TAMPERE UNIVERSITY OF TECHNOLOGY

PETRI SALONEN

DEVELOPMENT OF SCHEDULE MANAGEMENT SYSTEM FOR POWER PLANT PROJECTS

Master of Science Thesis

Prof. Miia Martinsuo has been appointed as the examiner at the Council Meeting of the Faculty of Business and Technology Management on October 5th, 2011.

ABSTRACT

TAMPERE UNIVERSITY OF TECHNOLOGY
Master's Degree Programme in Industrial Engineering and Management

SALONEN, PETRI: Development of Schedule Management System for Power Plant Projects

Master of Science Thesis, 92 pages, 4 appendices (10 pages)
October 2011
Major: Industrial Management
Examiner: Professor Miia Martinsuo
Keywords: project planning, project scheduling, project control, schedule management system, development project

The purpose of the thesis was to develop a schedule management system for power plant projects. In the theoretical part, a literature review was performed to explore the available concepts in project scheduling regarding to schedule management systems. In the empirical part, the current practice of project scheduling in the company was studied and analyzed through seven EPC (engineer, procure, and construct) projects chosen to represent the current best practice. The research material was collected in semi-structured interviews, and available documents were used to provide background and context for the interviews and analysis. The analysis was performed on a cross-case basis showing the similarities and differences between the projects. In addition, advanced practices and unique ways of working were emphasized.

The results confirm the assumptions about the projects and the current practice of project scheduling in the company. Most projects were assessed to be highly complex mainly due to customer requirements in scheduling, progress follow-up, and reporting. Schedules were not progressively elaborated, meaning that rolling wave planning was not utilized. The number of schedules developed for the projects and the division of work between the schedules varied. Project management activities were rarely defined or planned in the project schedules. Schedules were rarely updated, if the work was not progressing as planned, or changes occurred during execution. Progress was determined on the basis of various estimates, and project performance was measured with earned value analysis. Schedule was seen as a roadmap for the project only in one project.

The results indicated a general opinion that it is really important to focus more on project scheduling, and that there is a clear need for common practice. A schedule management system is proposed based on the literature review and the results of the study. Three recommendations are given based on the research: (1) verification and further development of the proposed schedule management system in few EPC projects, (2) improvement of project scheduling competence within the organization, and (3) pool of schedulers, who are assigned to the most demanding projects.

TIIVISTELMÄ

TAMPEREEN TEKNILLINEN YLIOPISTO
Tuotantotalouden koulutusohjelma

SALONEN, PETRI: Aikataulunhallintajärjestelmän kehittäminen voimalaitosprojekteihin

Diplomityö, 92 sivua, 4 liitettä (10 sivua)
Lokakuu 2011
Pääaine: Teollisuustalous
Tarkastaja: professori Miia Martinsuo
Avainsanat: projektin suunnittelu, projektin aikataulutus, projektin hallinta, aikataulunhallintajärjestelmä, kehitysprojekti

Työn tarkoitus oli kehittää aikataulunhallintajärjestelmä voimalaitosprojekteihin. Teoreettisessa osassa tehtiin kirjallisuuskatsaus, jossa selvitettiin projektien aikataulutuksen konsepteja aikataulunhallintajärjestelmiin liittyen. Empiirisessä osassa tutkittiin yrityksen nykyisiä käytäntöjä projektien aikataulutuksessa seitsemän EPC-projektin avulla, jotka valittiin siten, että ne edustivat nykyisiä parhaita käytäntöjä. Tutkimuksen aineisto kerättiin teemahaastatteluissa ja projektien dokumentteja käytettiin taustatietojen keräämisessä haastatteluja ja analyysia varten. Analyysi suoritettiin ”cross-case” -periaatteella, jossa keskityttiin projektien välisiin yhtäläisyyksiin ja eroihin. Lisäksi painotettiin edistyneitä ja poikkeavia käytäntöjä.

Tulokset vahvistivat oletukset projekteista ja yrityksen nykyisistä käytännöistä projektien aikataulutuksessa. Suurin osa projekteista arvioitiin erittäin kompleksisiksi lähinnä aikataulutusta, edistymisen seurantaa ja raportointia koskevien asiakasvaatimusten vuoksi. Aikatauluja ei tarkennettu progressiivisesti eli ”rolling wave planning” -tekniikkaa hyödyntäen. Projektia varten luotujen aikataulujen määrä ja työn jaottelu niiden välillä vaihtelivat. Projektin hallinnan aktiviteetteja määriteltiin tai suunniteltiin aikatauluissa harvoin. Aikatauluja ei useimmiten päivitetty, vaikka työt eivät edenneet suunnitellusti tai muutoksia tehtiin toteutuksen aikana. Edistyminen määritettiin erilaisten arvioiden perusteella ja projektien suorituskykyä mitattiin ”earned value” -analyysilla. Aikataulu nähtiin koko projektia ohjaavana etenemissuunnitelmana ainoastaan yhdessä projektissa.

Tulokset osoittivat yleiseksi mielipiteeksi, että on erittäin tärkeää keskittyä enemmän projektien aikataulutukseen ja että yhteisille käytännöille on ilmeinen tarve. Kirjallisuuskatsauksen ja haastattelujen tulosten perusteella tehdään ehdotus aikataulunhallintajärjestelmästä. Tutkimuksen perusteella annetaan kolme suositusta: (1) ehdotetun aikataulunhallintajärjestelmän verifiointi ja edelleen kehittäminen muutamassa EPC-projektissa, (2) organisaation osaamisen parantaminen projektien aikataulutuksessa ja (3) ryhmä aikatauluttajia kaikkein vaativimpia projekteja varten.

PREFACE

The research for this thesis has been conducted individually without being part of any other on-going development programmes or projects in Wärtsilä. The Gateway-team has been one of the stakeholders in the research and some of its members were also interviewed in the empirical study. I would like to acknowledge my supervisor, Professor Miia Martinsuo, who has provided valuable instructions and guidance during the thesis process, regarding to the approach and discussion of the subject, as well as, conduction of academic research in general. I would also like to acknowledge my instructor, Director Sami Myllyviita, who has provided instructions and guidance during the research process, regarding to the company's interests and arrangements in practice.

The thesis completes my studies for master's degree at the Tampere University of Technology. As the graduation is approaching, I cannot avoid looking back to my student days, which have offered not only lots of work, but also experiences I will always remember. I have had the opportunity to teach at the university and to work as a trainee in industry projects, which have certainly provided additional perspective. I would like to express my gratitude to my parents for all support and encouragement during my studies, which have been necessary to get me through. I would like to thank my dad also for proof-reading the thesis. In addition, I appreciate all support from my grandparents and my brother.

October 25th, 2011

Petri Salonen

TABLE OF CONTENTS

ABBREVIATIONS

ABM	Activity-based management
CC	Construction and commissioning
CCM	Critical chain method
CMA	Construction management agreement
CPE	Chief project engineer
CPI	Cost performance index
CPM	Critical path method
CV	Cost variance
DSM	Design structure matrix
EEQ	Engineered equipment delivery
EMO	Engineering management office
EP	Engineering and procurement
EPC	Engineer, procure, and construct
EVA	Earned value analysis
EVM	Earned value management
HSE	Health, safety, and environment
OBS	Organizational breakdown structure
PBO	Project-based organization
PCI	Project complexity index
PDM	Precedence diagramming method
PERT	Program evaluation and review technique
PMI	Project Management Institute

PMIS	Project management information system
PMO	Project management office
SPI	Schedule performance index
SV	Schedule variance
WBS	Work breakdown structure

1. INTRODUCTION

Project is defined by the Project Management Institute (PMI 2008) as: “a temporary endeavour undertaken to create a unique product, service, or result”, and project management as: “the application of knowledge, skills, tools and techniques to project activities to meet the project requirements”. Project management is accomplished through the appropriate application and integration of project management processes which are: initiating, planning, executing, monitoring and controlling, and closing. (PMI 2008) Scheduling is one of the basic requirements of planning a project (PMI 2007), and is defined by Mubarak (2010) as: “the determination of the timing and sequence of operations in the project and their assembly to give the overall completion time”. Schedule is a “roadmap” – how and when the project will deliver the deliverables defined in the scope. Schedule supports resource allocation in the most cost efficient way, as well as, coordination within the project and with other projects. It supports early detection of problems to enable corrective or preventive action, and what-if scenario analysis. Schedule is also a document for recording all delays, analyzing extensions of time, and financial loss claims. (Mubarak 2010)

Project scheduling is important for several reasons, which vary depending on the selected stakeholder perspective. From the contractors’ point of view, project scheduling is needed for the following:

- to calculate the project completion date;
- to calculate the start or end of a specific activity;
- to coordinate among subcontractors, and to expose and adjust conflicts;
- to predict and calculate the cash flow;
- to improve work efficiency;
- to serve as an effective project control tool;
- to evaluate the effect of changes; and
- to prove delay claims.

On the other hand, project owners and developers need project scheduling: to get an idea on project’s expected finish date; to ensure contractor’s proper planning for timely finish; to predict and calculate the cash flow; to serve as an effective project monitoring tool; to evaluate the effect of changes; and to verify delay claims. There are also other stakeholders involved in the project who need information from the schedule, such as consultants and financial institutions. The need for a project schedule varies with several factors. In general, the need increases with the increase in size and complexity of the project. (Mubarak 2010)

Project scheduling has been identified in various studies as a major factor in predicting project success or failure (Fortune & White 2006). As scheduling is an essential area of project management and schedule is one of the most critical tools to manage a project (Mubarak 2010), project scheduling practice in an organization must be managed and developed to enable success in projects. Schedule and the process to develop it provide also valuable information to project management, meaning that project scheduling is not only for managing time in a project; it also facilitates project management in the other areas (PMI 2008). In complex projects, schedules are developed for different purposes and in different phases of a project. This is mostly because of the varying needs of project stakeholders and progressive elaboration of schedules. (Mubarak 2010) Therefore, efficient schedule management system is required, especially in project-oriented business involving complex projects.

The research was conducted in Wärtsilä Finland Oy, which is the local company of Wärtsilä Corporation in Finland. Wärtsilä's mission is to "provide lifecycle power solutions to enhance the business of its customers, while creating better technologies that benefit both the customers and the environment". Wärtsilä's vision is to "be the most valued business partner of all its customers". Wärtsilä has divided its business into three divisions: Ship Power, Power Plants, and Services. The research concentrates on Power Plants, which supplies flexible power plants for the distributed power generation market including solutions for base-load, grid stability and peaking, industrial self-generation, and other oil, dual-fuel and gas fired power plants. Wärtsilä's net sales were 4,553 million EUR and profit before taxes was 548 million EUR in 2010. Globally, Wärtsilä has delivered 4,500 power plants in 168 countries with generating capacity totalling more than 47 GW. Wärtsilä has almost 18,000 employees and operations in 160 locations of 70 countries around the world. (Wärtsilä 2011)

The purpose of the thesis is to develop a schedule management system for power plant projects. The research is divided into two distinct sections: the theoretical part, and the empirical part. In the theoretical part, a literature review is performed to explore the essential concepts, methods, and tools in project scheduling, especially regarding to schedule management systems, and to create a theoretical framework for evaluation of the project scheduling practice. In the empirical part, the current practice of project scheduling is studied and analyzed in the company through seven EPC (engineer, procure, and construct) projects.

1.1. Research perspective, objectives and delimitations

The thesis examines the subject from the main contractor's perspective. In terms of technical scope in EPC projects, the contractor is responsible for the design, construction, and installation of the power plant, and in some cases, also for the maintenance of the plant. The projects have often tight schedules and fixed end dates, which create great contractual pressures. Any deviation beyond the contractual end date may cause heavy penalties to the contractor. In addition, many projects are delivered in countries where cultural differences, insufficient infrastructure, and less skilled local labor may cause problems. The projects are also characterized by many changes in scope and design. The projects comprise numerous sub-projects performed by subcontractors, who are responsible for managing their part of the project. The network of actors involved in a project has varying needs and requirements for project schedules. The large number of actors requires also effective communication and tools to accomplish it. The company has set a strategic objective to grow within the business, and achieving it requires being rewarded by more EPC projects instead of only equipment deliveries, and shifting to larger power plants is also needed. Therefore, it is crucial to have both the understanding and the tools to be able to successfully manage large and complex projects.

The thesis has two distinct sections with their own objectives. The first objective relates to the theoretical part and is defined as: "review literature to get an understanding of the essential concepts, methods, tools, and current research in project scheduling, especially regarding to schedule management systems". The second objective concerns the empirical part and is defined as: "study the current practice of project scheduling in the company and develop a schedule management system, which addresses the specific needs of the business". The thesis examines the subject in the context of power plant projects. The business is clearly project-oriented, as all customer deliveries are handled as projects. The projects are complex due to various reasons, such as size, customer requirements, and networked organization. Therefore, both research areas are relevant to the subject. However, the emphasis is on project scheduling and schedule management systems, which are discussed in more detail. The intention is to provide a broad view of available concepts, and not to concentrate on any particular concept in too much detail. Therefore, the fundamental methods and tools of project planning, scheduling, and control are presented only briefly. Project scheduling has fixed connections to many other knowledge areas of project management, for example scope management, cost management and risk management, but they are left out of discussion.

1.2. Research problem and questions

The purpose of the thesis is to develop a schedule management system for power plant projects. Accordingly, the research problem is defined as:

> "The current practice of project scheduling is varied, it is not based on any theoretical framework, and it does not support efficiently project management. Schedule management system is needed to harmonize project scheduling

> processes, facilitate control of projects, and support future growth of the business through managing large and complex projects successfully."

Based on the defined research problem, three research questions are generated. The first research question focuses on the theoretical framework to enable further discussion of the subject.

1. What are the essential dimensions of schedule management system in complex projects?

The second research question deals with the current practice of project scheduling in the company. It also states the need to identify the improvement needs and to evaluate their potential, in order to provide valuable recommendations.

2. How project schedules are currently managed and what are the improvement needs?

The third research question expresses the intention to develop a proposal for schedule management system, which suits the business and its specific needs the best. It also includes an illustration of the benefits of the proposed model.

3. What is the most suitable schedule management system in power plant projects?

1.3. Research methodology

The current practice of project scheduling was studied and analyzed in the company through seven EPC projects, which were chosen to represent the current best practice. The research material was collected in semi-structured interviews, and available documents from the projects were used to provide background and context for the interviews and analysis. From every selected project, the project manager and the project controller were interviewed. These interviews were supplemented by interviewing representatives from site management, program management, and the Gateway-team concentrating on project scheduling development in the company. Available documents included: project charters, project plans, and project schedules, as well as, records of changes, delays and their causes from the projects.

The analysis was performed on a cross-case basis showing the similarities and differences between the projects. In the analysis, focus was on:

- schedule development process, including activity definition and grouping, dependency determination, resource and duration estimation, assignment of resources to an activity, project schedules, scheduling in different project phases, and project management activities;

- schedule control process, including schedule updating, progress measurement, project performance measurement, project performance reporting, and use of schedule in change management and claim management; and
- perceived importance of schedule, including project team focus on scheduling, role of schedule in project management, and schedule as a roadmap for the project.

In addition, advanced practices and unique ways of working were emphasized. Based on the literature review and the results of the study, a schedule management system is proposed.

1.4. Structure of the thesis

The thesis consists of six chapters, of which the first is introduction to the subject and research. In the second chapter, theoretical background and available concepts regarding to project business, complex projects, and schedule management systems are presented. Synthesis of the theory is provided in the end of the chapter. In the third chapter, the environment, method, and material of the research are introduced. In the fourth chapter, results from the projects and expectations for schedule management system are presented, and an evaluation of the results is performed. In the fifth chapter, a schedule management system is proposed, an assessment of the results is performed, and the significance of the results is discussed. In the last chapter, conclusions from the results are made, and recommendations and suggestions for further research are presented.

2. LITERATURE REVIEW

The literature review chapter consists of four sub-chapters. In the first two sub-chapters, project business and complex projects are discussed to provide a theoretical background and to identify their requirements for project management. In the third sub-chapter, the essential concepts, methods, and tools in project scheduling, especially regarding to schedule management systems, are presented. In the last sub-chapter, a synthesis of the theory is provided. In addition, the requirements for advanced schedule management systems are presented and compared with traditional project management.

2.1. Project business

The significance of project business is continuously increasing. Recently, project-based business activities have become part of all private firms and public organizations, and even a key activity for an increasing number of them. Project research is also expanding its view towards wider aspects of project business. Artto and Wikström (2005) define project business as: "the part of business that relates directly or indirectly to projects with the purpose of achieving objectives of a firm or several firms". This definition refers to multiple projects and multiple firms. (Artto & Kujala 2008) Söderlund (2004) uses also the dimensions of single vs. multiple projects, and single vs. multiple firms. Engwall (2003) emphasizes the imperative of understanding the project's context and not simply the project as an isolated entity. Project business differs from other types of business, primarily due to its specific relational context, limited time, value creation properties, type of complexity, and its high degree of uncertainty and limited possibilities for standardization (Hellström 2005). However, individual firms navigate differently in this competitive environment through diverse strategies and business models, and combinations of business models with other firms in the same network. Even entire networks of firms may decide to combine their resources to establish a particular type of business model. In that respect, business models can play an important part in the firm's responses to the specific nature of project business – its context and content. (Wikström et al. 2010)

2.1.1. Project business framework

Conducting or enhancing the firm's business through its projects involves projects of two types: external production or customer delivery projects, and internal development or capital investment projects (Artto & Kujala 2008). Companies initiate and participate in projects to improve their innovative capacity, to carry out system-wide change efforts, and to enhance their adaptive capability (Wikström et al. 2010). Recent research has indicated that many projects serve as strategic arenas to develop new capabilities that can be re-used in future business (Davies & Hobday 2005). A parallel development trajectory concerns the role of projects in accommodating complex business transactions. Such transactions have been common in the construction industry for several decades, but they have more recently become significant in a range of other industries and sectors. Thus, technology-based and service-providing firms increasingly organize their operational activities in different kinds of projects and customer delivery projects (Hobday 2000; Davies 2004; Artto & Wikström 2005). In addition, many firms are project-based in terms of integrating their diverse and specialized intellectual resources in innovation, and research and development (R&D) projects (Gann & Salter 2000) producing complex project landscapes controlled by means of portfolio and program management (Pellegrinelli 1997).

Projects and firms are organizational entities that represent relevant players in the business context. Furthermore, the business contents of multiple projects and multiple firms are often related in a complex manner. The project business framework shows major areas of research and managerial application in a single firm or with several firms, and in a single project or with several projects crossing the business activities of one or several firms. The framework illustrates four distinctive areas: management of a project, management of a project-based firm, management of a project network, and management of a business network. (Artto & Kujala 2008) The project business framework is presented in Figure 1.

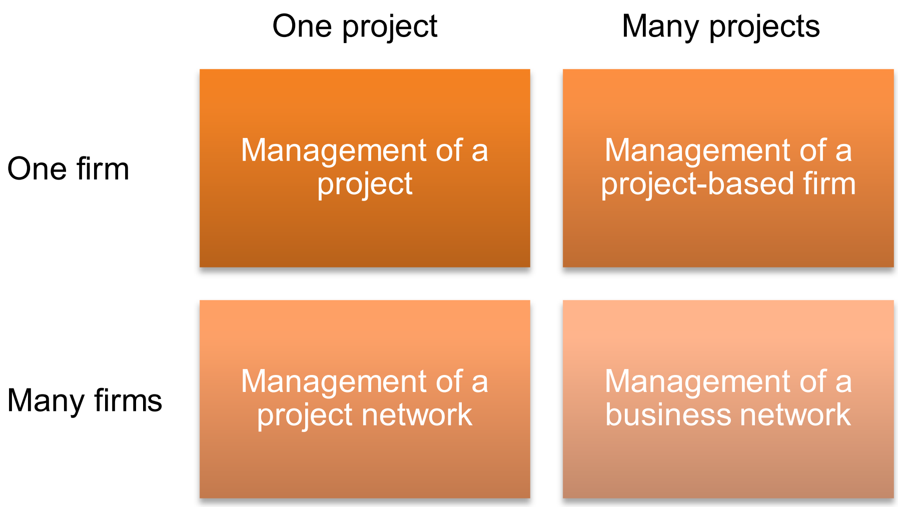

Figure 1 *The project business framework (Artto & Kujala 2008)***.**

The management of a project is a well-researched area in science. The existing extensive research in this area makes the field of management of a single project rather well known. This project management knowledge has been developed throughout the last 60 years of modern project management (Morris 1997). The standard documents of project management (PMI 2008) represent an excellent overview of what the management of a single project includes in its application area. International project management organizations have built their own guidelines for knowledge areas included in project management which should be useful for project management practitioners (Morris et al. 2006). Project management typically consists of the following broad areas of knowledge that all include procedures, methods, and tools that are characteristic of project management: integration management, scope management, schedule management, cost management, resource management, communication management, risk management, procurement management, and quality management (Artto & Kujala 2008).

The management of a project-based firm is an area, which addresses the managerial issues of a firm that conducts a specific part of its activities in a project. Conducting part of the firm's business through projects may involve projects of two types: external production or customer delivery projects, and internal development or investment projects. The management of a project-based firm is a rather new research area that includes research primarily on the firm's management ability, and consequently, the capacity of the firm to initiate and execute projects that either directly or indirectly benefit the firm's business. Projects are seen as business vehicles of the firm. (Artto & Kujala 2008) The management of the project-based firm includes project supplier firm's ability to sell and deliver projects to its customers (Cova et al. 2002), management of innovation (Gann & Salter 2000), and project portfolios and development programs (Pellegrinelli et al. 2007).

The management of a project network is a management area that covers a network consisting of several firms and other organizations from different businesses and from different institutional environments participating in a project. The network of firms and other organizations participating in a single project is called a project network (Hellgren & Stjernberg 1995). The management of a project network represents an area of novel research themes that relate to interpreting a project as a multi-organizational enterprise that involves a complex network of firms and other actors in its execution. (Artto & Kujala 2008) A project network has an intentionally constructed core of actors that participate in the project (Williams 2001); however, a project network may also include other actors that are, for example, stakeholders of the project (Floricel & Miller 2001). A project network is a temporary endeavor that includes several phases, each of which being different in nature. There is a continuously evolving constellation of actors in ever-changing roles. (Artto & Kujala 2008)

The management of a business network is another area, which includes novel research themes related to several firms' activities where the firms get engaged from time to time in mutual projects. The actors in the business network can have aims that are synergistic, and accordingly, there is room for partnership and collaboration. It can also be the case that the aims of the actors in the business network are contradictory and conflicting, which implies adverse relationships, competition, or rivalry. Networked firms and their business relationships affect the selection of participating firms in a project, and vice versa, the projects have an impact on the permanent businesses network. (Artto & Kujala 2008) Firms may participate in various projects in different roles and each project may have a different set of actors (Eloranta 2007). Project supplier firms may engage in several sequential or parallel global projects through different delivery scopes (Cova et al. 2002). The roles of the actors may change from one project to another making a partner company in one project a competitor in the next project or the customer in one project a supplier in the next project. Hellgren and Stjernberg (1995) argue that there is a dual relationship between project network actors, while organizations have a simultaneous mixture of opponent and partner relationships. For example, a short-term partner may become a competitor in future projects, and vice versa. A business network can include: competitors, financiers, customers and their clients, contractors and their subcontractors, suppliers, designers, architects, manufacturers, service providers, integrators, and consultants (Davies 2004).

2.1.2. Project-based organizations

Lindkvist (2004) argues that a project-based firm is an organization that conducts most of its work in projects and/or has an emphasis on the project dimension rather than on the functional dimension of its organizational structure and processes. Project-based firms are found in a wide range of industries, such as consulting and professional services, cultural and sports industries, and complex products and systems (Sydow et al. 2004). The majority of project-based firms engage in customized deliveries and extend their offerings beyond traditional project deliveries by integrating maintenance, spare parts and services, management contracts, and even partial ownerships in multi-actor-enterprises running the operations of a complex system, which leads to significant changes in scope and responsibilities, and increasingly complex projects (Artto et al. 2008; Wikström et al. 2009). This typically requires co-operation between the partners, suppliers, and customers, and in that respect, project-based firms need to cross organizational boundaries and knowledge bases. Therefore, an important consequence is the complex and difficult co-operation and coordination processes involving many technologies and individual organizations in the manufacture and delivery of complex systems. This makes systems integration a core capability in contemporary project-based firms. (Liinamaa & Wikström 2009)

Project represents a delivery system arising from a firm's internal development (Keegan & Turner 2002) and/or external business activities (Hobday 1998; Cova et al. 2002). An individual project may cross the boundaries of two firms, for example, design of products and services collaboratively by the project contractor firm and its client (Hobday 1998), or several firms, such as alliances and coalitions between several firms (Winch 2006), projects as multi-organizational enterprises (Grün 2004) or project networks (Hellgren & Stjernberg 1995). The need for adaption with other firms and other projects is important due to changing business environments and network dynamics (Hellström & Wikström 2005).

Project-based organizations (PBO) have received increasing attention in recent years as an emerging organizational form to integrate diverse and specialized intellectual resources and expertise (Thiry & Deguire 2007). Hobday (2000) makes a distinction between project-based and project-led organizations. Project-led organizations are firms in all types of industries that are undertaking projects as a growing part of their operations, even though their primary productive activity may be volume-based or operations-oriented. In the contrary, project-based organizations organize most of their internal and external activities in projects. Thus, they are pure project organizations with no functional links. In addition, PBO can refer to either entire firms (as in construction, consultancy, and professional services) or multi-firm networks (Hobday 1998); it is also possible that some large project-based organizations have functional support areas, or that the PBO is within subsidiaries or divisions of larger corporations. Many PBOs, as they move from single to multiple project management, have adopted enterprise level information systems that aim to manage the data produced at project level and to collate it at management level. (Thiry & Deguire 2007) Many larger PBOs have developed program or project management offices (PMO), which can have many functions, but are mostly used to generate data and develop standardized project management practices (Hobbs & Aubry 2005).

