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THE EFFICIENT COMMISSIONING OF CAPITAL EQUIPMENT

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Commissioning is a critical phase of project delivery which is the continuity of previous project management preparation after the negotiations and contracts and prelude of service business in the future. Commissioning shoulder not only the responsibilities of delivering the guarantees agreed on the contracts, but also the tasks of ensuring the credibility, in line with expectations from customers. Additionally commissioning should contribute to service business coming after the final acceptance of capital equipment. Traditional manufacturing-centric companies struggle in inefficiency and unpromising prospects of service business. Hence, finding the contributing factors for an efficient commissioning and bridging service business with commissioning is proved to be more pressing than any time in past. The objective of this thesis is to define the contributing factors of efficiency of commissioning qualitatively, analyze the close relationship between commissioning and service business, and provide insightful hints for managerial practices and attracting further studies in future.

The thesis is divided into two parts. In the literature study part, theoretical founding relating to efficiency, technical efficiency and management efficiency are carefully illustrated. Also, the trend of service-orientation and its way of representing in various business models are indicated to provide an evident situation in today's business world. In the empirical research part, the influencing factors of technical efficiency and management efficiency are investigated, compared and incorporated into the framework of drivers of efficiency in the literature review. The interview results are examined cautiously to complete the framework of the efficiency of commissioning.

The study revealed that technical efficiency and management efficiency are two integral parts of the efficient commissioning. Technical efficiency covers multiple perspectives such as performance, training and quality, and from each of the three main drivers, contributing factors are discovered. Similarly, management efficiency deals with frequently-debated topics of setting the common goal of value-creation, leadership, change control and deviations, coordination. Contributing elements are then deployed from those critical drivers of efficient commissioning. Furthermore, commissioning, as a platform of face-to-face customer contacts during coordination process, should include its readiness for service business as one of its ultimate tasks during life-long project cycle. The study suggests that further studies with the dyadic relationship between the elements of technical efficiency and management efficiency should be carried out to examine comprehensively the contributing factors of the efficient commissioning.

PREFACE

Commissioning of capital equipment takes a long process to accomplish, and its complexity and uncertainties leads to the inefficiency of project management, furthermore, commissioning discontinuation with services businesses made companies step into the dilemma of low customer satisfactions and struggling service business. A framework of the efficient commissioning needs to be discovered. The study suggests that the efficient commissioning can be analyzed through two dimensions: technical efficiency and management efficiency. Contributing factors developed from the drives of both of efficiencies are discovered. Furthermore, the study extends the traditional time span of commissioning; suggesting that the delivery of services should be continually extended as one integral part of commissioning, hence the readiness of service business constitutes the third dimension of commissioning.

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1. INTRODUCTION

1.1. Background

Capital equipment is a paramount part in manufacturing industries. It is discovered that in various industries capital equipment companies play vital roles in the economical activities, including design, manufacturing and delivery of capital equipment (Hicks et al. 2000). Because of huge investments required for capital equipment, only few customers are capable of implementing the resolution of capital equipment, while the suppliers of capital equipment are trying to secure their few key customers by providing customized capital equipment particularly in competitive industrial environment. Hence, the traditional Make-to-order in high-volume gradually evolves into engineering-to-order in low-volume, the demand of reliable, faster and complex packages supply of capital equipment throughout life-cycle solution is forming rather than the delivery of pieces of equipment. (Hicks et al. 2000) Nevertheless, the market share of capital equipment is growing increasingly matured, the tight bilateral relationship between the supplier and customer of capital equipment make the study of commissioning as a working whole interesting.

According to Kirsilä et al. (2007) commissioning is an essential focus of delivery chain, it is also a point that all parties come together as a working whole; commissioning is the stage where customers, suppliers and contractors have the most direct and complex interactions between each other. Hence, the varieties of commissioning process and complexity of relationship with each other in commissioning groups make it difficult to generalize the definition of commissioning among practitioners and scholars. The definition, measurements of efficient commissioning of project business seems more challenging to explore than the definition of commissioning.

1.2. Commissioning

According to the definition of project commissioning (Kubba 2010), commissioning is a quality assurance-based process that delivers expected technical performances, preventive maintenance plans, operation manuals, and readiness of applications. Kubba's definition defines the general functions of commissioning. According to Kutsmeda & Kenneth (2010), commissioning is the systematic process by which equipment, system and facility is tested to be in accordance with design capabilities and technical parameters specified during early contract stage between customers and suppliers. This perception takes commissioning as the final stage of a project when a facility is complete or nearly completed, and fails to explain most of practices with delivery of complex projects in nowadays. First of all, commissioning comprises a decisive time node: verification and

acceptation. Until equipment is shop-tested successfully according to technical standards defined by relevant parties, the delivery of facility could not be regarded as executed or finished, hence commissioning process extends beyond the execution or completion of facility. Secondly, commissioning is far away from the termination of product life-time cycle from the supplier's side point of view, it continues to maintenance stage. Commissioning is a specific process in the project life cycle; a life cycle is extended from the very beginning of engineering design until the life-time maintenance services. (Kirsilä et al. 2007) However, most of extant publications with regards to project terminations are inclined to perceive commissioning as a final stage of a project. Dvir (2005) claimed that one direct result is that most of extant literature focus on management of the relationship without customers in the picture and project premature termination after project completion or project commissioning.

Reviewing literature, it is found that much attention are paid on theoretical integration perceptions on project implementation of capital goods, or project delivery theories had been discussed to define the factors for an efficient project business. The majority of project delivery are focused on other research areas of project management such as project planning, control, success measurement, and risk assessment, relatively few paid attention to examine the project termination (Dvir 2004). Hällgren & Maaninen-Olsson (2009) stated that 29 percent of project management deal with planning, 23 percent with control while 1 percent is for implementation and execution phase of the project. Hence, practical researches of implementation and execution phase of the project is relatively small, articles exclusively relating to commissioning is even rare.

Two reasons could sum up to explain for the shortage of literature studies on commissioning. First, defining commissioning as the termination of project business at some degree alleviate the importance of further explorations of commissioning, the majority of research would just discuss generally commissioning as a part of project delivery process but rather than discover into a detailed commissioning process. The fact that commissioning phase of individual capital equipment, in particular large-scale capital goods, the commissioning phase are complex and demanding, first-hand materials of commission relating to practical guidance are hard to collect, could be another reason. Buell (1967) mentioned that the main reason for little information on project termination is that specific guidelines for this subject are difficult. Very rarely commissioning, as a separate topic, was explored profoundly from the point view of both technical achievements and strategic relationships with customers, which has customers in the pictures of commissioning activities and subsequent services relationship.

1.3. Objective and questions of the thesis

The fact that very few conclusions have been drawn upon the definitions of commissioning and relevant study of commissioning stages of industrial products proves to cause problems in practice. First, the attentions commissioning of capital equipment received as a part of delivery process is incompatible with the eminent role capital equipment play economically in production activities. The value of capital equipment

ranges up from hundreds of thousand euro to million euros, capital equipment account for a huge share of investment projects. The commissioning of capital equipment has especially important meanings for the success of the entire investment projects. Second, analyzing from the commissioning activities, commissioning constitutes an important procedure of project delivery and it should be observed thoroughly with the aims of contributing to the general efficiency of whole project delivery in industrial manufacturing companies. Third, adhering to the concept of life-cycle project delivery, commissioning is closely related with up brings of service business; its efficiency is manifested as a new way of service business in future. Hence, commissioning should be studied as an innovative means of developing service business. Nowadays, more and more companies with a base on manufacturing are starting to rethink their business model, shifting from traditional delivery of projects to long-term serviced-integrated solutions to customers. Varying from specific capital equipment, after services and maintenances solution plays an important role after commissioning is accomplished. Fourth, commissioning as the battlefield of combining customers, suppliers and sub-contracts, its efficiency has fundamental effects on all parties' operation and particularly the customers, and how to improve the efficiency of commissioning seems be a critical issue among commissioning parties. Therefore, commissioning efficiency should be carefully examined to deal with both from technical issues such as commissioning procedures, acceptance criteria and non-technical issues like relationship management since the latter affect at a large degree the service business.

Commissioning, as a key middle node of project life cycle, is not only involving the promises of technical function abilities, but also shouldering the pressure that subsequent technical services could be smoothly integrated into project delivery. Notwithstanding, efficient commissioning should deliver customers' expectations both from function abilities of capital equipment and expectations itself. Sometimes, customers are expected that they are given enough attentions and can even gain extra benefits from the project: the attained solutions are advanced; the process is optimal and more competitive than other competitors in industry. Besides, commissioning phase is a special period where various kinds of complex relationships could be intensified; relationship management during this particular period is definitely another key to the efficiency of commissioning. Hence, the efficiency of commissioning can be achieved from two major perspectives: technical efficiency and relationship efficiency. Deploying from both aspects, a comprehensive study of commissioning efficiency should be carried out to fill the gap between few researches and huge potential needs of improving the efficiency.

The objective of this thesis is to extract previous literatures of efficiency of commissioning, define the contributing factors of efficiency of commissioning qualitatively and illustrate the definitions through the empirical studies so as to enrich the existing researches and provide insightful hints for managerial practices and attracting further studies in future. Due to the limited researches in commissioning-specific area, the acquisition of sufficient literature on commissioning proved challenging, the literature relating to the efficiency of commissioning capital equipment was hard to gather. Dur-

ing the period of literature review about commissioning, most of researches are found out related with construction projects or building ,the studies of commissioning project is most often referred to construction projects. Although the specific processes of commissioning capital equipment and construction project might vary in many ways. The thesis attempts to present the previous researches on the commissioning and efficiency, and extracted relevant theories for the generation of commissioning theories since most of procedural and general theories including efficiency theories might apply similarly to commissioning, although the actual commissioning activities of the specific equipment or products vary from product to product.

In spite of unanimous understandings of commissioning, the thesis is inclined to interpret commissioning as a continuous activity process of project delivery; the concept of life-long customer solution and its effects on commissioning process has been studied, thus considering readiness for strategy implementation of business services as one of the dimension of efficient commissioning is established to explore the relationship between commissioning and service business. With the prerequisite of project life cycle and service-orientation, what are weighing factors on the efficiency of commissioning of capital equipment during the stage of international project commissioning? What kinds of issues are easily occurred and regarded as crucial for the success of commissioning from the point views of engineers, project engineers and designers? As an overwhelming trend towards service-centric business model in manufacturing industry, what are important issues which should be paid enough attentions already during commissioning stage for the sake of strategy implementation of services business after commissioning? The thesis intends to find answers for above-questions. In this thesis the theory that the commissioning could be understood as a connecting node of project delivery rather than as termination of project business is applied, furthermore, the boundary of “commissioning” is extend to the implementation of services business, since the readiness for services business should be planned before hand as one aspect of efficiency of commissioning. Later-stage technical services could be incorporated into a dimension of efficient commissioning of capital equipment project, former stage of installation, commissioning and even designing stage should concern for the sake of technical services. Besides, technical services can be guaranteed only after the efficient commissioning. Hence, extending the boundary of commissioning to service business is reasonable and necessary.

The thesis chooses to start the analysis with the delivery of capital equipment given the importance of capital equipment in manufacturing industry into consideration. In addition, commissioning of capital equipment takes longer time than batch-production, the commissioning process could follow certain patterns and possible to observe common factors which affect the efficiency of capital equipment. However, commissioning practices could slightly vary in different industries. The thesis is based on two international Finnish-based manufacturing companies (metallurgy industry) with attempts to reflect key issues relating to efficient commissioning. International companies normally deal with project business beyond national boundaries, issues occurred in commission-

ing phases are seemingly more typical, universally representative and avoiding limits of being extracted from one certain country. Besides, increasing amount of companies began implementing the strategy of globalization. We believe, the research based on international companies would prove to be a practical guidance for implementation of project delivery in international company. Additionally, commissioning process at abroad is normally regarded as more challenging in comparison with in domestic; all kinds of conflicts could be intensified while facing cultural differences, discrepancies of technical standards and such.

This thesis use a clinical approach: first reviewing previous literature in commissioning of project business and the measurement criterions of efficiency of project implementations, project delivery and general success of project-based business; and then narrowing down to commissioning process in addition to exploratory practical study of commissioning practices of two Finland-based manufacturing companies, Furthermore, introducing the concept of technical services into commissioning and to identify important factors from the perspective of technical services.

1.4. Structure of the thesis

The thesis is organized in five sections. Chapter 1 is a brief introduction of commissioning of capital equipment; the background of commissioning in industrial projects is presented and the research questions are defined. Chapter 2 is a literature reviews starting with topics of definitions of efficient commissioning, further exploring relevant arguments and perspectives of understanding commissioning from the angles of project delivery, installation, services. Readiness for implementation of service strategy is also reviewed for later discussion of generalizing factors of efficient commissioning thoroughly. Chapter 3 is an introduction about research methodology and structure of research process. Chapter 4 draws empirical results from structured interviews, explaining the cases and presenting data from the interviewees. Chapter 5 is a discussion of the case study and conclusion.

2. LITERATURE REVIEW

2.1. Definitions of efficiency and commissioning

The definition of efficiency has brought forth diverse discussions in literature. According to presented theory (Lee et al. 2000), the definition of efficiency is diverse and complex. Very often, efficiency is confusedly discussed together with another linguistically-related term, effectiveness. In order to gain deep understanding of efficiency, some illustrations of differences between two terms are necessary. Effectiveness is also inferred to “doing the right things”, stressing choosing the right things to accomplish, whereas efficiency is referred “doing things right”, stressing on right ways of doing things. Therefore, effectiveness can be interpreted as the efficient accomplishment of a task, describing the ways or degree at which efficiency is achieved. Efficiency is connected with the attainment of economic goals, seeking to achieve optimum (Ruhli & Sauter-Sachs 1993). The theory of efficiency unilaterally emphasized the economical maximum target as one function of efficiency, failed to apply the efficiency broadly to describe the general process. According to Ruhli & Sauter-Sachs (1993), many German management scholars such as Frese, Grochal and Welge do not make the differentiation between the two terms. Thus, differences do exist between these two terms from the point view of its original meanings as could be observed from each inferred analogies. However, the uses of two terms in management theories are perceived as similar, most of scholars agreed that it can be used alternatively to describe management topics. In this paper, efficiency of commissioning means to apply resources to attain the general objectives which are not limited to economical targets only, and expanding its context into the commissioning process. Thus, commissioning efficiency describes the relationship between the resource and “attainment of goals”; the contributing factors to the efficiency commissioning are an investigating process into how to achieve the goals of commissioning.

Efficiency has also inseparable relationships with productivity; productivity is often a substitute of efficiency in many cases, it's an indicator of performance. Efficiency and productivity are referred as the key drivers in firm performance. Most firms use financial indicators such as assets, return on equity to evaluate their financial performance; as a matter of fact, their financial performance is based on efficiency, productivity improvements. According to Hon et al. (2011), efficiency is a relative concept, a statement about the performance transforming a set of inputs into a set of outputs. The relative definition of efficiency illustrates the general concept of efficiency as describing the relationship between inputs and output, so as enabling its general applications of production and further to commissioning process as well. Hence, the efficiency of produc-

tion process, frequently referred as productivity, is defined systematically as the ratio of output to input. Therefore, the efficiency is considered to be improved if more output is produced using the same amount of input, and vice versa. The improved efficiency depends on the improved elements of production, such as substitution of old facility with new facility, production process or new materials, human-embodied know-how through learning, using organizational and managerial innovation (Lee 2000). Therefore, the contribution factors for improved efficiency could be explored from the activities itself, like the production or commissioning, observing the elements of commissioning activities to extract the contributing factors of efficiency of commissioning.

The theories of efficient production including measurements of production efficiency are reflected to other subjects. The majority of literatures relating to efficiency measurements, in particular two-stage efficiency are to a degree extended from above theory and adapted into different applications such as production, banking (Charnes 1978; Lee et al. 2000; Hon et al. 2011), and construction. The key point of accommodating theories into specific practices is to understand the great unity of efficiency, as well technical efficiency as an entire collective concept given the fact that very often efficiency is measured collectively from distinguished dimensions. The ideal resolution is to deal “efficiency” with “relative efficiency”, which is often illustrated by “ranking of observed results (Charnes et al. 1978; Hon et al. 2011).

Applying the efficiency concept into commissioning, the efficiency of commissioning can describe the collective effects of distinguished dimensions of commissioning activities; meanwhile it has to be born in mind the relativeness and collectiveness of efficiency concept, since the efficiency illustrate the collective assembly of various factors, but efficiency has its limitations on calculating the similar factors. Hence, functions of commissioning need to recognize distinguished elements of commissioning activities. Looking through the literature of the definition of commissioning, commissioning is understood as a process, beginning in the pre-design phase of a project and continuing through construction until the final acceptance for achieving commissioning success (Kutsmeda 2008; Gelfo 2011). However, detailed descriptions of commissioning activities in every stage is not available, it is hard to apply the collective concept of efficiency in details into the study of every stage of commissioning activities. Instead, the paper chose to define the relative elements from the functions of commissioning activities. Commissioning has been defined as a systematic, documented, collaborative process to attest the function ability of systems including component equipment to meet design intents and needs of customers (Kutsmeda 2008). Therefore, commissioning can be divided generally into two major functions: technical fulfillment and relationship management. Hence, the efficiency of commissioning can be analyzed collectively from those two elements.

Together with the collective concept of efficiency, the application of open system theory helps to understand collectively commissioning process as a whole. Open source system has been referred often to support the studies of other topics in project management, input and output concept has been observed in project management literature.

Generally, the extant literature on project management can be categorized into two groups with different focus of relationship, the first group focus on the management of projects and their organizational inputs, the other one prioritize on the internal process and expected outputs (Patanakul & Milosevic 2009). Two groups with the prerequisite of looking the organization as a central point have prioritized their own focus: either internal process or management, but both of groups implants open system concept. However, it has not been applied in commissioning. Commissioning as a multi-actor process consisting of complex activities and relationship management, suppliers, sub suppliers, customers and sub-contractors, third-party authority, the application of open system is beneficial to present a collective and comprehensive view of investigating the technical and management efficiency of commissioning.

First, open system illustrate the relationship the same way as technical efficiency is used to analyze the process from the view of achieving targets technically, or productivity in another word; second, open system grant the dynamic effects between different variable and prefer to regard that the outputs are based on collective sums of all variable, the same concept can be followed to analyze relationship management and management efficiency. Management efficiency is to investigate the unity inputs of the entire delivery organization including customers; management efficiency therefore can indicate how effectively the united commissioning activities (inputs in a whole) can affect the success of commissioning. Hence, except from technical efficiency, which stresses the method of assessing the performance based on set standards, another important dimension of efficient commissioning can be approached from the point view of management. The following sections will illustrate efficient commissioning from above two aspects: technical efficiency and management efficiency.

2.2. Efficiency metrics and technical efficiency

Efficiency has been widely examined as an economical term to judge and assess the profitability of business; therefore, different factors influencing the efficient business are examined to find the determinants of successful business. In order to distinguish different kinds of determinates of efficiency, efficiency metrics are introduced in practices. Efficiency metrics are usually classified into two groups: quantitative and qualitative indicators. The quantitative measures are usually based on numerical variables of inputs, such as costs, capital expenditure, time and other countable units of inputs. Whereas, the qualitative metrics are based on subjective evaluations, valued numerically and subjectively, some of them could be transformed and interpreted into quantitative indicators. (Sánchez & Pérez 2002) Customer (or stakeholders') satisfactions, performance of facility, enhanced relationship between suppliers and customers could be categorized into quantitative indicators. Commissioning is a system process with the main focus on the ultimate goals of accomplishing the delivery of equipment and fulfilling customers' unique needs. Hence, analyzing the efficiency from the qualitative metrics is reasonably achievable, although quantitative factors such as economical objectives,

time-schedule adherences are also direct indicators of efficient commissioning, this thesis mainly prioritize more on qualitative indicators than on quantitative measures.

