract system by trial and error through the past construction cases in construction work which has enough construction track records. However, for new type of construction work with no track record in the past, or construction with large contract risk, advanced contract design technique is needed. In addition, the contract is vulnerable to moral hazard problem of the contractor. In order to minimize the risk of moral hazard, it is required to minimize uncertainty of design condition by preliminary survey. When (probability of 0) arisen contractor's moral hazard is sufficiently small, it is possible to obtain desirable result by contract. In order to control disputes by moral hazard,1)contractor bearing risks of change of contract are distinguished clearly (Items, which is defined as covenants) 2)it is necessary to clearly define changes in the design conditions, changes in work period, the surplus sharing rules when change of contract occurs.

In particular, contractor has to describe contract change rule to estimate in advance the profit risks due to contract change by the method that transparency is high. In addition, although the surplus sharing rule in change of contract does not affect the social welfare which construction work brings, in order to affect risk allocation among contracting parties, it is necessary to study many aspects of surplus sharing rules. Finally , it is reaffirmed that above it has been assumed the employer takes social welfare maximization behavior . The contractor is sure of employer not adopting opportunistic strategic action, and the employer is also sure of "the contractor is confident".

In other words, it is common knowledge for the contracting parties that employer adopts social welfare maximization action, and this has made the environment in which good faith is established between both. With regard to moral hazard behavior of the contractor, it can be addressed by appropriate design of the contract . However, when employer not adopt social welfare maximization action (he cannot do), it is impossible to control it by contract.

In this sense , it means the ability or intention to comply with the " good faith " is whether to be provided as part of employer, greatly affects the efficiency of the construction contract . When employer is not public entity, the problem of double moral hazard of acting so that employer may maximize private profits may arise.

These findings were derived by ignoring transaction costs necessary to design cost and feasibility study costs, negotiation costs, etc. to conclude the contract and change of contract.

As a research challenge remains in the future ,1)In this research, it assumed that change of design condition would be made by the time construction work is started. However, change of design condition becomes clear in the middle of construction actually in many cases. From now on, it is necessary to approach the problem of the contract change in the construction stage. 2) In this research, the structure of the contract was analyzed only for the construction risk in which change of contract is possible. Finally contractor will take the responsibility of risks not being considered as the object of contract change. Amount of risk attributable to the contractor would also affect the contract .In order to design the contract method that considers the risk allocation, it is necessary to establish a method for the market evaluation and quantification of risk .3) Change of contract cost cannot be ignored in the market environment in which employer and contractor negotiate involving the surplus allocation after change of contract mutually. Not to mention, revised contract clause in the international construction contract (FIDIC) cannot also be compatible to such a situation completely. In the future , it is necessary to accumulate the research on construction optimal contracts by considering change of contract costs , such as transaction costs .4) The efficiency of contract is dependent on the extent of asymmetric information about the uncertainty of design conditions. In order to clarify contract effective ranges and limits, it is necessary to accumulate the empirical measurements for uncertainty for the design conditions. 5) There is a need to discuss the contract system which can ensure the quality and performance of construction work.

APPENDIX A – PROOFS

1) Optimization Conditions of Second Stage

It is $V^{*''}-C^{*}_{jj}=(V^{*''}-C^{*}_{qq})q^{*}_{jj}+(V^{*'}-C^{*}_{q})q^{*}_{jj}-C^{*}_{jj}$ from the equation (8) and (14). Subscript partial differential by the variable concerned , symbol 0 represents the total differential . The 2nd term is 0 from equation (14). The Hessian procession in problem (15) can be expanded with the same procedure. If the conditions (8) and (14) are used, it can prove that Hessian matrix of (15) is negative definite problem. The second stage optimization conditions of equation (28) and (29) can be evaluated similarly.

2) Derivation of Equation (19)

The totally differentiating both sides of the condition (18) were fixed j_0, i_0. $(V^{*''}-C^{*}_{qq})\,\mathrm{d}\,q^{*}=C^{*}_{q\hat{\varepsilon}}\,\mathrm{d}\,\hat{\varepsilon}$ is obtained. It is $V^{*''}<C^{*}_{qq}$, $C^{*}_{q\hat{\varepsilon}}<0$ from assumption. Therefore, $dq^{*}/d\hat{\varepsilon}<0$ is obtained.

3) Derivation of Equation (38)

The social optimal nature of the contract was shown from coincidence of the terms (17a) of a social optimal contract and the contractor optimization conditions (37a) of contract. Similarly, the Nash equilibrium solution which satisfies conditions (37a), (37b)is expressed as $i_0(q_0,\varepsilon_0)$, $j_0(q_0,\varepsilon_0)$.Social welfare (29) is expressed as a function of $i_0(q_0,\varepsilon_0)$, $j_0(q_0,\varepsilon_0)$ which formulizes the maximization problem of q_0 related to ε_0 . Further, to obtain the equation (38) to derive the optimized conditions, by substituting equation (37a), and (37b). Proof is omitted.

4) Employer's Investment Time

It is assumed the investment problem of the employer is at the time a. $j_0(i,q_0,\varepsilon_0)$ which satisfies conditions (37a) is expressed as j_0 as a function of i,q_0,ε_0 . $j_0(i,q_0,\varepsilon_0)$ is substituted for i,q_0,ε_0 to maximize social welfare function (29). If equation (37a) is substituted in quest of optimal condition, equation (37b) and (38) will be obtained. Proof is omitted.

5) Derivation of $\Delta\Pi<0$

It is $V^{*'}-C^{*}_{\varepsilon}=(V^{*'}dq^{*}/d\hat{\varepsilon}-C^{*}_{q}dq^{*}/d\hat{\varepsilon}-C^{*}_{\hat{\varepsilon}}<0$ under which fixed i_0 and j_0 (it carries out abbreviated of the account). $V(q_0)-C(q_0,\varepsilon_0)=\mathrm{V}(\mathrm{q}^{*}(\varepsilon_0))-\mathrm{C}(\mathrm{q}^{*}(\varepsilon_0),\varepsilon_0)$. From $\hat{\varepsilon}<\varepsilon_0$, it is $V_0-C_0-V^{*}+C^{*}<0$.

6) Inefficiency of Asymmetric Information Model

In the case of $\varepsilon \in \left(\underline{\varepsilon}, \bar{\varepsilon}\right]$, the 1st term of the left side of equation (48) and the 2nd term of the left side of equation (50) do not become zero. It becomes zero only at the time of $\underline{\varepsilon}$.

7) Derivation of Equation (57)

$q_0 < q_0^o$ is assumed and inconsistency is shown. $C_j(q_0^o, \underline{\varepsilon}) = C_j(q_0, \varepsilon_0)$ is satisfied from the equation (38) and (56).

If i_0 and j_0 (optional description) are fixed, the subscript of $C_{j\varepsilon} < 0$, $C_j(q_0, \underline{\varepsilon}) > C_j(q_0, \varepsilon_0)$ .C expresses the partial differential by the variable concerned. From the assumption $C_{qj} > 0$, $C_j(q_0^o, \underline{\varepsilon}) > C_j(q_0, \underline{\varepsilon})$. Therefore, $C_j(q_0^o, \underline{\varepsilon}) > C_j(q_0, \varepsilon_0)$. This is consistent with $C_j(q_0^o, \underline{\varepsilon}) = C_j(q_0, \varepsilon_0)$. Therefore, $q_0 \geq q_0^o$.

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