Stakeholders' interests and value creation are two major issues that affect the make-up of organizations and PBOs. The need for more integrated PBOs could be provided by a coherent project governance approach. A particular problem that is poorly understood is, how to create real added value for the organization through the interaction of the project portfolio, programs, and PMO, as well as, the double loop effect of strategy on projects and programs, and their on-going consequences on strategy. This iterative to and from process between implemented strategy through projects and the irreversibility of the effect of completed projects on the organization is yet to be fully appreciated, researched, and understood. (Thiry & Deguire 2007)

A well integrated PBO would be expected to display strong interrelationships between its projects, and both its business and corporate strategies. In such an organization, project managers would be expected to be appointed in senior management roles, or senior managers would be expected to view project management as an integrative process. A less integrated PBO should reveal a focus on single project, and multi-project management would focus on resource allocation and data gathering. In such an organization, project managers would be expected to play purely product delivery roles. There are three major issues to improve PBO implementation and the perception of project management at organizational level: horizontal integration process of projects across the product life-cycle from formulation of the business strategy to delivery of business benefits, vertical integration approach of projects across the project portfolio to link it to the corporate strategy, and integrative project governance structures that close the gap between corporate goals and product delivery. Horizontal integration is achieved through program management that can be defined as: “the governance and harmonized management of a number of projects and other actions to achieve stated business benefits and create value for the stakeholders”. Vertical integration is achieved through portfolio management that can be defined as: “the process of analyzing and allocating organizational resources to programs and projects across the organization on an on-going basis to achieve corporate objectives and maximize value for the stakeholders”. Governance is achieved by implementation of the concept of PMO. (Thiry & Deguire 2007)

Recent studies have indicated that the primary business case for implementing PMO is to achieve more successful projects, and to have predictable and reusable tools, techniques, and processes. Therefore, PMO mandates most often include measurable improvement in the management of projects – on time, on budget, and meeting customer requirements. They also identify as a major success factor the ability to align projects with the strategy and organizational goals, and to deplore the fact that PMOs are often used to consolidate and distribute data rather than to provide a valuable service to the organization. (Thiry & Deguire 2007) The dichotomy is interesting in the sense that, according to Hobbs and Aubry (2005), the primary tasks of PMO are monitoring, reporting, standardizing processes and procedures, as well as, ensuring training in project management skills, whereas success factors seem to be linked to the alignment with strategy. Based on recent organizational developments and practice, PMO is a governance structure for organizational project management (Thiry & Deguire 2007).

2.1.3. Project management in project-based firms

The business of a project-based firm can be addressed through its business model (Artto & Kujala 2008). Kujala et al. (2007) analyze contingency factors affecting both the choice of a business model for a project-based firm and the performance of its business model. A business model with a strategic focus is defined in terms of the logic of profit generation. An operationally focused business model concentrates on the internal processes that enable the firm to create value, such as production or service delivery methods, administrative processes, resource flows, knowledge management, and logistical streams (Morris et al. 2005). The integration of project sales and execution in a global project supplier firm is challenging. The sales organization may be distributed into several local sales offices, whereas the organization responsible for delivery project execution may be more centralized situating as specialized units in few locations (Dietrich et al. 2007).

Project marketing identifies central features of the business of a project-based firm (Artto & Kujala 2008). The features are: the uniqueness of individual projects, the complexity of the project offering and business network, the discontinuity of demand and business relationships between projects, and the considerable extent of financial commitment of the parties (Cova et al. 2002). Kujala et al. (2007) address various negotiation strategies and joint decision-making between project customer and supplier during the sales and delivery process. Procurement and supplier network management is important due to the trend of increased subcontracting and focusing on the firm's core capabilities. Indeed, firms and projects are more and more dependent on their suppliers, and therefore, the relational focus in subcontractor selection is relevant. (Eloranta 2007)

Hellström (2005) has studied modularity in the business of delivering projects. He argues that the products and their modularity do not only apply to physical products but also to project processes and project organization that represent the ultimate capability to create the desired solution as the outcome of the project. (Hellström 2005) Products or services produced in a project are often complex as they consist of a large number of interacting parts. The interaction often creates great interdependency, not only from an engineering design perspective, but also in an organizational sense. (Hobday 1998) The choice of product structure and organizational architecture interacts (Henderson & Clark 1990). One key issue is how to align project processes with the overall business processes (Gann & Salter 2000). Project typically involves several organizations for its execution. Therefore, the network perspective, when considering a project as a network of multiple firms or organizations, is most relevant (Hellgren & Stjernberg 1995; Floricel & Miller 2001; Eloranta 2007). Several actors participating in a project network causes uncertainties that are often due to: network effects, such as dependence on other actors; interest asymmetries; different identities; missing information; information asymmetry within the network; social and institutional risks; network risks; trying to behave rationally; and risk management procedures that do not fit into a networked context (Hellgren & Stjernberg 1995; Artto et al. 2008).

In the governance of large projects, organizational structure of a project with the use of contractors, the shaping of the project, the project's institutional framework, and the capacity of governance and self-regulation are essential (Miller & Lessard 2001; Miller 2006). The owner's competences and interests in putting resources into the process and carrying the responsibilities are crucial (Grün 2004; Miller 2006). It is the responsibility of project owners to establish the project management structure (Miller 2006). For example, based on empirical evidence from an analysis of a large project, Brady et al. (2007) argue that effective principles of project governance include: the owner's acceptance of all relevant risks in the framework agreement, incentive-based contracts, and interest alignment and identity building of the core integrated team. The financing party's involvement in an early phase is vital as this helps to shape the project right from the start, and the financiers' commitment to objectives would guarantee their support when financing the later phases of the project (Samset 2003). Extensive use of subcontractors releases the main contractor's capacity and enables it to concentrate on the core tasks. However, the main contractor should not allocate such risks to the subcontractor that relate more naturally to the main contractor's business, and therefore, are more appropriate to keep under the main contractor's responsibility. There should be balanced authority and responsibility among the different stakeholders. (Grün 2004)

2.2. Complex projects

Definitions of complexity are first reviewed before identifying the elements of project complexity. According to Geraldi (2009), there is lack of a clear, unambiguous definition for complexity of projects or projects in a complex environment. Or, as stated by Parwani (2002): "complexity refers to the study of complex systems of which there is no uniformly accepted definition because, well, they are complex". Baccarini (1996) defines complex project as: "one that consists of many varied interrelated parts" which he discusses in terms of differentiation, the number of varied elements, and interdependency, the degree of interrelation between the elements. The measures are to be applied in respect to two project dimensions: organizational complexity, and technological complexity. In organizational complexity, differentiation is the number of hierarchical levels, number of formal organizational units, division of tasks, number of specializations, and so on; and interdependency is the degree of operational interdependencies between organizational elements. In technological complexity, differentiation is the number and diversity of inputs, outputs, tasks, or specialties; and interdependency is the dependencies of tasks, teams, technologies, or inputs on each other. (Baccarini 1996)

It seems to be an accepted fact that the complexity of projects is continuously increasing, despite there is not a common definition for complexity. Baccarini (1996) states that: "construction projects are invariably complex and they have become progressively more so". Helbrough (1995) states as a given that: "increased complexity of projects and the project environment have meant that despite the improved methods, many projects still fail to meet expectations". Project failure in terms of cost overruns and time delays is a common practice. One of the reasons for project failure is the increasing complexity of projects, or an underestimation of the project complexity (Williams 2001). As an example, the process and energy industry is suffering from increasing project complexity (IEA 2006). Difficult circumstances, for example deep water or remote areas, increase the uncertainties in the projects. The increased uncertainties contribute to project complexity and increase the chance of budget and schedule overruns. (Williams 1999; IEA 2006)

In the 1990's, project complexity was already taken as one of the factors to classify engineering projects (Shenhar & Dvir 1996; Shenhar 1998). Their classification method was based on four levels of technological uncertainty and three levels of system scope. This method is characterized by its strong focus on technological complexity, primarily related to the content of the project under consideration. Complexity, however, was still treated as a black box; what factors exactly cause complexity in projects was not further discussed. (Bosch-Rekveldt et al. 2010) The need for new paradigms for complex projects was expressed, as well as, the need to include soft systems methods for project modeling to support its management (Williams 1999). More recently, research has been undertaken to better understand project complexity, and sketch the relationship between complexity theory and project management (Cooke-Davies et al. 2007). In addition, there are suggestions to look at project managers' competence development in the view of project complexity (Remington & Pollack 2008). Complexity as such is often taken intuitively or from previous experiences, although, the complexity of projects and their environment obviously influence important decisions in project management (Bosch-Rekveldt et al. 2010). Despite the inherent difficulty of defining complexity and the different views on complexity, definition of project complexity should include structural, dynamic, and interaction elements (Whitty & Maylor 2009). Describing projects as complex adaptive systems or socially constructed entities (Cicmil et al. 2006), complexity in projects can be considered to be related to structural elements, dynamic elements, and interaction of them; broader than the technical or technological domain. Three elements can be identified contributing to project complexity: structural complexity, organization and environment, and uncertainty and risk. (Bosch-Rekveldt et al. 2010) The elements of project complexity are presented in Figure 2.

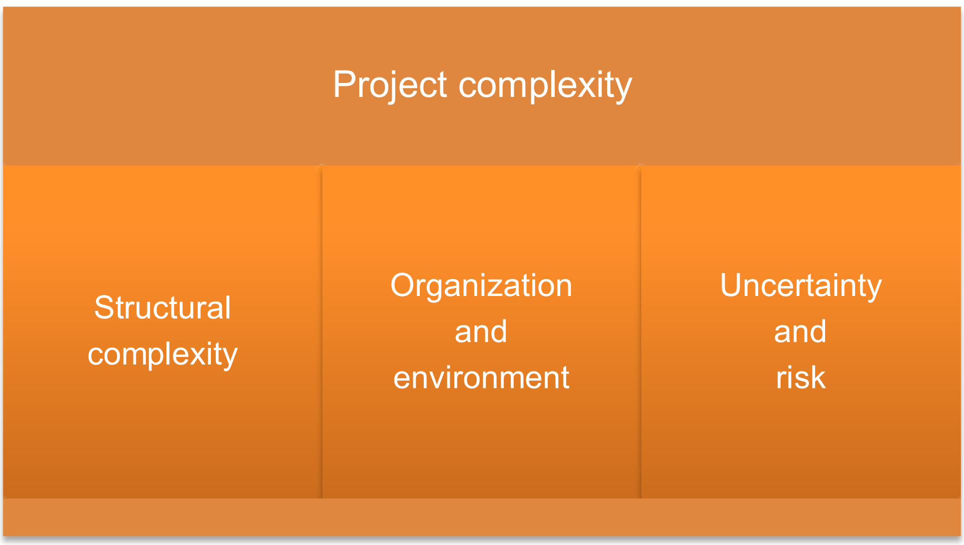

Figure 2 *The elements of project complexity (Bosch-Rekveldt et al. 2010).*

2.2.1. Structural complexity

In projects, such as design-and-manufacture or design-and-build, a major source of project complexity is product complexity, where the product is the physical deliverable. The more complex the product, the more complex the project, but it is useful to distinguish the cause and effect of product type of complexity. (Williams 1999) Product complexity, according to Baccarini (1996), is the number of sub-systems of a product and their interrelationships. When modeling or analyzing a project to produce a complex product measures of complexity can be propounded in order to quantify the interrelationships. Once the product complexity is measured, the measures can be used to analyze aspects of project complexity. For example, in order to evaluate the effect of customer changes on a project, consideration has to be given to how many changes to other systems are likely to be required, or how many finalized systems has to be revised. As new products are developed, which extend or improve previous generations of a product, the products become more complex because of added functionality, reduction in physical size, closer inter-element connectivity, and other similar reasons. Consequently, the projects developing and delivering the products appear to increase in complexity as a larger number of elements are included, and in particular, a greater degree of inter-element connectivity is required. (Williams 1999)

Baccarini (1996) points out that counting interdependencies is not sufficient, as the nature of the interdependencies is also important. Thompson et al. (2003) have examined the interdependencies and identified three types: pooled, sequential, and reciprocal. In pooled interdependency, each element gives a discrete contribution to the project meaning that each element proceeds irrespective of the other elements. In sequential interdependency, an output of one element is an input for another element. In reciprocal interdependency, each element's output is input for the other elements meaning that the actions of each of them must be modified to the actions of others. Particularly, the last type of interdependency increases project complexity. (Thompson et al. 2003) Some of the reciprocal effects can be clearly illustrated by using design structure matrix (DSM). But less easily modeled reciprocal interdependencies occur, for example, when there are functional aspects affected by and affecting many activities, or when events occur affecting many elements. Clearly, the more complex type of interdependency, the greater is the added complexity. While this is a general managerial definition, one driver in the project management domain causing an increase in reciprocal interdependencies is concurrent engineering. (Williams 1999)

2.2.2. Organization and environment

Focus has been on structural complexity and uncertainty but also softer aspects and influences from the environment are assumed to influence project complexity (Jaafari 2003; Geraldi & Adlbrecht 2007). Geraldi (2009) distinguishes the complexity of fact and the complexity of faith (Geraldi & Adlbrecht 2007), as well as, the complexity of interaction. The complexity of interaction, taking place at the interfaces between people and organizations, includes aspects like politics, ambiguity, and empathy which are considered as the softer aspects contributing to the overall project complexity. (Geraldi 2009) Explicit attention for softer aspects is found in the work of de Bruijn et al. (1996) who assume that project complexity can be broken down into technical, organizational, and social complexity. Here, technical complexity is related, among other things, to technological uncertainty, dynamics, and the uniqueness of the project. Organizational complexity is related, for example, to the organization structure, project team, and actors involved; and social complexity refers again to the actors involved, their interests, and the risks and consequences of the project in relation to its environment. (Bosch-Rekveldt et al. 2010) Also, other studies indicate the environment as an important element of project complexity (Jaafari 2003; Xia & Lee 2005; Mason 2007).

Projects have tended to become more time-constrained, and the ability to deliver a project quickly has become an important element in winning a bid. Furthermore, there is an increasing emphasis on tight contracts, using the main contractor's position to pass time-risk to the subcontractors, frequently with heavy liquidated damages for not completing on agreed schedule. As projects become shorter in duration, more parallelism and concurrency are required, which by definition increase project complexity. The increasing desire to reduce time to market and the subsequent development of concurrent engineering, which aims to support the integrated design of products and their related processes, including manufacture and support, are also increasing project complexity. All projects are by definition multi-objective with conflicting goals, which are either constraints or optimization. This adds complexity as the effects of activities on all goals have to be assessed and trade-offs have to consider the balancing effects of other activities. Projects have also multiple stakeholders, not only the obvious ones, such as the customer, project manager, and project team, but also the owner, champion, public, and so on. This adds complexity in a similar manner to the multiplicity of goals. (Williams 1999)

Many problems lay in the general environment of projects, meaning that they are beyond the control of project managers. However, project manager can try to manage the environment by dealing with, influencing, and adjusting to primary actors (individuals, groups, and institutes) and factors (trends, laws, and attitudes). (Youker 1992) Project team can identify potential problems and assess their probability of occurrence in order to pre-solve them. Thus, the project team needs to do the following:

- scan the project environment;
- identify the actors and factors influencing the project;
- define the degrees of dependency between the project and uncontrolled elements in its environment;
- estimate the nature of uncertainty and the probability of something going wrong;
- analyze the degrees of power they have to exercise over actors and factors; and

- develop contingency plans to deal with potential problems, and create linkages to increase their power and influence.

The scanning of the project environment can be focused on physical elements, hierarchical elements, or human factors. The elements of environment should be identified for each project and be rated for the degree of importance to the project success. Once the potential problems are identified, contingency plans can be developed to solve the problems in advance. (Alsakini et al. 2004)

2.2.3. Uncertainty and risk

Project complexity is often considered as being caused by uncertainties. Perminova et al. (2008) have introduced a new perspective on uncertainties in projects and how to manage them. They explain the link between uncertainties and risk management. Whereas the traditional risk management assumes risk as uncertainty, they rather understand risk as one of the implications of uncertainty. They define uncertainty as: "a context for risks as events having a negative impact on the project's outcomes, or opportunities as events that have beneficial impact on project performance". Risk as an important element of project complexity (Turner & Cochrane 1993; Williams 2001) is more focused on the first part of the wider definition of uncertainty. Risk management, in this sense, is seen as the core of modern project management and considered essential to successfully manage projects (Hillson & Simon 2007). With increasingly complex projects, risk management becomes more important and it should be done throughout the whole life-cycle of a project (Jaafari 2001). The number of risks, and their probability and impact can also be assumed to contribute to project complexity. For example, in a project with numerous risks, more dynamics and interactions may be expected, increasing project complexity. Careful identification of the project risks should not be considered as a goal as such, but rather as means to manage the project and its uncertainties. (Bosch-Rekveldt et al. 2010)

Turner and Cochrane (1993) classify projects by two dimensions: how well-defined are the goals, and how well-defined are the methods to achieve the goals. Then, they identify four distinctive types of project, depending on whether the goals are well- or ill-defined, and whether the methods are well- or ill-defined. Ultimately, they suggest different management, and particularly, different start-up methods for the various types of projects. They point out that, if the methods are uncertain, the fundamental building-blocks of project management will not be known: the work breakdown structure (WBS), tasks required to complete the work and their sequence, organizational breakdown structure (OBS), and so on. Even when they are planned, the plan will be subject to changes. Clearly, some of the characteristics of product complexity occur also here. As the project team structures the work and refines the methods, there are considerable interdependencies between sub-teams in the project. As the methods are tried and re-planned, feedback-loops naturally occur, and so on. (Turner & Cochrane 1993)

The first dimension of added complexity relates to the uncertainty in the goals. Project goals can be uncertain since the requirements are difficult to specify and often change during the process. Changes in some requirements may have implications to the interfacing elements, meaning that they need also to be changed resulting in cross-impacts, re-work, and feedback-loops. A key element of the added complexity that results from uncertainty in goals is that the changes often cause two separate increases in complexity. The action of making the changes does often not only increase the project complexity, but the individual changes are often combined with each other to increase product complexity, and thus, project complexity. For example, continuous addition of elements means eventually that it is extremely difficult to put in any more cable-ways, or fit all the elements into a constrained space. (Williams 1999) When evaluating a project, not only does the level of complexity has to be taken into account, but also the increase in complexity throughout the life-cycle of the project (Ackermann et al. 1996). It is important to remember that the effect of many changes in a project is more than the sum of the effects of individual changes (Williams et al. 1995).

The second dimension relates to the uncertainty in methods, which is well-known in terms of complexity. Shenhar and Dvir (1993) distinguish among good management styles and practices for different types of engineering projects. They classify projects by two parameters: system scope (assemblies, systems, etc.), and technological uncertainty (uncertainty in methods). Uncertainty is used here in a broad sense, including both elements that are stochastic and elements that result from the lack of knowledge. Thus, a project where a body of knowledge exists is less complex than a state-of-the-art project where there is no experience. (Shenhar & Dvir 1995) The decomposition models do not take into account the compounding effects when individual effects accumulate in a project (Williams et al. 1995). Nor can they deal with feedback-loops (Ackermann et al. 1996) or include the systemic effects that are present in complex projects (Williams 1995), and they are not able to deal with the uncertainty of goals or methods (Turner & Cochrane 1993). Both uncertainty measures are difficult to turn into quantifiable parameters. The vagueness of the goals may become measurable by how long it takes to establish whether the goals are satisfied, and changes in the goals may be measured in terms of contract changes. (Williams 1999)

2.2.4. Project management in complex projects

Increasing project complexity sets new requirements for project management, and it is clear that traditional project management is unsuitable for managing such projects (Williams 1999). Lack of timely and effective communication, lack of integration, uncertainty, changing environment, and increasing project complexity are the most common drivers of project change (Naoum 1994). There is a clear need for new ways of looking at complex projects, new models and techniques to analyze them, and new methods for managing them. There has to be suitable tools and techniques for complex projects, in order to support project management in planning, scheduling, and control.

The models can be developed from traditional methods, retaining the bottom-up decomposition of project elements. Network models can be improved to include stochastic effects, or the effects of management decisions. Models of time and cost risk can be developed by modeling the combination of many risk elements. Simulation models can be used to simulate the behavior of several project elements of different types in combination. Alternatively, top-down holistic models can be built, for example, system dynamics. While such models usually fail to capture the details desired by operational management, they allow a strategic overview and modeling of systemic effects that the bottom-up methods ignore. Traditional methods capture only quantitative data. It has become clear that softer inputs must also be included in project models if they are to be a useful representation of the real-life project. Soft systems methods and operational research methods have been proved useful in the field. Some of the data can be used in some holistic modeling techniques, particularly system dynamics. (Williams 1999)

Management techniques have to similarly adapt to the changing environment. Jones and Deckro (1993) explain how an increase in project complexity leads to an increase in internal conflicts within the project, indicating that management methods and style have to be adapted to deal with such conflicts. Changes need to be made to the internal management structures within projects. Particularly, the use of multi-disciplinary teams is becoming more widespread. (Jones & Deckro 1993) Laufer et al. (1996) state that there has to be a project management style for complex projects based on elements, such as integration, systemic management, simultaneous management, the use of teams, and managing functional plans simultaneously and inter-dependently. Looking wider than one project, new views have to be taken of the multi-project environment, meaning program management. Complexity naturally needs to be considered also in the establishment of joint ventures and other inter-corporate arrangements. Williams (1999) claims that contemporary project management practice is characterized by late delivery, exceeded budgets, reduced functionality, and questioned quality. As the complexity and scale of projects increase, the ability to bring the projects to a successful completion dramatically decreases. At first, it has to be questioned what contributes to project complexity. The complexity of the product and organization has been highlighted. In addition, environmental factors, such as numerous stakeholders and their varied demands, increase project complexity. All together, it can be said that project complexity is increasing as all of these elements get more and more complex, and the project schedules become tighter, requiring more simultaneity in project activities. (Williams 1999)

Few frameworks have recently been developed for assessing and managing the complexity of a project. Bosch-Rekveldt et al. (2010) have introduced the TOE (technical, organizational, and environmental) framework, which targets to integrate the elements contributing to project complexity in large engineering projects. Vidal et al. (2010) have defined a relative measure of project complexity, in order to assist decision-making. They propose a multi-criteria approach to project complexity evaluation through the use of analytic hierarchy process. Maylor et al. (2008) have published the MODeST dimensions of perceived managerial complexity. Their extensive framework provides a grounded structural model of managerial complexity. Regardless of the available frameworks, the most important thing is to acknowledge and manage the elements of complexity, and to remember, as stated by Geraldi (2009): “the assessment of complexity itself is a tool to enable active management”.

2.3. Schedule management systems

Definitions of project, schedule, and scheduling are first reviewed before defining the concept of schedule management system. Projects are generally complex endeavours and a schedule is essential to guide the execution of the project. As the project progresses, the remaining work requires reassessment in light of the new information. The execution of a project proceeds rarely as initially planned. The purpose of scheduling is to provide a “roadmap” that represents how and when the project will deliver the products defined in the scope. The dynamic nature of project execution is best served by a tool that allows modelling of the schedule and analysis due to the impact of progress and unforeseen events. The key to project success is to apply knowledge, experience and intuition to a project schedule, and then attempt to execute according to the schedule. Scheduling is one of the basic requirements of planning a project. (PMI 2007) Scheduling is defined by Mubarak (2010) as: “the determination of the timing and sequence of operations in the project and their assembly to give the overall completion time”. Schedule is a “roadmap” – how and when the project will deliver the deliverables defined in the scope. Schedule supports resource allocation in the most cost efficient way, as well as, coordination within the project and with other projects. It supports early detection of problems to enable corrective or preventive action, and what-if scenario analysis. Schedule is also a document for recording all delays, analyzing extensions of time, and financial loss claims. (Mubarak 2010)

Scheduling system comprises three factors: human factor, technology, and management. The factors of scheduling system are presented in Figure 3. The human factor stands for a proficient scheduler or scheduling team which understands the concepts, definitions, and applications of project scheduling. The technology means a good information system for scheduling, including software, hardware, and support. The management stands for a dynamic, responsive, and supportive management who believe in the use of scheduling as part of the management effort. If any of the factors is missing, the system will fail. (Mubarak 2010)

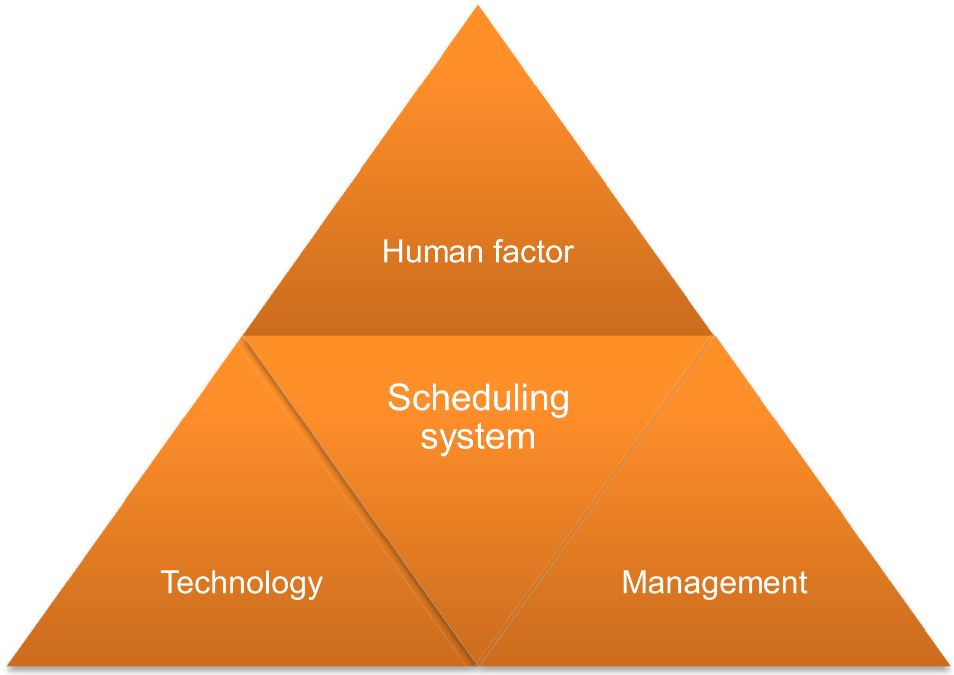

***Figure 3** The factors of scheduling system (Mubarak 2010).*

An increasing trend in all industries is to use software and other tools in project scheduling. However, specialized software requires knowledge of both the software and discipline. The person who is responsible for scheduling in a project must have three types of knowledge: knowledge of the software, knowledge of the principles of scheduling and control as part of project management, and knowledge of the specific technical field. The combination of good tools and an educated, experienced scheduler is the only path to success in project scheduling. (Mubarak 2010)

There is no definition of schedule management system available in the current project management or project scheduling domain. However, all essential dimensions of it are generally defined. Therefore, a definition of schedule management system is proposed: "schedule management system is a framework, consisting of processes, practices, and tools to plan and schedule all work in the scope of a project, and to enable active control of a project, in order to facilitate project management". According to the proposed definition, schedule management system is more than just scheduling methods and tools. In fact, the definition covers various aspects, such as: how and when project schedules are developed; how project schedules are controlled; who are involved in the scheduling process; what systems are used in the scheduling process; and how scheduling is done throughout the life-cycle of a project. Schedule management system comprises two inter-connected systems: planning and scheduling system, and control system. They are generally identified as the essential processes of project scheduling (PMI 2007; PMI 2008; Mubarak 2010). Both systems include processes and practices, which define the way of working in that particular area of project scheduling. In addition, there is a project management information system (PMIS), which provides the environment, where the other systems are embedded. The structure of schedule management system is presented in Figure 4.