The measurement of efficiency or productivity, deals with heterogeneous measurement objects within multiple dimensions. The early initiation of the systematic research on the measurement of efficiency is from Farrell (Farrell 1957, in Lee et al. 2000). Farrell suggested a systematic method of measuring efficiency collectively for the various aspects of a production process:

- technical efficiency: the ratio of actual output to ideal maximum output;
- allocative efficiency: the degree of choosing the lowest input mix to the general input mix according to price conditions;
- Overall efficiency: synthetic measure of the above two, computably combining the technical efficiency and allocative efficiency to the final result.

From Farrell's theory, it can be observed that technical efficiency is first one dimension of measuring performance and allocative efficiency is correlated with choice of costs, prices of inputs. Many scholars agreed that collective efficiency should prevail to perceive technical efficiency since the prices of inputs do not affect efficiency generally to a high degree. Hence, focus of research in efficiency is primarily shifting to technical efficiency rather than analyzing the price-depending allocative efficiency. Technical efficiency is therefore chosen as a primary term of evaluating the performance (Lee et al. 2000; Hon 2001) in previous literature.

As one of qualitative metrics, achieving the technical performance is the critical indicator of technical efficiency of commissioning. Technical efficiency is interpreted as barometer of a successful enterprise, a synonym of profitability, has attracted practitioners' attentions in wishes of finding the key to the profitable and competitive business, it has been explored often to examine quantitatively the economical activities, decision-making units in various industries, including manufacturing, pharmaceutical and financial as well. However, technical efficiency has rarely been studied to explain qualitatively the commissioning process from technical view point. The following sections will go further to find out the technical efficiency of commissioning.

2.2.1. Technical efficiency of commissioning

Technical efficiency measures the ability of a firm to produce the maximum output within given inputs and production technology (Coelli et al. 2005). Accordingly, technical efficiency is the conversion of physical inputs such as activities inputs into outputs relative to best practice. Technical efficiency is also a relative concept; it is a ratio of comparison of one firm's performance to the best practice input-output association. Therefore, the concept of technical efficiency has a value defined by the ratio of observed output divided by the potential maximum output. (Coelli et al. 2005) However, Hon et al. (2007) stressed that managerial practices, scale or size of operations affect technical efficiency based on the engineering relationships rather than prices and costs; in another words, technical efficiency is most likely decided by internal managerial rela-

tionships rather than external set prices. Developing from above theories, technical efficiency is mainly affected by managerial relationships.

Two scientific approaches can be used to measure a firm's technical efficiency, a non-parametric approach such as data envelopment analysis (DEA) and a parametric approach two-stage stochastic frontier analysis. DEA stresses the influences of efficient decision-making on the systems, while SFA examines the efficiency on the basis of the assumption that technical inefficiency and measurement errors exist at the same time. (Amornkitvikai & Harvie 2011) The researches on those two kinds of methods have been increasingly growing to analyze the technical efficiency in various industries in recent years. This thesis attempts to find out main quantitative driving factors of efficient commissioning, not to focus on the accurate quantitative and analytical calculation of efficiency ratio, therefore will not go further into the discussion of two approaches of measurements of technical efficiency. However, commissioning, as an integral part of project delivery, focusing on the procedures of implementations of projects, setting up its goal of abiding by design agreements and technical requirements; its technical efficiency should be understood collectively from above-mentioned two approaches and focus on the dynamic relationship between input and output with the help of open resource system.

Anderson (2010) argued that open system model is a good choice of holistic description of an enterprise, and consequently also a project, and open system model depicts the inputs, processes, and outputs of the enterprises. Open resource system can be applied into commissioning as well. On the one hand, open system model itself can be used to generally examine the relationships between those three elements, input, output and process. On the other hand, technical efficiency can further illustrate the efficient relationship of input and output from a comprehensive technical view. Technical efficiency together with open system model presents a good method of exploring the contributing factors of technically efficient commissioning.

2.2.2. Target of commissioning

Before going further to disclose the input and output of commissioning, it is important to understand the targets of commissioning from the technical point of view. Technical targets are the measurement of performance. Commissioning is quality-assured process, ensuring the compliances with the design intent which documents performance objectives, such as technical parameters, functionality and capacities of whole system. In addition, design intent also stipulates the criteria of acceptability on performance objectives.

According to Spengler (2001), the objectives from realizing a successful commissioning program include:

- High-quality of commissioning system and it can operate consistently with design capability, meeting with requirements from the customer

- Identification of system faults or discrepancies early in the construction process, meanwhile, increasing equipment reliability, contributing to the success of the whole project
- Improved documentation, training, and education for operators and facility managers to ensure longer equipment life and improved performance
- Reduced operation and maintenance costs
- Reduced potential for liability and litigation. This is true for minimizing both liability of owners due to occupant personal injury cases and litigation of engineers and contractors due to claims from function ability, familiarizing end-customers with operation and maintenance procedures

To sum up, technical targets of commissioning, or output in another word, could be concluded as to realize the design capacity according to agreed criterions, to ensure the function ability of equipment and provide sufficient technical trainings (operation and maintenance guidance) to users at the same time.

In order to achieve the targeted performance, inputs of commissioning should include wide range of activities since the definition of commissioning starts from the beginning pre-design stage to throughout acceptance stage. In the pre-design stage, owner's performance requirements have paramount affects on the attainments of commissioning performance. The development of performance requirements functions to clearly convey an owner's operating requirements for the system (Wiggin 2005). Wiggin claimed that commissioning authority should make specific recommendations to the owner regarding the design of the facility (or system), and information about the training and relevant requirements. Garvey (2005) also stated that master plan initiated by the commissioning party, customers and sub-contracts should include operational requirements of commissioning documents which are formulated by involved parties. He further emphasized the importance of documents of operational requirements to the validation of commissioning.

During the planning and justification phase, technical performance measures of an advanced manufacturing technology system should be identified already. The performance of system is primarily judged by the measures and requirements in the design and planning stages (Small & Yasin 2003). According to Martinsuo et al. (2008), one of the important methods of rating technical performance is meeting of performance specifications.

Therefore, technically operational requirements are a prerequisite for judging and assessing the performance of system under commissioning. Moreover, operational requirements should already be clearly formulated in pre-design stage. Furthermore, Wiggins claimed during the stage of pre-functional testing, commissioning team, contractor

and end-users are on-site full-time; technical supports from commissioning team given to the contractor are expected and fundamental for the success pre-test of the system. (Wiggins 2005)

2.2.3. Complexity, quality requirement with technology

In order to manage large projects efficiently, a great deal of researches have been done to explore the complexity of projects. From the concept of project complexity, some findings from technical complexity could be applied for the understanding of efficiency of commissioning as a part of project implementation. Barccarini (1996) observed the complexity from the technology view and the organizational view, he claimed that technology differentiation and interdependency, such as in the form of overlaps of design and construction, difficulty of location all contributes to the variable and diverse tasks in large engineering projects. However, further arguments of detailed forms of technology differentiations were not developed for understanding the complexity of projects. Bakker et al. (2011) investigated into a technical, organizational and environment framework of grasping project complexity, illustrating various aspects of each subcategories of the framework based on a practical case study and existing literature reviews. In Bakker's research, technical views cover the sub-categories of goals, scopes, tasks, experiences. In particular, technology-related aspects defined some important elements such as technical method, quality requirements regarding project delivery, correlation of technical process with existing system, conflicting standards and norms in specific countries, the newness of applied technology-dominated technology and experiences of specialists involved with the project. Bakker's theories fully presented a holistic technical view of project management and project complexity caused by various dimensions of technical view.

Nowadays, it is widely agreed that technology is a multi-dimensional concept, constituting an important part of project complexity, which also has fundamental effects on other elements within the sub-category of the framework (Barccarini 1996; Bakker 2011). Previously, technological dimension was integrated into social or organizational when observing the complexity of project management. Dewar & Jerald (1978) stated earlier at that time that technology-dimension had not exerted influences on an organizational level given the level of technology application into consideration; instead, technology was decomposed into social or structural characteristics. Hence, whether or not technology is risen up as a single dimension of project complexity is closely related with the current technology level. Considering changing environment in today's technology-dominant world, applying technology tactic to contenders of critical project complexity is appropriate and needed.

Today, the wide applications of technology and information technology establish technology as a single technical dimension of project complexity. Accompany with technology complexity in project management, quality management with its focus on applicability of technology, technical standards has gained increasing attentions during the validation of commissioning. Quality requirements, adapting to deal issues with

application of technology, technical standards, should be given enough considerations for the efficiency of commissioning. Meanwhile, many attentions should be given to quality implementation of special technology application into commissioning process: quality assurance. Until recently, commissioning was performed without relevant quality requirements, Garvey argued that commissioning documents were often prepared and executed without the supervision of quality assurance department. In most of cases, systems were commissioned and validated while operational requirements are not satisfied. (Garvey 2005)

2.2.4. Summary of previous research on technical efficiency

Technical efficiency, as an integral dimension of efficiency, has been widely discussed to analyze both the process of project management, to be specific economical performance, and the ability of turning inputs into output. Technical efficiency, as a barometer of enterprise's performance, measuring the ability of attaining the maximum output from inputs (Coelli et al. 2005) has been adopted to analyze the efficiency of a particular kind of activities. Some practical research has carried out in auto-manufacturing process, electrical engineering projects. Technical efficiency has further been studied to acquire quantitative efficiency results such as the efficiency of banking system with the help of the computing, combining the method of data envelopment analysis or stochastic frontier analysis. However, technical efficiency has not been applied to describe efficiency of general commissioning activities, technical fulfillments or performance as the qualitative results.

The concept of technical efficiency, together with open system model to find the contributing factors of technical efficiency of commissioning is an investigating process of looking into the commissioning from the technical point view. Technical efficiency is a common term of describing the relationship of input and out; it can reflect the efficiency of commissioning in the open resource system under the condition that commissioning activities as input and general successes of commissioning as output. Outputs are represented by technical goals or other performances including design capacity and function-ability, foundation outline, time schedule of project hand-over, installation and commissioning quality, operation and training, checking discrepancies and faults. Inputs mean technical resources, manpower, time and technological knowledge. Observing from previous literature of commissioning, the frequently mentioned criteria relating to the technical commissioning are mainly focused from the perspective of performances, operation specifications and quality. Incorporating the input and output concept from open resource system into the technical criteria of commissioning from literature, the thesis summarizes the drivers of technical efficiency are shown in Figure 1.1.

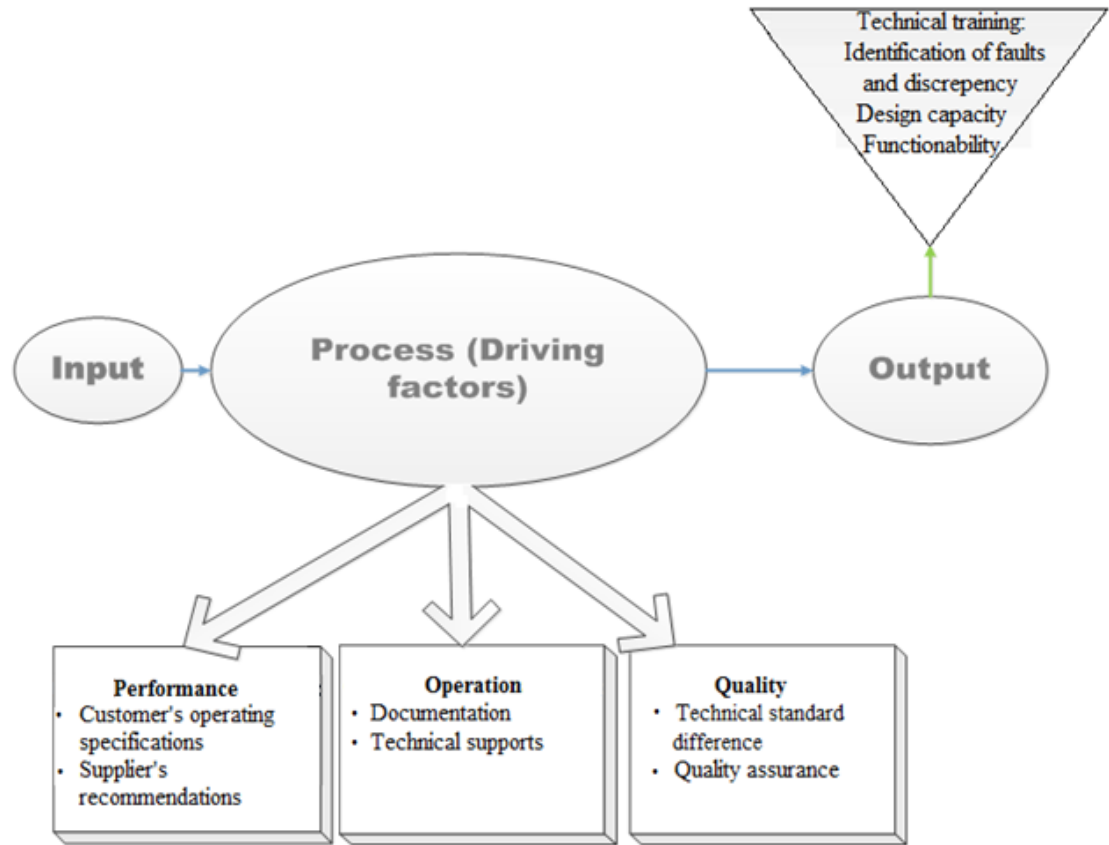


Figure 2.1. Driving factors of technical efficiency

Performance requirements are the base for assessing the technical efficiency of commissioning. Performances specifications encompass technical parameters, function ability and other expected features from customers. In some cases, flexibility for futuristic expansions is also considered particularly for capital equipment. Operation requirements require both parties' interactive activities, suppliers and customers or end-users of equipment. Operational training cover two parts, one part is theoretical studies and the other is practical guidance on site. Supplier should design complete operational training toward the operation and maintenance of the specific equipment and system. Customers should fully participate the operational familiarization process, interactively communicate with questions and requirements. Quality implementation acts as an effective tool of ensuring the quality of commissioning of specific technological equipment or process, its existence is beneficial to assess and measure the efficiency of technology-complex equipment.

2.3. Management efficiency

Over decades, great deals of concepts explaining efficiency have been developed from the point view of management theory. Management efficiency is understood as contributions of management to reach economical goals, issues such as relationship interaction, management techniques, polices and strategies and such are dealt with to find the drivers of management efficiency. In general, efficient management is a process of

seeking the controlling factors which bring forth contributing influences on the goals in a multi-personal productive system (Ruhli & Sauter-Sachs 1993).

Commissioning, as an independent process of business management, can be explored in the same way as theories of efficiency. Likewise, applying the concept of “efficiency” into commissioning, efficient commissioning could be interpreted as contributions of commissioning to project implementation goals. As in other much macro contexts such as productions, banking systems, the relatively narrow-defined scope of commissioning are also characteristic of multiple criteria and standards of assessing the efficiency of the entire process. In another word, causalities and determinants of a successful commissioning depend on various standards. Therefore, it’s hard to conclude the generating factors of an efficient commissioning.

In Ruhli & Sauter-Sachs’s article (1993), several different kinds of approaches of evaluating the efficiency are deployed in details. This thesis chose few for references. Among them, the economic approach pinpointing assessing the efficiency in micro-economy with costs given to considerations might be difficult to reflect the discussions of efficient commissioning, which is not included in this thesis. This thesis only emphasizes five of them: the goal approach, system approach, social approach, interaction approach and decision approach are stated respectively in following sections.

The goal theory is based on the conscious mindset and continuous pursuit of goals. Two kinds of goals are involved, economic (shareholder value) and social (work satisfactions). Causalities which influence the achievement of goals are developed from those two aspects. Some determining factors (determinants) are concluded based on those determinants which can be influenced by the management, originating a chain of causalities between measures adopted by the management and the degree of goal achievement. (Ruhli & Sauter-Sachs 1993)

The system approach focuses the relationship between the subjects and its environment. In particular, relationships to the public are central. The system views are deployed from understanding the interactive relationship with the environment. Ruhli & Sauter-Sachs illustrated four general aspects of an efficient system: the integration with the environment, setting and attaining of goals, integration and coordination of actions, the preservation of the social structure. The strategic planning process focus the fit with the environment, the causalities are formed during companies’ adaption to the environment. (Ruhli & Sauter-Sachs 1993)

The social approach is based on the aspects of behavioural science. Efficiency is measured against to social phenomena such as work satisfaction or group cohesion. The causalities and determinants are extracted from the field of society. (Ruhli & Sauter-Sachs 1993) Motivation and behavioural theories are central to the study of management style. One interesting managerial practices relating to this area is that cooperative management style does not necessarily lead to higher efficiency, but it definitely promotes job satisfactions, which constitutes one of the determinants of efficiency from the angle of social approach.

The interaction approach prioritizes the relationships between enterprises and stakeholders, both internal and external as the focus. Meeting the demands and expectations of stakeholders is crucial to efficiency, the interaction activities between enterprises and stakeholders determine the causalities and determinants. One persuasive example is that ecological enterprise, following and meeting up with ecological standards, environment-friendly, is proved to be more competitive than similar enterprises, since companies' positive image of their strong environment-consciousness in some way promotes the recruitment of qualified employees, impetus the efficiency. (Ruhli & Sauter-Sachs 1993)

The decision approach is discussed in large length and depth, since decision-making process is a fundamental part of management. The theoretical researches on efficiency of decision-making process combined with data envelopment analysis have risen dramatically in recent years, constituting a large part of the entire efficiency-related literature. Nevertheless, a managerial decision-making process consists of a string of separate decisions, efficiency is intercepted integrally. Often dealt topics from this approach are information-sharing, alternative problem solutions and overcoming the barrier which inhabits the former two kinds of activities (Ruhli & Sauter-Sachs 1993).

Each of above-mentioned approaches to efficiency has its own focal aspects and priorities on issues to be examined as shown in figure 2, it provides the possibility of examining efficiency from various focal points, so as giving rising to various causalities and determinants (Lee 2000; Hon et al. 2011), which is compatible with previous discussions about contributing factors of efficiency and relative efficiency. The goal approach discussed what are the weighing drivers for achieving economical and social goal; while system approach reinforces the fit of enterprise into marketing environment; the social approach touch the theories of behavioural science; interaction approach is from the relationship angle of dealing with stakeholders, decision approach is to generalize the drivers for efficient decision-making process.