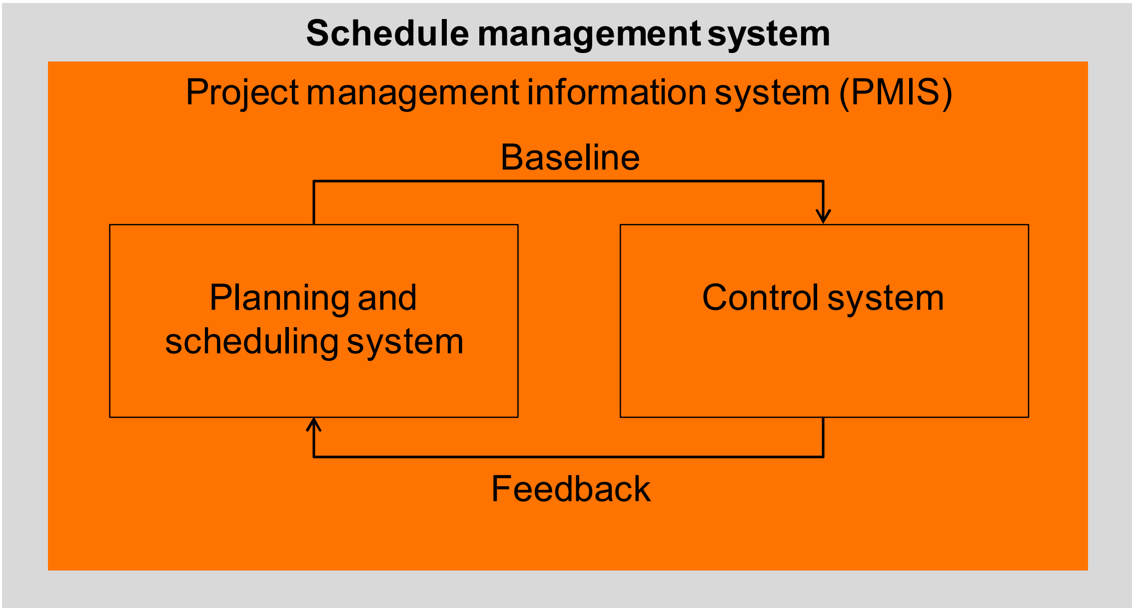

Figure 4 *The structure of schedule management system.*

The planning and scheduling system is used to develop schedules for a project. The activities are defined, sequenced, and their resources and durations are estimated. There are fundamental decisions to be made regarding to: the methods to be used in breaking down the work, the required level of detail, the types of work to be included, the methods to be used in scheduling the work, the schedules to be developed, and when the schedules are to be developed. As a result, schedule baseline for the project is defined. The control system is used to control the schedules for a project. The schedule is followed-up to track progress, and updated to manage changes in the schedule baseline. There are multiple decisions to be made here as well: the methods to be used in controlling the schedules, the requirements of progress follow-up, and the desired level of control. Feedback is provided to the planning and scheduling system, including information of executed activities and schedule deviations. The integration and cycle-time of the two systems are relevant dimensions of schedule management system. PMIS provides methodology for project planning, scheduling, and control by collecting, organizing, storing, processing, and disseminating data and information (Nicholas 2004).

2.3.1. Project planning and scheduling

Project planning is performed to establish the total scope of the effort, to define and refine the objectives, and to develop the course of action required to attain the set objectives. The planning process develops the project management plan and the project documents that are used to carry out the project. The multi-dimensional nature of project management creates repeated feedback-loops. As more project information or characteristics are gathered and understood, additional planning may be required. (PMI 2008) Project by definition is always unique and has never been executed before meaning that there is not specific experience of the project. Consequently, it is difficult to know precisely in the initial planning phase what needs to be done in order to complete the project (Morris 1997). The timing of planning creates a dilemma – if the time interval between planning and execution of an activity is long, the uncertainty concerning the planned activity increases. The higher the uncertainty in a project, the more difficult it is to plan. The earlier the person who is responsible for planning in a project gets involved with all relevant functional areas, the greater the planner's influence is on the execution. (Laufer & Tucker 1988) The dilemma indicates the need for progressive elaboration, rolling wave planning, which makes project planning an iterative and on-going process. In rolling wave planning, the work to be accomplished in the near term is planned in detail and future work is planned at a higher level. Thus, work can exist at various levels of detail depending on where it is in the project's life-cycle. (PMI 2008) However, the importance of the planning phase stands out relative to other phases in the project's life-cycle (Dvir et al. 2003). Inappropriate planning results in project failure, whereas high-quality project planning increases the project's chance of success, but does not guarantee it (Zwikael & Globerson 2004).

Scope statement works as a basis for future decisions in a project. Once the scope statement is finalized, the next step is to create a work breakdown structure (WBS). It provides a logical and deliverable-oriented hierarchical structure of all work in the project. Thus, the scope of the project is defined in the WBS and the work is subdivided into smaller entities, work packages. They can be scheduled and controlled at the lowest level of the WBS. Organizational breakdown structure (OBS) presents the hierarchical structure of the organization. Then, the WBS and OBS are combined to build up a responsibility matrix to indicate which organizational groups are responsible for which parts of the WBS. (Morris 1997; PMI 2008) When developing a project schedule, it is common to decide which is emphasized, either schedule or cost control. If schedule control is preferred, the scheduling of work is emphasized in the planning process. (Hendrickson 2008) In most of the project-based firms, the primary focus is on planning time while resource allocation and its cash-flow implications do not get that much attention. Scheduling is emphasized because of the high degree of interdependency between scheduling and the overall duration of a project. In addition, the management's ability to affect time goals is generally better than to affect cost or quality goals. (Laufer & Tucker 1987) Scheduling is one of the basic requirements of planning a project (PMI

2007). Project scheduling process comprises the following steps: activity definition, activity sequencing, activity resource estimation, activity duration estimation, schedule development, and schedule control (PMI 2008). The project scheduling process is presented in Figure 5.

Figure 5 *The project scheduling process (PMI 2008).*

Activity definition is for identifying the specific actions to be performed to produce the project deliverables. Activity sequencing means identification and documentation of relationships among the project activities. Activity resource estimation is the process of estimating the type and quantities of material, people, equipment, or supplies required to perform each activity. Activity duration estimation is the process of approximating the number of work periods needed to complete individual activities with estimated resources. Schedule development is the process of analyzing activity sequences, durations, resource requirements, and schedule constraints to create the project schedule. Finally, schedule control is the process of monitoring the status of the project to update project progress, and of managing changes in the schedule baseline. (PMI 2008)

There are several methods and tools for project scheduling. One of the oldest is Gantt chart, which was originally developed in 1917. It quickly became popular, especially in the construction industry, because of its ability to graphically represent a project's activities on a time scale. The activities are drawn as bars to show the duration, and the starting and ending points. Links between activities are not usually shown. Later many variations of bar charts have evolved for different purposes. (Mubarak 2010) Another type of chart which came into regular use in the 1950s is milestone chart and it is used along with Gantt charts. Major projects are subdivided into components with target dates set for completing activities required to achieve each milestone. Milestone charts are widely used, especially in management reporting. A major benefit is the easy communication of large amounts of information. (Cornish 2008)

Critical path method (CPM), and program evaluation and review technique (PERT) were developed simultaneously in the 1950s. The methods are quite similar to each other as they both use arrow diagramming method, but they were developed in fundamentally different fields. CPM was aimed for the construction and maintenance industry, where technologies and processes are known and activity duration estimation can be done with some accuracy. In contrast, PERT was focused on military research and development (R&D) projects, where time pressures are high and costs a secondary issue. In the R&D environment, activity durations are much more difficult to estimate. Thus, PERT emphasizes probability. (Morris 1997)

CPM is a schedule network analysis technique. It calculates the theoretical early start and finish dates, and late start and finish dates for all activities without regard to any resource limitations. This is done by performing a forward and backward pass analysis through the schedule network. The resulting dates are not necessarily the project schedule; they rather indicate how the time periods within each activity could be scheduled. The schedule flexibility is measured on any network path by the positive difference between early and late dates, and is termed total float. Critical path have a zero total float, and the activities on the network path are called critical activities. Any delay on the critical path impacts directly the project completion date. Networks often have multiple near critical paths, meaning that any adjustment to schedule constraints may change the critical path. Once the total float for a network path is determined, the free float, which is the amount of time that an activity can be delayed without delaying the early start date of any immediate successor activity, can also be calculated for each activity. CPM is useful because it draws attention to the most significant activities to complete the project in time. (PMI 2008)

PERT can be considered as an extension of CPM by incorporating uncertainty and risk in activity duration estimates. Uncertainty of activity durations is taken into account by using three estimates instead of one to define an approximate range for each activity. (Wei et al. 2002) In PERT, the estimates are: most likely, optimistic, and pessimistic. The most likely estimate is the duration of an activity considering the resources likely to be assigned, their productivity, realistic expectations of availability for the activity, dependencies on other participants, and interruptions. The optimistic estimate is the activity duration in the best-case scenario and the pessimistic estimate in the worst-case scenario. Then, PERT calculates an expected activity duration using a weighted average of the three estimates. Activity duration estimates generated by PERT analysis provide more accuracy, and the three points clarify the range of uncertainty of the duration estimates. (PMI 2008)

Network scheduling revolutionized the management of construction projects. It provides the management with an objective and scientific methodology. Network is a logical and chronological graphic representation of the activities composing a project. Basically, there are two types of network diagrams: arrow networks, and node networks. Arrow networks were popular in the 1960's and 1970's. Subsequently, precedence diagrams, which are an advanced form of node diagrams, became the method of choice for network scheduling. In traditional networks, the precedence relationships are indicated only with finish-to-start relationships, where the finish of a predecessor activity is linked to the start of a successor activity. Precedence diagramming method (PDM) allows using four types of relationships: finish-to-start, start-to-start, finish-to-finish, and start-to-finish. (Mubarak 2010) PDM is virtually the only commercially available computer-based method for scheduling today (Cornish 2008).

Critical chain method (CCM) is a schedule network analysis technique, which modifies the project schedule to account for limited resources. Initially, the project schedule network diagram is built using duration estimates with required dependencies and defined schedule constraints. Then, the critical path is calculated. Once the critical path is identified, resource availability is entered and the resource-limited schedule is determined. The resulting schedule often has an altered critical path. The resource-constrained critical path is known as the critical chain. CCM adds duration buffers that are non-work schedule activities to manage uncertainty. One buffer, placed at the end of the critical chain, is known as the project buffer which protects the target finish date. Additional buffers, known as feeding buffers, are placed at each point where a chain of dependent activities not on the critical chain feeds into the critical chain. The feeding buffers protect the critical chain from delay. The size of each buffer is determined based on the uncertainty in the duration of the chain of dependent activities leading up to that buffer. Once the buffers are determined, the planned activities are scheduled to their latest possible start and finish dates. Consequently, CCM focuses on the management of the remaining buffers against the remaining durations of activity chains. (PMI 2008)

Most project scheduling methods and tools concentrate on developing a baseline schedule, assuming that there is complete information available and the environment is deterministic without any variability. In reality, projects are subject to uncertainty and varying risks that are not considered in the project schedules. (Herroelen & Leus 2004) Dawson and Dawson (1998) state that because of the deterministic nature of traditional scheduling techniques, they are not suitable for projects with significant uncertainty. Recently, simulation techniques have been developed to consider the stochastic nature of projects. The most commonly used technique is Monte Carlo simulation. In the simulation, a sample value for each input variable is randomly selected from its statistical distribution, which can be defined based on the three estimates in PERT.

Then, the input sample values are used to calculate the network as in CPM. The procedure is repeated until the probability distributions are sufficient to achieve the desired level of accuracy. With Monte Carlo simulation, also the probability of an activity being on the critical path can be assessed, while CPM only indicates whether the activity is on the critical path or not. (Rolstadås 2004; Hendrickson 2008)

When projects become larger, it is difficult to present all activities and information in one schedule. Therefore, a schedule can be divided into smaller entities, hierarchy of charts. (Nicholas 2004) Sears et al. (2008) also argue that schedules must be established on a hierarchical basis, and a schedule at a particular level of detail must be expanded to more detail, when the execution of the work comes closer. Traceability between the different levels of schedule hierarchy is important, in order to maintain consistency throughout the scheduling process. High-level planning incorporates many lower-level plans, and plans of subcontractors. The lower-level plans often confirm the robustness of the higher-level plans. (Winch & Kelsey 2005) The hierarchy of charts is presented in Figure 6. In practice, the size and complexity of a project are to be considered, when deciding, how many levels are needed in the schedule hierarchy.

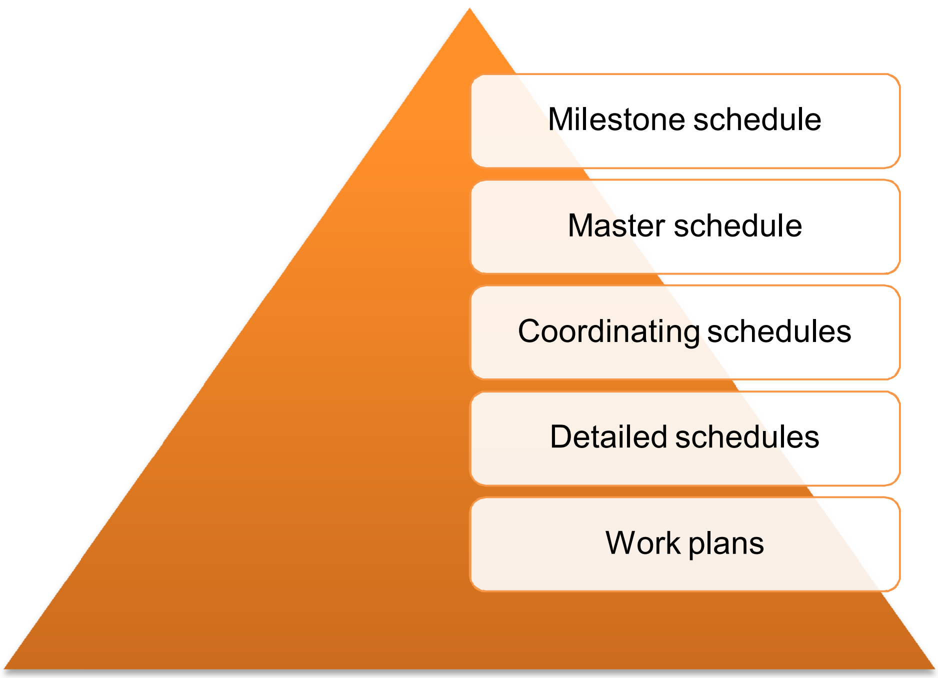

Figure 6 *The hierarchy of charts (Nicholas 2004; Winch & Kelsey 2005).*

On the top of the hierarchy is the milestone schedule, which can be considered as a strategic plan as it defines the intermediate deliverables of a project. The milestone schedule also specifies the sequence of states the project must go through, indicating what is to be achieved in each state, but not how it is to be achieved. The scope of a project is defined on this level of schedule hierarchy. (Turner 2008) On the second level is the master schedule, which outlines the main work packages and presents the milestones. The master schedule indicates the project activities without too much detail. Usually, it is used by the management for planning and reviewing the entire project. The master schedule is developed in the initial planning phase and updated periodically during project execution. The project manager develops the master schedule in collaboration with the project team in a top-down fashion. On the third level that is the intermediate-level of the hierarchy are the coordinating schedules, which present the high-level activities in more detail. This is done by breaking down the high-level activities into sub-activities. Usually, the coordinating schedules are used by the project and line managers to plan resources. (Nicholas 2004)

On the bottom levels of the hierarchy are the detailed schedules and work plans, which present activities derived from the activities of intermediate-level schedules. The detailed schedules contain activities at the work package level, and they also include high-level milestones and activities from the master schedule, which are broken down into detailed ones. The detailed schedules are used by the site personnel, supervisors, and technical specialists for planning, scheduling, and controlling activities on a daily or weekly basis. Consequently, the managers and supervisors are able to focus on the activities of their own discipline, and to achieve the required level of detail. The detailed schedules are developed by the line managers. The master schedule is also updated with necessary details gained from the detailed schedules. (Nicholas 2004)

The breakdown of work into work packages is essential in a project. Appropriate creation, maintenance, and use of WBS contribute significantly to the probability of successful completion of a project. (Hall 1993) When creating a WBS, there are two main issues to be addressed: structure, and level of detail. The decisions affect the size and contents of work packages. When developing a project schedule, the resources and time required to perform each activity are estimated. Estimates for smaller work packages are, in general, more accurate. There are two reasons for this: dividing the work into smaller, homogenous entities helps focusing on the activities involved, providing a better information basis for the estimation; and estimation errors decrease with the larger number of estimates because of their statistical nature. (Raz & Globerson 1998) In addition, smaller work packages facilitate project control, because it is easier to monitor the completion of whole work packages than it is to estimate completed portions of work packages still in progress. Therefore, the greater the number of work packages defined in a project, the greater the precision of measuring performance, and the better the control of the project. (Globerson & Shtub 1995)

The modularity of projects is discussed by Phillips et al. (1999). They define modular project as: “one that consists of several similar entities, or modules, which are the object of similar functions or processes applied repeatedly”. Many large projects require similar or identical operations to be applied repeatedly to a number of objects. By completing a single module prior to releasing the work on subsequent modules, the project team is able to encounter areas of uncertainty and decision-points, requiring assumptions or judgements to be made. At this stage, a set of standardized procedures can be prepared for the entire project, in order to deal with potential problems. The fist module serves as a template for the subsequent modules. The advantages of the modular project approach include: standardization, increased efficiency, and more rapid overall progress in large projects. (Phillips et al. 1999)

2.3.2. Project control

Project schedules are a useful tool for managing and controlling a project. However, this tool can be effective only if used properly. The most important use of schedules is project control, which includes comparison of actual project performance with the baseline and discernment of any deviation. Using schedules as an effective tool requires a serious commitment from the project management to adopt and use the schedule throughout the project. There is a difference in attitude between a contractor, who is using the schedule because of conviction that it is an effective tool for project management, and a contractor, who is using the schedule because the customer requires doing so. Project control comprises the following continuous processes:

- monitoring work progress;
- comparing it with the baseline schedule and budget;
- finding any deviations, determining where and how much, and analyzing them to discover the causes; and
- taking corrective action whenever and wherever necessary to bring the project back on schedule and within budget.

Along with the basic functions, other functions of project control may be to help identifying areas for improving work efficiency, compressing the schedule, or reducing cost. There is a difference between project control and project monitoring, as the latter is by definition passive. (Mubarak 2010) The term “project tracking” is also used in the same context as project control (Oberlender 2000).

Schedule updating is simply reflecting the actual performance information, including time of occurrence, and amount or percentage of work completed, on the schedule and indicating any changes to future work (Mubarak 2010). Popescu and Charoenngam (1995) define an updated schedule as: “a revised schedule reflecting project information at a given data date regarding completed activities, in-progress activities, and changes in the logic, cost, and resources required and allocated at any activity level”. The data date is the date, as of which all progress in a project is reported. Many kinds of information are needed for updating the project schedules. In general, any new information that was not known for the previous update and relates to the schedule must be recorded on and implemented in the schedule. This information falls into two main categories: past information, and future information. (Mubarak 2010) The categories of information needed for updating a schedule are presented in Table 1.

Table 1 *The categories of information needed for updating a schedule (Mubarak 2010).*

Past information	Future information
Activities that have started: the actual start date, percent complete, and the remaining duration for each of them	Any activities that have been added, along with their information
Activities that are complete: the actual completion date for each of them	Any activities that have been deleted
On-going activities: their new percent complete and the remaining durations	Activities that have changed in duration, logic, budget, resources, constraints, or otherwise
The actual budget spending or resource consumption for each activity	Any change in the imposed finish date for the entire schedule, or in the constraint dates for certain milestones
	Any schedule-related, but not activity-specific, changes, such as a change in the cost or availability of resources, calendar workdays, or responsibility

Schedules may be updated monthly, biweekly, weekly, or according to another time interval. Too long period between updates may eliminate the effectiveness of schedule as a control tool, because, by the time progress is reported and analyzed, the time and opportunity to take corrective action may have passed. In addition, the amount of work required to update the schedule may be overwhelming, which easily leads to out-of-date schedules. Conversely, a reporting period that is too short may be consuming in terms of time, and reporting costs. The frequency of updates typically increases at certain times, such as in the last month or two of the project, or before a certain deadline. (Mubarak 2010)

The single most important step in schedule updating is probably the measurement of work progress, because it has an effect not only on the schedule status, but also on the progress payments to the contractor and subcontractors. Measuring work progress is mainly calculation or estimation of the percent complete for each activity and the entire project. (Mubarak 2010) There are several methods for measuring work progress: units completed, cost or time ratio, start-finish, supervisors' opinion, incremental milestones, and weighted or equivalent units. In the units completed method, percent complete is determined by dividing units completed by total units. In the method of cost or time ratio, percent complete is calculated by dividing time elapsed by total duration or cost to date by total budget. The start-finish method allows assigning only two stages: not started, and finished. The supervisors' opinion is the most subjective method, where a supervisor uses judgement to determine percent complete. In the incremental milestones method, each stage of an activity is assigned a weight which equals to its portion of effort in the activity. Then, each stage is treated as in the start-finish method. The weighted or equivalent units method involves five steps, and it is used for large and complicated activities that usually comprise several consecutive or overlapping sub-activities. (Construction Industry Institute 1987) Once the percent complete for individual activities is estimated, the percent complete for the entire project can be determined.

Performance reviews measure, compare, and analyze schedule performance, such as actual start and finish dates, percent complete, and remaining duration for work in progress. If earned value management (EVM) is utilized, schedule variance (SV) and schedule performance index (SPI) are used to assess the magnitude of schedule variations. An important part of schedule control is to decide, whether the schedule variation requires corrective action or not. For example, a major delay of any activity not on the critical path may have little effect on the overall project schedule, while a much shorter delay on a critical or near-critical activity may require immediate action. If using CCM, the amount of buffer remaining is compared to the amount of buffer needed to protect the target completion date, in order to determine the schedule status. The difference between the buffer needed and the buffer remaining indicate the need for corrective action. (PMI 2008)

EVM in its various forms is a commonly used method for performance measurement. It integrates project scope, schedule, and cost measures, in order to facilitate assessing and measuring project progress and performance. EVM requires formatting an integrated baseline, against which performance can be measured for the duration of the project. In earned value analysis (EVA), three key dimensions are developed and monitored for each work package and control account: planned value, earned value, and actual cost. The planned value is the authorized budget assigned to the work to be accomplished in an activity or work package. The earned value is the value of work performed, as expressed in terms of the approved budget assigned to that work. The actual cost is the total cost actually incurred and recorded in accomplishing work performed for an activity or work package. The parameters are monitored and reported both periodically and cumulatively. The EVA data is usually displayed by using s-curves. Cost variance (CV) and schedule variance (SV) are also monitored to measure the project's performance against the baseline. The variances can be converted to efficiency indicators, in order to reflect the cost and schedule performance of a project for comparison against other projects. Cost performance index (CPI) measures the value of work completed, as compared to the actual cost or progress achieved in a project.

Schedule performance index (SPI) measures progress achieved in comparison to the progress planned for a project. The variances and indices are useful for determining the project status, and providing a basis to estimate project cost and schedule outcome. (PMI 2008)

Changes are the main causes for delays and cost overruns in construction projects, where they are also very common issues (Assaf & Al-Hejji 2006). Any additions to, deletions from, or revisions of project goals or scope are to be considered as changes, regardless of whether they increase or decrease the project schedule or cost (Ibbs et al. 2001). In a large and complex project, the causes of change are more complicated. Project changes have obvious impacts on the construction process, not only on the project's schedule and cost but also on the project's performance. (Hanna et al. 1999) Change is a major cause of delay, disruption, and disputes between customers and contractors (Motawa et al. 2007). Furthermore, it is hard to predict changes in construction projects. This is mainly because of the uniqueness of each project and the limited resources that can be spent on planning, executing, and delivering the project. (Hanna et al. 2004) Zou and Lee (2008) argue that cost related to changes in a project is one of the most sensitive aspects of construction project management, but it is also one of the most difficult to control. Project teams need to predict changes in a timely manner as, according to Kartam (1996), conflict is minimized when problems are found at the earliest possible stage of a project, enabling the implementation of counter measures.

Change management is an essential area of project management, especially in construction projects. Few change management systems have recently been developed for minimizing the impacts of changes and facilitating effective project management. Zhao et al. (2010) propose a change prediction system, using activity-based dependency structure matrix (DSM) to facilitate change management. DSM was originally developed by Steward (1981) to achieve more efficient representation of dependency relationships between activities by means of matrix. The matrix contains the input and output information of all activities, for example, what information parameters are needed to start a particular activity and which other activities within the matrix utilize the output information (Browning 2001). In the change prediction system, DSM is used for modeling the process that may occur as a result of changes. Consequently, changes can be predicted by setting the change criteria for each activity in the form of re-work scope. Furthermore, Monte Carlo simulation is used for analyzing the probability of change in the activities involved in a project. The change prediction system enables project teams to manage changes proactively and efficiently. (Zhao et al. 2010)

2.3.3. Need for advanced systems

Advanced systems are needed for project planning, scheduling, and control in order to overcome the issues caused by the nature of projects and present project environment. Alsakini et al. (2004) have studied schedule deviations in international construction projects to anticipate their causes and consequences, and to find new solutions for preventing them. The results reveal that the causes for schedule deviations are embedded primarily in the local customer and officials with their cultural background, but also in the contractor itself and its local subcontractors and suppliers. In other previous studies performed by the Research Institute for Project-Based Industry (PBI), it has been detected that various deviations from the original plans always take place in projects abroad. However, most projects have finished almost on time, despite the work that had not progressed as planned, but the deviations have caused major problems in the projects. Schedule management system is needed instead of the traditional approach, where a detailed schedule is developed at the initiation. The system should be based on continuous detailed planning during execution of the project to allow incorporation of the forthcoming events and action-taking against their effects in advance. When performing continuous detailed planning, the representation of the work ahead becomes better, which changes the focus of project management from the past to the work to be done. Consequently, the management has enough information to act on, in order to prevent future delays rather than waiting until a milestone is missed. (Laufer et al. 1992; Alsakini et al. 2004)

Oberlender (2000) argues that planning should be considered as a process and not as a discrete activity, and it should be applied to the entire project from the initiation to the closing. This includes planning of the design, as well as, the construction work at site. Ballard (2000) advocates the same that it is really important to realize what work should be done, over what duration, and using what resources and methods throughout the life-cycle of a project. This requires viewing the project schedule as a dynamic device as emphasized by Sears et al. (2008), who state that any project schedule represents the best thinking at the time it is developed and implemented. However, no such plan is ever perfect – the need for change is inevitable as the work progresses. The schedule needs to be continuously modified to reflect the progressive precise thinking of the project team. Antill and Woodhead (1990), and Sears et al. (2008) both argue that schedules, in practice, must be developed on a hierarchical basis. Schedule at a particular level of detail must be expanded to greater detail, as the execution of the work becomes closer and with input from the users of the schedule. Westney (1985) also argues that the level of detail used in developing a schedule can vary with the level of management, for which it is intended. Consequently, different schedules are developed to meet the needs of a particular user: master schedule, which includes the time goals monitored by the project team during execution; and detailed schedules for the subcontractors, which indicate the progress of the work, for which they are responsible (Alsakini et al. 2004).