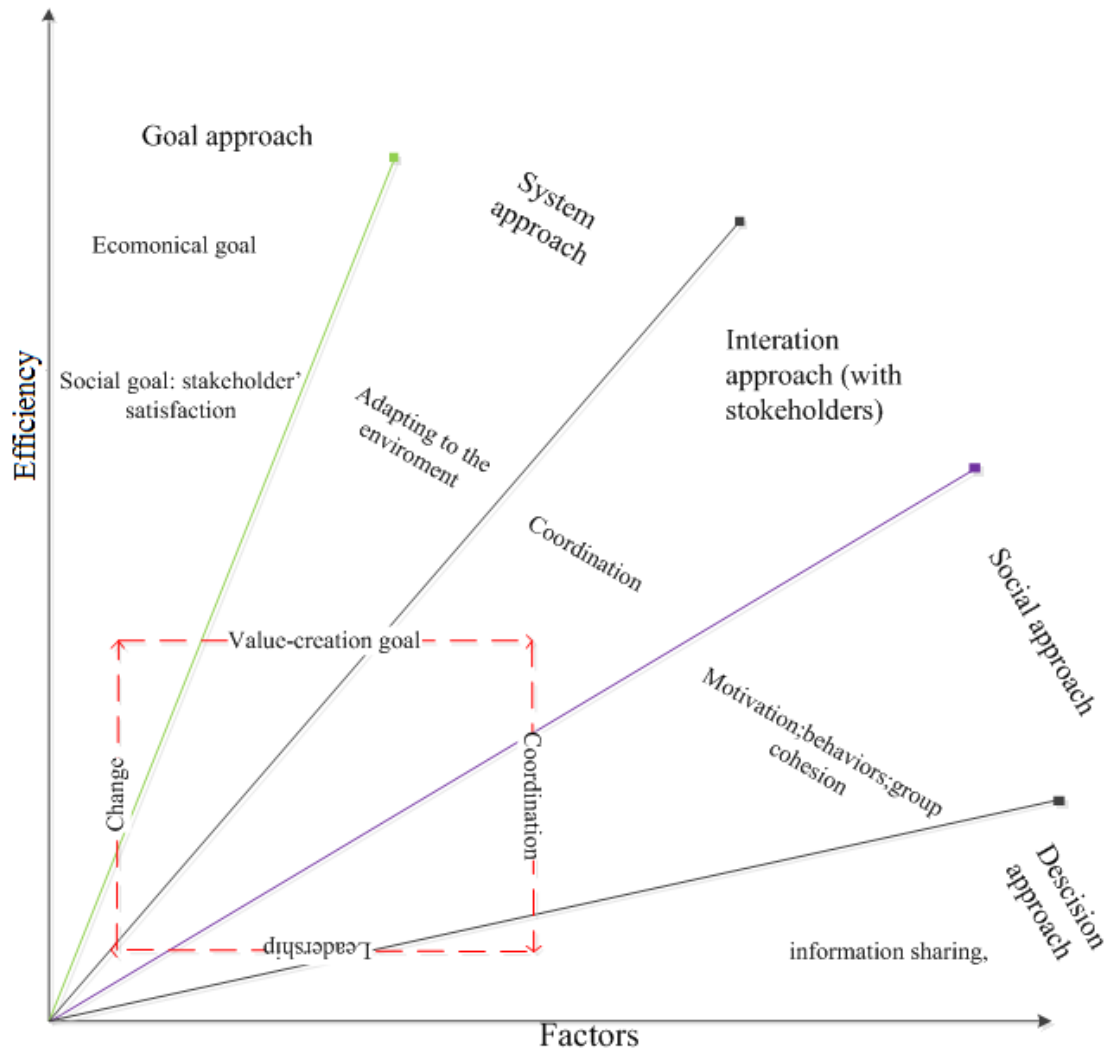


Figure 2.2. Five approaches of management efficiency and four drivers

Based on the various view points of efficiency, it is important to seek the possible ways of defining efficiency collectively and integrally, grouping and finalizing the main drivers of efficiency of management, although each of five approaches illustrate the causalities relationships of management efficiency from different focal perspectives. When applying basis theories of five approaches into commissioning, the thesis mainly focuses on the relationships among participated parties, decision-making process and realization of customer value. Economical goal and other qualitative factors in Ruhli's approaches are not covered in this thesis. Hence, based on Ruhli & Sauter-Sachs five approaches of management (1993), the thesis categorize the four drivers of efficient management: value-creation goal, coordination, leadership, change control and deviation.

The goal approach stresses both economical goal and social satisfactions; however, the thesis analyzed qualitative metrics of efficiency, customers' satisfactions and value-creation on the process of commissioning becomes the main driver of achieving goals. The interactions with different parties of commissioning group comprise of the majority part of relationship management, it is a process of coordination of relationship management among multi parties. Hence, the coordination has decisive effects on the effec-

tive interactions during commissioning; it is another driver of management efficiency. Social approach and decision approach deal with information-sharing, motivations and cohesions during decision-making where leadership has an important influencing effects. First, leaderships has close relationship with the binding of groups and members' work satisfactions, furthermore leadership style to some degree decides the method of information-sharing and learning. Hence, leadership is regarded as the third driver of efficient commissioning. The last issue with commissioning is related to adapt to the environment, which is the theme of system approach. The corporations with environmental protection organizations or other third-party authorities proved to play an increasingly important role during commissioning. The key of adaptations to external environment is change and deviation control management while implementing commissioning plans, planning and changes have to be dealt with hand by hand. Hence, change and deviation control is the fourth drive; it is also one big share of project management. The four drivers of efficient commissioning are shown respectively in figure 2.1.

In order to explore contributing factors to efficient management in commissioning, to examine the causal relationship and determinants of efficiency of commissioning, the thesis choose to discover the contributing factors from the drivers of the value-creation common goal, coordination, leadership during decision-making and change adoptions to the environment. The following sections will go in details into every driver of efficient management.

2.3.1. The common goal of value-creation

As for the commissioning process, one of contributing factors to efficiency is establishing a common goal in commissioning group. Kutsmeda (2008) stated that commissioning is most effective and beneficial to the project when a complete commissioning team is working together toward a common goal of establishing a fully functional, efficient facility. Except for a functional facility, customers' satisfactions are another target of commissioning activities. According to Kirsilä et al. (2007) increasing project complexity brings pressures on the project mangers not only to deal with internal management activities but also to cater for customers' satisfactions, customer satisfactions generally indicated the success of commissioning.

The efficient commissioning starts with the common goal of involved parties: satisfying customer's expectation, customer satisfactions are one of the most important goals of commissioning; it is also the ultimate goal of commissioning. The statements about the role of planning and tactical operationalization during the project progress could provide some clues on how customer satisfactions evolve as the ultimate goal of the entire project delivery, so as the final goal of commissioning. During the whole life cycle of project progress, the roles of project planning and tactical operationalization play vary across the project life cycle. According to the literature, at the beginning of project initial planning, tactical operationalization over planning factors are perceived to be highly important to meet with measures of internal successes, financial budget, schedule and performance goal. As the project progresses, "external success measures" which are

more perceived by the customers or end-users, perceived value of the project and client satisfaction are becoming more critical dimensions of project success, planning has dominant importance instead. (Dvir & Lechler 2004) Thus, it is evident that customer satisfactions have become the dominant dimension of the success of project deliverable at the later stage of project delivery. Commissioning as the later stage of project delivery should have the goal of satisfying customers. Kirsilä et al. (2007) also mentioned that integration capabilities among involved parties during the delivery of project aims for ensuring customer satisfactions, it reflects the goal of customer satisfactions as well. Reasoning from above statements, commissioning, as the later-stage of project execution, its' value and success are most likely judged by customers or end-users based on "external success measures": satisfactions rather than on the internal operationalization dimensions. Hence, the ultimate goal of project delivery is to satisfy customers' various demands, focusing the customers as the major stakeholder.

Satisfaction is a conscious and subjective word, and always related to expectations. Satisfaction is fulfilled when expectations like objective goals are met. Meanwhile, it's known that for a multi-party involved commissioning process, different parties have different goals or even conflicting goals, conflicts of interests from each party do exist in project management. The same kind of conflicts even exists in two-dimension relationship, the principal and project party. The agency theory, one party delegates the work to another party, is normally used to help describe the relationships between the principal organization and the project party (Andersen 2010). According to Andersen (2010), the agency theory pointed out that the project owner and the project manager have different preferences or even conflicting goals in some circumstances, the project manager and owners might have different views on some important issues.

During commissioning, firms and networks of firms are seen as complex adaptive systems, comprising of interacting sets of organizational and social relationships where each actor is pursuing its own goals. The common goal of value-creation of is needed to be set up for aligning different objectives in the commissioning team. According to proposed literatures, the essential to any business net is the underlying system through which value is produced. The value-system construct is based on the notion that each product or service requires a set of value-creating activities performed by a number of actors, performing a value-creating system in the net. The definition of value-creating system can be concluded as "a set of activities creating value for customers. (Möller & Rajala 2007) In order to fulfill customer's satisfactions, each actor in the commissioning network has to contribute to value-creation activities, forming a value-creation system in commissioning. Hence, reasoning from value-creation views of the network of organizations, it is easy to assume commissioning environment is constituted by the network of various organizations and each actor can only be guiding toward the common goal of value-creation of the process although each of them might have conflicting interests.

No matter discussing performance goals or financial goal from the point views of companies, or "social goal" as being to satisfy the stakeholders in the system where companies are only parts of the surrounding environment, the concept of value-creation

should constitute a major part of its goals, in particular for manufacturing companies aiming for to implement a customer-centric strategy shifting from a product-orientation strategy. Value-creation concept can encourage supplier companies to be more involved with customer's operation activities and mobilize customers for contribution of value creation as well. The literature claimed that customer's involvements are especially beneficial for the value-creation of the entire value-creation system.

According to extant Norman's value-creating model, the customer is no longer just a receiver of offered products or services, but actually a co-producer, and co-designer of value creation. Hence, a company should focus on the customer of the customer as the major stakeholder, and to purposely engage oneself as part of the customer's business, shifting away from the traditional industrial view of the customer offering as output of its production system but to a view that customer offering is one part of inputs in the customer's value-creating process. (Szczepanek & Winter 2008) From the perspective of value-creation, Norman's model emphasized that the focus is the second-level relationship, focus of customer's customer value, seeing the output of a particular project less as entirely an output, but as input of customer's own value-creating process in the case of multiple stakeholder group. Szczepanek & Winter reiterated that the essential message of Norman's theory lies in that the goal of a project or programme is not to create value for customers but to mobilize customers to create their own value from the project or programme's various offerings. Norman's model can also be applied to multi-discipline projects or programme (Szczepanek & Winter 2008). As a long-term part of project management, applying value-creating theories and setting the goal of value-creation will help resolve the conflicts of single parties, assembly the net activities toward a same goal and mobilize the actors including customers to contribute for value-creation for customers; furthermore, the value-creation goal can interactively stimulate customers to engage into commissioning activities, which is beneficial for the efficiency of commissioning. However, how the value-creation common goal is perceived and implemented in practice and how setting a common goal affects the commissioning activities is left for further explorations from the empirical studies.

2.3.2. Effective leadership

Apart from the setting of the common goal, a commissioning group should also include leadership, such as facility director and operations staff, the general contractor or construction manager (Kutsmeda 2008). A commissioning team consists of various members with different interests, arriving at a common goal proves to be challenges and requires effective leaderships. As one of important drivers of the efficient commissioning, a successful commissioning as well, another critical factor is to build up effective leadership in a commissioning team.

Organizations, based on projects, are increasingly focusing on effective leadership as one important criterion of success, assessing the capabilities of executive sponsors and project leaders in today's complex business environment (Legris & Collette 2006). Dynamic and responsive, flexible and reacting accordingly to external changes

and demands, leadership brings forth cohesive groups around the organization. Leadership is not only a factor of criteria of success, but also an actively influencing element of other criteria of success, such as performances, customer satisfactions. Leaderships are not simply about the orderly transfer and execution of commands, it empowers individuals and enables them to react and take responsibilities in the team (Cowan-Sahadath 2010). With the help of behavioral sciences, collaborative and democratic management, from down-to-up management model is gaining more and more attentions, traditional vertically chain of command is losing its ground in today's business world due to the structural barriers for information-sharing.

Nowadays, fierce competitions, impacts of globalization, maturity of business process and market facilitate changes in technology area rapidly. In order to adapt to ever-changing business environment and to sustain competitive, interdependence between all parties pull them to cooperate and collaborate in order to seek for value-creation in the network, no one can survive long by isolation. Only through increase of customer value-creation, company can sustain their competitiveness. Stimulated by this trend, strategic relationships among concerted parties have developed, project delivery is no exception. Project alliance has become one of hot-debated phenomena in last decade, especially companies' outsourcing decisions in the supply of equipment and technology has brought multiple participants into the project network. Parties under a project alliance agreement work as a collaborative team, acting with integrity and making unanimous decisions relating to key project delivery issues, meanwhile risk is also shared within the group. Walker claimed that the goal of "best-for-project" decisions requires alliance partners to work together to provide innovative solutions to problems. As the gluing power, soft skills for project leadership are undoubtedly required (Lloyd-Walker & Walker 2011). Effective leadership is central for the facilitation of innovative solutions through constructive high levels of communications and dialogues. Toor & Ofori (2008) identified that authentic leaders are those who successfully operate in the increasingly complex working environment; the distinguishing features of authentic leadership include leader self-awareness and self-regulation, emotional contagion, and commitment to be enabling follower's success through their development.

As a successful project manager, technical skills and engineering experiences have been largely debated not the foremost important character of effective leadership; instead, the soft skills, the capabilities of integrating the group into a cohesive group, are the key of being efficient project managers. Likewise, the efficient commissioning lies in the orchestrating involved parties toward a common goal of enabling value-creation beyond only the smooth internal operation activities within own companies. The leadership identified the need for a proven project management method that included effective communications, change management plans, employee engagement, however, a final agreement on specific effective leadership on commissioning site, what expected of a successful leader, needs to be tested from empirical studies.

2.3.3. Change control and deviation

Changes are the ever-lasting theme of project management nowadays. Changes control and planning, particularly for project delivery where all parties assembly together as a working whole counter-facing expected and unexpected change issues constitutes a integral routine of project management (Kirsilä et al. 2007; Cowan-Sahadath 2010). Accompanying with leadership, changes is another basis topic of management. Apart from the fact that leaders, who inspire and innovate creative approaches and work toward a common goal, leaders appear to implement a systematic approach to change, greater accountability through expectations, cultivating competencies for taking responsibility for change, opening channels of dialogue. All contributes to creating the right climate for facilitating and adapting to changes (Barrett et al. 1995; Griffith-Cooper & King 2007).

Planning and change control constitutes as important dimension of knowledge area of project management (Kirsilä et al. 2007). According to proposed theories (Griffith-Cooper & King 2007), most projects caused change and in order for the project to be successful the changes need to be proactively managed to minimize the impacts. Present literature stated that, organizations interpret their business less as a rigidly operated structure, but more as flexible at improving every aspects of their operation for constantly occurring changes. The change perceptions help us to use an integrated change approach to understand the process of project delivery, in particular commissioning process; a proven project management methodology has to cover a integral change control, given into considerations the people, processes, policies, strategies which could be influenced by changes. (Cowan-Sahadath 2010)

Change and deviations is an essential part of project management (Hällgren & Wilson 2007), project deviations come in many forms. Interruption, tensions, difficulties, snags are all called deviation, primarily deviations from project plans but also from expectations surrounding the project and its activities. Studies on projects show that deviations from a general, planned schedule do happen (Hällgren & Wilson 2007). Furthermore, project management is carried out together with uncertainties, which give us strong justifications for a project planning and preparation, in a way to recognize the unusual circumstances, further proceed with problem-solving and progress as planned and expected. In addition to uncertainties, unforeseen interruptions can rise and disrupt the progress of projects. Therefore, changes and deviations from the plan invariably occur and commonly faced by the people within the project. Some deviations are first encountered and managed on a local site level, mightily further pushed up to the corporate project team. (Wilson & Hällgren 2011) Based on practical projects, it showed that changes in plans as well as project objectives reduced productivity and customer satisfactions in technical projects (Dvir & Lechler, 2004). Hence, change control and deviation is designed to minimize its disturbing influences on projects.

Project management together with change control is therefore aimed at avoiding changes or dealing with changes with proper manner (Andersen et al. 2011). During the

process of commissioning, there are multiple parties surrounding the principal party and project parties such as sub-suppliers of component system, subcontractors, service providers, and the network relationship management tends to be even more complex and inter-weaved with each other. The change control and management in commissioning site is crucial for the whole process of project management.

Changes occur not only during the project execution, but also after delivery to the customers, customers operate in an environment of high uncertainty and diverse changes rise at anytime, such of changes as technological advances, volatile business environment in customers' main field of business and other changes in the supply chain and in logistics. In some circumstances, customer is not necessarily aware of the latest technological development regarding the supplier's equipment. The ultimate goal of change control and deviation during commissioning, implementing the customer-centric strategy of complying with customers' need is to prevent breakdown and failure in later stage when the customer is in the control of delivered products and equipment; in another words, change control and deviation management during project delivery is to reduce the uncertainties, to adopt preventative measures and minimize the forthcoming either technological or non technological changes to customer. (Liinamaa & Gustafsson 2010; Kirsilä et al. 2007)

Practically, the commissioning period is starting years after the initial concept designs, substantial amount of engineering revisions, manufacturing and installation standards and material innovation could occur during long time spans. On the one hand, change controls and deviation are inevitably part of daily routine of project commissioning. On the other hand, from the view of an efficient organization structure, the system itself has to be flexible and responsive to adapt to changing environment, or commissioning group needs to include the plans for change and deviations and prepare for the changes from the point view of organization structure. How to manage the changes and deviations affects the efficiency of commissioning and the project delivery in a whole, measures on change controls and deviation is worthy further exploration for managerial practices during commissioning.

2.3.4. Coordination

In today's turbulent, ever-changing environment, comprehensive contracts and plans are approved not sufficient to guide large projects according to practical examples. Anderson stated that although contractual innovations have been used and responsibility articles has been more accurately described, there are a number of interdependencies and a high degree of uncertainty that cannot be resolved by sophisticated contract language, other forms of coordination outside of the scope of contracts are necessary and required in project-based business. (Anderson et al. 2012) The interdependency between prime suppliers, other contractors, subcontracts, clients pull every-party together and collaborate on the basis of more than the contractual articles. The problem of coordination tends to more obvious in commissioning process due to the facts of multi-party involvements and interactions.

If value-creation is the ultimate goal and eternal arena of relationship management, the vehicles of getting to the arena are coordination. Coordination is a must tool of arriving in the target. Since the statement about projects as a temporary organization is widely accepted by majority of practitioners in the study of project management (Tsoukas & Chia 2002; Winch et al. 2012), one obvious feature of a temporary organization is the barriers of information-sharing. However, knowledge sharing, efficient communication contributes to an effective decision-making process. Thus, coordination activities in commissioning stages faces even more challenges where the function activities of each party has its own way meanwhile the general commissioning group has to proceed with under a common goal.

The literature concerning supply chains highlighted the importance of relationship management from the respective of coordination. There exist two kinds of coordination, coordination of the forward physical flow of deliveries from sub-suppliers and suppliers to the customers and the backward coordination of information, data from the customers to the supplier and sub-suppliers as shown in figure 2.3. (Frohlich & Westbrook 2001, Liinamaa & Gustafsson 2010)

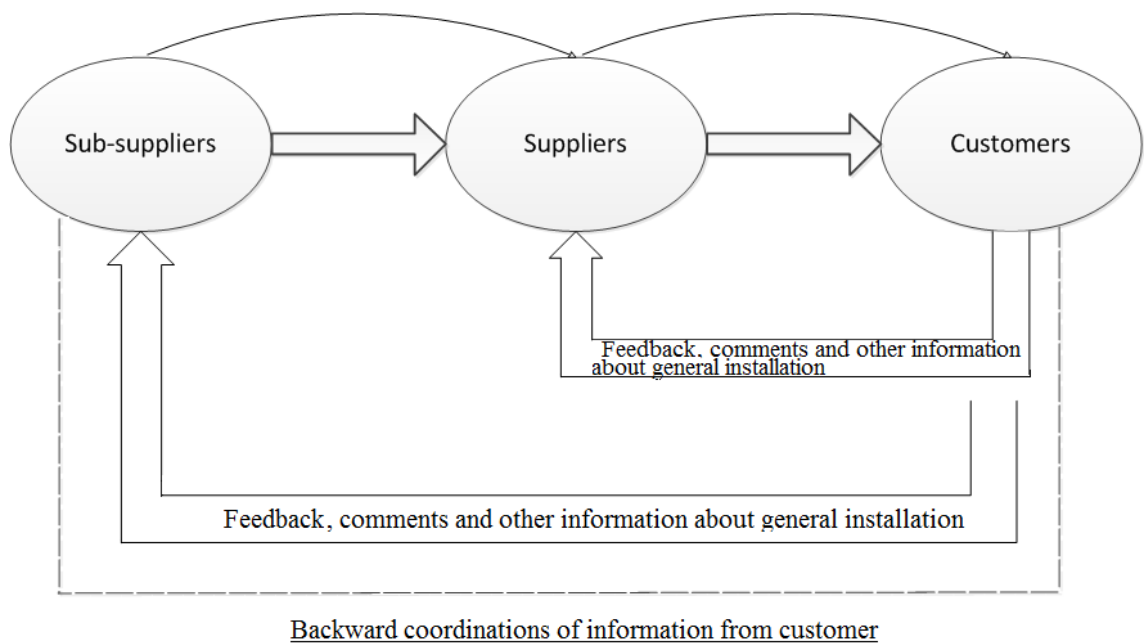


Figure 2.3. *Dual-way coordination: physical forward delivery of equipment and backward information from the customer*

Kirsilä et al. (2007) mentioned that common understandings of functionalities, quality and delivery time of other stakeholders is crucial among delivering organizations. The purpose of commissioning and outcomes should be explicated to all delivery organizations, apart from the clear performance guidelines and procedures. The clear understanding amongst involved parties is crucial for relationship management in the network of all actors. This certainly requires the collaborative interactions and learning of all participants. Kirsilä also mentioned that the commissioning activities are not meeting the desired level due to several factors; one critical reason is the lack of coordi-

nation for the commissioning activities and to create supporting units which results in effective and less time-consuming. (Kirsilä et al. 2007) Kirsilä's propositions of supporting units are based on the concept that supporting units can facilitate the coordination smoothly. It is shown that in forward physical delivery, coordination problems exist often and lack of relevant supporting units for commissioning activities is one reason.

Backward coordination of information from customers is reflected equally in commissioning. Suppliers, as influencing and value-added parties, need to incorporate customers' information and feedback into the commissioning process. According to presented interview results, the knowledge of customers' business and the general states of installation are critical elements of value-creation (Liinamaa & Gustafsson 2010). The suppliers, sub-suppliers and customers are all integrated into activities throughout the project life-cycle; affecting the final outcome of commissioning, and the entire project in the end. Backward information feeds from customers is necessary and a must for efficient interactions. The commissioning is a preparation process for the customers' receiving of the delivery, rather than a problem-solving process. Customers should be incorporated into the project already pre-commissioning, thus they can participate, learn and comment on the activities during commissioning, and be prepared for the receiving of the delivery, achieving the objectives assured by suppliers. (Kirsilä et al. 2007) Dual-way coordination describe the process of commissioning from two aspects, one as focusing on the commissioning activities and the other one focusing on the information feedback, which way is obviously present and in what status in commissioning site requires further data from empirical studies.

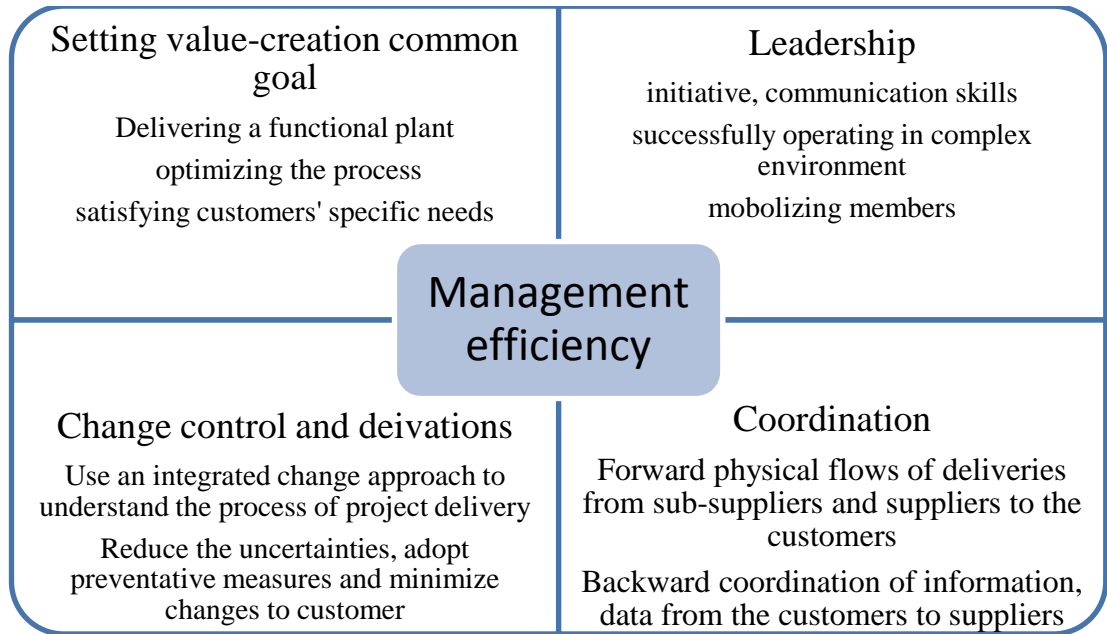
2.3.5. Summary of previous research on management efficiency

During the literature review, the large share of project management is dealing with business management, or relationship management. The complexity of involved parties in commissioning has undoubtedly made the study of management efficiency worthy, since management is not only a daily routine of internal relationship management, but also a stimulating factor for achievement of technical efficiency. Among voluminous literatures and empirical results, the approaches of perceiving the efficiency of management, together with criteria and standards of evaluating the efficiency of management range from various studying perspectives, just as every project implementation differ from each other in one way or another. Ruhli & Sauter-Sachs's five approaches provided comprehensive views of approaching the efficiency from different angles: goal, system, interaction with stakeholders, social behaviors and decision-making process. Goal approach is goal-oriented; performance goal and social goal are all included. Social approach is a supplement of micro individuals, behavior-based study of fulfilling the expectations, satisfying stakeholders. System approach, interaction approach and decision approach is reinforcing the interactive influences among involved parties.

Developing from these five approaches, combined with the characteristics of commissioning, four drivers are regarded as the most influential elements of the efficient

commissioning: setting a common-goal, leadership, coordination, change control and deviation as shown in Table 2.1.

Table 2.1. *Factors of management efficiency*



Setting the common goal of value-creation, optimizing the process and satisfying customers can orchestra commissioning activities toward one direction and eradicate conflicting interests among individual parties, therefore, increasing the efficiency of commissioning. Leader is the conductor of the orchestra, so as the harmony is achieved under the conductor, efficiency of the general efficiency of commissioning activities depends on the effective leadership, and the frequently argued leadership is self-regulation, contagious character, and initiative and communication skills. In addition, change control and management skills are also discovered to be important. Apart from project planning, changes and deviations are unavoidable as a mediocre during commissioning. The way of handling changes and deviations affects project plans and scheduled progress, and in the end it affects the efficiency of project commissioning. Coordination penetrates through the whole life cycle of project implementation, with its extraordinary significances with the performance of commissioning activities. Coordination can be represented evident in two ways: forward physical deliveries and backward information flows from customer. As the forward delivery of physical products, knowledge of equipment's current situation or function ability should be known to the receiver of equipment's lower system or equipment so as to maintain the continuity of equipment information in commissioning system; as the backward transfer of customers' feedback, customers should be encouraged to actively engage into the commissioning, their feedbacks contribute greatly to innovations and advances for the commissioned system, value-creation in the whole.

The goal of commissioning is to turn over to the owner the equipment that meets the design intent, finally to customers' demands (such as operator training and required documentation). Hence, the goal of management during commissioning is to initiate and motivate the mutual commitments of the owner, contractors, and commissioning authority to ensure its success of commissioning. As the owner, contractors, architects, and engineers have begun to set up a common goal and spurring for the benefits of commissioning, they are incorporating it into their building projects, contributing to a process of value-creation beyond separate goal-seeking process.

Furthermore, it is of strategic importance to understand the fact that commissioning is not only a pure quality assurance program, but also an intermediate node of customer value-recreation chain. Considering long-term strategy in transition to service-centric business model, the efficient commissioning necessarily has to include the readiness of technical services or services in later stage, although the vast amount of literature stressed that the main focus of commissioning is the adherence to quality assurance program regarding the acceptance of equipment or system. Naturally, a clear and unequivocal set of standard acceptability, design intent, commissioning authorities, has become the priorities of commissioning-related research. Obviously, service business concept is not planted or planned far before-hand during project delivery. Commissioning, as a connecting platform with customers and the prelude for potential subsequent services business, plays a strategic role in cultivating and bringing forth services prospects. In Lee & Yong-Tae's (2000) observations into Korean's telecom industry, success of project depends on not only enhanced managerial and technical efficiency, but also the extension of services. The following sections will explore the unique relationship between commissioning and service business.

2.4. Services business

Recent business literature has shown some of the world's leading firms have adopted their strategic focus to complete by providing "solutions" rather than individual products or services (Kirsilä et al. 2007; Brady et al. 2008; Foote et al. 2008). This trend has particularly affected the high-value, engineering-intensive capital goods or equipment division, and companies start to combine the supply of a whole package including design, integration, delivery of complex products and systems on a project basis, integrated solutions in another word. Delivering integrated solutions to meet with user needs means incorporating services into products and systems in order to specify, design, deliver, finance, maintain, support and operate a system throughout its life cycle. (Brady et al. 2008) Herein, Brady stressed that the life cycle of project delivery extends the traditional life cycle backwards into pre-project phase, concept design with customers and beyond the delivery phase into the operational phase, which consists of operating and providing services and product life cycle supports. In particular, the operational service capabilities ranging from maintain, operate, upgrade and renovate a product through its operational life cycle is highlighted for value-creation process of integrated solution.

Integrated solutions signified that the operations and maintenance phases after commissioning should be still regarded equally important by the supplier. Subsequent and continuous communication process with customers should go beyond the delivery stage, even though the control of the delivered products is in the hand of the customer after commissioning. The practical studies proved that acknowledging of customer's operations, providing prompt expertise knowledge about products can greatly create value to customers (Liinamaa & Gustafsson 2010). Although the trend of supplies of integrated solutions take in shape in today's manufacturing companies, the significance of service business account for in the life cycle solutions and the relationship between commissioning and service business and what degree commissioning affects service business is not explored in previous literature. The following sections will follow the trends and attempts to present the possible connections between the two specific stages of project life cycle solution.

2.4.1. The trend of service-orientation

The shift to services and solutions for some companies, specializing in designing and manufacturing complex products and equipment has occurred in many sectors, such as telecom, hardware business. One driving factor of this shift is from customer's outsourcing strategy. Benette et al. argued that customers start to increasingly focus on their provision of services to final consumers, which make their buying-decision strategy inclined to outsource non-core in-house activities, such as design, systems integration, project management, maintenance and even some parts of daily operation to their suppliers. (Benette et al. 2001) Hence, project suppliers were drawn to implement the servitization in capital goods to develop and offer total solutions with the attempts of reducing customer's operation costs through the life cycle of projects (Artto et al. 2009). Another further drive for suppliers was the lucrative market. High-cost capital goods and equipment tend to be bought at irregular intervals, operation time is relatively long, and making suppliers of capital equipment rely on services to sustain stable incomes (Brady et al. 2007). Especially, volatile global political and economical situations throw the destiny of some traditional industries up in the air, like the impacts of government deregulations on telecom industry in Europe, excessive investments on non-ferrous metal industry and blinding constructions of smelting factories made the prices of finish product plunge to the bottom and the profits of investment shrink in China during last decade. All this factors push suppliers of capital goods to seek much stable means of surviving in business than only manufacturing and selling to the customers.

Service business becomes an important source of increased revenues and stable cash. Usually service margin is around from 30% to 50% of services prices based on installed equipment. Except continuous revenue streams, Mathieu (2001) proposed that services provided throughout the product life cycle offer the advantage of marketing and strategy benefits as well. Marketing benefits include the increased customer satisfactions, improved and quick entry to market of new products and enhanced supplier' cred-

ibility. From strategy perspective, quality services with competitive differentiation aspects can prompt building up industry barriers and keep new comers away.

2.4.2. Commissioning and services

The trend of service-orientation has been implemented or started implementation in companies, the success or failure of project termination are not confirmed in literature as crucial for service business except for the after-evaluation from client. According to proposed literature, the impacts of termination stage of the project on the technical success or failure of the project have not received agreements among practitioners; project termination is certainly perceived as related with residual attitudes toward the project, referred to as “the after-taste in the mouth” of the client (Andreas & Wolfgang 2006). Thus, to what degree the commissioning affect the general technical success of the project is not confirmed. However, conclusions can be drawn that the residual attitude of commissioning of project has inevitable influences on the post-implementation of projects, subsequent provision of services. Therefore, except from the point view of project life cycle ranging from pre-bidding until operational services stage, commissioning should pave the way of providing services, managing relationship in a long-term high level rather than just focusing the current project execution. As an integral part of efficient commissioning, the readiness of provision of services should be given into sufficient consideration. Efficient commissioning, as one core of preparing for the future and visioning long-term project success, should encompass the preparation of provision of services coming during post-implementation stage.

Services become an integral part of capital-equipment-supplier business strategy, and services concept has to be implemented already during project implementation stage. Commissioning, as a perfect platform of direct customer contacts, instead of following traditional project management process of planning, organizing, directing and controlling company resources for a short-term objective established to achieve specific goals, should focus on the customer value creation and lay solid basis for future’s service provision. (Brady et al. 2005)

2.4.3. Value-creation services

From a value-creation perspective, suppliers of service business create value in the outsourcing process, customers can gain benefits from supplier’s service support and personal interactions. The value-added services represent a general service category covering technical services and beyond. Suppliers’ capabilities of providing value-added services are proved to one critical driver of strategy relationships between suppliers and customers. With the establishment of strategy relationship, enhanced inter-personal relationships helps to improved problem-solving, communications and lead to better understanding of each other’s goal, and contributing to further value-creation for both. Commissioning process involves a great deal of inter-personal contacts, which lay a solid foundation for the start of close relationship. According to Andreas & Wolfgang (2006)

personal contacts at all levels of managers during commissioning should be facilitated. High level of managers from the customer's side and suppliers' side exchange information about the strategy cooperation and general progress of commissioning progress, while commissioning managers and project managers communicating over the instantly arising issues, engineers and sub-contractors discussing the actual installation issues. In particular, the frequent technical interactions relating to requirements of equipment installation, operational instructions and maintenance training becomes a daily routine on commissioning stage.

Suppliers' capacity to manage exchange of information during commissioning is highly appreciated by customers, its one paramount dimension of value-creation (Andreas & Wolfgang 2006). Customers expect to have sufficient information exchange from suppliers regarding equipment not only limited to operational instructions during commissioning, but also provision of technical services and information about keeping products updated to latest technology is equally to their interests. Customers expect supplier to quickly provide them with quality parts and maintenance that takes installation, knowledge of advance into account, and perceiving this kind of capabilities as critical dimension of value. (Liinamaa & Gustafsson 2010)

2.4.4. Core projects and services

From the practical operation perspective, the installation provided by suppliers influence the customer's operations in many ways during the post-delivery of products, there exist close relationship between the core projects or installed base and services (Artto et al. 2008). Core project represents building an installed base, which includes proprietary components or relevant software. Usually software is the main areas which require supplier's maintenance and update activities after the delivery; software updates and service is a significant source of stable profits for suppliers during product or equipment's long-term product cycle.

The empirical studies stated that the practical commissioning process has to spend substantial amount of time on software commissioning, sometimes automation and software commissioning take few months or even years. Although great efforts have been put into software commissioning, it still proves to be difficult and problematic part of commissioning process; problems relating to software and applications often arise after project acceptance. Especially customers are lack of equal amount of knowledge in software applications as their suppliers, frequently-occurring problems have to turn to suppliers' for helps after the delivery of projects. Therefore, customers' active participation with software commissioning should be implemented to solve the problem. On the one hand, suppliers should accomplish software commissioning and tests successfully, enhance the applicability of software, avoid system loop-holes; on the other hand, trouble-shootings and relevant system information should be introduced explicitly to customers' personnel during commissioning. In this way, suppliers are already carrying out one form of technical services and facilitating an interactive relationship build-up with customers. Furthermore, since the subsequent services help to reconnect the communi-

cations between customers and suppliers, contribute to continuous learning. Suggestions coming from the customer speed up advances and update of new products after post-delivery of projects (Kujala et al. 2012).

The core project commissioning and service business should be studied comprehensively from both the value-creation and operational perspective over the entire life cycle of project deliverable. Commissioning and service business complements each other with the process of value-creation, meanwhile, implementation of service business are represent during commissioning. When suppliers realize and focus on how provided installation and technology base affects the customer's business (such as smooth duty time of equipment, rate of breakdown and maintenance costs), suppliers can provide highly valuable customer-specific services from the customer's perspectives, and customers become more interested in the necessary know-how and advances from technology base (Liinamaa & Gustafsson 2010) and considering to order service from suppliers *since customers* are obviously not capable of acquiring latest technological development regarding supplied equipment, nor do have the same technology or supplier base from which to attain quality spare parts and relevant update services.

2.4.5. Summary of previous research on services and commissioning

Commissioning, as the battle field of meeting with performances and complex relationship management, its potential in bringing up potential services business, is particularly worthy to explore beyond the surface definition of hand-over the equipment to the customers. Efficient commissioning framework has to analyze from the technical view and management view, together with the readiness of services of the whole project life cycle covered as well.

Although the extent literature claimed that transformation from the product-centric to service-orientation is increasingly attracting companies' attention, even companies specializing in product engineering and manufacturing. The transaction in well-established organization is not easy, what seems more challenging is to integrate the concept of service in the stage of commissioning. Very rarely the impacts commissioning exerts in product-services have been recognized, less likely enough attention has been paid to include service dimension for an efficient commissioning in previous researches.

Commissioning matters for service business to a very large degree. The previous empirical studies showed that a close relationship between core projects and services exists; the essence of value-added services is derived from the close relationship and developed on interpersonal contacts at all level, including contacts at operation level. A face-to-face contact on site during commissioning requires the activate participations from the customers' side with software commissioning. Meanwhile, suggestions and feedbacks from customers should also be given consideration during this stage. Interactive exchanges of information between customers and suppliers in commissioning leads to long-term customer relationships and promising cooperation in all scales in future.

3. METHODOLOGY

3.1. Research design

The thesis uses clinical research methods to analyze the contributing factors of efficient commissioning. First, the paper reviewed theoretical propositions in the project delivery, project management and project business, summarized and presented specific theories applying into efficiency of commissioning; then the empirical studies were proceeded to testify and enrich contributing factors of drivers of efficiency commissioning from the point views of commissioning specialists, their responses towards the issues dealt in literature summery presented realistic elements into commissioning activities and commissioning efficiency. The research design can be described as theory elaboration; the main idea is to interweave data and theory to illustrate a theory in a specific context (Siggeklow 2007; Artto et al. 2012). The empirical studies were chosen in three companies, specializing in engineering, manufacturing and supply of services of capital equipment in manufacturing industry. The interviews are semi-structured to testify the primary propositions of what consist of driving forces of the efficient commissioning from the literature review. The questionnaire sample is arranged as the structure of theoretical review since the purpose of empirical study is to present a rich and multi-faceted illustration of contributing factors of the efficient commissioning (Kujala et al. 2012). One questionnaire is even sent to two case supplier's customer project manager, seeking to present a different view from the customer.

Because of the uncertainties of project business and the complexity of equipment commissioning, the efficiency of commissioning has not been studied comprehensively in the past, in particular capital equipment; only some empirical studies have been conducted in construction, or software implementation. The thesis had its specific concerns to choose the delivery of capital equipment as the objectives of project delivery. First, from financial conscious view, the initial investment in capital equipment normally requires huge capital inputs while investment returns stay unpredictable. Second, project uncertainties intensified relationship management issues and conflicts due to the long duration of process and lead time even make technical compliances more challenging during commissioning. Therefore, commissioning of capital equipment is characteristics of huge financial risk, complexity and uncertainties, its success have weighing influences to the general success of the entire project; hence, the research of the efficiency of commissioning of capital equipment has specially practical meanings for project commissioning.