Woodward (1997) and Oberlender (2000) state that in engineering and construction projects, especially in EPC projects, the CPM diagram must interface the design work with procurement and construction activities as separate work schedules that are linked to a summary schedule, an outline of the whole network. Then, the summary schedule is extended by subdividing the diagram into sub-networks which can be scheduled and controlled by the people directly concerned, and can stand on their own for additional work. The contractor sets the general timing reference for the overall project, and individual subcontractors review their portions of the schedule and help to develop additional details relevant to their operations. (Woodward 1997; Oberlender 2000) The procedure brings the contractor and subcontractors to discuss the project, which enables problem detection at an early stage and solving them well in advance (Alsakini et al. 2004). The participation of subcontractors and suppliers in developing detailed schedules is emphasized by Walker (2007) and Sears et al. (2008), who argue that construction planning and scheduling must be done with the participation of people experienced in and familiar with the type of work involved. Ballard (2000) advocates a similar idea in the "Last Planner" concept, which enables participation in producing directives to drive direct work process assignments. Failing to prepare good assignments by planning at crew level, prevent plans from being realized even if the upstream planning is good. The principle requires selection of assignments from activities that are known. In this way, the uncertainty and variation of work flow can be prevented, which results in a lower percentage of non-productive time. The principle includes: sequencing decisions, which are made by the planners based on their knowledge of working conditions and constructability issues; and selecting the right amount of work, which uses the labor and equipment capacity as directed in the schedule. (Ballard 2000)

Project planning and scheduling, as they are understood based on the traditional approach of project management, need to be questioned. The traditional detailed planning at the project initiation is unable to provide simultaneously the required level of detail and certainty. Therefore, detailed planning should be done during execution of the project. As there is much uncertainty in the schedules because of the upcoming events in project execution, flexibility of the schedules is required instead of pre-determined actions. The uncertainty generated by the fact that the CPM network does not reflect the difficulties in work flow can be compensated by utilizing rolling wave planning to develop workable detailed schedules for the near term. The concern is to make the operational environment stable and decrease the number of surprises during the execution of the activities by monitoring the work at site, decreasing the need for re-work, and organizing better the site. Thus, the site team is aware of what to do and when to do, and they can better allocate the resources to reduce interference among working teams. (Alsakini et al. 2004)

In traditional project control, as the standard documents of project management (PMI 2008) describe the process, the first step is to collect data, which represents what is really going on in the project. Then, the data is analyzed by comparing it with the schedule baseline to identify variations. Finally, the analysis gives an indication of how a project is progressing and the assessment is summarized in a project performance report. After reading the report, the management makes a decision, how to proceed by recommending corrective actions followed up to assure that the intended impact is achieved. The traditional approach of project management puts the project manager in a position, where the reactive approach is the only choice. While the causes of project deviations develop throughout the project, the project manager is forced to try to minimize the negative potential of projects. Traditional project management requires that, in controlling project performance, the degree of fit between work completed and the schedules is measured to identify root causes of failure, in order to complete the work as planned, and to eliminate the causes to prevent them from repeating. (Alsakini et al. 2004)

It is really important to determine the effect of schedule deviations and plan changes on the remaining work in the project, including both the unexpected departure from the schedule and the corrective actions taken to recover from specific problems. The issue is not, how often the schedule is updated; instead, it is how well the schedule continues to fit for the actual work. As many of the critical problems of implementation lay in the project environment and are not under the direct control, project teams must look outside the project and ahead to anticipate problems and to develop contingency plans. This can only be achieved by means of continuous planning and control during the project, instead of the traditional detailed planning at initiation and reporting during execution. Active control of the project is the key, not planning itself. The change from serial to parallel execution in projects is expected to have a major impact on how projects are planned and controlled in the future. The new ways of creating value in projects are more or less happening in open systems, where projects are considered to be impacted by internal and external factors. Project processes in parallel value creation are strongly affected by external factors that are difficult to plan and control. The impact of external factors increases in short lead-time projects due to the limited time available to react to the factors. Consequently, the demand increases for new ways of managing projects, which is to affect the factors proactively rather than to react to them. (Alsakini et al. 2004)

2.3.4. Advanced systems in project scheduling

Advanced systems in project planning, scheduling, and control have been developed to address the needs of project management in the present project environment. The “Last Planner” concept by Ballard (2000) is introduced, because it is widely acknowledged by the researchers in the field, and many developed systems are based on this concept. The proactive schedule management system by Alsakini et al. (2004) is presented in detail to provide an example of recently developed schedule management system models that aim to integrate the scheduling and control processes.

Design and construction require planning and control done by different people, at different places within the organization, and at different times during the life-cycle of a project. Planning high in the organization tends to focus on objectives and constraints, which govern the entire project. The objectives drive lower-level planning processes that specify means for achieving the ends. Ultimately, someone decides what physical, specific work will be done tomorrow. That type of plans has been called assignments. They are unique, because they directly drive the actual work rather than production of other plans. The person or group that produces assignments is called the "Last Planner". (Ballard & Howell 1994) The term "assignments" stresses the communication of requirements from the Last Planner to design or construction. Although, the products of planning at the production unit level are also commitments to the rest of the organization. Failure to proactively control at the production unit level increases uncertainty and deprives workers of planning as a tool for shaping the future. What is needed is to shift the focus of control from the workers to the flow of work that links them together. The Last Planner production control system is a philosophy, rules and procedures, and a set of tools that facilitate the implementation of the procedures. Regarding the procedures, the system has two components: production unit control, and work flow control. The first is to make progressively better assignments to direct workers through continuous learning and corrective action. The function of work flow control is to proactively cause work to flow across production units in the best achievable sequence and rate. (Ballard 2000)

The key performance dimension of a planning system at the production unit level is the quality of plans produced by the Last Planner. The critical quality characteristics of an assignment are: the assignment is well defined; the right sequence of work is selected; the right amount of work is selected; and the work selected is practical or sound. Well-defined means described sufficiently so that it can be made ready and completion can be unambiguously determined. The right sequence is consistent with the internal logic of the work itself, project commitments and goals, and execution strategies. The right amount is that amount the planners judge their production unit is capable of completing after reviewing the budget unit rates and examining the specific work to be done. Practical or sound means that all prerequisite work is completed and all resources are available. Work flow control is to cause work to move between production units in a desired sequence and rate. In the hierarchy of plans and schedules, the "look-ahead" process has the job of work flow control. Look-ahead schedules are common in current industry practice, but typically perform only the function of highlighting what should be done in the near term. In contrast, the look-ahead process within the Last Planner system serves multiple functions, such as:

- shape work flow sequence and rate;
- match work flow and capacity;
- decompose master schedule activities into work packages and operations;
- develop detailed methods for executing work;
- maintain a backlog of ready work; and
- update and revise higher-level schedules if needed.

These functions are accomplished through activity definition, constraints analysis, pulling work from upstream production units, and matching load and capacity. (Ballard 2000)

The Last Planner planning system is presented in Figure 7. The vehicle for the look-ahead process is a schedule of potential assignments for the next 3 to 12 weeks. The number of weeks, over which a look-ahead process extends, is decided on the basis of the project characteristics, the reliability of the planning system, and the lead times for acquiring information, materials, labor, and equipment. The look-ahead schedule is not just a simple drop out from the master schedule. Indeed, it is often beneficial to have the team doing the work in the next phase of the project to collectively produce a phase schedule that serves coordination actions that extend beyond the look-ahead window. Prior to entry into the look-ahead window, master schedule or phase schedule activities are exploded into a level of detail that is appropriate for assignment of weekly work plans, which typically has multiple assignments for each activity. Subsequently, a constraints analysis is performed for each assignment to determine, what must be done, in order to make it ready to be executed. The general rule is to allow into the look-ahead window only activities that can be made ready for completion on schedule. If the planner is not confident that the constraints can be removed, the potential assignments are held for a later date. (Ballard 2000)

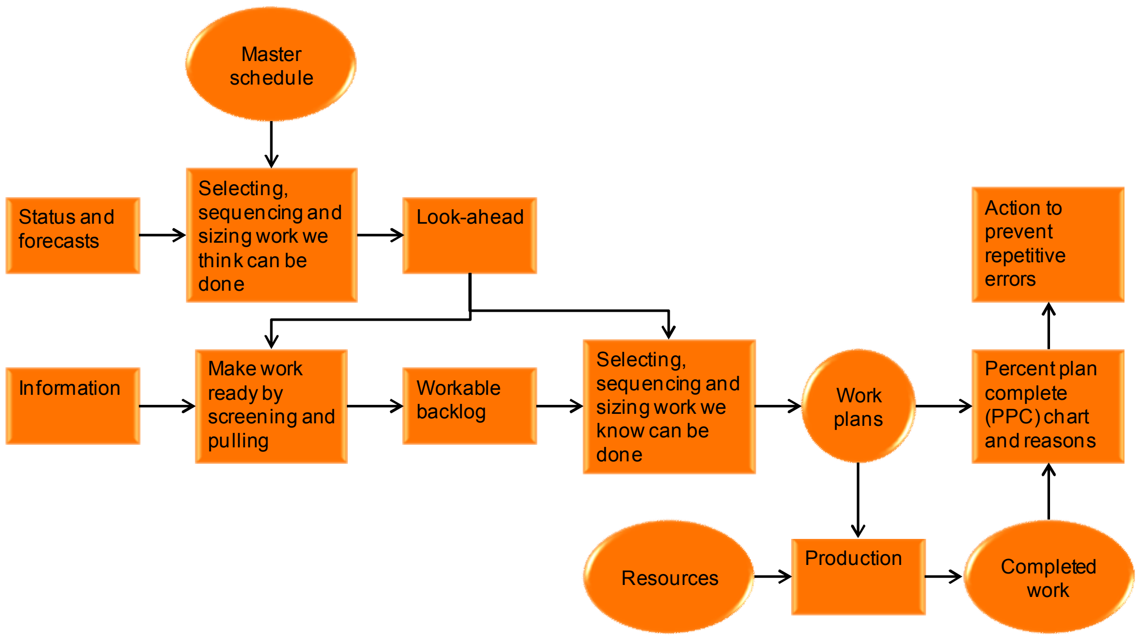

***Figure** 7 The Last Planner planning system (Ballard 2000).*

The look-ahead process is presented in Figure 8. In the look-ahead process, the work flows through time from right to left. Potential assignments enter the look-ahead window six weeks ahead of scheduled execution, and then move forward week by week until they are allowed to enter into workable backlog, indicating that all constraints have been removed and that they are in the proper sequence for execution. If the planner were to discover a constraint that could not be removed in time, the assignment would not be allowed to move forward. The objective is to maintain a backlog of sound work, ready to be performed. Weekly work plans are then formed from the workable backlog, thus improving the productivity of those who receive the assignments and increasing the reliability of work flow to the next production unit. (Ballard 2000)

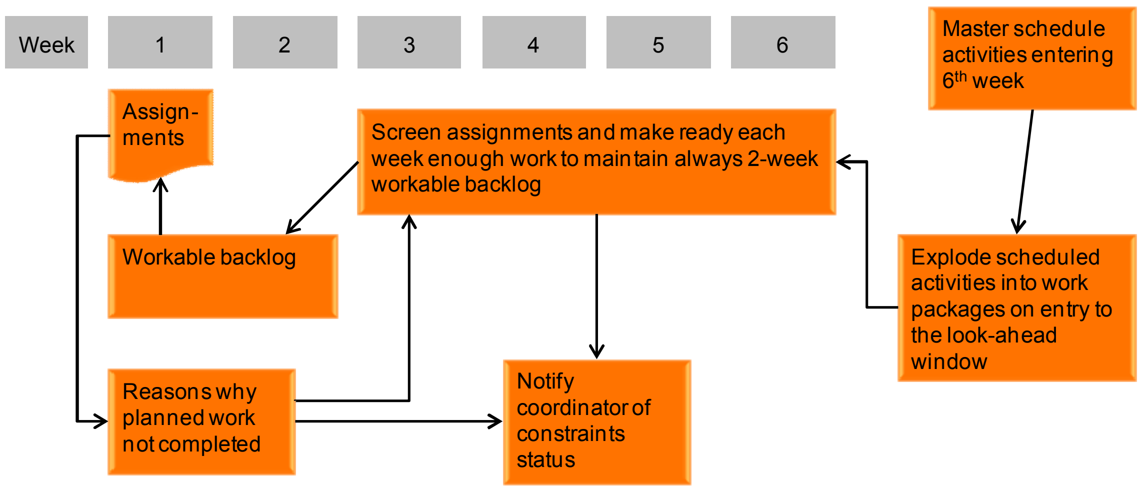

***Figure 8** The look-ahead process (Ballard 2000).*

Alsakini et al. (2004) recommend an integrated planning and scheduling system based on performing continuous detailed planning throughout project execution to incorporate the forthcoming events and to act proactively to their effects. As the core parts of projects are often designed and manufactured in the contractor's home country and constructed abroad, the proactive schedule management system is built to take this into account by allocating less detailed planning and scheduling to the head office, and incorporating the site organization into detailed planning and control processes. Thus, the system is capable of producing the required information to the right people at the required time. The idea is that detailed planning processes produce so comprehensive schedules that they reflect the work as it should be implemented. In project control and reporting, changes are accomplished so that proactive and reactive schedule control is enabled when deviations occur. The system enables proactive and reactive dialogue between the project stakeholders. Subcontractors are able to express their ideas and incorporate their views concerning the implementation of their work in order to meet the requirements of the site manager, who in turn reflects the contractor's main views on the project objectives and how to realize them. Consequently, the project manager is relieved from following every small detail, so that he/she can concentrate on the more demanding tasks of project management. (Alsakini et al. 2004)

New breakdown structure, which has two views, is recommended, in order to identify interdependencies between activities for better resource planning and avoiding any interference between activities and idle times in site performance. The first view is a location breakdown structure by dividing the entire project area into identifiable locations or facilities, and the work in each location is divided based on an activity breakdown structure. In the second view, the project work is divided to the disciplines (mechanical, electrical, and civil) and then further into sub-activities, indicating the work to produce each part or each location of the final product. The two views of the breakdown structure are to be used concurrently. (Alsakini et al. 2004)

The proactive schedule management system is presented in Figure 9. It consists of the following elements: master schedule, earned value analysis (EVA), work schedules, and activity plans/schedules. The master schedule is developed for the entire project, and it contains the main activities to be performed and the trades performing the activities without too many details. Durations for the activities are estimated based on the required man-hours. For control purposes, the critical path and milestones are made clear together with their dependencies. All disciplines in the head office are contributing to the development of the master schedule which is meant for the use of upper management level. Earned value diagram is prepared for tracking and controlling the project as a whole. The first diagram is done at the same time with developing the master schedule by plotting the work to be performed on the basis of man-hours against time. Work schedules are developed by extending and deepening the master schedule into more representative work programs by using the "rolling window" method. For example, in a project which has one year execution time, the schedules are developed for a span of two months at one-month intervals. The project manager and site manager are responsible for developing and distributing the schedules to the site and head office. Activity plans/schedules are developed, where each activity in the rolling window is presented in detail, just before it starts to show what work is to be executed on site and how. Planned work volume chart is also prepared based on work volume in units. The site manager develops the activity plans/schedules in collaboration with the subcontractors; by input from the subcontractors and under the consent of the site manager. (Alsakini et al. 2004)

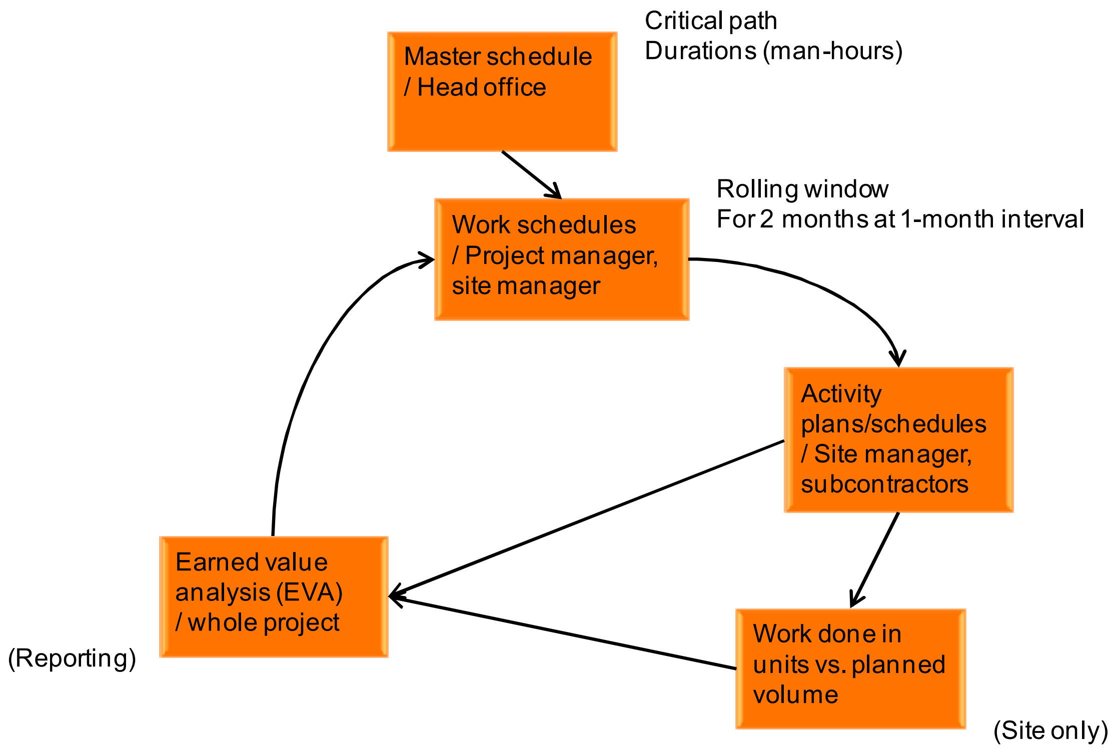

Figure 9 *The proactive schedule management system (Alsakini et al. 2004).*

When using the system, at the end of each period, the management is able to plan in detail for the next period by taking into account the results of the previous period, including any corrective action due to deviations and the requirements of the remaining work, as well as, producing detailed schedules and information they can use to act proactively to any potential deviations and delays. The work schedules and activity plans/schedules developed during the work progress reflect the actual conduct of work, and incorporate any corrective action that have been made to bring the project back on track. The point is that the master schedule is the reference point for milestones, while the detailed planning during execution provides the chance to manage work and bring it back on track without need to update the master schedule. The issue is not how often the schedule is updated; instead, it is how well the schedule continues to fit to the actual conduct of the work. (Alsakini et al. 2004)

The actual times and quantities required to perform the activities are collected in activity status reports, and then compared with the activity plan/schedule of that specific period in order to identify any deviations from the work schedule and determine the status of the critical activities. The project status is determined based on EVA. The CPI and SPI are plotted on a chart and compared with the results of the previous periods. If a deviation is serious enough, the causes are detected and the decision on corrective action is made. The overall project status is measured as a percent complete matrix based on the budget for each work package by using only two variables for each work package: estimated cost and percent complete. Then, a spreadsheet is used to calculate the rest of the data, including: cost to date, percent unit, percent project, and percent complete project. The updated schedule and EVA results are compared with the previous periods to determine, how the project is progressing. (Alsakini et al. 2004)

Changes to work are inevitable in every project and they may rise due to the customer, who wants to make changes to achieve a better outcome of the investment, or the contractor may decide to make some changes in the design. Change orders may increase or decrease the contractor's cost, and/or affect the duration of the project if they are performed. The contractor should evaluate various aspects, such as: the structure of customer's organization, customer's knowledge and experience of investment projects, authorities given to different levels within customer's organization, and personal characteristics of customer's key persons responsible for the project. In order to reduce the impact of a customer-initiated change order, the contractor's project team needs to understand the structure and behavior of customer's organization. When dealing with large customers, who have bureaucratic forms of organizations, the project team must understand the customer's needs more thoroughly and deal directly with the decision-makers, in order to act proactively to future changes that may delay the project progress. In overseas projects, uncertainty and complexity arising from the nature of customers are compounded because the contractor's project team may not be familiar enough with the cultural and historical background of the customer. Maintaining the maximum amount of up-to-date information on customer's requirements during design phase reduces the probability for change orders during execution phase. Also, using time allowances in planning the project execution provides flexibility in the contractor's performance to avoid delays when change orders inevitably take place. (Alsakini et al. 2004)

New project management methods that address the shortcomings of traditional methods by adding flexibility to the execution of construction projects, create additional challenges to material delivery processes (Ballard 2000). The new methods acknowledge the challenge of creating an exact schedule beforehand for a large and complex project. Instead, the methods use continuous planning by creating short-term schedules for project tasks based on constraint analysis of project resources. Such an approach places two requirements for the material deliveries: the analysis of material constraints requires transparency of material availability for site inventories and other stages of the supply chain, and the short time-span of planning demands short response times along the supply chain. Ala-Risku and Kärkkäinen (2006) propose a solution consisting of tracking-based approach for building inventory transparency for short-term supply chains, and proactive material delivery model for the materials for specific project tasks.

2.3.5. Project scheduling framework

The methods of project planning, scheduling, and control can be categorized based on their systemic approach, and system dynamics. The project scheduling framework illustrates four distinctive areas: basic, ad-hoc, aggressive, and progressive. The project scheduling framework is presented in Figure 10. Systemic approach refers to perceiving project scheduling more as a system than only as methods and tools. System dynamics relates to the flexibility of project scheduling to incorporate changes and required actions during project execution.

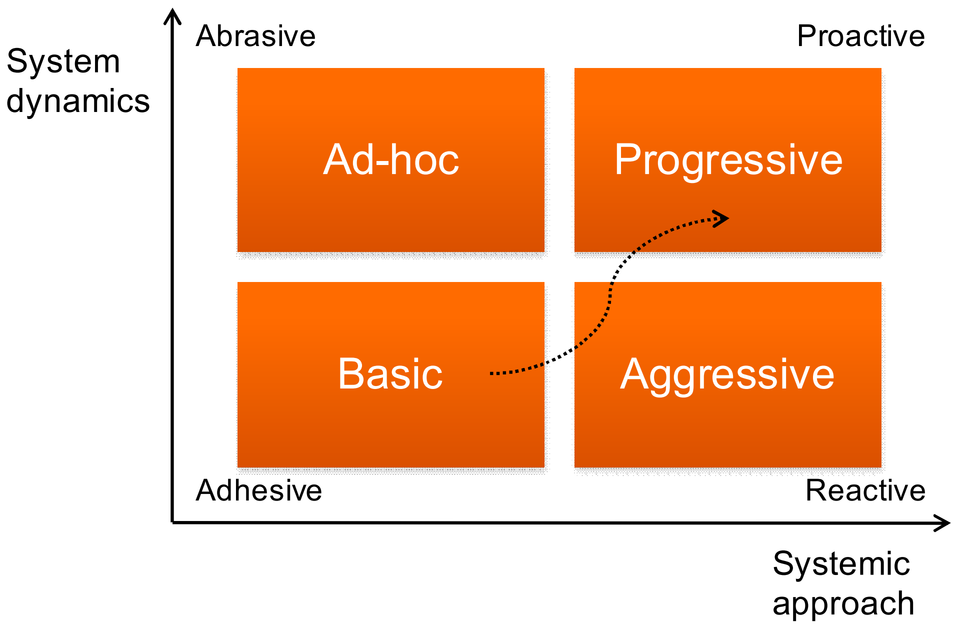

Figure 10 *The project scheduling framework.*

Basic is an area, which includes the traditional project scheduling methods, tools, and techniques. For example, CPM and CCM represent this area, when used individually. Adhesive approach describes the basic area, because the methods constitute the fundamentals in project scheduling, but they do not correspond to the present needs and requirements, when used alone. Ad-hoc is an area, which represents minimal planning and dynamic decision-making based on the information available at the moment. Planning the work, as it progresses, captures the essence of this approach. Abrasive approach describes the ad-hoc area, because no decent schedule is developed at all. Aggressive is an area, which represents extensive planning at the expense of dynamics, as planning is forced on more detailed level than what is appropriate, considering the available information at the moment. Planning the work in detail too much in advance results in plenty of changes during execution. Reactive approach describes the aggressive area, because relying on the once developed schedule enables only reacting to the upcoming events. Progressive is an area, which represents detailed and simultaneously dynamic planning, because it is done by increasing the level of detail, as the available information becomes more complete and reliable. Planning the work first on the high level and in detail just before it is performed results in fewer changes during execution. Proactive approach describes the progressive area, because elaborating schedules progressively enable more proactive management.

The arrow in the figure illustrates the typical development trajectory of project scheduling in an organization. Once the improvement need is acknowledged, the first attempts to develop the project scheduling practice usually lead to increased systemic approach, but not to increased system dynamics. Aggressive scheduling causes lots of extra work, but due to the inevitable changes during project execution, the effort is not rewarded. Instead, lots of re-scheduling is required to maintain the schedule. Eventually, the need for further development is acknowledged and system dynamics is increased to enable effective project scheduling.

2.4. Synthesis

Significant changes are taking place in the research and practice of project management. They rise mainly from the acknowledged need for a change in the project management approach, but also from the remarkable changes in the project environment over the years. The significance of project business is continuously increasing. Recently, project-based business activities have become part of all private firms and public organizations, and a key activity for an increasing number of them. (Artto & Kujala 2008) Project business differs from other types of business, primarily due to its specific relational context, limited time, value creation properties, type of complexity, and its high degree of uncertainty and limited possibilities for standardization (Hellström 2005). The integration of project sales and execution in a global project supplier firm is challenging. The central features of the business of a project-based firm are: the uniqueness of individual projects, the complexity of the project offering and business network, the discontinuity of demand and business relationships between projects, and the considerable extent of financial commitment of the parties (Cova et al. 2002). Procurement and supplier network management is important due to the trend of increased subcontracting and to focusing on the firm’s core capabilities. Indeed, firms and projects are more and more dependent on their suppliers, and therefore, the relational focus in subcontractor selection is relevant. (Eloranta 2007)

The complexity of projects is continuously increasing, which sets new requirements for project management, and it is clear that traditional project management is unsuitable for managing such projects (Williams 1999). Products or services produced in a project are often complex, as they consist of a large number of interacting parts. The interaction often creates great interdependency, not only from an engineering design perspective, but also in an organizational sense. (Hobday 1998) Complexity as such is often taken intuitively or from previous experiences, although, the complexity of projects and their environment obviously influence important decisions in project management (Bosch-Rekveldt et al. 2010). Describing projects as complex adaptive systems or socially constructed entities (Cicmil et al. 2006), complexity in projects can be considered to be related to structural elements, dynamic elements, and interaction of them; broader than the technical or technological domain. Three elements can be identified contributing to project complexity: structural complexity, organization and environment, and uncertainty and risk. (Bosch-Rekveldt et al. 2010) One of the reasons for project failure is the increasing complexity of projects, or an underestimation of the project complexity (Williams 2001). There is a clear need for new ways of looking at complex projects, new models and techniques to analyze them, and new methods for managing them. There has to be suitable tools and techniques for complex projects in order to support project management in planning, scheduling, and control. (Williams 1999)

Project planning and scheduling, as they are understood based on the traditional approach of project management, need to be questioned (Alsakini et al. 2004). The timing of planning creates a dilemma – if the time interval between planning and execution of an activity is long, the uncertainty concerning the planned activity increases. The higher the uncertainty in a project, the more difficult it is to plan. (Laufer & Tucker 1988) The traditional detailed planning at the project initiation is unable to provide simultaneously the required level of detail and certainty. Therefore, detailed planning should be done by progressive elaboration during project execution. (Alsakini et al. 2004) Schedules must be established on a hierarchical basis, and a schedule at a particular level of detail must be expanded to more detail, when the execution of the work comes closer (Sears et al. 2008). Traceability between the different levels of schedule hierarchy is important, in order to maintain consistency throughout the scheduling process. High-level planning incorporates many lower-level plans, as well as, plans of subcontractors. The lower-level plans often confirm the robustness of the higher-level plans. (Winch & Kelsey 2005) The most important use of schedules is project control, which includes comparison of actual project performance with the baseline and discernment of any deviation. Using schedules as an effective tool requires a serious commitment from the project management to adopt and use the schedule throughout the project. (Mubarak 2010) Changes are the main causes for delays and cost overruns in construction projects, where they are also very common issues (Assaf & Al-Hejji 2006). As plenty of changes are anticipated due to the upcoming events in project execution, flexibility of the schedules is required instead of pre-determined actions (Alsakini et al. 2004).