The study of the efficiency of commissioning is designed from two dimensions: technical efficiency and management efficiency. Although the literature review showed

that the traditional applications of technical efficiency focused on quantitative performance figures based on scientifically computing method, this thesis chose to introduce technical efficiency of commissioning with the help of open resource system to discover the driving forces of achieving the outputs qualitatively. The commissioning is analyzed as a process, technical efficiency is supposed to define qualitative factors of the efficiency of an open commissioning system from the technical views. The output or the technical achievements cover design capacity and functionalities, end-customer's familiarization with operation and maintenance, identifications of faults and discrepancies and quality. Performance, operational specifications are mentioned often as the criterions of efficiency. With technology, penetrating into every respects of project managements, technological complexity has made performance measures more challenging than ever, therefore quality requirements together with quality assurance plan has been highlighted to clarify the technical details, furthermore to improve the validation of project commissioning stage in last decade. Hence, the technical efficiency can draw its conclusion from three drivers: performance, operations and quality.

The framework of management efficiency has many versions. In order to analyze the efficiency for the specific process of commissioning, the thesis chose Ruhli & Sauter-Sachs's framework as a starting point and categorized the drivers from the goal approach, system approach, social approach, interaction approach and decision approach. Different approaches analyze the causalities of efficiency from different angles. As the context of commissioning and limited pages in this thesis, a comprehensive approach of understanding the efficiency is applied instead of going in details into every approach. Hence, setting the common goal of value-creation, leadership, coordination, change control and deviation are analyzed as the driver of efficiency of commissioning. Within each of the driver, the contributing factors should be explored to construct the framework of contributing factors of management efficiency. After the commissioning, the development of service business is rarely connected up with previous stage of project delivery; even the service-centric business model is marching its way in traditional manufacturing companies. The indispensable relationships from the value-creation and operation point view should be analyzed to present a picture of integrating service concept into the implementation of project deliverables.

3.2. Case companies

The case companies include 3 companies. The interviews were hold in the selected case company (Outotec, Espoo), and the rest information was acquired through sending questionnaires to another supplier company (Kumera, Riihimäki) and JiangXi Copper (China, Guixi). Two supplier companies are Finland-based suppliers of key metallurgy equipment and technology: Outotec (Outotec OYJ) and Kumera Corporation (Hereinafter referred as Kumera); the customer is China-based copper smelter (Hereinafter referred as JCC), which imports most of capital equipment from Outotec, some from Kumera too. Both supplier companies provide large-scale equipment for copper-smelting process, offering design, manufacturing and commissioning and have established long-

term relationships with the customer JCC in the field of technology transfer and equipment supply over three decades. The value of supplied equipment is normally over million Euros, delivery time lasts mostly two-three years, and commissioning time is from up to half a year down to few weeks. Commissioning is normally accomplished at Jcc's factory. In addition, Outotec is not only a supplier, but also a representative for other auxiliary equipment or sub-system which are neither designed nor manufactured by them. Outotec has arrived agreements with other branch equipment suppliers from Finland and beyond for the supply of the entire production line of smelting process. The specialties, project business of each company are illustrated as in Table 3.1.

Table 3.1 *Specialties of case companies*

<i>Company</i>	<i>Specialty or business range</i>	<i>Products/equipment delivery</i>	<i>Other information</i>
Outotec	the global leader in minerals and metals processing technology; offers innovative solutions for the chemical industry, industrial water treatment and the utilization of alternative energy sources; The technologies offered cover the processing of ferrous metals (iron and steel), ferroalloys, copper, zinc, nickel, precious metals, niobium, alumina and aluminum, industrial minerals and sulfuric acid.	single equipment to manufacturing lines and large turn-key plants; Spare parts support and delivery, site and equipment maintenance and plant audits to optimization and upgrades, project management and training.	A complete zinc roasting line to Cajamarquilla, Peru; Modern iron ore pelletizing technology to Caofeidian, China; Pioneering Flash Furnace process; Outotec's process takes accounts of 50% of sulfuric concentrate smelting capacities in global.
Kumera	serving copper and nickel smelters as well as the metallurgical and mining industries generally, by supplying main process equipment and process modernization services; active subcontractor of equipment for the mining and metallurgical industry. We have supplied dozens of converters, furnaces, kilns and other rotary type of equipment all over the world.	Kumera Steam Dryer for concentrates; Kumera Anode Furnace - with drive unit and control systems; P-S Converters, Kumera Bucket Excavator, Kumera Roll Crusher Kumera Drag Conveyor	
JCC	The largest copper producer and copper fabricator in China, also a fundamental supplier for gold, silver, selenium, tellurium, rhenium, sulfuric acid.		

Outotec has proven reputations on providing the systematic solutions with copper smelting process to its global customers. No matter it is regarding a new green field or modernization of existing facility, Outotec can offer tailor-made and modularized solu-

tions to satisfy various needs from their customers. Jcc, as the biggest copper smelter in China, has constantly improved production capacity with the application of proficient process and high level of automation, the capacity has increased by three-fold through expansion and modernization. From Jcc's first production line to today's expansion engineering of copper smelting engineering, Outotec has become a strategy supplier and a key partner. The latest expansion engineering in Jcc in 2007, both kumera and Outotec were key suppliers, the installation and commissioning process accomplished in about 2 years, the first start-up was successful.

Although the final start-up and test run was successful, lots of problems arose during commissioning: slow progress, unexpected quality issues, so as commissioning engineers were sometimes called back to fix remaining issues from commissioning. Furthermore, the implementation of services business strategy made both project managers and services managers concern the subsequent effects that problematic and inefficient commissioning caused. Service managers scratched their heads of considering over smooth service businesses coming after the handover of equipment or system, however, it did not happen as smoothly and automatically as they had expected. The table 3.2 categorized the respondents' answers from case companies (Outotec, Kumera) with regard to the problems affecting the efficiency of commissioning.

Table 3.2. *Problems from case companies*

Outotec	Quality	Coordination	Change controls	Operation requirements	Leadership
Frequency of problems mentioned (4 interviewees in total)	3	1	1	1	1
Kumera	Coordination	Change controls	Quality	leadership	Training
Frequency of problems mentioned	2	2	1	1	1

With the question of improving efficiency of commissioning and the intentions of building up a connection between commissioning and services business, the interviews were carefully designed to provide a window of enriching previous literature findings of commissioning and contributing to the explorations of contributing factors of the efficient commissioning.

3.3. Data collection and analysis

The empirical data was collected in summer 2012 through a total of 5 semi-structured interviews together with 3 copies of questionnaires. One of the interviewee was representing customer as a consultancy. Each of interviews was arranged in Outotec's meeting room and lasted about 40-50 minutes. In order to increase the reliability of research results and present a comprehensive view of commissioning, interviewees in one company representing different commissioning responsibilities were asked to respond generally to the questions according to their experiences rather than over a specific project. The interviewees included electrical and automation engineers, mechanical engineers, designers, consultant representing the customer and project managers. All of them are experienced commissioning specialists on site over 5 years; some of them even had few decades of working experiences in different projects including both domestic and foreign commissioning sites. The interviews were carefully recorded in paper during the period of face-face conversations, was later transferred into computer. Some directly inferred paragraph was originally from interviewees, others are the results of writer's interpretations basically from interview's own ideas.

The semi-structured interviews focus on following topics

Technical efficiency

What is commissioning in practice

What should we focus for improving efficiency from the point view of technical achievements

Performance specifications: what important points should be included

Operation training: what important points should be included

Quality implementation: what important points should be included

Management efficiency

The common goal: Is it possible for every party to have a common goal? What kind of common goal?

Leadership: What kind of leadership is the most required in commissioning

Changes and deviation: What is the effective way of avoiding those from happening

Coordination: Which way is less implemented in practice and why during Dual-way coordination process: forward physical delivery of products and backward feedback info from customers.

The role of commissioning for services business in future:

How commissioning matters considering about services based on installed equipment in future?

Delivery of projects normally range from few months to few years, commissioning time on site is relatively few months, in some cases commissioning time is much longer. Although the issues dealt with on commissioning site might exist in different forms,

opinions from supervisors working on many projects might provide some patterns of similarities and disagreements of commissioning at the same time. Moreover, questionnaire from the customer could present different views on same questions. I believe the data from suppliers, customers, third-party consultant can provide a fairly integral view on issues of commissioning, and a good opportunity of looking into the drivers of the efficiency of commissioning extracted from literature review, thus to provide managerial hints for project commissioning. The empirical result is also presented as the order of literature findings.

4. RESULTS

The results of empirical studies were presented as following: first, the definitions of commissioning from commissioning specialists were collected to perceive the efficiency of commissioning into two main dimensions: technical efficiency and management efficiency. Secondly, respectively exploring from technical efficiency and management efficiency, different influencing factors were observed for the contributing factors of efficient commissioning. Thirdly, close relationship between commissioning and service business was identified, commissioning should be perceived as paving the way for operational running and maintenance, in another word, commissioning is preparing readiness for potential business. A summary of the results is shown in appendix 1.

4.1. Commissioning and technical efficiency

All of interviewees came up with almost similar definitions of commissioning in the point of technical achievement. Understanding that commissioning is to implement design intent, to accomplish the delivery of the project, to accomplish function abilities, to start-up equipment and put equipment into ready use for end-customers within the budget allowance according to schedules. In addition, operation and maintenance training for customers is also an inseparable share of commissioning. The other respect, customer satisfactions, optimizing the performances and maximizing the benefits of equipment and products and satisfying the customers was identified by 2 commissioning specialists. To sum up interviewee's response, commissioning can be understood in two ways, one is technically achieving performances tests of equipment, and another way is related with relationship management of commissioning parties: satisfying customers' needs and maintaining good customer relationship. In addition, all of them agreed with that commissioning is one of the most crucial parts of the project; it is the platform of direct communications between suppliers, sub-suppliers and clients. The following table categorized specialists' opinions on commissioning.

Table 4.1. *The definitions of commissioning*

Commissioning	Performance	Operation/training	Quality	Others
Electrical engineer	Hard-wiring, parameters setting; software commissioning with loads	Operation training, Maintenance instruction;	Cabling according to circuit drawings.	

Mechanical engineer	Installation, help customers with using the machines, start-up the equipment	Operation training and Maintenance guidance	Quality strictly followed by both parties	Maintenance of good relationships with customers, promote services
Project manager	Optimizing the performance, maintenance of customer relationship, safety	Familiar customers or end-users with equipment	Following intents of design	
Designers	Layout and foundation, design capacity			

“One of the most important parts of the project, where both supplier and client can confirm at everything is working correctly. As all projects are different from each other’s, commissioning is like “The last frontier” before all equipment’s final adjustments is found and fully operational line can be started. Also this is the time to educate future operation and maintenance staff for their duties.”

–Mechanical engineer from Kumera

“Commissioning is a final test for the facility, buildings, equipment, installations and trainings, a pre-test for designed capacity, approaching the goal of meeting with production and standards under the instructions of safety rules. The participated personal is multiple, the work loads of relationship management is huge. ”

-project manager from JCC

Achieving performance requirements from the customers is the unanimous content of commissioning from all 5 interviewees. The specific performance requirements like the technical figures can vary from one project to another, as Kirisilä et al. (2007) found in empirical research that there existed X different definitions if asking x engineers. Even in some cases, customers require special-tailored functions to their needs. However, general performance requirements include design capacity, stable function abilities, high-quality standards of equipment and installations. Therefore, meeting up with performances was interpreted as one criterion of technical efficiency of commissioning. Second, except technical performance, technical documentation and instructions for technical trouble-shooting was judged as another dimension of technical efficiency. Additionally, safety instructions should also be strictly followed by participating parties, which was confirmed by 4 interviewees and one project management from the customer’s side. Hence, observing from the empirical research, technically efficient commis-

sioning consists of three essential dimensions: performance fulfillments; operational and maintenance instructions; quality and safety of installation.

One interesting fact from empirical disclosure that whether the project was a new project or modernization project influenced commissioning in many aspects, such as design, installation plan and quality of commissioning. Implementation of modernization projects proved to be much troublesome and complex than the green-field factory. Normally, the installation plans have to provided with few choices (4-5 solutions sometimes) for fitting into customers' existing system; besides, the installation quality was much lower compared with a green field, supervisors spent much longer time on site for trouble-shooting. Furthermore, subsequent services in later stage were much difficult to implement successfully due to quality problems from commissioning.

4.1.1. Commissioning performance

Performance specifications range from one project to another, it conveys customer's expectations on commissioning system, and normally it is clearly stated in technical contract during contract negotiation. During interviews, all 5 commissioning supervisors responded that technical articles in the contract was clearly stipulated what technical targets should be achieved during commissioning. Technical figures such as setting value of equipment, capacity and other relevant functions were clearly written in the contract.

“What we need to do is to follow the circuit-drawing and cable drawing in the documentation, step by step, in the end, the whole system should be working fine.”

- Electrical engineer

The main body of technical articles were negotiated between supplier's sale managers and purchase personnel from the customer side, designer and technical experts might attend to or confirm technical appendix in the end, depending on the command of knowledge of sale managers with the negotiated equipment or system. Since all commissioning activities are striving for performance with the stick yard of technical articles in the contract, performance stipulations in technical contract should be foremost important for the efficient commissioning, the stipulation about technical performance should be accurately and sufficient in content to guide through commissioning. In practice, technical contract is a combination of both customers' requirements and recommendation from supplier's knowledge. During the process of contract negotiation, customers expressed their needs, suppliers proposed relevant solutions for choices, the final contract was normally hammered down through few rounds of negotiations after thorough considerations from both side's key personal involving designers, technical experts and project managers.

“We want advanced and proven technology, so we can stay competitive in the industry, at the same time we consider low-cost installation and running. “

-Jcc's project manager

The case company Outotec has delivered their products for decades; their products won international reputation and set up technical standards of similar products. Sale managers have known products well to technical details, they know what they were offering to customers, which was one reason that commissioning supervisors were completely confident with sufficient technical stipulations in the contract, and their commissioning work was to follow the contract, there was one exception. One interviewee mentioned that their customer only expressed that they wanted a different design after the inspection of equipment in Outotec's workshop. Obviously, it was a very late message from the customer. One fact is worth mentioning here, delivery of products in particular with capital equipment is long after the initiation of purchase order, there existed possibilities that the original order was updated by a new technology, or customers' expectations on products' performances could change as one scenario told by above project manager.

In this situation, certain risks with the delivery of products are unavoidable; customers in the very beginning of contract negotiation stage should have given the risks into consideration. Customers should have reasonably achieved agreements with what they want, incorporating voices of designers, operators and maintenance engineers. Sometimes the sole decisions from negotiations tables are not delivering the opinions of other important personnel on site. Only in this way, the final articles in the contract could illustrate desired performances as much as possible.

The interview also showed that during commissioning some extra discussions about the performance also existed, end users might require something else than the contents of contracts.

"Sometimes customers asked us to add or change some functions, we normally do that instantly if it doesn't cost too much otherwise we need to consult our office first for further actions."

--Electrical and automation engineer from Outotec

Commissioning site assemble the most participants representing different equipment suppliers, it is a process of accomplishing the goals in the contract, it is also a live stage where suppliers, sub-system suppliers and customers, work together to discover and solve problems on spot. Customers might spontaneously bring forth some extra requirements to suit specific needs. In the end a group of experts went through discussion and proposed a new solution to satisfy customer's needs, new performances could also be supplemented. In this case, commissioning is more than following the performances in the contracts but also a trouble-solving campaign and a process of seeking for optimal solution for customers.

To sum up, in order to achieve technical performance of commissioning, technical performance should be explicitly stipulated in the technical contracts representing cus-

customer's comprehensive opinions; relevant descriptions with performance in documentation should also be accordant. Normally, technical contracts cover the wide ranges of topics of technical performances of equipment together with articles of warranty and guaranty, spare parts lists for operations and maintenance. Meanwhile, prompt performance requirements could also be expected during commissioning from customers as suggested by interviewees.

4.1.2. Operation and maintenance training

Commissioning is a perfect chance of efficient communications between suppliers and customers, commissioning specialists can provide timely answers for all kinds of questions from customers. Providing sufficient training about operation and maintenance of equipment, ensuring the readiness of equipment's use to customers was reinforced by all 5 interviewees, the response from JCC project manager also stressed the goal of training and education during commissioning.

"Operator and maintenance engineer can follow the installation and pre-startup, they ask questions, we can answer and show them how to do."

--Mechanical engineer from Outotec

An important part of commissioning is to hand over equipment to customers, familiarizing customers with operation and maintenance of equipment; hence customers can operate equipment smoothly and efficiently at their own hands. Training and education is an integral part of commissioning, it is a contribution factor of efficient commissioning. Operation manuals and maintenance guidebook are the main documentation of training and education. Most of commissioning engineers regarded that information contained in manuals were sufficient for actual guidance on site, it was a bible for commissioning even though lots of improvements were still needed to be done, like the understandability of language. In addition, modifications in the content should be updated in time. Normally in the supplier company Outotec, at the end of the project everyone who involved with project would get together and drew conclusions upon the finished project, relevant information and updates relating to achievements and deficiency on commissioning site were documented as reference for next projects.

"Most of my time spent on receiving phone calls from site, checking the drawings, and confirmed the modifications and updated the drawings and documents."

--Designer of supplier

From the data of both supplier companies, it showed that installation and commissioning time in some projects lasted relatively long and progress was slow. One reason was related to the level of client's knowledge of equipment; the other reason is regarded as frequently incorrect translations especially the explanations of technical terms in the documentation. 2 interviewees emphasized that customer's knowledge level of commis-

sioning equipment substantially affected the progress of commissioning. Relevant training should be arranged not only during the later stage of commissioning stage, but also during the installation to increase customers' or end-user understands of installed equipment. Pre-familiarization with equipment would speed up the learning process and commissioning as a whole, operators could more actively participant the installation, which enable the further operation and maintenance training easily proceed. Furthermore, some misunderstandings with technical documents due to inaccurate translations into local languages should be avoided for causing big mistakes in commissioning and training.

Interviewees stated that documentation cannot possibly fully explain every technical detail; supervisors are on site for answering questions and illustrating technical details. Free information output from suppliers about operation specifications and maintenance requirements is supposed to one key of effective training with equipment. According to the results of 2 interviewees from Outotec, all information relating to equipment should be available except for patented "black box", which is unknown to suppliers themselves. Black box is encrypted function block with separate software groups. Only the software engineers from the original manufacture know the access to embedded software, it is a standard block, operator or maintenance engineers are not necessarily capable of accessing or understanding or modifying it. Both mechanical and electrical engineers expressed that they were willingly to give out whatever information to customers; customers could acquire all necessary information through training or practical learning regarding nearly every question from them. This attributed partly to trustful and beneficial bilateral relationship between the supplier and customer in the case. However, open information transfers might not be expected in another case where two companies' co-operation are not as stably established as in the case, for example responses from Kumera were not positive as in Outotec.

The free information transfer from commissioning engineers to customers constitute as an essential part of training process. On the one hand, operation manuals and maintenance instructions should compose accurate, understandable descriptions of technical issues, on the other hand, verbal exchanges between commissioning engineers and customers' relevant persons should be expected to proceed while commissioning. In addition, safety rules are also a forever accompanying topic with commissioning, operation documentations should conclude enough coverage of safety rules, and safety is always the first principle. All interviewees, customer project manager confirmed the position of safety in commissioning.

"First, we want to have a safe, healthy operations running in the factory, then we aim for high productivity and low costs in maintenance."

--Project manager of JCC

Training process is a long process, starting from the initial installation and ending with the final hand-over of the equipment. Operational specifications and maintenance

requirement, covering safety rules is a affecting factor of the efficient and smooth commissioning, but more importantly, the face-to-face information exchanges in the ways of free questing-and-answering is stressed by commissioning engineers from Outotec commissioning engineers and project manager of customer side. It is reasonable to supplement the later as another contributing factor of efficient training process during commissioning.