Advanced systems are needed for project planning, scheduling, and control in order to overcome the issues caused by the nature of projects and present project environment. Schedule management system has to be based on progressive elaboration of schedules during project execution, because it is the only way to simultaneously achieve the required level of detail and the certainty of schedules. Performing continuous detailed scheduling, the representation of the work ahead becomes better, which changes the focus of project management from the past to the work to be done. In addition, it allows incorporating the upcoming events and acting proactively to their effects in advance. (Laufer et al. 1992; Alsakini et al. 2004) There are certain requirements for advanced systems which distinguish them fundamentally from the traditional approach of project management. The requirements for advanced systems are presented and compared with traditional project management in Table 2.

Table 2 *The requirements for advanced systems and comparison with traditional project management.*

	Traditional project management	Advanced systems
Approach to scheduling	Aggressive	Progressive
Scheduling	In the planning phase	In the planning and execution phases
Detailed scheduling	At the project initiation	Continuous
Development of schedules	By the project team	On different levels
Uncertainty of schedules	Higher	Lower
Scheduling and control processes	Discrete	Integrated
Focus in control	Work completed	Work ahead
Approach to changes	Reactive	Proactive
Action on deviations	Corrective	Preventive

3. RESEARCH METHOD AND MATERIAL

The research method and material chapter consists of three sub-chapters. In the first sub-chapter, the research environment is described, including information of the company, business, and project management organization. In the second sub-chapter, the research method is presented from the chosen research strategy to the arrangements in practice. In the last sub-chapter, the research material is presented with the basic information of the projects.

3.1. Research environment

The research was conducted in Wärtsilä Finland Oy, which is the local company of Wärtsilä Corporation in Finland. Wärtsilä's mission is to "provide lifecycle power solutions to enhance the business of its customers, while creating better technologies that benefit both the customers and the environment". Wärtsilä's vision is to "be the most valued business partner of all its customers". The company values are energy – capture opportunities and make things happen; excellence – do things better than anyone else in our industry; and excitement – foster openness, respect and trust to create excitement. Wärtsilä has divided its business into three divisions: Ship Power, Power Plants, and Services. Ship Power focuses on ship power systems including main and auxiliary engines, propulsion, automation, and power solutions. Power Plants supplies flexible power plants for the distributed power generation market including solutions for base-load, grid stability and peaking, industrial self-generation, and other oil, dual-fuel and gas fired power plants. Services provides operation and maintenance to the customers of other businesses and also directly to the market in the industries. (Wärtsilä 2011)

Wärtsilä's net sales were 4,553 million EUR and profit before taxes was 548 million EUR in 2010. Order intake was 4,005 million EUR in 2010 and order book at the end of 2010 was 3,795 million EUR. Wärtsilä Corporation is listed on the NASDAQ OMX Helsinki, Finland. Net sales by business in 2010 were: Ship Power 26 %, Power Plants 34 %, and Services 40 %. Globally, Wärtsilä has delivered 4,500 power plants in 168 countries with generating capacity totalling more than 47 GW. Wärtsilä has almost 18,000 employees and operations in 160 locations of 70 countries around the world. (Wärtsilä 2011)

The research was carried out in the Power Plants business, and more specifically, in its project management office (PMO). Power Plants' own mission is to "provide superior value to its customers with flexible, efficient and environmentally advanced energy solutions, which enable transition to more sustainable and modern energy infrastructure”. Power Plants is a major supplier of flexible base-load power plants operating on various liquid and gaseous fuels. Power Plants provides unique, dynamic solutions for grid stability, reserve, peaking, load following, and intermittent power generation, as well as, multi-fuel solutions to the oil and gas industry for reliable power generation, pumping, and compression. All applications are supported by tailored lifetime operation and maintenance services. Power Plants offers flexibility both in products and services to meet the customer requirements and expectations. Customer support includes services for project development, financing support, and carbon finance expertise. Project management services are offered for global EPC delivery of modular pre-fabricated power plant product with minimized site work, scope of supply flexibility, and short delivery time. Global service support includes local service outlets, long-term operation and/or maintenance agreements, technical support, field service, and spare parts. (Wärtsilä 2011)

There are some fundamental trends and drivers in the global energy market which have direct effects on the Power Plants business. Electricity demand is continuously growing due to electrification, GDP (gross domestic product) growth, and increasing standard of living. Climate change requires search for sustainability. Renewable energy generation is rapidly growing, in which politics and subsidies have also a big role. Need for flexibility is increasing because of daily, weekly and seasonal fluctuation in demand, and rapid introduction of intermittent wind and solar energy. Also, the roles of fuels are changing, which makes new coal power plants difficult to permit, nuclear energy to grow, and gas to become an intermittent and balancing fuel. (Wärtsilä 2011)

There is a global improvement program and strategic initiative, called Gateway, to ensure consistent project management in Wärtsilä. The objective is to develop and implement a set of consistent project management processes and a supporting tool to enable project personnel to plan and monitor projects, programs and portfolios more effectively and in line with the international project management standards. The new processes and the supporting tool will be taken into use in all project categories and by all people dealing with project management. Gateway started with a pilot verifying that the needed functionalities are supported in the selected software. Since February 2010, the pilot has been in use of selected users. In September 2010, the deliverables of the pilot were approved and the full roll-out was initiated. (Wärtsilä 2011)

Project management of customer-delivery projects in Power Plants is organized in four geographical areas: Africa, Americas, Europe, and Middle East and Asia. There is also one area for the oil and gas industry, and nuclear projects. In addition, project management office (PMO) and engineering management office (EMO) belong to the project management organization. The PMO is responsible for developing the project management excellence within the business. The role of PMO is defined as: “to coach and support other functions within the business in the development of the capability to implement projects in order to achieve their organizational goals by applying company's project management methodology". The development areas of PMO are: processes, tools, and people. The PMO organization includes a pool of project controllers, where from they are assigned to projects. This enables close interaction with the project teams and facilitates organizational integration. (Wärtsilä 2011)

New projects are first handled by the sales function, which is responsible for business development and contract negotiations with the customer. At this stage, the project management function supports sales in project management related issues. Other functions are also involved, for example technology, if the project has special requirements. When the contract is signed, the project management function takes over the project and the delivery process begins. Customer delivery projects are usually managed by a project team (see Figure 11), which comprises project manager, project controller, and chief project engineers (CPE). Project manager and CPEs of mechanical and electrical disciplines form the core team that works always together. Project controller and other required people, such as CPE of civil discipline and project engineers, are assigned to the project from pools.

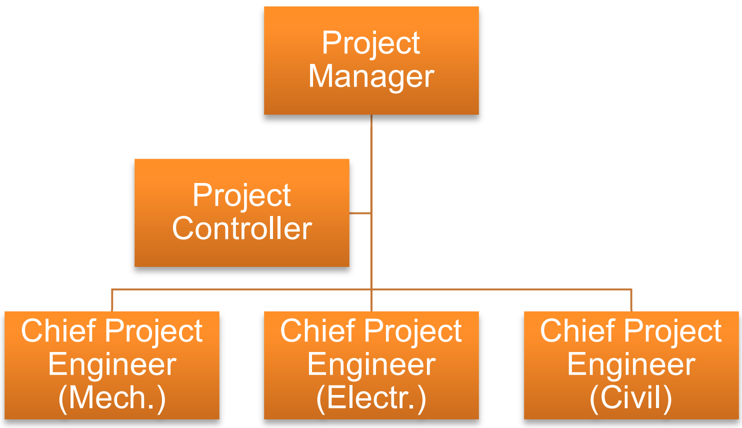

Figure 11 *Organization chart of a project team.*

Site team is assigned to the project by the installation and construction services function before site works begin. The site team is responsible for installation and construction at site, while the project team remains responsible for the entire project. Site works are usually managed by a site team (see Figure 12), which comprises site manager, site engineer, section managers, and supervisors. Site manager and site engineer are assigned to the project from pools, but section managers and supervisors are mostly consultants and freelancers. The composition of and the work distribution within the site team varies based on the project scope, size, and other requirements.

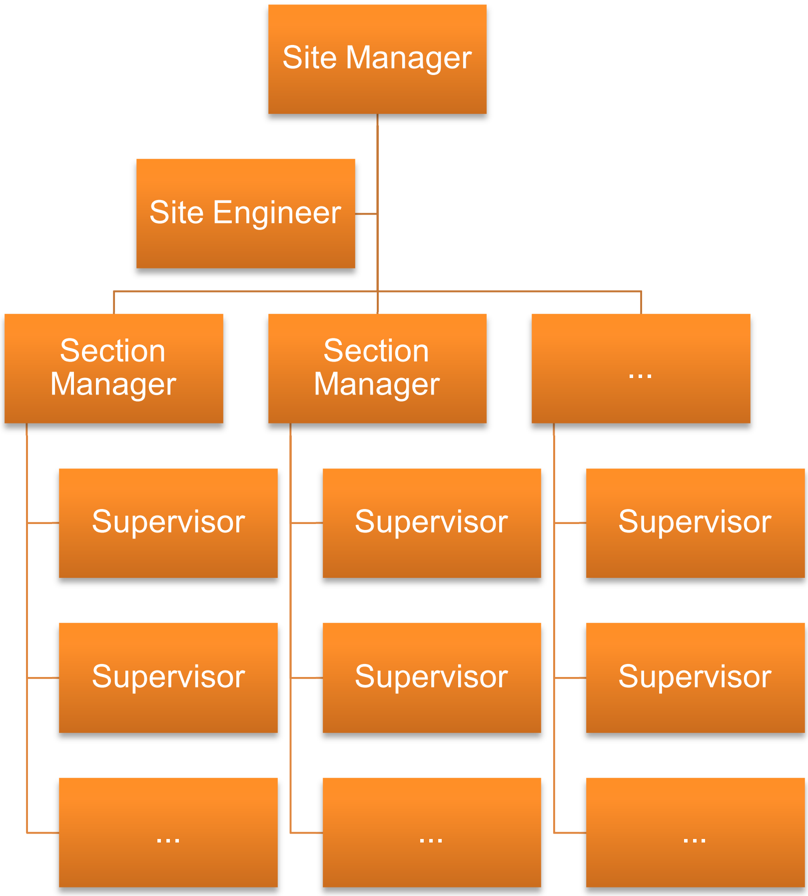

***Figure 12** Organization chart of a site team.*

3.2. Research method

The research strategy is embedded case study, because it is the most suitable one, considering the objectives and set up of the research. Case study is defined, according to Robson (2011), as: "a strategy for doing research, which involves an empirical investigation of a particular contemporary phenomenon within its real-life context using multiple sources of evidence". Case study provides the required intensity of analysis and is an appropriate approach to investigate the scheduling practice in projects. The research includes multiple cases within the organization to enable generalization from the results. (Yin 2008) The sample is selected purposively, because it serves the best answering to the research questions and accomplishing the objectives. This type of sample is often used in case study research, especially, when it is preferred to select cases that are particularly informative (Neuman 2009). More specifically, the sampling strategy is heterogeneous, because it enables collecting data to describe and explain the key themes that can be observed. Although, this may create a contradiction, as a small sample may contain cases that are completely different from each other, Patton (2001) argues that this is in fact a methodological strength. Any patterns that do emerge are likely to be of particular interest and represent the key themes.

The research material is mainly collected in semi-structured interviews. In addition, available documents from the projects are analyzed, in order to provide context and required information for the analysis of the interviews. The research approach is multi-method, because only qualitative data collection techniques and analysis procedures are used. Collection of quantitative data is not reasonable, considering the research material and the objectives of the research. The time horizon is cross-sectional, which gives a static illustration on a certain moment of time. Longitudinal research is also found interesting, but it is not possible within the available time frame. (Saunders et al. 2009) The research material consists of seven EPC projects, which were chosen to represent the current best practice in the company. The selection of projects was done on the basis of proposals by the project management area directors. They were requested to name one or two projects within their area, which appeared to be the most suitable for the research. Also, a short description, why the project is of particular interest, was requested. Decision of the projects to be included in the research was made based on their availability and suitability.

The primary data were collected in semi-structured interviews, which are non-standardized and often referred to as “qualitative research interviews” (King 2004). Semi-structured interviews are suitable for case study research, because the gathered data is normally analyzed qualitatively (Saunders et al. 2009). From every selected project, the project manager and the project controller were interviewed. These interviews were supplemented by interviewing representatives from site management, program management, and the Gateway-team concentrating on project scheduling development in the company. A total of 17 interviews were conducted (see Appendix 1): 10 related to project teams, three to site management, one to program management, and three to the Gateway-team.

A list of themes was used to provide a standardized structure for all interviews. The list of themes was developed on the basis of the literature review for this research to cover the essential dimensions of schedule management system. The themes were (see Appendix 2 for more details): schedule development process, schedule control process, and perceived importance of schedule. In addition, respondent’s background and project overview were used as the opening and other issues as the closing of the interview. Issues and aspects within the themes varied according to the function represented by the respondent. The list of themes was sent to the respondents in advance to allow them to prepare themselves for the interviews. A more detailed interview guide (see Appendix

2) was developed for the researcher’s own use. The interviews were conducted on a one-to-one basis, and meetings in company conference rooms were set up to enable face-to-face contact in a comfortable and peaceful environment. The conversations were not recorded, but the researcher took notes on laptop during the interviews.

The secondary data were used to provide background and context for the interviews, and required information for the analysis. Secondary data is frequently used as part of case study research (Saunders et al. 2009). The secondary data included available documents, such as project charters, project plans, and project schedules, as well as, records of changes, delays and their causes from the projects. The documents were either accessed in the company databases or requested from the project team.

The collected data were processed according to template analysis procedure (King 2004). The analysis is based on a template, which is essentially a list of the codes or categories that represent the themes revealed from the collected data (Saunders et al. 2009). The codes were pre-determined based on the literature review, but they were revised during the process to facilitate data display and analysis. The data were coded and analyzed to identify and explore similarities and differences between the selected projects. Other issues brought up by the respondents were analyzed separately to identify the most frequent themes for each group of respondents and all together.

3.3. Research material

The research material consists of seven EPC projects, which were chosen to represent the current best practice of project scheduling in the company. Therefore, the projects do not illustrate the whole range of current practices. However, the projects are good examples of complex EPC projects delivered by the company and of more advanced project scheduling in the company at the moment. The projects illustrate well the level of practice in project scheduling, in order to identify improvement needs and get insight of project scheduling in practice. The basic information of the projects is presented in Table 3. Six projects were traditional EPC projects, and one project was of EEQ (engineered equipment delivery) type complemented with CMA (construction management agreement), which together make the project equivalent to the EPC projects. Total output in the projects ranged from 16 MW to 380 MW. The Suape II project was on the largest power plant the company has ever delivered. Three projects were delivered in the Africa, two projects in the Americas, and two projects in the Middle East and Asia areas. Delivery time of the projects ranged from 13 to 25 months. Five projects were on-going and two projects were already handed over at the time of the interviews. Four projects were on schedule and two projects were delayed – one due to difficult climatic conditions and the other due to multiple change orders initiated by the customer and permitting related issues. In addition, one project was on-hold until further notice to proceed due to customer payments.

Table 3 *The basic information of the projects.*

	Ewekoro	Hera	Humboldt	Kribi
Type of project	EPC	EEQ + CMA	EPC	EPC
Total output	100 MW	120 MW	166 MW	216 MW
No. of engines	6	7	10	13
Fuel type	Gas, HFO, LFO	HFO	Gas, HFO, LFO	Gas, LFO
Country	Nigeria	East Timor	USA	Cameroon
Delivery time	25 months	14,5 months	22 months	24 months
Status	On-going	On-going	Handed over	On-going

	Liberty	Suape II	Victoria C Extension
Type of project	EPC	EPC	EPC
Total output	200 MW	380 MW	16 MW
No. of engines	11	17	2
Fuel type	HFO	HFO	HFO
Country	Pakistan	Brazil	Seychelles
Delivery time	22 months	18,5 months	13 months
Status	Handed over	On-going	On-going

4. RESULTS

The results chapter consists of six sub-chapters. In the first four sub-chapters, the results from the projects are presented, regarding to the themes discussed in the interviews. The results are presented on a cross-case basis showing the similarities and differences between the projects. In addition, advanced practices and unique ways of working are emphasized. The results are presented in more detail in Appendix 3. In the fifth sub-chapter, the results from the other issues, which are considered as expectations for schedule management system, are presented. In the last sub-chapter, the results are evaluated, including error sources, deviations from the anticipated results, and reliability of the results.

4.1. Project complexity

Before the first actual theme, the respondents were asked to provide an overview of their project. An essential part of the overview was the assessed level of complexity of the project, and the identified factors contributing to it. The results for project complexity are presented in Table 4. Five projects were assessed to be highly complex mainly due to customer requirements in scheduling, progress follow-up, and reporting. Other major issues increasing project complexity were: project size, technical issues, short delivery time, and country related issues. Project complexity was assessed to be average in one project, and low in one project. These were more standard projects with no identified specific challenges. However, also the standard projects delivered by the company may be defined as complex projects.

Table 4 *The results for project complexity.*

	Ewekoro	Hera	Humboldt	Kribi
Level of complexity	High	Average	High	High
Factors of complexity	Customer requirements, country	New type of contract	Customer requirements, regulations, site location	Customer requirements, HSE related issues
Unique	First EPC project in the country	First CMA contract	Project team also in the local office, scheduler	Site team

	Liberty	Suape II	Victoria C Extension
Level of complexity	High	High	Low
Factors of complexity	Project size, technical issues, short delivery time, country	Project size, customer requirements	None
Unique	Steam turbine	Largest project ever delivered	None

Unique features of the projects included various technical, organizational, and project management related issues. The Suape II project is the largest project ever delivered by the company, which causes several challenges in almost every area, not least in project scheduling and control. The Hera project is unique because of the contractual setting. It is the first project delivered on a construction management basis, instead of traditional EPC delivery. The Humboldt project is managed by two project teams, one in the head office, and one in the local office. The idea is that the project team in the head office is in charge of the entire project, and the project team in the local office provides support in certain issues, such as regulations, and subcontracting. The site team including construction manager and site manager without site engineer is unique in the Kribi project. The construction manager concentrates more on project management, including interaction with the project team, while the site manager is able to concentrate more on coordinating the work at site. The set up has proven to be effective, and therefore, will be used in future projects.

4.2. Schedule development process

The first theme covered the schedule development process in the projects. The results for schedule development process are presented in Table 5. Activities were mostly defined by expert judgement based on project team experience and scope of supply. In addition, technical specification was mentioned in two projects. In the Humboldt project, the subcontractor was responsible for the whole scheduling process for site activities. Rolling wave planning (PMI 2008) was not utilized in any project as a planning technique, but in four projects, some activities were first planned on high level and then in more detail before executing them. Most frequently, the technique was applied to site activities, which were planned on high level in the project schedule and then elaborated in the project schedule or in a separate site schedule. In the Suape II project, it was noted that rolling wave planning was not suitable because of the customer demand for a complete project schedule in the sales phase. Templates were randomly used; only in one project an old project schedule of similar project was used. The WBS-tool, which was recently developed in the company for creating activities according to activity-based management (ABM) methodology, was used only in the Victoria C Extension project. In the other projects, no tools were used in activity definition. In general, activity definition was not found especially challenging, as it is always done based on the scope of supply. Site activities caused more trouble for the project teams, which had not much experience of site work.

Table 5 *The results for schedule development process.*

	Ewekoro	Hera	Humboldt	Kribi
Activity definition	By expert judgement	By expert judgement	By expert judgement / subcontr.	By expert judgement
Activity sequence	By expert judgement	By expert judgement	By expert judgement / subcontr.	By expert judgement
Activity resources	No	No	Subcontr. resources	No
Activity durations	By expert judgement	By expert judgement	By expert judgement / subcontr.	By expert judgement
Project schedules	Off-shore / on-shore	Master / equipment supply / construction	Master / site	Master
Scheduling in different project phases	Off-shore at initiation / on-shore before start at site	Master at initiation / equipment supply before start / construction before start at site	Master at initiation / site before start (later only updated schedule)	Master at initiation, elaboration in planning phase
Responsible	Project manager / site manager	Project manager / site manager	Project manager, project controller / subcontr.	Project manager, project controller, construction manager

	Liberty	Suape II	Victoria C Extension
Activity definition	By expert judgement	By expert judgement	With WBS-tool
Activity sequence	By expert judgement	By expert judgement	By expert judgement / subcontr.
Activity resources	No	No	Subcontr. resources
Activity durations	By expert judgement, suppliers	By expert judgement	By expert judgement / subcontr.
Project schedules	Master / site / commiss.	Master	Master / site (sub-project)
Scheduling in different project phases	Preliminary schedule in sales phase / master at initiation / site and commiss. before start	Master at initiation	Master at initiation / site before start
Responsible	Project manager / site manager / commiss. manager	Project controller	Project manager, project controller

Defined activities were sequenced by expert judgement based on project team experience and logic in all projects. Site activities were sequenced by the subcontractor in two projects. In the Humboldt project, the subcontractor was responsible for the site schedule, and in the Victoria C Extension project, the subcontractor determined the dependencies between already created activities according to the preferred work order and available resources. In general, it was not found difficult to determine the dependencies between project activities, as they are mainly logical and same in every project. Problems occurred usually with site activities, where the dependencies are not always clear, and the project team may not have sufficient experience.

Resources for activities were estimated in two projects, and this was only for site activities. In the Humboldt project, the site schedule was developed by the subcontractor and it included detailed estimates for resources that were also assigned to the activities. In the Victoria C Extension project, the subcontractor estimated the required resources to perform the site activities within the available time frame, but the resources were not assigned to individual activities. In general, resourcing was not found necessary for project activities, but the benefits of including resources for site activities were widely acknowledged. Resource allocation and levelling may be problematic because of the high level of subcontracted activities.

Durations of activities were estimated by expert judgement based on project team experience and gathered information in all projects. Durations of site activities were estimated by the subcontractor in two projects. In the Humboldt project, the subcontractor was responsible for the site schedule, and in the Victoria C Extension project, the subcontractor estimated activity durations on the basis of the required work effort and available resources. In most projects, the person responsible for developing the project schedule collected the estimated delivery times from chief project engineers (CPE), who had requested them from suppliers, and requested estimates from the engineering partner, and other functions. For example, in the Liberty project, the supplier of the steam turbine was consulted for an estimate for installation activities, of which the project team had no previous experience. In general, the estimation of durations for site activities was found particularly difficult, if it was not possible to involve the site team to the process.

The scheduling method was critical path method (CPM) in all projects, but there were serious problems in using the method effectively. The main problem was the missing dependencies between activities, which makes identification of the critical path impossible, or results in showing an incorrect path. In general, the importance of identifying the critical path and managing the critical activities on the path were widely acknowledged, but the determination of all dependencies between the activities was found difficult and time-consuming. Contingency was reserved to the schedules in four projects. A buffer was added to the end in two projects to allow some delay from the targeted completion date. A buffer or several buffers were added between activities in two projects to protect the critical path and the completion date of the entire project.

The number of schedules developed for the project and how the work was divided between them were varied. In two projects, there was only one project schedule that contained all project and site activities. In three projects, there were two project schedules. There were master and site schedules in two projects, and off-shore and on-shore schedules in the Ewekoro project. In the other two projects, there were three project schedules. The Hera project had a master schedule for the entire project, an equipment supply schedule, and a construction schedule. The division reflected the contractual setting of the project. In the Liberty project, there were master, site, and commissioning schedules. The schedules were developed as separate documents in all projects, except for the Victoria C Extension project, where the site schedule was developed as sub-project in the master schedule. This allowed having the site activities in a separate document, which helped the management at site, and still all activities were found in one schedule. The master schedule was developed at initiation in all projects. Usually, only additions and corrections were made to the master schedule after developing it. Other schedules, such as site schedule, and commissioning schedule, were developed one to two months before starting to execute the activities included in that particular schedule. In the Liberty project, a preliminary schedule outlining the entire project was developed in the sales phase to ensure that the project is executable within the agreed time frame.

Project management activities were rarely defined and planned in the project schedules. In few projects, some of the project management activities, such as subcontracting, were included. The reason for ignoring project management activities, while developing project schedules, was usually that they were found unnecessary and difficult to plan. In experienced project teams, the things that needed to be done were taken care of without planning them in the project schedules. Project management activities caused trouble in choosing the correct level of planning, as breaking them down in a reasonable manner, and determining the exact start and finish dates for each of them may be difficult. Instead of planning, for example, procurement activities in the project schedules, there were several different ways in the project teams to keep track on things to be done. The persons responsible for certain activities had usually a check list in some form to help organization of their own work. An evident problem in using separate documents was that their information is sometimes out-of-date and other members of the team do not have access to them.

The scheduling tool was Microsoft Project in all projects. In addition, Primavera was used in the Humboldt project by the subcontractor. The site schedule, which was developed, updated, and followed up in Primavera, was exported to Microsoft Project, where it was combined with the master schedule. This proved to be difficult and it was stopped when practically all remaining activities were in the site schedule, which then became the only updated schedule for the project. In general, Microsoft Project was found to be an efficient and easy-to-use tool for scheduling projects. However, the competence required to use the software, especially the more advanced features of it, was found to prevent from gaining the full advantage of the software.