4.1.3. Quality

Quality is often brought up to the discussion table during the period of commissioning. The entire commissioning process occupy relatively long time in the total delivery time of projects, quality issues occurs on every stage of commissioning, and in the end it affects the efficiency of commissioning and the success of the whole project. Whether or not quality standards are followed and strictly implemented has a weighing effect on the implementations and continuation of projects. The interviews showed that all of commissioning specialists expressed the existence of installation quality issues, even customers and commissioning engineers from suppliers considered quite differently about quality.

“ We have systematic quality standards in the documentations and in the details when we work on site, but the actual thing is that both the customer and us need to arrive an agreement on what quality we should aim for, quality really depends on what kind of quality the customer wants.”

--Mechanical engineer/project manager

During commissioning, the controlling role is mainly at the hands of suppliers, they are in charge of erections, test-run and hand-over of equipment, and quality implementation is no exception. Since suppliers have better knowledge of equipment supplied by them, in particular with some high-technology products; the customer has less information about the operation of equipment and the importance of quality standards attached to products. The responsibilities of supervising and checking the quality during installation are granted to supplier's engineers. However, the actual implementer of installation, who installed equipment (sometimes they were the third-party sub-contractors) hold different views from just following instructions given by suppliers, they might doubt about the authorities of suppliers. In worst cases, they insisted in doing things in a different way, and the solution was that a separate warranty of freeing supplier's responsibilities from the upcoming effects caused by the action was issued from the customers. The imbalance knowledge of equipment and understanding of the importance of quality rules are the main reasons for the divergence on the quality. One interviewee remarked that the technology level of customers or the sub-contractors affected their understanding of quality and thus the execution of quality plan, furthermore the progress of the commissioning.

“An agreement on the quality has to be fully understood and approved by both parties, some simple problems like tightening torques should be easily done, but it happened all the time, it’s a matter of attitude. ”

--Mechanical engineer/project manager

Standard difference and discrepancy in technology level do affect the implementation of quality plan. Inch or metric units, voltages difference, it does exist in commissioning foreign projects and could not be avoided. Local facility limitations also affect the implementation of quality plan. When it is regarding modernization project, great deal of modifications are done by customers, quality is even harder to guarantee and more troublesome in comparison of a green field. Quality had to be subject to actual conditions with existing system since the installation was based on the same facility and common sources like power supply.

The faulty parts became other serious issues with quality according to empirical study. Very often, the equipment was manufactured in Finland and imported to China, some faulty parts were manufactured and still sending to the customer even the workshop was known about the mistakes. Instead of informing the faulty parts and correcting the mistakes at early stage, workshop personnel covered up their irresponsibility. With the flaw parts, the quality of installation was starting on the basis of the thesis. And upper-stream or lower-stream equipment suppliers had no actual information about the faultiness; hence it was difficult for them to stick with their quality plans. The commissioning of equipment involves many parties including sub-system suppliers, suppliers and sub-contractors, quality implementation relies on every party’s active cooperation, the actual condition of each sub-system should be clearly and openly known to its upper-stream or lower-stream equipment suppliers during commissioning.

“Very often, there’re all kinds of mistake from the workshop, wrong drawings, careless machining work, in the end low-quality parts are the results. The project manager in charge of the project should start carrying his responsibilities, supervising the manufacturing quality in the workshop. At the same time, designers should visit workshop more often and identify the compliances of matching with drawings.”

--Designer from Outotec

Third-party quality authorization plan has recently drawn increasing attentions among customers, its introduction into commissioning is expected to solve this embarrassing situation where suppliers decide the quality requirements and customers do not have fairly sufficient information about quality standards, customers do not have total trusts on something they do not know well. Besides, third-party quality plan could also supervisor suppliers, and guarantee quality requirements are satisfied, customers can gain the confidence that executive quality standards are competitive among their competitors. However, quality authorization plan has not been widely applied in practice; it is merging only in high-technology projects like telecom applications, software engi-

neering. Neither of the case companies had implemented or tested this plan, but 2 of interviewees from Outotec was interested and positive to the third-party quality assurance plan.

Quality is considered to be an important dimension of efficient commissioning. Its successful implementation starts far before actual installation and commissioning. The empirical results showed that the effective supervision with quality from the part-manufacturing workshops was definitely neglected. Moreover, third-party authorization plan could be introduced to ensure the abidance of quality requirements during commissioning in future.

4.2. Effective relationship management

Commissioning is a process of realizing the intents of design, fulfilling performance requirement with high standard quality, it is also a stage of cultivating relationship with customers and bringing the cooperation forward to services business in future. Commissioning involves the most parties, bringing various relationships up to the front stage like a big orchestra directed by customers, while suppliers, sub-suppliers, contractor and other stakeholders collaboratively surrounding around customers. The relationship management in a big group is vital for the success of commissioning. As one project manager mentioned maintenance of customer relationship and promotion of services business is one target of commissioning.

Effective relationship management, which deal with supplier-customer relationship, supplier-supplier relationship, and other dyadic relationship in the network of commissioning authorities, is not only a goal of commissioning, but also a influencing and catalyzing factor of technical efficiency discussed in previous sections, because the achievement of technical efficiency is closely connected with relationship and even at some degree decided by the stage of relationships. For example, quality plan can be implemented smoothly if trusts between suppliers and customers are already established; performance specifications could be more carefully formulated with the recommendations from partnership suppliers, who really consider customers' operation and business as part of their own business.

The empirical study confirmed that a common goal of optimizing the process and maximizing the performance could set a tune on all commissioning activities, guiding the process of quality plan in an invisible way, easily engaging every personal into the big group. Meanwhile, leader's personal charisma and organization ability could greatly help the schedule-meeting of commissioning. Change control and deviations from design was unavoidable and thus necessary to handle it properly for the efficiency of commissioning. Likewise, effective communications and coordinator certainly prompted the effective training with operation and maintenance instructions. The following sections will analyze efficiency of management from above four dimensions: setting a common goal, leadership, change control and deviations, and coordination.

4.2.1. Setting the common goal of value-creation

During the interviews, all 5 interviewees confirmed the importance of goal such as meeting with deadline, safety and delivering functional equipment. Especially, satisfying customer's needs were mentioned often as a common goal among all goals. Observing from the interviews, the case company Outotec proved to provide a good example of project delivery, which attributed partly to the efficient internal project management structure, partly to long-term cooperation experience with customers. Kick-off meeting clarified the common goal to all participated parties before commissioning; making sure that everyone was working toward the same goal at the same step. Hence, schedule plan, quality of delivery, performance specification and safety consciousness was well-delivered to every commissioning supervisor.

"It's surely important to understand the common goal; however everyone should take care of their own responsibilities."

--Electrical engineer from Kumera Finland

A common goal is a guideline for the concerted commissioning activities; it is based on responsible duties of every participant in commissioning site. An efficient commissioning is a general assembly of every success of every joint of productions lines, in another word; it is a total of single efficiency of separated equipment along the production line. Undoubtedly, the achievement of the common goal is with prerequisite of a completely well-functioned plant, every party has their own targets in mind beside the common goal. Only with the efforts of fulfillment with their own performance, the general efficient commissioning is promising and achievable. From the interviews, the importance of a common goal was confirmed by commissioning engineers, but more profoundly, personal responsibilities were stressed and expected to follow, or own companies' assignment should be focused first.

"Common goal must be a well-functioning plant. In the long run it's the only way to save costs and frustrations caused by only partially functioning equipment. All participants must be able to say proudly, I did that..."

--Mechanical engineer

However, the ideal harmony within the complex group is always hard to achieve, conflicting interests always occur. Customers expected good quality supply of products and services, but budgeting limits of spending on the project always perplexed project manager's mind in the supplier's side. Suppliers preferred to carry out installation step by step, while customers might have concerns on supervisors' services fee; customers pay little attentions to the impacts commissioning or productions caused to environment, while environmental protection was the first agenda of officials from environment supervisor authority. According to interviewees, commissioning group faced this kind

of situation every day; a resolution was needed for the continuation of project delivery. The common goal of satisfying customers' need was then recommended by all interviewees, always for the best of projects was implemented into actions on site during their commissioning activities.

A new definition of common goal, optimizing the process or equipment and creating value for the customers' business can joint every party together for the best of the project, shouldering own responsibilities and contributing the ultimate goal of a well-functioned plant, which means suppliers sometimes need to sacrifice their own interests for the benefits of the project. The value-creation common goal is an indispensable tool of assembling strength of commissioning authorities and turning them into a functional group with the aims of bringing value to customers. Hence, it can be inferred that setting the value-creation common goal is one prerequisite of arriving agreements in commissioning groups when conflicts arise; it is the only solution for solving conflicting problems effectively.

4.2.2. Leadership

As tasks in commissioning site is high-density, commanders of the commissioning group from multi backgrounds are expected to be good organizers with excellent organization ability to guide the group through commissioning process step by step. The following table showed different opinions about leadership from five interviewees. Observing from the table, organization ability was emphasized by 5 interviewees: mechanical engineers, electrical engineers, project managers and additionally one consultant from customer side.

Table 4.2. *The styles of leadership*

<i>Interviewees</i>	<i>Mechanical engineer</i>	<i>Automation/ electrical engineer</i>	<i>Project manager</i>	<i>Consultant</i>	<i>designer</i>
Leadership	Logical and systematic, well-experienced	Organizing, engaging others into the group	Assigning work; following safety and quality	Open-minded, straight-forward, contact persons	What he's doing known to others

Organization and arrangement ability for breaking down assignments is an important characteristic of an efficient leader. Beyond assigning and organizing work schedules and time schedules, leaders are not expected to be a tyrant commander, giving direct orders what to do and what are next, but rather as task initiators of mobilizing group members into the group and taking their responsibilities. The complex commissioning activities are mainly based on team work; everyone is responsible for his own

duties. As a leader, engaging team members into carrying out their tasks is foremost important to the success of commissioning.

Communication on a daily base is also recognized by 3 of five interviewees as an important way of managing commissioning work effectively. Keeping the channel of communications open, information flowing among all involved parties is essentially important for the implementation of project delivery. As a temporary organization, commissioning authorities do face the challenges with overcoming the barriers of efficient communication and learning so as everyone and everybody's work is kept update of the status of project commissioning. Daily-base meeting is definitely necessary to improve the situation. As leaders, being open-minded and able to keep the communication open is most valued by team players. Furthermore, extension of communication after the delivery of project should also be considered by one interviewed project manager for the sake of services business of installed base and other potential project with customers in future.

"The project is a temporary group, supervisors, project manager are assembled from different department. After the project is handed over, it is hard to find the contact persons both from the side of suppliers and customers, that's bad for the learning and potential business in future. "

--project manager

Therefore, ideal leaders are expected to create open communication channel both during the commissioning and after the commissioning, facilitating the exchanges of information regarding the progress of commissioning on daily routine, also planning the methods of contacting with customers and relevant parties even after the commissioning.

Moreover, leaders should supervise the work progress, and the quality of work implementation according to one interviewed project manager. The process of supervising the work of team members actually is an efficient way of guaranteeing the accomplishment and quality of commissioning activities. Team members are motivated and driven to play their roles and being active team members in the big group when they receive more attentions. Usually, they can even accomplish beyond only their responsibilities with high excellence, as a contributing molecules in the group.

Apart from the organization and communication ability, other characters like personal charisma, experiences were also mentioned for a efficient leader. Just as the in the literature about the discussions of the importance of leaders' technical skills and attractive management skills, the interview data also showed the importance of both kinds of skills of an effective leader. In the case company Outotec, most of project managers had solid technical backgrounds, most likely mechanical supervisors were chosen as project manager at the same time, and therefore, technical background was the basis for being an efficient leader. If good knowledge of equipment, organization and communication ability is hard skills expected of an efficient leader, attractive charisma might enshrine all of them and create an attractive and efficient leader. Charisma lies in the fact that

leaders set a good example for their dedications, responsibilities and motivations, and inspire and motivate team players to accomplish their duties in naturally invisible ways. However the real truth is that charisma normally does not come just automatically, it has to do with leaders' ways of dealing with his or her responsibilities and inner nature of personality, like honesty, kindness.

Experiences were also repeatedly mentioned as characteristics of leaders by 3 interviewees. Experiences represented in many ways such as management relationships with customers, cooperation with the safety party. Experiences are accumulated through many projects; many skills discussed previously are developed upon long practices with project management, particularly organization skills and communication ability. The more experienced leaders are, the more efficiently leaders organize the job and arrange for delivering the information to team players. Experiences are also a process where leadership is polished towards the way of attractive charisma and contagious personality. The more experienced leaders are, the more efficiently team players can be motivated to accomplish their tasks.

During the interview with 4 commissioning specialists, resources shortage was often mentioned, and it seemed that no matter what kind of leaders, the foremost important thing was to supply more resource. Commissioning supervisors complained too many responsibilities at the same time, so that they could not focus on improving their performance since lots of other responsibilities consumed their time. Hence, leaders should weigh the balances of working assignments; over-stressed working environment might not be beneficial to create efficiency to commissioning, it will reduce the efficiency and further affect the health of team members as well.

Efficient leadership is undoubtedly a catalyst of efficient management. Organizational ability, communication skills, valuable personality and experiences are often considered as weighing indexes for judging effective leadership in commissioning sites, they are the decisive factors for an efficient commissioning. Moreover, resources problems should also be paid enough attentions from leaders. The frequent calls for resources from commissioning specialists should be heard by the upper leaders in the company, whether or not this issue could be resolved affects not only the success of current projects, but also other projects.

4.2.3. Change control and deviations

Various changes and deviations occur on site during the checking the readiness of installed equipment. Just like the mentioned mistakes from the workshop in previous section as one example, some changes needed to be done during the final test stage of commissioning, or some deviations cannot possibly be corrected due to specific reasons, such as installation accuracy and standards.

“You cannot avoid changes from happening, sometimes customers ask to do things differently than planned. You need to listen to customers first but rather stubbornly stick with plans.”

--Mechanical engineers

All interviewees responded positively that changes and deviations cannot be avoided; two of them firmly stated that listening to customers was an effective way of reducing the risks of changes and deviations; a customer-centric concept was well-rooted in the minds of commissioning supervisors. Observing the responses from the interview, they carefully listened to customers' feedback and made necessary changes tailoring to their needs, if changes did not cause major subsequent effects on their supplied equipment or other equipment. Before doing that, all modifications or actual deviations figures were confirmed with designers. Customer project manager also reiterated that every resolution needed to be tested applicable by both the designers and the experienced commissioning experts. The interview with designer from Outotec showed that most of his time was occupied with dealing with phone-calls from commissioning sites, confirming the design drawings, and modifying the data, which explained that changes and deviations on site did happen frequently, also indicated that communications of changes confirmation and modifications were well-handled between commissioning site and design office.

Three interviews mentioned another important issue with regard to changes and deviations is to document modification and update changes timely, the documentation was important for designers and services people, since service people normally did not participate the process of installation and commissioning. It happened sometimes that, service people did not know the deviations and recommended the wrong choices of spare parts for installed equipment.

“Changes and deviations need to be documented for references, specifying components in a more general way, so that background information for choosing alternatives is available there.”

--Mechanical engineer in Kumera

In order to manage changes and deviations efficiently, Outotec is currently implementing standardization and modularity plan. The plan was striving to reduce the costs of project engineering and manufacturing and the cost of project delivery in a whole; it also could greatly reduce the changes occurring during commissioning. Since standard parts and modular are chosen, there are much rooms for substitute parts instead of a specific one, it relieves customers from the burden of searching for only specific parts from specific manufacturers, because standard parts are easy to purchase and install; moreover modular greatly decrease the risks of deviation. Therefore, the implementation of standardization and modular generalization can to some degree minimize the

possibilities of changes and deviation during commissioning, improving the quality of installation and commissioning.

“We are working on m modularity and design generaliability, providing customers with a solution rather than customer-specific products, so customers can freely choose modular functions as they wish. It will reduce our costs, increase new ways of services business. Of course, the discrepancies or deviations in different project delivery will decrease too.”

---Project manager in Outotec

With design and modular generalizability proceeding, specifications for substitute parts should provide enough information for commissioning supervisor's choices when deviation occurs and changes are necessary. With the help of specification information, thorough checking of the performances of substitute parts can be done, thus substitute parts were recommended by commissioning supervisors as long as they were compatible with original design and suitable for changing according to the interview with one electrical engineer. But as for the deviations caused by flaw parts like the example of manufacturing mistake from workshop, communications with customers, down-line or upper-line product providers were necessary for a final resolution.

Changes and deviations are unavoidable daily scenarios in the middle of relationship-interweaved commissioning, whether or not they can be managed appropriately might have a central effect on the progress of commissioning. Therefore, change control becomes a central part of project management; it is one dimension of efficient project management. The case study provided some hints of successful changes controls: modular and design generalization, general specifications for substitute parts. Modular and design generalization is certainly the emerging topic for most of manufacturing-companies in order to reduce the cost and solve the problems of mixed product ranges, standardizing the supply of design and equipment. By doing this, the deviations and changes occurred on site would drop on a large scale; the efficiency of commissioning is improved accordingly. Moreover, generalization of specification might provide useful information for commissioning supervisors to choose suitable substitutes products and compare performances of substitute products. In this way, deviations and changes would not cause subsequent effects for commissioning and later stage as well.

4.2.4. Coordination

Commissioning, as one way of delivering equipment from sub-suppliers to customers, as another way of feedbacks from sites up to design departments, its coordination process vary in different company. Both Kumera and Outotec had projects in China, their responses with back forward coordination process formed a big contrast; the following was the comments from Kumera:

“Most of the time feedback from the customer is insufficient.” ---Mechanical Engineer from Kumera

”Receiving feedback from customers for future project is important, however, it’s difficult to get message through to the design department since the ready-delivered project is not prioritized in company’s management.”

--- Automation Engineer from Outotec

From above comments, it was observed that in Kumera backward coordination process leading from the customer was inefficient and less implemented in practice, the coordination channel was not open for feedback flows. The interviews with designers, commissioning supervisors and project managers in Outotec company showed the total different results, all 4 interviewees believed feedbacks from customers were timely, and effectively updated to designers both in verbal and written form. One project manager even showed me a two-page question list from the customer while commissioning engineers were working on site.

“We have open channel of coordination activities with customers, after kick-off meeting, every month we write report regarding the process of design, purchase and manufacturing in the way of accomplished percentage and inform customers and all relevant participated colleges of the progress, it’s a very effective way for information sharing. During commissioning, we follow the same, customers give instant feedbacks to commissioning supervisors or project managers on site, and that information is immediately forwarded to our designers as well.”

--project manager from Outotec

According to his statements, after-project meetings were also a routine for the project management team and sub-supplier team. In the meeting, all the feedbacks from customers, the achievements and insufficiency of project delivery were reviewed for the final conclusions of the project. In comparison with two companies, openly internal management system is a key node for the efficient backward coordination activities; it can either block or guide the information flows starting from the customer side. Since two case companies have different internal management system, results in responses to the same questions turned to be different.

Coordination process is an interactive process, requiring active integration activities from both customers and suppliers, the sacred tasks of coordination is to engage both parties or multi parties into fruitful dialogues regarding issues in commissioning. Their communications, integrations with each other construct a fundamental part of project management, and creating value for commissioning process. The value-created coordination process should be sufficiently implemented in both forward physical delivery and backward feedback. In the forward delivery, customers are recommended to be more

involved with installation and commissioning; while in backward delivery, suppliers should pay efforts with unblocking the channel of information flowing up to its design department and further improving internal management system. Observed from the empirical data, it was most likely that backward delivery was not implemented well.

The interview from the consultant of project management presented a unique angle of observing coordination process from the customer side; he claimed that customers' resource and willingness played a key role in coordination process as well.

“How actively customers give feedback sometime is affected by their resource, how much manpower the customer wants to allocate for the project. The actual situation is that customers are very busy with many projects at the same time; they do not have enough manpower on site especially for one project. Beside, the importance of the commissioning project in company's strategy also has a say on how actively they are willing to pay attention to give feedbacks for improvements.”

--consultant for customer's project management

Coordination process is a continuous process implementing and penetrating throughout the whole commissioning time, extending far before the initiation of commissioning and down to later phase of project delivery, the efficiency of coordination implementation depends on both the supplier's internal management system and customer's engagements, furthermore, the successful coordination process bring forth the value-added exchanges, thus the efficiency of project management. Internal management system is substantially important in enabling the opening of feedback channels. Whether or not its management system supports the flows of feedback could be observed already before the actual commissioning on site, the patterns of internal coordination can be shown in its daily practice of management. The two case companies gave an illustration of how internal management system could affect the efficiency of feedback transfers and the efficiency of commissioning in a whole. Customers' devotion to projects also has an equal role of maintaining a efficient coordination process.

4.3. Commissioning and service business

A successful commissioning is expected by every participant, on-time delivery of project, high level of quality and safety are the ultimate goal of commissioning. Services, arising after the delivery of installed base are very often not connected directly with commissioning, or the causality relationship between commissioning and services business is not illustrated in previous studies of project delivery or other relevant fields. However, five interviewees, working on the front line of commissioning, even though their responsibilities were not much focused on strategy planning for the company's transition to a service orientation like head managers, all agreed firmly that commissioning is very important to services business in future.

“During commissioning, you really build up relationship with customers face to face; you gained good reputations and trusts for the base of service business in future. We need to remember that relationship maintenance is one goal of commissioning. As long as customers are satisfied with our performances, services business will come naturally”

--Project manager from Outotec

The direct connections between a successful commissioning and potential service business were recognized as one part of commissioning by interviewees, and service business was not born without the base of successful commissioning. From the view point of customer's side, commissioning was a preparation process for operations and maintenance.

“Commissioning is important, but the later operation of equipment last much longer than commissioning time, we think the smooth operation and maintenance weighs more than commissioning itself. So commissioning is actually a process paving the way for smooth operation in future, commissioning has strategically effects on future.”

--project manager from Jcc

Service business is closely connected with commissioning either from the preparation process of service business or the automatic initiator of service business. If service business is the expected result of commissioning, and if service business is supposed to be alive over a much longer time span during the project life cycle which is expected from customers, service business is strategically more important than commissioning in one point; and the long-vision final goal of commissioning can be expanded or reflected as smooth operation and maintenance, and supply of service business. Service business after the delivery of equipment constitutes one part of efficient commissioning. Hence, service business could be regarded as one dimension of efficient commissioning. The interview with one commissioning specialist indicated there were also concerns, accompanying with the prospects of long-term service business arising out of good reputation, satisfactions.

“ The project is successful delivered and efficiency accomplished, operation and maintenance training really reached its targets, customers might have a fairly good knowledge of equipment and have a good idea of how much they know, they might handle themselves rather than order services from suppliers.”

--project manager from Outotec

The concern that high quality delivery of equipment might close the door business of services is not baseless; it obeys the same logic as a pair of good shoes might face the situation of less repairing business. However, the risks of delivering a low-standard project are huge, as the subsequent impacts might be fatal to the survival of company busi-

ness; suppliers can never afford such risks. A bad quality shoes might shut down the business door, customers stop buying the same bad shoes; while good shoes might persuade customers into buying other adjacent products under the same brand, like shoe shiner. 4 out of five interviewees were positive that delivering a good project lead to potential service business in the long-term.

With specific applications for connecting up commissioning with service business, interviewees recommended that documentation during commissioning, all the updates, and modifications should be available for service people to provide maintenance guidance and spare part services. Documentation is one aspect, personal involvements with commissioning was another message conveyed from commissioning supervisors and designers. The frequently-mentioned issue by interviewees was services people's lack of detail technical knowledge, particularly services people did not have details of what had done during commissioning, which might be a big barrier for developing business opportunities. Service people should be more involved with commissioning in order to proceed with services business with installed business.

Incorporating services business into the process of commissioning, defining the readiness of services business as one goal of commissioning is certainly stimulating the implementation of concept of services into commissioning, especially the background of it lies in the fact that traditionally manufactured-focused business model is marching its way in deploying derived services-centric business. The readiness of service business could be regarded as one factor of efficient commissioning.

5. DISCUSSION

The objective of the thesis is to find the contributing factors to the efficient commissioning and the relationship between the commissioning and subsequent service business. The theoretical sections presented previous findings about commissioning over a wide range of discussions, although theories of project delivery relating to commissioning process in particular as specific to equipment commissioning site only consists of a relatively small percentages, theories and ideas generated in project delivery in other industries are applied into commissioning. The empirical study summarized different views of commissioning supervisors, presenting their innovative and novel ideas about commissioning and project delivery as a whole. Developing from three criteria, performance, operation and quality, technical efficiency is comprehensively analyzed for generating decisive factors in the commissioning groups. Beyond that, interview results showed that environmental and executive regulations evolved into new themes in practical commissioning. Other than limited three technical criteria, the commissioning environment needs to be studied for investigating new influential elements of technical efficiency. As the shortages of concrete agreements on the efficiency of management, value-creation of the process and effective interactions among participant parties are accounted as the main concepts of efficiency from the view points of a common goal, leadership, changes and deviations, coordination. Besides, integrating service concepts into commissioning requires service manager's active participations and updated documentation during commissioning process. Meanwhile, it is inferred that established project management system including documentation system in case company Outotec affected the results of project delivery, and the internal management structures became another interesting perspective of observing the efficiency of commissioning.

5.1. Technical efficiency

The concept of technical efficiency of commissioning delivers the messages how efficiently technical performances are met up with or technical targets are achieved (Lee et al. 2000; Coelli et al. 2005) with high level of quality during commissioning. Technical efficiency of commissioning reflects the technical-achievement transforming ability, considering the commissioning process as an open system. Observing into each stage of commissioning activities such as pre-design, installation, test-run and final acceptance is difficult, the study of technical efficiency can be relatively easier approaching from the general activities of commissioning, regarding the commissioning as an entity with the output of technical achievements. The literature has limited proofs regarding technical performances, operations requirements respectively, supplier's recommendation and

customer's requirements are mentioned as important issues. interview results revealed much comprehensive views about different criterions of technical efficiency, and inferred some potential new criterions of efficiency relating to the commissioning environment, for example environment protection, authority regulation adherence and other relevant third-party plans were not emphasized or covered under technical achievements in previous literature, except that Spengler (2001) stated the safety issue, as one target of commissioning from the point views of litigations of operation engineers and contractors.

Responses from interviewees clearly stressed the effects of safety rules and cooperation with official authorities for the efficiency of commissioning and success of project delivery. Compliances with safety rules and adheres to environments or other executive regulation had far more impacts on the progress of commissioning than identified on the extant studies in the field of project delivery. The empirical study showed that, the concept of safety was penetrated throughout the commissioning, far before even the stage of the concept design, since commissioning involved a great deal of activities, not only the safety of using equipment after commissioning but also the safety during installation and commissioning matters for the general efficiency. All interviewees including one questionnaire from the customer confirmed that safety rules needed to be followed strictly during every stage of commissioning.

Furthermore, commissioning process involves multiple stakeholders; the strict adherences with environmental and other executive regulations affect the schedule, costs of commissioning and even the approval of the continuation of the whole project. Some countries have strict regulations with regard to waste extractions standards, hence the less consideration with those issues into commissioning resulted in suspensions to installation and commissioning, afterward corrections or alternative resolutions were needed to take in place before resuming commissioning.

As our society is evolving to a closer interactive and environment-conscious net, aspect such as safety, environmental issues are risen up into new contributing factors of the efficiency. Previously less cared issues in academics study of project delivery become the highlights of commissioning group, which was certainly realized by commissioning specialists. Hence, apart from hard targets: performance specification, training with customers, and quality standard of commissioning. The thesis proposes that adherences to safety rules and executive regulations by the third-parties can be incorporated into another dimension of technical efficiency. More studies of the impacts safety and government regulations exerted on commissioning should be proceed further to complete the discussion of technical efficiency.

Performance specifications convey customers' requirements with the delivered products or equipment; it reflects customer's expectations and their technical and operational needs. The delivery of project is formulated on the basis of customer expectations and technical requirements in project sales phase (Artto et al. 2012). The formulation of performance specifications take a long process, starting from the primary concept design to the hammering-down of technical articles in the contract, it is the result of both

parties' interactions and inter-adaption (Wiggin 2005; Garvey 2005). Herein, the focus of performance specifications were around the table of contract negotiations, customer's active participations, and supplier's recommendations considering about customer's business were emphasized as the contributing elements of the criterion of performance specification.

Three patterns were found from the empirical results. First, the empirical study confirmed the functions of performance specifications in commissioning. Performance specifications were commented by interviewees as the stick yard for assessing the success of installation and commissioning. Second, the literature findings reflected that the formulation of technical stipulations should combine different opinions from customers sides especially from operation level so as the ordered system or equipment is satisfying practical applications. Different from negotiation table where traditional sales and other manager play the main roles, this hint broadens the decisive elements of performance specifications, incorporating the operators of installed equipment into the picture and making the study of efficiency of performance fulfillments characteristic of reasonably practical guidance in commissioning. Third, the interview results revealed the happenings of instant requirements out of contract during commissioning, it proved that commissioning is more than delivering written guaranties; some extra requirements in the way of "small or big favors" were also part of customer's expectations and expected to be satisfied. As a matter of fact, upcoming requirements indicated the dynamic process of commissioning since the commissioning activities continue and new requirements grow as well. Hence, the emerging requirements can be studied as a natural phenomenon and granted as one characteristic of specific commissioning process. As a matter of fact, commissioning supervisors were ready to do "small favors" or even big favors were also possible after discussions with the office. Undoubtedly, the flexible mindset of "listening to customers" was not coming automatically, it had a close relationship with the implementation of "a common goal, best for the project" and prepared minds of understanding risks with project deliverables and accordant new requirements.

Therefore, the thesis provides a broad view of studying the criterion of performance, including comprising the needs of operation level and perceiving the emerging requirements as a natural element accompanying commissioning activities, and recommends that technical stipulations representing the needs from operation level and flexibility for extra requirements reflect qualitatively the dimensions of performance, whether or not handling them properly will have decisive impacts for the efficiency of performance criterions.

Training of technical manuals is understood as a process of educating customers to familiarize with the operations of equipment, as well as maintenance knowledge (Spengler 2001), it was emphasized by interviewees as another important goal of commissioning. Operational requirements are clearly contained in technical documentation (Wiggins 2005), which is also accounted as the main source of training process. The theoretical literature has little touches on the process of face-to-face communication and information exchange during commissioning. The interview results showed that on-site

explanations from commissioning supervisors acted as an important supplementary part of training process apart from technical documentation, since misunderstanding with technical topics due to the mistakes of interpretations and complexity of technical terms occurred often. Commissioning supervisors' personal instructions on site were also highly valued as a good opportunity of learning by customer project manager from Jcc.

The effective exchanges of information through instant ask-answer are interactive dual-channel of information sharing rather than one-way teaching. On one hand, customers are encouraged to suggest or comment on commissioning; on the other hand, commissioning supervisors listened and were expected to give customers' concerns into consideration. Therefore, the exchanges stimulated and engaged customers into dedicated, active participations with installation and commissioning activities, it increases the efficiency of training process, and the efficiency of commissioning in the end.

Communications between customers and commissioning supervisors are training and learning process. Communication and information sharing contributes to value-creation. Training is certainly an essential part of value-creation process, since customers bringing forth their comments and ideas, contributing to the learning process in the temporary learning organization (Tsoukas& Chia 2002; Winch et al. 2012). Moreover, training process is also a perfect chance of cultivating stable long-term customer relationship. Both case supplier company already established partnership with customers, they unanimously agreed with the value of training, regarding training as a platform of strengthening customer relationship.

Proved by empirical study, the thesis manifests the efficiency of training from the angle of the value-creation through communications and the relationship development during the training process, and the thesis recommends that effective exchanges on site has equally important role of training as operation documentation, completing with it during commissioning. Just as the unavoidable misunderstandings or shortages from the documentation exist, the instant instructions from commissioning supervisors can compensate and provide sufficient explanations to written documentation. Therefore, in the thesis it is stressed that explicit documentation and effective exchanges on site become two important aspects of efficiency of training.

Quality is one centric part of efficient commissioning, the increasing attentions have been given to the quality of installation and commissioning both in academic research and practical project implementation, since the complexity of projects dealing with technology products is growing (Barccarini 1996). It is not exaggerating that quality is described as the soul of production, quality implementation starts with the first essential step: quality installation and commissioning, only quality of production can be ensured as long as the production line is first installed with high-quality standard. Although the unique position of quality was easily recognized by commissioning supervisors; however, the empirical study revealed that quality implementation was not easily fixed as written standards, but depending on attitudes of implementers. Interviewees claimed that involved parties should agree with an applicable standard according to local levels, and it was unrealistic to formulate a general standard and force it to every commissioning

site, local standards and technology level of the customer affected the applications of quality plan. Strict quality standards were difficult to precede, and need to bend to actual situations on site, but customers were well informed of subsequent effects due to bended quality standards. The empirical study revealed practical issues accompanying with quality implementation, and provided valuable hints of dealing with the conflicts of general quality standards and discrepancies of technology level in commissioning site.

Quality issues with fault parts from workshop was not often discussed in previous literature, but often discovered by commissioning supervisors, and from interviewers' opinion, it was very difficult to correct this kind of quality mistakes, since in most of international project the manufacturing workshop and installation factory was so far away from each other, frequently turning a blind eye to the mistakes done in workshop always caused a problem in commissioning. The worst cases is that mistake parts were hidden from knowing at the beginning, the subsequent effects on its upper-or-lower products in the system was difficult to assess. Project manager, designers' frequent visits in workshop was suggested by a commissioning engineer to solve this kind of issues. In their opinions, quality was not an issue of written standards, it was in the hands of every involved person, and responsibilities from every one of them built up together the quality.

As a new phenomenon, third-party quality assurance plan is recently implemented in project management (Garvey & William 2005), its study was mostly carried in software and other high-technology projects. Its applications were not present in the case companies of this thesis. The up-brings of third-party quality plan is to strength quality standards and supervise the results. The imbalance knowledge of equipment and products, to be specific, high-technology products between suppliers and customers, together with mistrusts and risks on relying on one party prompted the third-party's participations with quality implementation. One interesting result from empirical study was that mind-set of customers; together with management structures affected the implementation of quality assurance plan, except for some situations where third-party inspections and approval of quality or standards was a must. Whether or not customers were willing to invest on quality implementations decided to some degree whether or not to implement such a plan. However, the interviews showed that commissioning specialists were open to the implementation of third-party quality plan; it could be a good option for adopting to strengthen the quality standards. The further study regarding details with quality assurance implementations in general project management project is worthy to carry out.

The commissioning site is often described as a problem site too, since all kinds of problems and new issues keep coming all the time. Quality, as one indicator of efficiency of commissioning, is a key issue faced by every involved party and extremely challenging to be guaranteed, which is one of reasons of delayed project delivery. Undoubtedly, the complexities and uncertainty issues made the study of quality implementation even harder, and it is less likely the resolutions to quality issues can be found from the written quality plans transplanted from written guidance. The empirical researches with

specific issues and their impacts on quality implementation during the commissioning have to be thoroughly examined and analyzed. The thesis discovered that the environment of implemented project should be examined, such as standards of the technology level of the commissioning country, since issues relating to quality like different local quality standards, faulty parts presented one daily phenomenon and alerted us into investigating into more similar scenarios, from which new elements of the efficiency of quality implementation could be explored. Apart from flexibility to local standards implementation of quality plan; further considerations such as customers' determination, other participant's attitude, and technology level of local customers could affect the practical implementation of quality plan and the efficiency of commissioning as a whole.

5.2. Management efficiency

Different from the realization of technical requirements or implementation of quality standards, maintenance of customer relationship is another critically important task of installation and commissioning. Relationship management requires the engagement and the collaborations of involved parties; it has strategy impacts not only for suppliers' services business but also its survival in the long-term. The great deal of literature publications in the field of business management demonstrates the unique role relationship plays in project management (Ruhli & Sauter-Sachs), and the responses from interviewees confirmed and stated that relationship management was the pillar of project management particularly in commissioning process, where participants of commissioning were multiple from different parties.

The study of business management, relationship management constitutes a big part of project management literature, dealt topics in business management reaches nearly every aspect, so as the standard of evaluating the efficiency Ruhli & Sauter-Sachs's five-approaches provided a good example to define management efficiency (Ruhli & Sauter-Sachs 1993), however it should be born in mind that each of approach has its own priorities and focus (Lee 2000; Hon 2011). The thesis chose four approaches: goal approach, system approach, social approach and decision approach to categorize the drivers of efficient management: setting the common goal of value-creation, leadership, changes control and deviation, coordination, and factors of efficient management is analyzed respectively from above drivers.

Setting the common goal of value-creation is vital for the success of the commissioning, it is the guiding pilot wherever conflicts arise and a resolution has to make on site. The interview manifested that "The best for the project", satisfying the customers, was well-rooted in minds of commissioning supervisors, it reflected Norman's value-creation theories of customers' satisfactions, satisfying customers' needs of an operational factory (Artto et al. 2012). The concept of focusing on the second-level relationship, mobilizing customer into value-creation can be observed in the empirical studies and was actually implemented as a guideline of commissioning activities. Commission-

ing supervisors explained that a functional plant, a plant customers can produce high quality products for its own customers, was the goal every party worked together for.

The practical studies also revealed that each company had slightly different approaches towards the meaning of the common goal, even though all of them agreed with the significance of the common goal. It is known that the pre-conditions of an accomplished common goal are on the basis of every single functional sub-system, every party should first of all be responsible for their own duties in their designated position. Commissioning is a high-density and demanding job, 24-hours testing and running the production line is required in later stage. Every commissioning supervisor is expected to accomplish his or her own part as for the flow of the whole commissioned system; otherwise the continuation of commissioning is interrupted and postponed. In case company Kumera, the importance of responsibilities with own duty for their supplied system was stressed, sticking to own responsibility sounds more realistic than conveying the message of the common goal among all parties. However, in the other case company Outotec, interviewees emphasized implementation of the common goal among participated party, and communicated with customers about project timely progress and achieved goals. Commissioning specialists explained in details with customers about the progress of commissioning and encountered issues during project meetings every month. Certainly, monthly meetings and reporting system was closely related and supported by company's internal management system, which influenced the means of approaching the common goal. It is not hard to conclude that the communications between involved parties enhanced the delivery of messages and kept every party towards the common goal. Most likely, efficient communications about the goal and achieved progress is inclined to create value for the process like Norman's value theory indicated by engaging customers and other parties into commissioning. In the end, it increases the efficiency of commissioning and customer satisfaction as a whole (Szczepanek & Winter 2008).

Although personal responsibilities are the basis for an efficient commissioning customer satisfactions, value-creation for the process are beyond the level of accomplishing responsibilities, contributing to efficiency of the project in a high and profound way. Setting the value-creation common goal can encourage involved party to engage into commissioning as a group rather than working on their own and limited to follow solely responsibilities, it increases the efficiency of commissioning and generally the delivery of project. The empirical studies indicated that the mindset of project managers and organizational internal management system had decisive impacts on either setting the common-goal of value-creation or stressing the personal responsibilities inferred that. It can also be inferred that a common-goal of value-creation posed profound impacts on supplier's management systems since to keep the customer updated with every progress requires commissioning specialists and managers to follow routine reporting system. The relationship between internal organizational management structures and the implementation common goal of value-creation is bilateral and interdependent, organizational

structures supports the implementations of a common goal, and implementation of the common goal requires an open and customer-centric structure of the supplier company.