The persons responsible for developing the project schedules were the project manager and the site manager in most projects. The project manager gathered the required information and developed the schedule for the project in collaboration with the project team. The site manager, in turn, developed the schedule for site activities according to the project schedule in collaboration with the subcontractors. The role of the project controller in the schedule development process varied significantly in the projects. In the Suape II project, the project controller was mainly responsible for developing the project schedule. In three other projects, the project controller was partially responsible for the project schedule. The commissioning manager developed the schedule for commissioning activities in the projects, where it was possible to be involved. The roles of the team members in the schedule development process usually reflected their individual interests and competences.

4.3. Schedule control process

The second theme covered the schedule control process in the projects. The results for schedule control process are presented in Table 6. Project schedules were updated at least once a month in all projects. Updates were also more frequent if necessary. Project schedules were updated once in two weeks in two projects, and once a week in the Suape II project. In general, project schedules were updated more seldom than site schedules that were usually updated every week in the site meetings. Updating a schedule included: collecting the required information, determining progress for each activity, and updating the progress to the schedule. However, project schedules were rarely updated, even if the work was not progressing as planned, or changes occurred during execution, meaning that the remaining activities were usually not re-scheduled. The main reason was the required effort to update the schedule, which ensues from not developing the schedule to be dynamic.

Table 6 *The results for schedule control process.*

	Ewekoro	Hera	Humboldt	Kribi
Schedule updating	Once a week or in two weeks	Once a month / once a week at site	Once a month	Once a month
Progress measurement	With detailed customer templates, completed activities	In project schedules, estimated activity progress	With templates, estimated activity progress	With templates, estimated activity progress
Project performance measurement	EVA	EVA	EVA	EVA
Project performance reporting	Monthly to customer	Monthly to customer	Monthly to customer and authorities	Monthly to customer
Use of schedule in change management	No change orders	Change order from customer to come, effects on schedule	Plenty of change orders from customer and subcontr., effects on schedule	No change orders
Use of schedule in claim management	No claims	No claims	Schedule used to indicate reasons for delays	No claims
Responsible	Project manager / site engineer	Project controller / site engineer	Project controller / site engineer	Project controller, construction manager, site manager

	Liberty	Suape II	Victoria C Extension
Schedule updating	Once a month / once a week at site	Once a week	Once in two weeks / once a week at site
Progress measurement	In project schedules, estimated activity progress	With detailed templates, completed activities	With templates, completed activities
Project performance measurement	EVA	EVA	EVA
Project performance reporting	Monthly to customer	Weekly and monthly to customer	Monthly to customer
Use of schedule in change management	No change orders	No change orders	No change orders
Use of schedule in claim management	Schedule used to indicate reasons for delays	No claims	No claims
Responsible	Project controller / site engineer	Project controller, site engineer	Project controller / site manager

Progress was measured in all projects either in project schedules or with templates. In two projects, progress was measured in the project schedules, meaning that the estimated progress for each activity was updated directly to the schedule to determine progress for the entire project. In five projects, progress was measured with templates. The progress for each activity was updated to the template, which then calculated progress for the entire project. In two projects, the templates were significantly more detailed than in the other projects. In the Ewekoro project, the templates were received from the customer, and in the Suape II project, the templates were developed by the site team.

Activity progress was followed up based on physical progress in all projects. Progress follow-up was always more detailed for site activities than project activities. It was always the person responsible for controlling the project schedule, who estimated the progress for the project activities using expert judgement. Progress follow-up with suppliers was not systematic in any project. Progress for the site activities was usually estimated by the subcontractors or the site team based on expert judgement, which was sometimes backed up with suitable data, for example, installed piping in meters vs. all piping to be installed. Instead of generating a random number, progress for the activities was usually selected from pre-determined levels, such as zero, 25, 50, 75, and 100 percent, or estimated "as planned", if no deviations had occurred. In three projects, progress for the site activities was determined based on, whether the activity was completed or not, and the information was updated to the template. Then, activity progress was aggregated in the template up to the level used in the site schedule, and the progress was updated to the schedule accordingly. This required breaking down the site activities into smaller work packages than in the site schedule. Progress follow-up for the site activities was done on an extremely detailed level in the Ewekoro and Suape II projects. Activities were weighted for tracking progress based on budgeted cost in five projects, and work effort in two projects. Work effort in man-hours was preferred for site activities, because it was found to correspond better with the portion in each activity of the work to be performed than the budgeted cost.

Project performance was measured with earned value analysis (EVA) in all projects. The analysis included calculating the earned value that is the value of work performed, and the actual cost that is the total cost actually incurred. The parameters were usually calculated separately for the different disciplines and the entire project. In addition, they were sometimes calculated for systems, sub-systems, subcontracts, and locations. The parameters were calculated and reported both periodically and cumulatively. S-curves were prepared to display the actual progress and to compare it with the baseline in all projects. The number of prepared s-curves and the level, on which they were displayed, varied between the projects. Schedule and cost variances and indices were not calculated in every project. Forecasts were made mainly in order to compare the actual progress with the baseline. In few projects, forecasting was also used to anticipate the effects of changes. When significant changes were made to the schedule, a new forecast was made to determine, if some actions were necessary to keep the project on schedule. In general, the planned progress for each activity was not found as important as the estimated completion date, because it defines when it is possible to start the following activities.

Project performance was reported monthly to the customer in all projects. In addition, a brief report was prepared weekly for the customer in the Suape II project. Project progress was reported also to the authorities in the Humboldt project. The project schedule was included to the monthly report in five projects. The site schedule was either delivered to the customer or gone through with the customer in the site meetings that took place once a week in three projects. In addition, every project team reported project performance to the management by using a common template.

Microsoft Project was used in progress follow-up in all projects. Microsoft Excel was used in EVA calculations and preparation of the s-curves, as it was found the easiest tool to get these things done. Activity progress was usually updated to the schedule in Microsoft Project, and then copied to Microsoft Excel to perform EVA calculations and prepare the s-curves for the project. In projects, where progress measurement was done with templates, Microsoft Excel was used differently as the progress follow-up was not done in the schedule. Progress for each activity was first determined and updated to the template. Then, activity progress was aggregated in the template up to the level used in the site schedule if needed, and the progress was copied to Microsoft Project.

There were such change orders that had effects on schedule in two projects. In both projects, the change orders were initiated by the customer. In the other projects, there were no significant change orders neither from the customer nor the engineering partner. Schedule was used in the change management to assess the effects of changes on the schedule before accepting the change order. Schedule was found useful when discussing the requested change with the customer and explaining the possible extensions of time. This certainly required a complete and detailed schedule showing the critical path in order to detect at least the most of the emerging effects.

There were claims in two projects. In the other projects, claims were either not allowed in the contracts or there were no reason to issue claims. Schedule was used in claim management to indicate the reasons for delays, especially in commissioning, where the customer had certain responsibilities, such as providing fuel and grid connection. Schedule was found effective in illustrating the dependencies between activities, and the causes for delays. However, this required inclusion of the customer’s responsibilities to the schedule in some way, and also explicit presentation of the dependencies between them and the contractor’s activities.

The persons responsible for controlling the schedules were the project controller and the site engineer in most projects. The project controller gathered the required information and updated the schedule for the project in collaboration with the project team. The site engineer updated the schedule for site activities in collaboration with the section managers, supervisors, and subcontractors. Updating a schedule included: making required changes, correcting errors, and updating activity progress. The project controller was also responsible for preparation of the project reports. The roles of the team members in the schedule control process usually reflected their individual interests and competences.

4.4. Perceived importance of schedule

The third theme covered the perceived importance of schedule in the projects. The results for perceived importance of schedule are presented in Table 7. Project teams were highly focused on scheduling in all projects. The main reason for putting more effort on scheduling was the customer requirements in four projects. Another source of motivation was identified in three projects, where the goal was to have such scheduling and control processes that facilitate the management of the project. In the Victoria C Extension project, the project team piloted some new scheduling tools, such as the WBS-tool for site activities, and some scheduling practices, such as involving the subcontractor more intensively to the schedule development process.

***Table** 7 The results for perceived importance of schedule.*

	Ewekoro	Hera	Humboldt	Kribi
Focus on scheduling	High	High	High	High
Role of schedule	High	High	High	Average
Schedule as a roadmap	No	No	No	No

	Liberty	Suape II	Victoria C Extension
Focus on scheduling	High	High	High
Role of schedule	High	High	Average
Schedule as a roadmap	No	Yes	No

The role of schedule in project management was assessed to be high in five projects, and average in two projects. The essential role of schedule was shown in detailed schedules and progress follow-up, which were done to have a better and active control of the project. In two projects, the schedule was seen as the most important tool in the management during project execution. In the projects, where the role of schedule was assessed on average level, the project team did not see a need for detailed schedules and progress follow-up. A great example of how to use schedule in project management, was the Suape II project, where the project schedule was a common tool for the whole project team in regard to the management of the project from the start to finish. The schedule was first developed by the project team working together. The project controller was mainly the responsible person, but the schedule was developed in the project team meetings, where everyone had the opportunity to take part in the schedule development process. Subsequently, the schedule was updated in the project team meetings every week. Thus, the schedule was not forgotten once it was developed; instead, everyone in the project team understood the big picture, and the issues that came up were solved right away.

Schedule was seen as a roadmap for the project only in the Suape II project. In the other projects, the schedule was found to be a critical tool in four projects, and a reporting and control tool in two projects. In the Suape II project, the schedule was used to manage the entire project, which was shown in the essential role of schedule, as well as, in the effective and collaborative scheduling and control processes. In general, it was found that the processes and competence in the organization are not yet on the required level to allow using schedule as a roadmap for the project. However, the need and desire to use schedule more effectively in project management were strong.

4.5. Expectations for schedule management system

After the last actual theme, the respondents were asked to share their expectations for schedule management system, and to identify the critical improvement needs in the current practice of project scheduling in the company. The top ten issues brought up by all respondents are presented in Table 8. The results were also analyzed according to the positions of respondents. Thus, the respondents were divided into three groups: project teams of selected projects, other respondents, and all respondents. The project team group was sub-divided into project managers, and project controllers. The issues and differences between the groups of respondents are discussed in descending order. The results are presented in more detail in Appendix 4, where the top ten issues by each group are highlighted.

Table 8 *The top ten issues brought up by all respondents.*

Issues	Portion of all respondents (%)
It is really important to focus more on project scheduling, and it is good that the subject is studied	88 %
Scheduling should always be done based on the project-specific needs and customer requirements	71 %
There is a clear need for common practice in project scheduling	71 %
Project scheduling competence should be improved in the whole organization, including the understanding of importance	71 %
Large EPC and otherwise complex projects require much more effort in scheduling than standard projects	65 %
Concentrating more on scheduling is not possible in project teams without additional resources with specific competence	65 %
Scheduling should always be done on a correct level, which should be determined on the basis of the need for control	59 %
Understanding and commitment to the project schedule are results from involvement	47 %
Development of detailed project schedules takes time, but the effort is rewarded in an easier control of the project	41 %
The development in project scheduling has recently concentrated on reporting, and not on how to manage projects successfully by effective practices	41 %

Almost 90 percent of all respondents found that it is really important to focus more on project scheduling, and it is good that the subject is studied in the company. There were only small differences between the groups. Most of the respondents stated that scheduling is a critical area of project management, and it has not received enough attention in the organization, considering how relevant it is in the business. They also hoped that project scheduling will be developed based on the results of the research.

Over 70 percent of all respondents stated that scheduling should always be done based on the project-specific needs and customer requirements. The project teams felt more strongly this way than the other respondents. The idea is that scheduling should facilitate the management of the project, not to cause much unnecessary work. The customer requirements should be the only reason to exceed that level. The same portion of all respondents found that there is a clear need for common practice in project scheduling. There were no significant differences in these opinions between the groups. Most of the respondents felt that there are currently as many practices in project scheduling as there are project teams. Instead, there should be common guidelines, how to develop and control schedules in projects. The guidelines would help the project teams to concentrate on the project matters, and enable centralized development of the project scheduling practice in the company. The same portion of all respondents stated also that the project scheduling competence should be improved in the whole organization, including the understanding of importance. The other respondents felt somewhat more often this way than the project teams. The respondents found that the competence in scheduling methods and tools is not on adequate level, especially considering how relevant they are in the business. The competence was generally identified as one of the major challenges in developing the project scheduling practice. The understanding of importance was also brought up as a challenge, which is directly related to the competence issue, and therefore, should not be overlooked.

The portion of 65 percent of all respondents found that large EPC and otherwise complex projects require much more effort in scheduling than standard projects. The project teams were much more confident about this than the other respondents. Some of the respondents suggested that projects could be assessed at initiation, in order to determine the required level of effort in scheduling. In the most demanding projects, additional resources could be assigned to the project, which would not only improve scheduling, but also contribute to other areas of project management, as there would be more people to take care of the project matters. The same portion of all respondents stated that concentrating more on scheduling is not possible in project teams without additional resources with specific competence. There were only small differences in these opinions between the groups. Some of the respondents suggested that there could be a small group of project scheduling experts, who would be assigned to the most demanding projects to concentrate entirely on scheduling. They could also provide support to the other project teams in scheduling related issues.

Almost 60 percent of all respondents found that scheduling should always be done on a correct level, which should be determined on the basis of the need for control. The project managers felt more strongly this way than the other groups. The idea is that scheduling should provide the desired level of control to the management during project execution. The correct level varies according to the project-specific needs and requirements. The more accurate progress follow-up is desired, the more detailed schedule should be developed.

The portion of 47 percent of all respondents stated that understanding and commitment to the project schedule are results from involvement. The other respondents were much more confident about this than the project teams. The respondents found that the other functions and subcontractors may have valuable inputs to the schedule, and they would be much more committed to, it if they had a chance to participate in the schedule development process.

Over 40 percent of all respondents found that development of detailed project schedules takes time, but the effort is rewarded in an easier control of the project. The project teams felt more strongly this way than the other respondents. The idea is that the required time to develop a complete and detailed schedule for the project should be somehow arranged because it always pays off later. If a schedule is not properly developed, controlling the project with it will not be effective. The same portion of all respondents stated that the development in project scheduling has recently concentrated on reporting, and not on how to manage projects successfully by effective practices. There were only small differences in this issue between the groups. The respondents felt that the development has currently caused extra work without any additional value for them. They hoped that project scheduling will also be developed from their point of view in the future.

4.6. Evaluation of the results

The results are reliable enough to make conclusions considering the objectives of the research. Of course, the selection of projects and respondents may affect the results. The projects were chosen to represent the current best practice of project scheduling in the company. Therefore, the results do not illustrate the whole range of current practices. However, the results provide an empirically grounded basis for identification of the critical improvement needs, and development of a schedule management system to address the specific needs of the business. The evident themes of the results combined with the number of respondents generate confidence in the results.

There are only minor sources of error in regard to the results. In all projects, the project manager and the project controller were interviewed to have at least two respondents from each project. Thus, the material concerning the projects was collected from two individual sources, and later combined in the analysis, in order to decrease the probability of errors due to misunderstanding or obliviousness. There were no significant deviations or conflicts between the responses of respondents from the same project. In addition, it is always possible that the researcher understands the respondent incorrect, makes an error while taking notes, misreads the notes while processing the material, or misinterprets the collected material. However, the probability and the impact on the results of such errors are relatively low.

The results are rather close to the anticipated results. There were similarities between the projects, which indicate that some common practices could be found. On the other hand, the significant differences detected between the projects proved that scheduling, in fact, is done differently in each and every project team. The processes, methods, and tools of project scheduling and of schedule control presented in the literature review were not used distinctly in any project. This was anticipated as typical of the current practices. The amount of ideas and thoughts the respondents had about project scheduling, and how to develop it, exceeded the expected level. However, the issues brought up by the respondents were parallel to the anticipated results.

5. DISCUSSION

The discussion chapter consists of three sub-chapters. In the first sub-chapter, the proposal for a schedule management system is presented. In addition, the benefits of the proposed model are illustrated and an implementation plan is provided. In the second sub-chapter, the results are assessed to determine, whether they correspond with the objectives and the thesis answers to the research questions set in the beginning of the research. In the last sub-chapter, the scientific and practical significance of the results is assessed.

5.1. Proposal for schedule management system

A schedule management system is proposed based on the literature review and the results of the study. The available concepts in project scheduling, especially regarding to schedule management systems, provide a basis for the model. The results from the projects were used to identify good practices, improvement needs, and possible solutions. The results from the other issues are considered as expectations for the schedule management system to focus on the critical areas and provide valuable solutions. The proposed schedule management system is built up on progressive elaboration, meaning that rolling wave planning (PMI 2008) is utilized in the scheduling process from the initiation to the closing of a project. The proposed system is presented in two views: schedule hierarchy, and system model.

5.1.1. Schedule hierarchy

The proposed schedule hierarchy provides schedules for different purposes in different phases of a project. The hierarchy comprises four levels described as: milestone level, master level, coordinating level, and detailed level (Nicholas 2004; Winch & Kelsey 2005). Schedules in the hierarchy are named, respectively, as: preliminary schedule, master schedule, engineering and procurement (EP) schedule, construction and commissioning (CC) schedule, and detailed schedules. The level of detail and the number of schedules increase from the top to the bottom of the hierarchy. The schedules are developed at different stages of a project, as the work is executed. Consequently, activities are always scheduled on the level of detail, which is reasonable, considering the available information of the activities and the certainty at that moment. The proposed schedule hierarchy is presented in Figure 13.

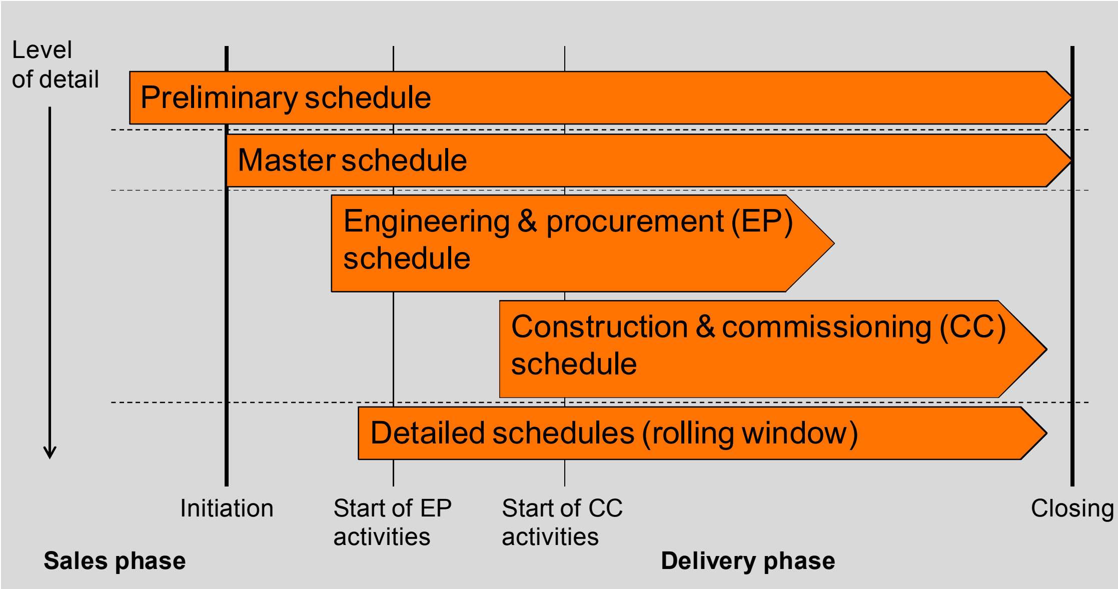

Figure 13 *The proposed schedule hierarchy.*

Schedules are developed on a hierarchical basis, and a schedule at a particular level of detail is expanded to more detail, when the execution of the work comes closer. The procedure has been suggested by Antill and Woodhead (1990), Nicholas (2004), and Sears et al. (2008). Thus, the amount of information on one schedule does not become overwhelming, but the required level of detail is achieved to enable effective control (Nicholas 2004; Mubarak 2010). The level of detail used in developing a schedule varies with the level of management, for which it is intended (Westney 1985). Traceability between the different levels is accomplished by the hierarchy, where all schedules are connected to other schedules, in order to maintain consistency throughout the scheduling process. High-level schedules incorporate many lower-level schedules and work plans, which ultimately confirm the robustness of the higher-level schedules. (Winch & Kelsey 2005)

On the top of the hierarchy is the preliminary schedule, which defines the intermediate deliverables to be produced in the project. It also specifies the sequence of states the project must go through, indicating what is to be achieved in each state, but not how it is to be achieved. The scope of a project is defined on this level of schedule hierarchy. (Turner 2008) The preliminary schedule is developed in the sales phase to outline schedule for the entire project from the initiation to the closing, and to ensure the project is executable within the agreed time frame. Consequently, the contractual delivery time is set with confidence in ability to deliver the promises. This provides also a good starting point for planning and scheduling the delivery phase. Development of a decent preliminary schedule requires dialogue and collaboration between the sales and the project management functions.

On the second level is the master schedule, which outlines the main work packages and presents the milestones. The master schedule indicates the project activities without too much detail. It is used for planning and reviewing the entire project. (Nicholas 2004) The master schedule is developed at the initiation of the delivery phase to present all the work in the project and the milestones on high level. The master schedule provides a compact overview of the work in a project, dependencies between the activities, and progress for the entire project. It is really important that the whole project team is involved to developing the master schedule, and the required information to identify all possible schedule constraints is requested and collected from the suppliers and other functions. Thus, the master schedule is developed on the basis of the best available knowledge, and everybody becomes committed to it (Walker 2007; Sears et al. 2008).

On the third level are the EP and CC schedules, in which the high-level activities are presented in more detail. This is done by breaking down the high-level activities into sub-activities. The schedules are used for planning and reviewing the work packages of certain type or performed by certain function. They are mainly used for planning resources. (Nicholas 2004) There can also be other coordinating schedules, for example, a shipment schedule. The schedules provide compact overviews of the engineering, procurement, construction, and commissioning activities in the project for easier management and communication. The EP schedule is developed well before starting the engineering and procurement activities. It is developed by the project team in collaboration with the engineering partner and other functions. The CC schedule is developed well before starting the construction activities at site. It is developed by the project team in collaboration with the site team, whenever it is possible to get them involved. Thus, the schedules are developed on the basis of the best available knowledge, and everybody becomes committed to them (Walker 2007; Sears et al. 2008).

On the bottom level are the detailed schedules, which present activities derived from the activities of coordinating schedules. The detailed schedules contain activities at the work package level, and they also include high-level milestones and activities from the master schedule, which are broken down into detailed ones. The detailed schedules are used for planning, scheduling, and controlling activities on a daily or weekly basis. Consequently, they enable focusing on the activities to be performed next and achieving the required level of detail for effective control. (Nicholas 2004; Mubarak 2010) There can be various detailed schedules, for example, engineering schedule, procurement schedule, shipment schedule, construction schedule, installation schedule, and commissioning schedule. The detailed schedules are developed by using the rolling window method (Alsakini et al. 2004), meaning that only those activities of the coordinating schedule, which are scheduled to be executed within a certain period of time, are scheduled in detail and included to that particular detailed schedule. The detailed schedules are developed by the project team and site team in collaboration with the engineering partner, suppliers, other functions, and subcontractors.

5.1.2. System model

The proposed system model provides integrated processes of scheduling and control, in order to enable active control of a project and to facilitate project management. The system comprises: schedule hierarchy, progress measurement, and performance measurement. Project activities are scheduled and controlled in the upper cycle of the system, and site activities are scheduled and controlled in more detail in the lower cycle of the system. The system has two feedback-loops: long for the project activities, and short for the site activities. They provide feedback to the scheduling process, including deviations, their causes, and other information relevant to scheduling the remaining work. The proposed system model is presented in Figure 14. The system is adapted to the project-specific needs and requirements based on project evaluation, which is performed at initiation.

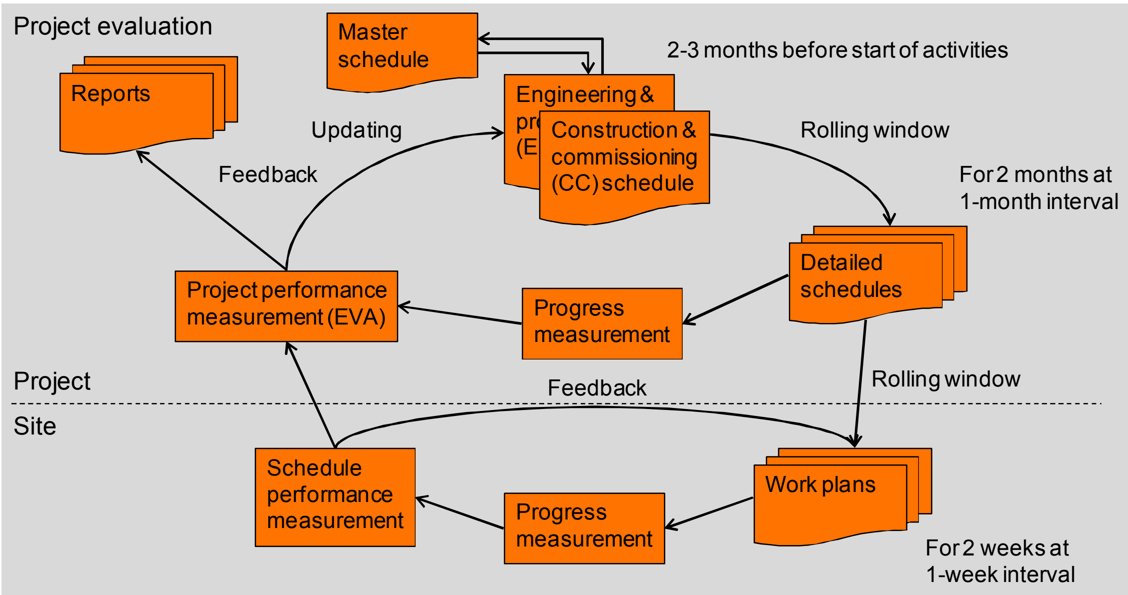

Figure 14 *The proposed system model.*

Schedule development is based on progressive elaboration and continuous detailed planning during project execution. The procedure has been suggested by Laufer et al. (1992) and Alsakini et al. (2004). Thus, the representation of the work ahead is better and the focus of project management changes from the past to the future. Planning is considered as a process and not as a discrete activity, and it is applied to the entire project from the initiation to the closing (Oberlender 2000). As any project schedule represents the best thinking at the time it is developed, and the need for change is inevitable as the work progresses, the schedules are continuously modified to reflect the progressive precise thinking of the project team (Sears et al. 2008).

Project evaluation is performed for each project at initiation to identify the project-specific needs and requirements. The more complex project, the more effort is required in planning, scheduling, and control of the project. The elements contributing to project complexity are identified with the TOE (technical, organizational, and environmental) framework (Bosch-Rekveldt et al. 2010). Then, a relative measure of project complexity is defined based on multi-criteria approach through the use of analytic hierarchy process (Vidal et al. 2010). The derived project complexity index (PCI) enables categorization of projects into standard, complex, and highly complex projects. The required effort, competence, and level of detail in project scheduling and schedule control are determined on the basis of the PCI. In addition, the project evaluation facilitates identification of the parts in the schedule, which require special attention.