Leadership is one often discussed topic in project management (Toor & Ofori 2008; Lloyd-Walker & Walker 2011), however there are no unanimous agreements about what kinds of leaderships are most valued during commissioning. According to the interview results, organization ability and communication ability were identified, soft skills was prioritized over technical skills since most of project managers showed a strong technical background with the undergoing projects, working as mechanical engineers at the same time. The ability of managing the commissioning group was repeatedly emphasized by customer project manager too. As a matter of fact, the majority of leadership articles are also more interested in leaders' soft skills rather than technical skills (Legris & Collette 2006; Cowan-Sahadath 2010; Lloyd-Walker & Walker 2011), soft management skills are the essential important for being an effective leader, in part because that soft management skills are essentially important for being an effective leader, in part soft management skills are difficult to generate and hard to cultivate.

Apart from organization and communication ability, experiences, personal charisma, emotional contagion are also important for leaders (Toor & Ofori 2008) according to the literature reviews in the study of social science and organization behavior, this statement is based on scientific analysis over the characteristics and its impacts for group activities, it can widely apply to any general group. The interview results indicated that experiences, leader's personalities were also important for being a successful leader. They stressed leaders' experiences, which reflected their expectations of leaders as sophisticated in handling with management issues during commissioning.

The effective leadership is to assemble, to unite and glue the strengths of a group for a common goal, the soft skills representing by organization and communication abilities are typically regarded and proved by interviewees as the first element of an effective leader. Meanwhile, it is worth mentioning that, complaints with over work and limited resources should be brought up to the agenda of not only project managers but also senior managers in the company. On the one hand, project managers should give enough considerations into appropriate amount of assignments of work load for its member; on the other hand, senior directors should give orders to provide supports for commissioning groups in the way of manpower and supporting units in the organization (Kirsilä et al. 2007; Artto et al 2012).

Changes and deviations like a daily routine, take place every day during commissioning (Kirsilä et al. 2007, Cowan-Sahadath 2010), the interview results with the designer from Outotec certainly confirmed this statement. His majority of his time was occupied with answering and confirming changes issues about piping arrangements, installation guidance and design reviews.

Changes or deviations are present in many forms and from different resources. Generally speaking, changes or deviations from external environment like technological advances (Kirsilä et al. 2007, Liinamaa & Gustafsson 2010) are related with adaption to environment, while changes dealing with commissioning activities is more about coor-

dination among commissioning groups and supportive units. According to the empirical study, both of them existed, for example, the new emission regulation caused installation of equipment into a pause, and the installation place of a particular part had to be modified to fit into customer's existing facility. Additionally, the responses from interviewees mainly emphasized the later changes with commissioning activities. One reason can be inferred that both of case companies for decades manufactured and provided large scale of metallurgy products which are less susceptible to latest technology innovations, therefore their comments were mainly focusing on internal changes; if the interview was carried in other industry, the focus of types of changes might be different.

From the empirical studies, modularity and generalization of function blocks in equipment or process was found to be an efficient way of reducing the changes and deviations occurring on its global installation sites, although its primary goal was to cut down manufacturing costs and increasing margins. Moreover, through the implementation of modularity and generalization in the system, customers were entitled to choose components or products out of their own preferences, thus supplied solutions or equipment was proved to be more competitive in the industry, relevant services businesses emerged accordingly on the installed base.

No matter changes or deviation from industry itself or installation site, both of them are integral parts of project management in commissioning site. An efficient project management should focus on both sides, especially nowadays the environment protection and sustainability has invariably been the more concerned topic than ever (Ruhli & Sauter-Sachs 1993), and the external environment has evolved into a substantially important element in the change controls and deviation management.

Coordination tends to be a common problem in commissioning site, when interdependency and interaction with each other is desired for the smooth implementations of project delivery (Anderson et al. 2012), in both forward physical delivery of products and backward information feedback leading by customers (Frohlich & Westbrook 2001, Liinamaa & Gustafsson 2010). The empirical study presented that backward information feedback from customers was less implemented in commissioning site according to case company Kumera, while the results from case company Outotec showed the opposite, that information and feedback from customers and other party was efficient. The converse comparisons from both companies demonstrated that open information channel which facilitate information-sharing thus value-creation is the key to the effectiveness of coordination.

Project management group, commissioning team is temporary organization, sharing and learning process is limited due to the temporary structure (Tsoukas & Chia 2002, Winch et al. 2012). The more possibilities information is shared and learned in an organization, the less wasted time on the coordination and higher efficiency of project management activities are achieved (Kirsilä et al. 2007). As a matter of fact, backward feedback during coordination is a process of information-sharing and value-creation. Customers' feedback about the installation and commissioning provided value information for suppliers' knowledge of the progress of the whole commissioning project,

and other suppliers' information. In case company Outotec, monthly project meetings, post-project meetings and spontaneous exchanges with customers engineers opened an interactive channel of information feedbacks, centering on the customers; the effectiveness of coordination was greatly increased. Certainly, the open channel was at some degree depending on supplier's information system, through which customer feedback can be delivered all the way back to the design department and provide references for other project.

The interview with consultancy of customer project management provided another viewpoint of information channel, customers' attentions and resources affected flows of backward feedback as well. The importance of ongoing project in customer's development strategy decided customer's attentions and input of resources, which directly affects how often and how much feedback was given either in formal or verbal forms. Therefore, the thesis suggests that the effective coordination in backward information transfer lies in the both ends of open information channel: the suppliers' information system and the customers' devotions, both aspects should be concerned for the efficiency of commissioning.

5.3. Potential services business

The literature about the relationship between commissioning and service business is rarely established, although commissioning and service business occupy the continuing time span during life time project delivery. However, the facts that project life cycle has now extended beyond over the point of project delivery or handover the equipment or products, supplier's ability of providing technical services and operation become one important figure of choosing the supplier in the beginning of contract negotiations (Andreas & Wolfgang 2006), not even to mention in some cases suppliers shoulder some part of customer's operation business after the delivery of equipment and products, technical service has certainly been one centre part of the package of supply and a new business opportunities, separating from the installed equipment (Brady et al. 2008). All the interviewees unanimously expected potential service business or other projects coming after a successful commissioning.

According to the empirical results, interpersonal contacts during commissioning formulated the basis for services business, just like Andreas & Wolfgang (2006) claimed that there were no better opportunities of developing or promoting services business than delivering high-quality products and equipment, presenting the proficiency of operational instructions and other service skills to customers face-to-face. At one hand, the reputations built up during commissioning have reference value for service business; on the other hand, ability of supplying quality parts and technical services is viewed as one of the most valued characteristic of choosing suppliers by customers.

The questionnaire from the customer project manager presented a new thinking about the relationship between commissioning and service, and believed commissioning was important but the longer period of smooth running of equipment was customer's ultimate target. Applying the presented theory that commissioning is a pre-test for nor-

mal operation, commissioning should also prepare for necessary technical services and support to ensure the smooth running (Brady et al. 2008). In this way, readiness for services business naturally becomes one target of commissioning.

The upcoming problems with installed equipment affected potential business such as software commissioning. The empirical study indicated that incomplete software design often lead to troubles during operation; and affected customer's confidences with provided technology and services as well. Customers should be encouraged with automation and software commissioning at early stage of commissioning, even commissioning specialists explained that they were very willing to teach customer's engineers about the control system, as long as it was not embedded software function blocks. Moreover, customer's participation into commissioning can stimulate and speed up innovation in their products (Liinamaa & Gustafsson 2010) too. The thesis recommends that the concept of service business should be incorporated into commissioning process, and credibility of a successful commissioning and supplier's sophistications in providing technical services is the prelude of potential service business and other projects, readiness of service business is one element of commissioning; furthermore, supplier should improve the delivery of automation and software commissioning and engage customers' participation in early stage.

5.4. Recommendations for case companies

Case supplier companies (Outotec, Kumera) faced different challenges when implementing the delivery of capital equipment. As for Outotec, the most pressing issues affecting the commissioning is quality issues, automation and software commissioning issues frequently called software engineers back to customer facility even after the acceptance of equipment, some of project were even not final accepted until few times call-back for modifications with software application. A comprehensive and flexible quality plan is the first step of ensuring the quality of installation and commissioning, it should be agreed by involved parties of commissioning. Outotec should beforehand design a applicable quality plan combined with the opinions of customer's sub-contractors, executive authority party and deliver it to involved parties. Furthermore, effective interactions with third-party supervisors could eradicate customers' concerns and entrusts and strengthen the implementations of quality plans.

As for Kumera, the most severe issue of efficiency of commissioning lies in coordination, customer's feedback information was blocked in the way of backward transfer process; customer was not actively contributing to the process of value-creation through sharing and learning. The internal management structure should be adaptive to channel through flows of information from customers and other parties up to the design department. Furthermore, the inefficient information feedback resulted in the lack of ability of change control, slow adaption to customer's change needs. On a large scale, documentations and training, service business could also be affected negatively.

Services business is not, and should not develop automatically on the based installation. For service managers, listening to commissioning specialists, working closely with

them might be the way-out of searching for service business instead of sitting in the offices and mapping the strategy of potential technical business. Actively participating the commissioning will be helpful to bring forth and proceed with potential service business. Both case companies should encourage the integration of services with commissioning activities, implementing a service strategy penetrating throughout the commissioning process.

6. CONCLUSION

6.1. Findings of the thesis

Commissioning is a special stage of project delivery, occupying a relatively long time span of project delivery, particular with the delivery of capital equipment. There are three important findings from this thesis. First, the thesis has presented the extant researches in commissioning and providing some references for further researches about approaching the efficiency of commissioning. Second, the thesis recommends that holistic observations into the environment including all stakeholders not limited to main bodies like suppliers and customers could open new windows of discovering the influential elements of the efficiency commissioning. Third, the thesis demonstrates that the concept of value-creation and effective communications within an organization are two important tools of perceiving efficiency of the organization, its applications into commissioning groups reflects the dynamics of value network of project business. Efficiency of commissioning affects not only the targets of technical accomplishments, beneficial customer relationship but also the prospects of potential service business. Traditional studies of commissioning efficiency falls into the categories of budgeting controlling, and design and planning of commissioning procedures, rarely the efficiency of commissioning was examined comprehensively from point views of the technical achievements, management efficiency and service readiness through the careful observations of commissioning activities as a whole.

The thesis presented previous studies on commissioning, and applied technical efficiency into commissioning with concept of macro open resource system to analyze qualitatively the contributing factors of technical efficiency, perceiving the commissioning activities as a whole assembly rather than going deep into every specific step of commissioning ranging from pre-design all through final acceptance. Thus, the findings are based on general commissioning activities rather than narrowly limited to observe one aspect of commissioning activities. Hence, the generalization of driving factors of efficiency is based on the general activities; driving factors from this thesis can easily apply to every commissioning example and every stage of commissioning. Apart from the three dimensions of technical efficiency, performance, training and quality, the thesis discovered that environmental regulations, safety and executive rules are playing a more important role than even and adherence to safety rules and executive regulations has evolved into a new dimension of technical efficiency of commissioning. Meanwhile, the findings of third-party executive regulations provided a hint that rather than only focusing on players such as customers, suppliers, the commissioning environment

should be examined comprehensively; other stakeholders and their influences should be studied further in order to explore holistically contributing factors.

Developing from criterion of performance, the thesis discovered that performance specifications should reflect both the customer's comprehensive technical specifications and their expectations as well. The birth of technical specifications requires supplier's recommendations and customers' comprehensive opinions from operational level during contract negotiation stage. Furthermore, satisfying the customer's expectations and preparing for extra needs arising spontaneously from commissioning site constitutes a natural element accompanying commissioning activities and thus a central factor for the technical efficiency. Therefore, be accurate with technical stipulations and be prepared for extra needs work hand in hand for achieving efficiency. The importance of training and the reasonability of it being one dimension of efficiency were rarely argued, but the study of how to achieve the efficiency of training is limited to the illustrations of operational documentations. The thesis concluded that effective instant exchanges is proved to be equally important as the accurate documentation, highlighting the importance of customer's or end-user active participations in the early stage of commissioning. Observing from the customer's view, longer time smooth operation free of malfunctions is their ultimate target. Except for detailed documentation, on-site effective exchanges are not only one part of coordination, but also helpful method of decreasing misunderstandings and wasted time on communications; hence both perspectives are crucial for efficiency of training and efficiency of commissioning as a whole. Quality is the root of efficiency, high-quality standards can guarantee the progress of commissioning activities as planned, however the implementations of quality plans need to study the environment of implemented project, to subject to the limits of customer technology level and other conditions. Furthermore, third-party quality assurance plan is slowly adopted into project delivery to resolve the quality issues, and its applications are coming on a large scale in near future.

The measurements of management efficiency range from various observing respects. Based on the concept of value-creation and effective communications of a learning organization, the thesis selected Ruhli & Sauter-Sachs's approach (1993) and analyzed contributing factors of four drivers: a common goal, leadership, change and deviation, and coordination. The thesis argued that setting the common goal of value-creation can unite all involved parties into a value-creation process, a process of delivering a functional plant and competitively optimized process, since everybody can be assembled under the flag of "The best for the project". Furthermore, the thesis summarized that organization and communication ability is the most valued for the concerted commissioning group, additionally, experiences and charisma can enshrine the ability of organization and communication and other quality expected from an effective leader. According to the empirical study, modularity and generalities of components has been implemented to deal with changes and deviations by many manufacturing companies although the initial aim was to reduce the costs of manufacturing, but its implementation greatly lessen the changes due to non-standard applications according to the interview

results; documentations on deviations is necessary for subsequent services. The thesis also recognized the less implementation of back forward information transfer at installation site, supplier companies should take its responsibilities on opening up its information management system to feed in the customers' feedback, also actively engaging the customer into contributing of an optimized process.

Service-orientation business model is marching its way in traditionally manufacturing-dominant companies, seeking for innovative methods of developing potential business opportunities in the supplies of resolution and packages is coming to the top agenda of service managers and senior directors in those companies. This study provided a new view through which the unique relationship between commissioning and services is examined and a profound recommendations for the implementation of service strategy: service engineers should actively take part in commissioning events and be involved with the delivery of projects even from the beginning. Service people should continue with coordination process with customers.

6.2. Limitations of the thesis

The empirical study of the thesis is based on 5 interviews from one company and 3 questionnaires from another 2 companies, the limited resources of interview data affected the applicability, generalizability, and the validity of findings in the research. Particularly, commissioning process of different projects could vary; hence the contributing factors of different projects could be presented slightly different in different industries or even in different projects. Moreover, the data collection indicated that commissioning engineers were easier to correspond from technical views than relationship management, which might influence the assumption of equal importance of technical efficiency and management efficiency, although the thesis aimed for defining the efficiency of commissioning equally both from the technical and management point of views which is beneficial to recognize various contributing factors of efficient commissioning. Besides, the dyadic relationships between two kinds of efficiencies are not deployed in this thesis, practically they are inter-acted and inter-influenced with each other, consisting of an integral process of installation and commissioning. Hon et al. (2007) stressed that managerial practices, scale or size of operations affect technical efficiency based on the engineering relationships rather than prices and costs, relationship management exerts impacts on the results of technical efficiency. Therefore, future study should include the analysis of dyadic relationships of technical efficiency and management efficiency, collecting more data from different industries and specific projects.

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APPENDIX 1. THE RESULTS OF EMPIRICAL STUDY

<i>Topics</i>	<i>Literature review</i>	<i>Empirical observations from inter-views/questionnaires</i>
The definitions of commissioning	<ul style="list-style-type: none"> Commissioning has been defined as a systematic, documented, collaborative process to attest the functionality of systems including component equipment to meet design intents and needs of customers, starting with pre-design stage and extending to final acceptance (Kutsmeda 2008, Spengler 2001, Kubba 2010) 	<ul style="list-style-type: none"> Implement design intent, to accomplish the delivery of the project, to accomplish function abilities, start-up equipment and put equipment into ready use for end-customers within the budget allowance according to schedules; operation and training maintenance; maintenance of customer relationship, safety abidance
Technical efficiency of commissioning is included in three dimensions: Performance	<p>Technical efficiency of commissioning measures the ability of a firm to achieve technical performance (Coelli et al. 2005)</p> <ul style="list-style-type: none"> Performance requirements conveys the customer's requirements and was designed and specified as performance specifications, encompassing technical parameters, functionality and other expected features from customers (Wiggin 2005, Garvey 2005, Small & Yasin 2003) 	<p>Performance:</p> <ul style="list-style-type: none"> Explicitly stipulated performance specification during contract negotiation; given multiple people's opinions into consideration from customer side
Operation	<ul style="list-style-type: none"> Technical supports from commissioning team given to the contractor are expected and fundamental for the success pre-test of the system of equipment (Wiggins 2005) 	<p>Preparing for upcoming new requirements during commissioning</p> <p>Training and education</p> <ul style="list-style-type: none"> Accurate and understandable operation instructions;

Quality	<ul style="list-style-type: none"> Quality requirements act as an effective tool of ensuring the quality of commissioning of specific technological equipment or process; commissioning was performed without relevant quality requirements, commissioning documents were often prepared and executed without the supervision of quality assurance department. In most of cases, systems were commissioned and validated while operational requirements are not satisfied (Dewar & Jerald 1978, Garvey & William 2005) 	<ul style="list-style-type: none"> Familiarization customers with equipment at the beginning of installation and commissioning; Effective and exchange on site except property limited knowledge Collective understanding of quality standards and cooperative implementation among multiple parties; Third-party quality assurance plan (in high-tech product delivery)
Common goal	<ul style="list-style-type: none"> A complete commissioning team is working together toward a common goal of establishing a fully functional, efficient facility; cater for customers' satisfactions (Kirsilä et al. 2007, Kutsmeda 2008, Dvir & Lechler 2004, Szczepanek & Winter 2008) 	<ul style="list-style-type: none"> Schedule plan, high-level quality of delivery, performance requirements and safety consciousness, well-functioning plant
Leadership	<ul style="list-style-type: none"> Leadership is not simply about the orderly transfer and execution of commands, it empowers individuals and enable them to react and take responsibilities in the team (Cowan-Sahadath 2010); authentic leaders are those who successfully operate in the increasingly complex working environment (Toor & Ofori 2008, Legris & Collerette 2006) 	<ul style="list-style-type: none"> Organization and arrangement ability Communication Experienced, personal charisma Capable to balance the workload of each member
Change and deviations	<ul style="list-style-type: none"> Organizations interpret their business less as a rigidly operated structures, but more as flexible at improving every aspects of their operation for constantly occurring changes (Cowan-Sahadath 2010.); deviations from the plan invariably occur and commonly faced by the people within the project, some devia- 	<ul style="list-style-type: none"> Listen to customers' feedback and made necessary changes tailoring their needs Document modification and update changes timely specifying components in a general way,

Coordination	<p>tions are first encountered and managed on a local site level (Wilson & Hällgren 2011)</p> <ul style="list-style-type: none"> • Projects, as a temporary organization (Tsoukas& Chia 2002, Winch et al. 2012), learning and information sharing is difficult to facilitate other forms of coordination outside of the scope of contracts are necessary and required in project-based business (Anderson et al. 2012); <p>two kinds of coordination, coordination of the forward physical flow of deliveries from sub-suppliers and suppliers to the customers and the backward coordination of information, data from the customers to the supplier and sub-suppliers (Frohlich & Westbrook 2001, Liinamaa & Gustafsson2010.) ;commissioning activities are not meeting the desired level (Kirsilä et al. 2007)</p>	<ul style="list-style-type: none"> • Standardization and modularity • Internal management system opening information flowing from commissioning facility to design department • Customer's engagements into commissioning in the very beginning
Services business	<ul style="list-style-type: none"> • Success of project depends on not only enhanced managerial and technical efficiency, but also the extension of services (Lee & Yong-Tae's 2000 • Services provided offer the advantage of financial benefits through continuous revenue streams, marketing and strategy benefits (Mathieu 2001) • "The after-taste in the mouth" of the client, which is important for future projects. (Andreas & Wolfgang 2006.) 	<ul style="list-style-type: none"> • Service business is closely connected with commissioning, credibility guarantee the service business in the long-term • Modifications should be documented • Service people should participant some parts of commissioning activities