The master schedule is on the highest level of schedule hierarchy, including only the schedules, which are updated during project execution. The master schedule outlines the main work packages and presents the milestones. It is developed at the initiation of the delivery phase. The EP and CC schedules are derived from the master schedule by breaking down the high-level activities into sub-activities. The EP schedule is developed two to three months before starting to execute the activities, or as early as possible, if the time is limited. The CC schedule is developed in a similar manner two to three months before starting to execute the activities at site. The detailed schedules are derived from the coordinating schedules by breaking down the intermediate-level activities into sub-activities. The detailed schedules are developed by using the rolling window method (Alsakini et al. 2004) for two months at one-month interval. The period of time is long enough to get prepared for performing the activities, but short enough to have reliable information for planning and scheduling the activities in detail. For the site activities, the system has a more detailed level, on which work plans are developed. The work plans are derived from the detailed schedules by breaking down the detailed-level activities into sub-activities. The work plans are also developed by using the rolling window method, but now for two weeks at one-week interval. The period of time is long enough to make adjustments to work order and resources, but short enough to have reliable information for planning and scheduling the site activities in detail. Every time a more detailed schedule is developed, the new schedule represents the revised baseline at that particular level of detail, while the original baseline is remained in the higher-level schedules. In addition, the higher-level schedules are also updated with the revised baseline.

Activities are defined progressively by expert judgement or with the WBS-tool developed in the company. The activities should have a standard format, which makes them unambiguous and enables collecting historical data. Activity-based management (ABM) methodology provides these characteristics, and therefore, it is recommended. The activities are given attributes, such as discipline, system, and location, to enable different views of the work breakdown structure (WBS), and to make management of the activities easier. Activities are sequenced by expert judgement or with design structure matrix (DSM), which could be useful for the most challenging cases. All logical dependencies between the activities should be determined. Resources for the activities are estimated, whenever suitable. The estimation of resources should be done carefully, especially for the site activities, and the subcontractors should be involved to the process. Durations of the activities are estimated as work effort in man-hours, whenever suitable. This applies especially to the detailed schedules and work plans. Of course, durations should be estimated as elapsed time for the activities that are not actual work, or the effort required to perform the activity is not relevant – for example, if the activity is performed by a supplier and the duration just represents the delivery time. It is recommended to utilize always the best available knowledge, while defining activities, determining dependencies, and estimating activity resources and durations. This means involvement of the whole project team to the scheduling process, including collaboration with the site team, engineering partner, suppliers, other functions, and subcontractors.

Progress measurement is done differently for the project activities and the site activities. Progress determined for the project activities is based on deviations. If there are no deviations, the progress is determined to be as planned. If any deviations have occurred, the progress is preferably calculated or estimated by using a suitable method (Construction Industry Institute 1987). It is recommended to have appropriate progress follow-up with the engineering partner and suppliers to avoid any surprises at the time of expected delivery. Focus should be on the estimated activity finish date, instead of the exact percent complete, which is practically almost irrelevant. Progress determined for the site activities is based on completion of the activities, meaning that the progress of each activity can only be either not started or completed. Obviously, this requires breaking down the site activities into sub-activities of relatively short duration. The procedure provides accurate progress information and eliminates the question about objectivity in the estimation process.

Performance measurement is done separately for the project activities and the site activities, and eventually for the entire project. For the project activities, both cost and schedule performance are measured once a month by utilizing earned value analysis (EVA). Budgeted cost is used as weighting factor for the project activities. Once the activity progress is determined, the actual progress is compared with the baseline. Cost and schedule indicators are calculated separately for engineering, procurement, shipments, and so on. The EVA data is displayed with s-curves against the baseline. For the site activities, only schedule performance is measured once a week. Work effort in man-hours is used as weighting factor for the site activities. Once the activity progress is determined, the actual progress is compared with the baseline to determine how the work is progressing at site. Schedule variance (SV) and schedule performance index (SPI) are calculated separately for all site work, disciplines, systems, and locations. The schedule performance data is displayed with s-curves against the baseline. Eventually, project performance is measured once a month by combining the produced data, calculating cost and schedule indicators for the entire project, and displaying the data with s-curves against the baseline.

Project performance reports are prepared as a tool for communicating the project information to the stakeholders. The reports are prepared monthly to provide an update on the progress of a project, and they contain: milestones achieved; planned and actual schedule overlays; change orders; encountered problems, their causes, and proposed actions; EVA results (required data and s-curves, variances, indices, and estimates at completion); and explanations of the changes and deviations in the values compared with the previous reporting period. The EP and CC schedules are updated with actual performance information, including the time of occurrence and the percentage of work completed. Then, the actual performance is reflected on the schedule and required changes to the remaining work are made. The master schedule is simultaneously updated to maintain consistency in the schedule hierarchy. The system has two feedback-loops: long for the project activities, and short for the site activities. They provide feedback to the scheduling process, including deviations, their causes, and other information relevant to scheduling the remaining work. The feedback-loop is one-month long for the project activities, and one-week long for the site activities. The feedback-loop is shorter for the site activities to achieve effective control of the site work, in order to increase efficiency and avoid problems.

5.1.3. Benefits of the model

The proposed model addresses the identified improvement needs and takes into account the expectations of the respondents. Project evaluation is performed at the initiation of the delivery phase to ensure that scheduling is done on the basis of project-specific needs, instead of only customer requirements. Of course, the customer requirements have to be acknowledged, but they should not be the driving factor when deciding, how scheduling is to be done in a project. The model can be used to harmonize the currently varied practice, targeting to creation of a common practice in project scheduling. A unified way of working would also facilitate further development in the field. The model is flexible, meaning that it can be adjusted to varying needs and requirements, which makes it suitable for large EPC and otherwise complex projects, as well as, standard projects. The level of detail, on which the activities are scheduled, can be determined on the basis of the desired level of control during project execution. Some of the activities may be scheduled on higher level and some in more detail, depending on the need for control. The model supports involvement of the site team, other functions, and subcontractors to the scheduling process, which leads to a stronger commitment of all of them to the schedule.

The proposed model has multiple benefits, which are achieved through the approach to project scheduling, and the integration of scheduling and control processes. Schedules are progressively elaborated during the project by utilizing rolling wave planning (PMI

2008). The technique moves detailed scheduling closer to the execution of activities, which decreases the uncertainty concerning the planned activities and makes them easier to plan (Laufer & Tucker 1988). It also distributes the scheduling effort from the planning phase to the execution phase, and supports collaboration in the scheduling process. Several schedules are developed, because schedules are needed for different purposes in different phases of a project. It is also difficult to present all activities and information in detail in one schedule (Nicholas 2004). The schedules are managed in the schedule hierarchy, which ensures traceability between the different levels, in order to maintain consistency throughout the scheduling process (Winch & Kelsey 2005). Progress measured at site is based on completion of the activities, which is not only the most objective method (Mubarak 2010), but it also provides the most accurate progress information (Globerson & Shtub 1995). Using the method requires dividing the work into relatively small work packages in the work plans. The smaller work packages lead also to more accurate resource and work effort estimates (Raz & Globerson 1998). As a result, greater precision is achieved in measuring performance, which leads to better control of the project. Process for schedule updating keeps all schedules up-to-date and ensures consistency in the schedule hierarchy. It also produces as-built schedules, which contain actual information of the activities, providing valuable feedback to the scheduling process (Mubarak 2010). Short feedback-loop for the site activities enables active control and early problem detection during execution. Any corrective and also preventive action can be taken immediately to minimize the effects on the schedule (Kartam 1996).

Some other issues regarding to the current practice of project scheduling need also to be acknowledged. Appropriate use of critical path method (CPM) requires determination of all logical dependencies between the activities. No single activity should be left without a predecessor and a successor, excluding the first and the last activity in a project. Determining all dependencies between the activities also makes the schedule dynamic, meaning that making changes in it becomes much easier. Ideally, no additional changes are needed, while making a change in the schedule. CPM is an effective method, which draws attention to management of the critical activities in a project. It should be used efficiently in all schedules. Contingency should be reserved to the schedules by adding buffers to protect the critical path and targeted completion date from delay. The buffers are added to the master schedule, and split to the EP and CC schedules according to the activity breakdown. The added buffers should be hidden and communicated only to a limited group of people. Project management activities should be included to the schedules, in order to plan and schedule also the work required to manage the project. The activities to be included and the level of detail should be determined on the basis of project-specific needs and requirements. Templates for repeatedly performed work packages could be developed to reduce the need for detailed scheduling (Phillips et al. 1999). Historical data could also be collected, especially for the site activities, to facilitate scheduling and improve accuracy (Gray & Larson 2008).

5.1.4. Implementation plan

The implementation of the proposed model is recommended to be conducted in two phases according to the following plan. In the first phase, the proposed model is piloted in few EPC projects, in order to verify its applicability and to illustrate the benefits of the model. Necessary modifications are made to the model based on the experiences and feedback from the piloting phase. The selected projects should be EPC projects, for which the model was developed, and they should preferably be at least average in size. The model should be utilized from the initiation to the closing of the projects. There should be a team, which is responsible for piloting the model. The team instructs the project teams to use the model in practice, and works in collaboration with them providing support and collecting feedback. Based on the experiences and feedback, the team develops the model further to better suit the specific needs and requirements of the business. The piloting phase takes roughly two years, considering the average delivery time of EPC projects.

In the second phase, the proposed model with necessary modifications from the piloting phase is prepared for full roll-out. The objective should be that the model is utilized in all EPC projects, as well as, other project types with narrower scope. This requires careful planning and appropriate training to all personnel working in the projects, either in the office or at site. The training should include hands-on exercises in addition to the fundamentals of theory. There should also be more advanced training targeted to the people in certain positions, such as project managers, project controllers, and site engineers. There should be a team, which is responsible for implementing the model. The team provides training and support to the project teams, and manages the implementation process. Collection of feedback should not be ignored either at this stage to enable further development of the model. The implementation phase takes two to three years, depending on the available resources.

5.2. Assessment of the results

The results correspond with the objectives set in the beginning of the research. The first objective related to the theoretical part and was defined as: “review literature to get an understanding of the essential concepts, methods, tools, and current research in project scheduling, especially regarding to schedule management systems”. Literature review was performed, where background and context for the subject was provided by discussing project business and complex projects. Thereafter, concepts, methods, and tools of project scheduling were presented and schedule management systems were introduced with two examples of recently developed system models. Only little literature was found, where schedule management systems were discussed in particular. However, the problems in the traditional approach of project scheduling, the need for advanced systems, and partial solutions were widely acknowledged. Consequently, the first objective is accomplished.

The second objective concerned the empirical part and was defined as: “study the current practice of project scheduling in the company and develop a schedule management system, which addresses the specific needs of the business”. The current practice of project scheduling in the company was studied through seven EPC projects to evaluate the level of current practice, and to identify good practices, improvement needs, and possible solutions. In addition, expectations for schedule management system were investigated. Based on the results, a proposal for schedule management system was presented, and the benefits of the proposed model were illustrated. Consequently, also the second objective is accomplished.

The thesis answers the research questions set in the beginning of the research. Based on the defined research problem, three research questions were generated. The first research question focused on the theoretical framework to enable further discussion of the subject.

1. What are the essential dimensions of schedule management system in complex projects?

The first research question is answered in the literature review, where the elements of project complexity, the structure of schedule management system, and the different approaches of project management are presented and discussed. The essential dimensions of schedule management system are highlighted in the synthesis. The second research question dealt with the current practice of project scheduling in the company. It also stated the need to identify the improvement needs and to evaluate their potential, in order to provide valuable recommendations.

2. How project schedules are currently managed and what are the improvement needs?

The second research question is answered in the results of the study, where the schedule development and control processes of the selected projects are presented. The improvement needs were identified based on the respondents’ own reflection, and the analysis of the results in the theoretical framework created in the literature review. The third research question expressed the intention to develop a proposal for schedule management system, which suits the business and its specific needs the best. It also included an illustration of the benefits of the proposed model.

3. What is the most suitable schedule management system in power plant projects?

The third research question is answered in the discussion, where the proposal for a new schedule management system is introduced. The improvement needs and respondents’ expectations, which the proposed model addresses, are discussed. The benefits of the proposed model are also illustrated. In addition, some other issues regarding to the current practice of project scheduling are brought up to facilitate development in the field.

5.3. Significance of the results

The results have moderate significance both scientifically and practically. The results from the projects are rather close to the anticipated results, and therefore, do not contain any big surprises. They confirm the assumption of varied practice in project scheduling, although, the projects were selected to represent the best practice in the company. The results indicated also multiple improvement needs, where developing the practice would lead to better performance. The results from the other issues are more significant, as they indicate a general opinion that it is really important to focus more on project scheduling, and there is a clear need for common practice. In addition, there are other issues, which provide valuable insight into the expectations. These issues have remarkable significance, as they were brought up by the professionals managing the current projects.

The proposed model does not comprise anything revolutionary. However, the approach to project scheduling, and the integration of scheduling and control processes into an advanced system model represent a novel perspective in the project management domain. The need for advanced systems is acknowledged by various researchers in terms of new requirements set by the present project environment and the obvious limitations of the traditional approach. Some system models have been developed (Laufer et al. 1992; Alsakini et al. 2004), but they have offered rather general solutions, leaving open many questions relevant to their implementation. The proposed model provides a more comprehensive solution, for example, including project evaluation to adjust the model to the project-specific needs and requirements, as well as, practices for scheduling and controlling a project.

The proposed model offers, above all, a comprehensive and practical solution, which covers the scheduling and control processes from the initiation to the closing of a project. The steps are well-defined and instructed to provide a complete system model, which takes into account the specific needs of the business. One major issue is the set up of projects, where the work is clearly divided to activities performed in the office, and to activities performed at site. The work is also managed by different teams, although, the project team is responsible for the entire project. This set up is common in the industry, which makes the proposed model with only little modifications suitable for the other companies, too. Eventually, more important than the proposed model is the approach to project scheduling and the systemic thinking, which it represents.

6. CONCLUSIONS

The conclusions chapter consists of three sub-chapters. In the first sub-chapter, the conclusions from the results are presented. In addition, the success of the work is assessed. In the second sub-chapter, three recommendations are given to the company based on the research. In the last sub-chapter, some interesting opportunities for future research are suggested.

6.1. Conclusions from the results

The results from the projects proved that the current practice of project scheduling is clearly varied in the company. The evaluation of the current practice in the theoretical framework created on the basis of the literature review indicates multiple improvement needs and possibilities. A fundamental issue is the combination of timing and the level of detail in project scheduling. Schedules are not progressively elaborated, meaning that rolling wave planning is not utilized, but some activities are first planned on high level, and subsequently, in more detail before executing them. Scheduling is usually forced straight to the detailed level, although, there is not adequate or reliable information of the activities available at the moment. This leads to increased uncertainty in the schedules and less effective use of schedules in project management. In addition, the amount of activities requiring to be updated becomes easily unmanageable during project execution, and the schedule is left out-of-date.

Schedules are currently developed for different purposes in different project phases, but they are not developed on a hierarchical basis or connected to each other to maintain consistency. Thus, the information in different schedules becomes often fragmented during project execution. However, the use of other schedules and their development process support the idea of moving detailed scheduling closer to the execution of activities. The procedure decreases uncertainty in the schedules and enables effective use of schedules in project management. Much of the work performed in the office is left unplanned and invisible in the schedules, as project management activities are rarely included to them. Thus, it is on each person's, and ultimately, on the project manager's responsibility to make sure that everything gets done in time. This leads to use of separate documents for planning and tracking the things to be done. However, they do not support communication nor resource planning in the organization.

Project control should be the most important use of schedules. Schedules are updated regularly, and more frequently, if necessary. However, schedules are rarely updated, if the work is not progressing as planned, or changes occur during execution, meaning that the remaining work is not re-scheduled. Thus, schedules become easily forgotten and they are not used to provide an active control of the project. Progress for the activities is usually measured on the basis of estimates, which are sometimes backed up by suitable data. Progress measurement based on estimation is neither accurate nor objective. This is problematic, because the measured progress should provide feedback to the scheduling process, and it is generally used as a basis for the customer payments. Project performance is measured with earned value analysis (EVA), which enables integrated schedule and cost control, and comparison between projects. However, there is some confusion about EVA, in terms of performing it right and interpreting the data correctly.

Schedule should provide a roadmap for the project. The role of schedule in project management is found essential; however, schedule is now rarely seen as a roadmap for the project. Only in the Suape II project, the schedule was used to manage the entire project, which was shown in the essential role of schedule, as well as, in the effective and collaborative scheduling and control processes. In general, it was found that the processes and competence in the organization are not yet on the required level to allow using the schedule as a roadmap for the project. Therefore, it is important to develop the processes and competence in the organization to enable more comprehensive and effective use of schedules in project management. It would also improve the capability to meet the increasing customer requirements in scheduling, progress follow-up, and reporting.

The results from the other issues indicated a general opinion that it is really important to focus more on project scheduling, and there is a clear need for common practice. Scheduling should always be done based on project-specific needs, instead of only customer requirements, and on a correct level, which should be determined on the basis of the need for control. It should also be acknowledged that large EPC and otherwise complex projects require much more effort in scheduling than standard projects, and concentrating more on scheduling is not possible in project teams without additional resources with specific competence. In addition, project scheduling competence should be improved in the whole organization, including the understanding of importance. These issues have remarkable significance, as they were brought up by the professionals managing the current projects. Therefore, these issues should be carefully considered and actions taken.

A schedule management system is proposed based on the literature review and the results of the study. The proposed model provides integrated processes of scheduling and control, in order to enable active control of a project and to facilitate project management. The system comprises: schedule hierarchy, progress measurement, and performance measurement. The proposed model addresses the identified improvement needs and takes into account the expectations of the respondents. It has multiple benefits, which are achieved through the approach to project scheduling, and the integration of scheduling and control processes. Schedules are progressively elaborated, meaning that detailed scheduling is done closer to the execution of activities, which decreases the uncertainty concerning the planned activities and makes them easier to plan. Several schedules are developed, because schedules are needed for different purposes in different phases of a project. The schedules are managed in the schedule hierarchy, which ensures traceability between the different levels, in order to maintain consistency throughout the scheduling process. Progress measured at site is based on completion of the activities, which is not only the most objective method, but it also provides the most accurate progress information. Process for schedule updating keeps all schedules up-to-date and ensures consistency in the schedule hierarchy. It also produces as-built schedules, which contain actual information of the activities, providing valuable feedback to the scheduling process. Short feedback-loop for the site activities enables active control and early problem detection during execution.

The research is successful as a whole. The objectives were accomplished and the research questions were answered. Consequently, the research provided the results defined in the beginning. The process was not straight forward, rather iterative, which illustrates learning while doing. Certainly, the process has taught a lot about the subject and conducting academic research. The most challenging part of the research was to collect data from the projects, which is simultaneously in-depth and consistent enough to perform a cross-case analysis. The most interesting part of the research was to build up a proposal for schedule management system, which was also demanding, in terms of combining all aspects from the literature review and the results of the study. Hopefully, the proposed model and the other issues regarding to the current practice of project scheduling are found useful and they facilitate further development in the field.

6.2. Recommendations

Three recommendations are given based on the research. The first concerns the verification and further development of the proposed model, the second the project scheduling competence in the company, and the third the project scheduling resources in the company. The recommendations are focused directly on the company and they do not apply to the field in general.

1. Verification and further development of the proposed schedule management system by piloting the model in few EPC projects. Thus, the applicability and benefits of the model can be verified and illustrated. Necessary modifications can be made to the model based on the experiences and feedback from the piloting phase. The selected projects should be EPC projects, for which the model was developed, and they should preferably be at least average in size. The model should be utilized from the initiation to the closing of the projects.
2. Improvement of project scheduling competence within the organization. This can be accomplished by arranging appropriate training to all personnel working

in the projects, either in the office or at site. The training should include hands-on exercises in addition to the fundamentals of theory. There should also be more advanced training targeted to the people in certain positions, such as project managers, project controllers, and site engineers. In addition, the importance of project scheduling should be emphasized in the trainings, as well as, by the management in general.

3. Pool of schedulers, who are assigned to the most demanding projects. They would provide the required specific competence to manage the scheduling and control processes successfully in large EPC and otherwise complex projects. Thus, the resource problem in project teams would also be solved. In addition, the schedulers would support other project teams in scheduling related issues and develop the project scheduling practice in the organization.

Realizing the recommendations would have significant impact on the project scheduling practice in the company. Eventually, it would lead to much more harmonized practice, better control of projects, and ability to manage large and complex projects successfully.

6.3. Suggestions for further research

The need for advanced systems has been widely discussed by various researchers. Some system models have been developed to address the needs and requirements of project scheduling in the present project environment. However, the benefits of the proposed models have rarely been verified or illustrated empirically, which is also the case in this research. Consequently, verification of the benefits of the proposed models would offer an excellent opportunity for further research. The requirements, which the proposed models set to the processes, have also been left unexamined. Consequently, definition of the requirements of the proposed models would also be an interesting topic for further research. In general, it can be said that despite the extensive research in project scheduling over the years, there remain several areas, such as stochastic models and simulation techniques, which offer tempting research opportunities for the future.

REFERENCES

Ackermann, F., Eden, C. & Williams, T. 1996. A persuasive approach to delay and disruption – using “mixed methods”. Interfaces. Vol. 27, Issue 6, pp. 48-65.

Ala-Risku, T. & Kärkkäinen, M. 2006. Material delivery problems in construction projects: A possible solution. International Journal of Production Economics. Vol. 104, Issue 1, pp. 19-29.

Alsakini, W., Wikström, K. & Kiiras, J. 2004. Proactive schedule management of industrial turnkey projects in developing countries. International Journal of Project Management. Vol. 22, Issue 1, pp. 75-85.

Antill, J. & Woodhead, R. 1990. Critical Path Methods in Construction Practice. 4th Edition, Wiley. 448 p.

Artto, K. & Kujala, J. 2008. Project business as a research field. International Journal of Managing Projects in Business. Vol. 1, Issue 4, pp. 469-497.

Artto, K. & Wikström, K. 2005. What is project business? International Journal of Project Management. Vol. 23, Issue 5, pp. 343-353.

Artto, K., Eloranta, K. & Kujala, J. 2008. Subcontractors’ business relationships as risk sources in project networks. International Journal of Managing Projects in Business. Vol. 1, Issue 1, pp. 88-105.

Artto, K., Wikström, K., Hellström, M. & Kujala, J. 2008. Impact of services on project business. International Journal of Project Management. Vol. 26, Issue 5, pp. 497-508.

Assaf, S. & Al-Hejji, S. 2006. Causes of delay in large construction projects. International Journal of Project Management. Vol. 24, Issue 4, pp. 349-357.

Baccarini, D. 1996. The concept of project complexity – a review. International Journal of Project Management. Vol. 14, Issue 4, pp. 201-204.

Ballard, G. 2000. The last planner system of production control. Doctor’s thesis. The University of Birmingham, Faculty of Engineering, School of Civil Engineering. 192 p.

Ballard, G. & Howell, G. 1994. Stabilizing work flow. Proceedings of the 2nd Annual Conference of the International Group for Lean Construction, Santiago, Chile, October 1994.

Bosch-Rekveldt, M., Jongkind, Y., Mooi, H., Bakker, H. & Verbraeck, A. 2010. Grasping project complexity in large engineering projects: The TOE (Technical, Organizational and Environmental) framework. International Journal of Project Management. In Press, Corrected Proof.

Brady, T., Davies, A., Gann, D. & Rush, H. 2007. Learning to manage mega projects: the case of BAA and Heathrow terminal 5. Project Perspectives. Vol. 29, pp. 32-39.

Browning, T. 2001. Applying the design structure matrix to system decomposition and integration problems: a review and new directions. IEEE Transactions on Engineering Management. Vol. 48, Issue 3, pp. 292-306.

Cicmil, S., Williams, T., Thomas, J. & Hodgson, D. 2006. Rethinking project management: researching the actuality of projects. International Journal of Project Management. Vol. 24, Issue 8, pp. 675-686.

Construction Industry Institute. 1987. Project Control for Construction. The University of Texas, Construction Industry Institute, Bureau of Engineering Research, Publication no. 6-5. 52 p.

Cooke-Davies, T., Cicmil, S., Crawford, L. & Richardson, K. 2007. We're not in Kansas anymore, Toto: mapping the strange landscape of complexity theory, and its relationship to project management. Project Management Journal. Vol. 38, Issue 2, pp. 50-61.

Cornish, J. 2008. A Brief History of Project Scheduling. Micro Planning International Ltd. Available: http://www.pmworldnetwork.com/History-of-Project-Scheduling.php.

Cova, B., Ghauri, P. & Salle, R. 2002. Project Marketing: Beyond Competitive Bidding. Wiley. 236 p.

Davies, A. 2004. Moving base into high-value integrated solutions: a value stream approach. Industrial and Corporate Change. Vol. 13, Issue 5, pp. 727-756.

Davies, A. & Hobday, M. 2005. The Business of Projects: Managing Innovation in Complex Products and Systems. Cambridge University Press. 330 p.

Dawson, R. & Dawson, C. 1998. Practical proposals for managing uncertainty and risk in project planning. International Journal of Project Management. Vol. 16, Issue 5, pp. 299-310.

Dietrich, P., Kujala, J., Lampenius, M. & Artto, K. 2007. Integration of project sales and execution in a global organization. 7th Annual Conference of the European Academy of Management (EURAM), Paris, France, May 2007.

Dvir, D., Raz, T. & Shenhar, A. 2003. An empirical analysis of the relationship between project planning and project success. International Journal of Project Management. Vol. 21, Issue 2, pp. 89-95.

Eloranta, K. 2007. Supplier relationship management in networked project business. Licentiate’s thesis. Helsinki University of Technology, Department of Industrial Engineering and Management.

Engwall, M. 2003. No project is an island: linking projects to history and context. Research Policy. Vol. 32, Issue 5, pp. 789-808.

Floricel, S. & Miller, R. 2001. Strategizing for anticipated risks and turbulence in large-scale engineering projects. International Journal of Project Management. Vol. 19, Issue 8, pp. 445-455.

Fortune, J. & White, D. 2006. Framing of project critical success factors by a systems model. International Journal of Project Management. Vol. 24, Issue 1, pp. 53-65.

Gann, D. & Salter, A. 2000. Innovation in project-based, service-enhanced firms: the construction of complex products and systems. Research Policy. Vol. 29, Issue 7-8, pp. 955-972.

Geraldi, J. 2009. What complexity assessments can tell us about projects: dialogue between conception and perception. Technology Analysis & Strategic Management. Vol. 21, Issue 5, pp. 665-678.

Geraldi, J. & Adlbrecht, G. 2007. On faith, fact, and interaction in projects. Project Management Journal. Vol. 38, Issue 1, pp. 32-43.

Globerson, S. & Shtub, A. 1995. Estimating the progress of projects. Engineering Management Journal. Vol. 7, Issue 3, pp. 39-44.

Gray, C. & Larson, E. 2008. Project Management: The Managerial Process. 4th Edition, McGraw-Hill/Irwin. 608 p.

Grün, O. 2004. Taming Giant Projects: Management of Multi-Organization Enterprises. Springer. 271 p.

Hall, W. 1993. Scope management through a WBS. PM Network. Vol. 7, Issue 5, pp. 12-18.

Hanna, A., Camlic, R., Peterson, P. & Lee, M. 2004. Cumulative effect of project changes for electrical and mechanical construction. Journal of Construction Engineering and Management. Vol. 130, Issue 6, pp. 762-771.

Hanna, A., Russell, J., Nordheim, E. & Bruggink, M. 1999. Impact of change orders on labor efficiency for electrical construction. Journal of Construction Engineering and Management. Vol. 125, Issue 4, pp. 224-232.

Helbrough, B. 1995. Computer assisted collaboration – the fourth dimension of project management? International Journal of Project Management. Vol. 13, Issue 5, pp. 329-333.

Hellgren, B. & Stjernberg, T. 1995. Design and implementation in major investments – a project network approach. Scandinavian Journal of Management. Vol. 11, Issue 4, pp. 377-394.

Hellström, M. 2005. Business concepts based on modularity. Doctor's thesis. Åbo Akademi. 189 p.

Hellström, M. & Wikström, K. 2005. Project business concepts based on modularity – improved maneuverability through unstable structures. International Journal of Project Management. Vol. 23, Issue 5, pp. 392-397.

Henderson, R. & Clark, K. 1990. Architectural innovation: the reconfiguration of existing product technologies and the failure of established firms. Administrative Science Quarterly. Vol. 35, Issue 1, pp. 9-30.

Hendrickson, C. 2008. Project Management for Construction – Fundamental Concepts for Owners, Engineers, Architects and Builders. 2nd Edition prepared for www-publication. Available: http://pmbook.ce.cmu.edu.

Herroelen, W. & Leus, R. 2004. Robust and reactive project scheduling: a review and classification of procedures. International Journal of Production Research. Vol. 42, Issue 8, pp. 1599-1620.

Hillson, D. & Simon, P. 2007. Practical Project Risk Management: The ATOM Methodology. Management Concepts. 241 p.

Hobbs, B. & Aubry, M. 2005. A realistic portrait of the PMOs: the results of an empirical investigation. Proceedings of the PMI North American global congress 2005, Toronto, Canada. Project Management Institute.

Hobday, M. 1998. Product complexity, innovation and industrial organization. Research Policy. Vol. 26, Issue 6, pp. 689-710.

Hobday, M. 2000. The project-based organization: an ideal form for managing complex products and systems? Research Policy. Vol. 29, Issue 7, pp. 871-893.

Ibbs, C., Wong, C. & Kwak, Y. 2001. Project change management system. Journal of Management in Engineering. Vol. 17, Issue 3, pp. 159-165.

International Energy Agency (IEA). 2006. World Energy Outlook 2006. International Energy Agency. 600 p.

Jaafari, A. 2001. Management of risks, uncertainties and opportunities on projects: time for a fundamental shift. International Journal of Project Management. Vol. 19, Issue 2, pp. 89-101.

Jaafari, A. 2003. Project management in the age of complexity and change. Project Management Journal. Vol. 34, Issue 4, pp. 47-57.

Jones, R. & Deckro, R. 1993. The social psychology of project management conflict. European Journal of Operational Research. Vol. 64, pp. 216-228.

Kartam, N. 1996. Making effective use of construction lessons learned in project life cycle. Journal of Construction Engineering and Management. Vol. 122, Issue 1, pp. 14-21.

Keegan, A. & Turner, R. 2002. The management of innovation in project-based firms. Long Range Planning. Vol. 35, Issue 4, pp. 367-388.

King, N. 2004. Using interviews in qualitative research. In: Cassell, C. & Symon, G. (eds.). Essential Guide to Qualitative Methods in Organizational Research. Sage Publications, pp. 11-22.

Kujala, J., Ahola, T., Westerholm, T., Lehtonen, M., Laitinen, E. & Artto, K. 2007. Performance measurement in project business networks. 8th International Conference of the International Research Network on Organizing by Projects, Brighton, United Kingdom, September 2007.

Laufer, A. & Tucker, R. 1987. Is construction project planning really doing its job? A critical examination of focus, role and process. Construction Management and Economics. Vol. 5, Issue 3, pp. 243-266.

Laufer, A. & Tucker, R. 1988. Competence and timing dilemma in construction planning. Construction Management and Economics. Vol. 6, Issue 4, pp. 339-355.

Laufer, A., Denker, G. & Shenhar, A. 1996. Simultaneous management: the key to excellence in capital projects. International Journal of Project Management. Vol. 14, Issue 4, pp. 189-199.

Laufer, A., Howell, G. & Rosenfeld, Y. 1992. Three modes of short-term construction planning. Construction Management and Economics. Vol. 10, Issue 3, pp. 249-262.

Liinamaa, J. & Wikström, K. 2009. Integration in project business: mechanisms for knowledge integration. International Journal of Knowledge Management Studies. Vol. 3, Issue 3-4, pp. 331-350.

Lindkvist, L. 2004. Governing project-based firms: promoting market-like processes within hierarchies. Journal of Management and Governance. Vol. 8, Issue 1, pp. 3-25.

Mason, R. 2007. The external environment's effect on management and strategy – a complexity theory approach. Management Decision. Vol. 45, Issue 1, pp. 10-28.

Maylor, H., Vidgen, R. & Carver, S. 2008. Managerial complexity in project based operations: a grounded model and its implications for practice. Project Management Journal. Vol. 39, Supplement, pp. S15-S26.

Miller, R. 2006. Principles of governance for major investments projects. Concept Symposium 2006, Norwegian University of Science and Technology (NTNU), Trondheim, Norway.

Miller, R. & Lessard, D. 2001. Understanding and managing risks in large engineering projects. International Journal of Project Management. Vol. 19, Issue 8, pp. 437-443.

Morris, M., Schindehutte, M. & Allen, J. 2005. The entrepreneur's business model: toward a unified perspective. Journal of Business Research. Vol. 58, Issue 6, pp. 726-735.

Morris, P. 1997. The Management of Projects. Thomas Telford Publishing. 376 p.

Morris, P., Crawford, L., Hodgson, D., Shepherd, M. & Thomas, J. 2006. Exploring the role of formal bodies of knowledge in defining a profession – the case of project management. International Journal of Project Management. Vol. 24, Issue 8, pp. 710-721.

Motawa, I., Anumba, C., Lee, S. & Peña-Mora, F. 2007. An integrated system for change management in construction. Journal of Automation in Construction. Vol. 16, Issue 3, pp. 368-377.

Mubarak, S. 2010. Construction Project Scheduling and Control. 2nd Edition, Wiley. 480 p.

Naoum, S. 1994. Critical analysis of time and cost of management and traditional contracts. Journal of Construction and Engineering Management. Vol. 120, Issue 4, pp. 687-705.

Neuman, W. 2009. Social Research Methods: Qualitative and Quantitative Approaches. 7th Edition, Allyn & Bacon. 640 p.

Nicholas, J. 2004. Project Management for Business and Engineering: Principles and Practice. 2nd Edition, Butterworth-Heinemann. 602 p.

Oberlender, G. 2000. Project Management for Engineers and Construction. 2nd Edition, McGraw-Hill. 384 p.

Parwani, R. 2002. Complexity: an introduction. National University of Singapore.

Patton, M. 2001. Qualitative Research and Evaluation Methods. 3rd Edition, Sage Publications. 688 p.

Pellegrinelli, S. 1997. Program management: organizing project-based change. International Journal of Project Management. Vol. 15, Issue 3, pp. 141-149.

Pellegrinelli, S., Partington, D., Hemingway, C., Mohdzain, Z. & Shah, M. 2007. The importance of context in program management: an empirical review of program practices. International Journal of Project Management. Vol. 25, Issue 1, pp. 41-55.

Perminova, O., Gustafsson, M. & Wikström, K. 2008. Defining uncertainty in projects – a new perspective. International Journal of Project Management. Vol. 26, Issue 1, pp. 73-79.

Phillips, J., Phillips, A. & Bailey, R. 1999. Management of modular projects: a templating approach. Project Management Journal. Vol. 30, Issue 4, pp. 33-41.

Popescu, C. & Charoenngam, C. 1995. Project Planning, Scheduling, and Control in Construction: An Encyclopedia of Terms and Applications. Wiley. 573 p.

Project Management Institute (PMI). 2007. The Practice Standard for Scheduling. Project Management Institute. 113 p.

Project Management Institute (PMI). 2008. A Guide to the Project Management Body of Knowledge (PMBOK Guide). 4th Edition, Project Management Institute. 459 p.

Raz, T. & Globerson, S. 1998. Effective sizing and content definition of work packages. Project Management Journal. Vol. 29, Issue 4, pp. 17-23.

Remington, K. & Pollack, J. 2008. Tools for Complex Projects. Ashgate. 232 p.

Robson, C. 2011. Real World Research. 3rd Edition, Wiley-Blackwell. 584 p.

Rolstadås, A. 2004. Time and cost. In: Morris, P. & Pinto, J. (eds.). The Wiley Guide to Managing Projects. Wiley, pp. 781-804.

Samset, K. 2003. Project Evaluation: Making Investments Succeed. Tapir Academic Press. 233 p.

Saunders, M., Thornhill, A. & Lewis, P. 2009. Research Methods for Business Students. 5th Edition, Prentice Hall. 656 p.

Sears, S., Sears, G. & Clough, R. 2008. Construction Project Management: A Practical Guide to Field Construction Management. 5th Edition, Wiley. 408 p.

Shenhar, A. 1998. From theory to practice: toward a typology of project management styles. IEEE Transactions on Engineering Management. Vol. 45, Issue 1, pp. 33-48.

Shenhar, A. & Dvir, D. 1995. Managing technology projects: a contingent exploratory approach. Proceedings of the 28th Annual International Conference on Systems Sciences, Hawaii, USA, January 1995.

Shenhar, A. & Dvir, D. 1996. Toward a typological theory of project management. Research Policy. Vol. 25, pp. 607-632.

Steward, D. 1981. Systems Analysis and Management: Structure, Strategy and Design. Petrocelli Books. 287 p.

Sydow, J., Lindkvist, L. & DeFillippi, R. 2004. Project-based organizations, embeddedness and repositories of knowledge. Organization Studies. Vol. 25, Issue 9, pp. 1475-1490.

Söderlund, J. 2004. On the broadening scope of the research on projects: a review and a model for analysis. International Journal of Project Management. Vol. 22, Issue 8, pp. 655-667.

Thiry, M. & Deguire, M. 2007. Recent developments in project-based organizations. International Journal of Project Management. Vol. 25, Issue 7, pp. 649-658.

Thompson, J., Zald, M. & Scott, W. 2003. Organizations in Action: Social Science Bases of Administrative Theory. Transaction Publishers. 192 p.

Turner, R. 2008. The Handbook of Project-based Management: Leading Strategic Change in Organizations. 3rd Edition, McGraw-Hill. 452 p.

Turner, J. & Cochrane, R. 1993. Goals-and-methods matrix: coping with projects with ill defined goals and/or methods of achieving them. International Journal of Project Management. Vol. 11, Issue 2, pp. 93-102.

Vidal, L.-A., Marleand, F. & Bocquet, J.-C. 2010. Measuring project complexity using the Analytic Hierarchy Process. International Journal of Project Management. In Press, Corrected Proof.

Walker, A. 2007. Project Management in Construction. 5th Edition, Wiley-Blackwell. 328 p.

Wei, C., Liu, P. & Tsai, Y. 2002. Resource-constrained project management using enhanced theory of constraint. International Journal of Project Management. Vol. 20, Issue 7, pp. 561-567.

Westney, R. 1985. Managing the Engineering and Construction of Small Projects. CRC Press. 300 p.

Whitty, S. & Maylor, H. 2009. And then came complex project management. International Journal of Project Management. Vol. 27, Issue 3, pp. 304-310.

Wikström, K., Artto, K., Kujala, J. & Söderlund, J. 2010. Business models in project business. International Journal of Project Management. Vol. 28, Issue 8, pp. 832-841.

Wikström, K., Hellström, K., Artto, K., Kujala, J. & Kujala, S. 2009. Services in project-based firms – four types of business logic. International Journal of Project Management. Vol. 27, Issue 2, pp. 113-122.

Williams, T. 1995. Holistic methods in project management. Proceedings of the Internet Symposium, St. Petersburg, Russia, September 1995.

Williams, T. 1999. The need for new paradigms for complex projects. International Journal of Project Management. Vol. 17, Issue 5, pp. 269-273.

Williams, T. 2001. Modeling Complex Projects. Wiley. 275 p.

Williams, T., Eden, C., Ackermann, F. & Tait, A. 1995. The effects of design changes and delays on project costs. Journal of the Operational Research Society. Vol. 46, Issue 7, pp. 809-818.

Winch, G. 2006. The governance of project coalitions – towards a research agenda. In: Lowe, D. & Leiringer, R. (eds.). Commercial Management of Projects: Defining the Discipline. Wiley-Blackwell, pp. 324-343.

Winch, G. & Kelsey, J. 2005. What do construction project planners do? International Journal of Project Management. Vol. 23, Issue 2, pp. 141-149.

Woodward, J. 1997. Construction Project Management: Getting it Right First Time. Thomas Telford Publishing. 296 p.

Wärtsilä Oyj Abp. 2011. Global website. http://www.wartsila.com. Accessed: June 7th, 2011.

Xia, W. & Lee, G. 2005. Complexity of information systems development projects: conceptualization and measurement development. Journal of Management Information Systems. Vol. 22, Issue 1, pp. 45-83.

Yin, R. 2008. Case Study Research: Design and Methods (Applied Social Research Methods). 4th Edition, Sage Publications. 240 p.

Youker, R. 1992. Managing the international project environment. International Journal of Project Management. Vol. 10, Issue 4, pp. 219-226.

Zhao, Z., Lei, Q., Zuo, J. & Zillante, G. 2010. Prediction system for change management in construction project. Journal of Construction Engineering and Management. Vol. 136, Issue 6, pp. 659-669.

Zou, Y. & Lee, S. 2008. The impacts of change management practices on project change cost performance. Construction Management and Economics. Vol. 26, Issue 4, pp. 387-393.

Zwikael, O. & Globerson, S. 2004. Evaluating the quality of project planning: a model and field results. International Journal of Production Research. Vol. 42, Issue 2, pp. 1545-1556.

List of the interviews

Project	Position	Interview					
		Date	Time	Actual time	Duration	Location	Notes
Ewekoro & Victoria C Extension	Project Manager	12.4.2011	9:00-12:00	9:00-11:40	160 min	CR Africa	
Ewekoro & Victoria C Extension	Project Controller	13.4.2011	12:00-15:00	12:15-14:50	155 min	CR Europe	
Kribi	Project Manager	14.4.2011	13:00-16:00	13:00-15:20	140 min	CR Africa	
Humboldt	Project Manager	19.4.2011	12:30-15:00	12:40-14:45	125 min	CR Africa	
Humboldt	Project Controller	20.4.2011	9:00-12:00	9:15-10:55	100 min	CR Europe	
Hera & Liberty	Project Manager	20.4.2011	13:00-16:00	13:00-14:55	115 min	CR Europe	
Humboldt	Site Engineer	26.4.2011	13:00-16:00	13:00-14:25	85 min	CR Africa	
Suape II	Project Controller	28.4.2011	13:00-16:00	13:05-15:00	115 min	CR Africa	
	Program Manager	3.5.2011	9:00-12:00	9:00-11:05	125 min	CR Africa	
Suape II	Project Manager	4.5.2011	9:00-12:00	9:05-10:55	110 min	CR Performance	
Ewekoro	Site Engineer	4.5.2011	14:00-17:00	14:05-16:20	135 min	Live Meeting	
Hera & Liberty	Project Controller	5.5.2011	9:00-12:00	9:20-11:35	135 min	CR Africa	
Gateway	Project Controller	10.5.2011	14:00-17:00	14:10-16:05	115 min	CR Africa	
Kipevu III	Site Engineer	11.5.2011	9:00-12:00	9:00-10:40	100 min	CR Africa	
Kribi	Project Controller	11.5.2011	13:00-16:00	13:05-15:10	125 min	CR Europe	
Gateway	Project Manager	12.5.2011	9:00-12:00	9:05-11:10	125 min	CR Americas	
Gateway	Project Manager	14.6.2011	9:00-12:00	9:05-11:25	140 min	CR Americas	

Interview Guide

1. Could you tell me something about your background?
   1.1. Where have you studied?
   1.2. What work experience do you have?
   1.3. What are your previous projects in the company?
2. Could you tell me about the project?
   2.1. What is the status of the project at the moment?
   2.2. How complex was the project seen and why?
   2.3. Who were identified as the project stakeholders?
   2.4. Was there something unique in the project?
   2.5. Was the project successful?
   2.6. What are the lessons learned in the project?
3. How was the schedule developed in the project?
   3.1. How were the activities defined?
      3.1.1. Progressive elaboration, rolling wave planning
      3.1.2. Templates
      3.1.3. Tools
   3.2. Were the dependencies determined and how?
   3.3. Were the activity resources estimated and how?
      3.3.1. Assignment of resources to an activity
   3.4. How were the activity durations estimated?
   3.5. What schedules were developed in the project?
   3.6. How was scheduling done in different phases of the project?
   3.7. Were project management activities included in the schedule?
      3.7.1. Project management activities / project work activities
   3.8. What tools were used in schedule development?
   3.9. Who was responsible for schedule development and who were the main contributors in the process?
4. How was the schedule controlled in the project?
   4.1. How was the project performance reported?
      4.1.1. Included / required information
      4.1.2. Reporting period
   4.2. Was the schedule updated and how often?
      4.2.1. Sources of information
   4.3. Was the schedule used to track progress and how?
   4.4. Was the schedule used to make forecasts?
   4.5. What tools were used in schedule control?
   4.6. Was the schedule used in change management and how?
      4.6.1. Change orders
   4.7. Was the schedule used in claim management and how?
      4.7.1. Record of changes, delays and their causes

4.8. Who was responsible for schedule control and who were the main contributors in the process?

5. How important was the schedule seen in the project?
   5.1. Was the project team focused on scheduling?
   5.2. What was the role of schedule in project management?
   5.3. Was the schedule seen only as required or as a roadmap for the project?
6. How the current practice of project scheduling should be developed?
   6.1. What are the critical improvement needs?
7. Is there something you would like to add?

Results from the projects

Themes	Projects						
	Ewekoro	Hera	Humboldt	Kribi	Liberty	Suape II	Victoria C Extension
Project overview							
Status	Installation	Construction	Handed over	Construction (on-hold)	Handed over	Installation	Installation
Complexity	High; customer requirements in scheduling, progress follow-up, reporting, country	Average; responsibilities in new type of contract	High; customer requirements in scheduling, regulations, site location	High; customer requirements in scheduling, reporting, HSE related issues	High; large project, combined cycle, short delivery time, country	High; large project, customer requirements in scheduling, progress follow-up, reporting	Low; no specific challenges
Unique	First EPC project in the country, large engines	First CMA contract, site reporting directly to customer	Project team also in local office, including scheduler	Site team; construction manager and site manager, no site engineer	Steam turbine	Largest project ever delivered	
Progress	Delayed due to climatic conditions	On schedule	Delayed due to customer and permitting related issues	On-hold due to customer payments	On schedule	On schedule	On schedule

Themes	Projects						
	Ewekoro	Hera	Humboldt	Kribi	Liberty	Suape II	Victoria C Extension
Schedule development process							
Activity definition	By expert judgement based on project team experience and scope of supply	By expert judgement based on project team experience, scope of supply and technical specification	By expert judgement based on project team experience and scope of supply (master) / subcontractor (site)	By expert judgement based on project team experience and scope of supply	By expert judgement based on project team experience, scope of supply and technical specification	By expert judgement based on project team experience and scope of supply	With tools based on scope of supply (ABM)
Rolling wave planning	Site activities planned in off-shore only on high-level	Engineering and procurement planned first on high-level, more detailed schedule before start	Site and commissioning activities planned in master only on high-level, more detailed site schedule before start, elaborated site schedule for three week window once a week	No rolling wave	Some activities planned first on high-level, more detailed schedule before start	No rolling wave	No rolling wave
Templates	From old projects (off-shore)	No templates	No templates	No templates	No templates	No templates	No templates
Tools	No tools	No tools	No tools	No tools	No tools	No tools	WBS-tool (master, site)
Activity sequence	By expert judgement based on project team experience and logic	By expert judgement based on project team experience and logic	By expert judgement based on project team experience and logic (master) / subcontractor (site)	By expert judgement based on project team experience and logic	By expert judgement based on project team experience and logic	By expert judgement based on project team experience and logic	By expert judgement based on project team experience and logic (master) / subcontractor (site)
Activity resources	No resources	No resources	Subcontractor resources (site)	No resources	No resources	No resources	Subcontractor resources (site)
Assignment of resources to an activity	No assignments	No assignments	Subcontractor resources (site)	No assignments	No assignments	No assignments	No assignments
Activity durations	By expert judgement based on project team experience and gathered information	By expert judgement based on project team experience and gathered information	By expert judgement based on project team experience and gathered information (master) / subcontractor (site)	By expert judgement based on project team experience and gathered information	By expert judgement based on project team experience and gathered information, activities of which no experience from suppliers	By expert judgement based on project team experience and gathered information	By expert judgement based on project team experience and gathered information (master) / subcontractor (site)

Themes	Projects						
	Ewekoro	Hera	Humboldt	Kribi	Liberty	Suape II	Victoria C Extension
Schedule development process							
Schedule development							
Methods	Critical path method (CPM)	Critical path method (CPM)	Critical path method (CPM)	Critical path method (CPM)	Critical path method (CPM)	Critical path method (CPM)	Critical path method (CPM)
Contingency reserves	No buffers	Buffer in the end of the project	No buffers	No buffers	Buffer in the end of the project	Buffers between activities	Buffer between installation and commissioning
Project schedules	Off-shore / on-shore	Master / equipment supply / construction	Master / site	Master	Master / site / commissioning	Master	Master / site (sub-project)
Scheduling in different project phases	Off-shore at initiation, only additions and corrections later / on-shore before start at site, only additions later	Master at initiation / equipment supply before start / construction before start at site	Master at initiation / site before start (later only updated schedule)	Master at initiation, elaboration in planning phase, only additions and corrections later	Preliminary schedule in sales phase / master at initiation / site and commissioning before start	Master at initiation, only few additions and corrections later	Master at initiation, only few additions later / site before start
Project management activities	Sub-contracting	No activities	No activities	No activities	No activities	No activities	No activities
Tools	Microsoft Project	Microsoft Project	Microsoft Project, Primavera (subcontractor)	Microsoft Project	Microsoft Project	Microsoft Project	Microsoft Project
Responsible	Project manager (off-shore) / site manager (on-shore)	Project manager (master, equipment supply) / site manager (construction)	Project manager, project controller (master) / subcontractor (site)	Project manager, project controller, construction manager	Project manager (master) / site manager (site) / commissioning manager (commissioning)	Project controller	Project manager, project controller
Contributors	Project team (delivery times from CPEs), Citec (engineering), project purchasing (delivery times), logistics (shipments)	Project team (delivery times from CPEs), logistics (shipments), customer (site), subcontractors (site)	Project team (delivery times from CPEs), project purchasing (delivery times), logistics (shipments)	Project team (delivery times from CPEs), project purchasing (delivery times), logistics (shipments)	Project team (delivery times from CPEs), suppliers (steam turbine installation), logistics (shipments), subcontractors (site)	Project team (activities, dependencies, durations from CPEs), project purchasing (delivery times), logistics (shipments), subcontractor (site)	Project team, logistics (shipments), subcontractor (site; dependencies, resources, durations)

Themes	Projects						
	Ewekoro	Hera	Humboldt	Kribi	Liberty	Suape II	Victoria C Extension
Schedule control process							
Schedule control							
Schedule updating	Once a week or in two weeks	Once a month (master, equipment supply) / once a week (construction)	Once a month	Once a month	Once a month (master) / once a week (site, commissioning)	Once a week in project team meetings	Once in two weeks (master) / once a week (site)
Progress measurement	With detailed customer templates, completed activities; no progress follow-up with suppliers	In project schedules, estimated activity progress	With templates, estimated activity progress; no progress follow-up with suppliers	With templates, estimated activity progress; no progress follow-up with suppliers	In project schedules, estimated activity progress, no actual start and finish dates	With detailed templates, completed activities; no progress follow-up with suppliers	With templates, completed activities
Activity weighting	Work effort (man-hours)	Budgeted cost	Budgeted cost	Budgeted cost	Budgeted cost	Budgeted cost	Work effort (man-hours)
Project performance measurement	Earned value analysis (EVA)	Earned value analysis (EVA)	Earned value analysis (EVA)	Earned value analysis (EVA)	Earned value analysis (EVA)	Earned value analysis (EVA)	Earned value analysis (EVA)
Project performance reporting	Monthly to customer (off-shore included), on-shore to customer once a week	Monthly to customer, construction to customer once a week	Monthly to customer and authorities	Monthly to customer (master included)	Monthly to customer	Weekly and monthly to customer	Monthly to customer (master included)
Tools	Microsoft Project (project schedules), Microsoft Excel (completed activities, EVA calculations, s-curves)	Microsoft Project (project schedules), Microsoft Excel (EVA calculations, s-curves)	Microsoft Project (project schedules), Microsoft Excel (activity progress, EVA calculations, s-curves)	Microsoft Project (project schedule), Microsoft Excel (activity progress, EVA calculations, s-curves)	Microsoft Project (project schedules), Microsoft Excel (EVA calculations, s-curves)	Microsoft Project (project schedule), Microsoft Excel (completed activities, EVA calculations, s-curves)	Microsoft Project (project schedules), Microsoft Excel (completed activities, EVA calculations, s-curves)
Use of schedule in change management	No change orders	Change order from customer to come, effects on schedule	Plenty of change orders from customer and subcontractor, effects on schedule	No change orders	No change orders	No change orders	No change orders
Use of schedule in claim management	No claims	No claims	Schedule used to indicate reasons for delays	No claims	Schedule used to indicate reasons for delays, especially in commissioning	No claims	No claims
Responsible	Project manager (off-shore) / site engineer (on-shore)	Project controller (master, equipment supply) / site engineer (construction)	Project controller (master) / site engineer (site)	Project controller, construction manager, site manager	Project controller (master) / site engineer (site, commissioning)	Project controller, site engineer	Project controller (master) / site manager (site)
Contributors	Subcontractors estimate progress, supervisors check, site engineer approves (on-shore)		Subcontractor updates schedule and estimates progress, site engineer approves (site)	Section managers estimate progress			Subcontractor updates schedule and estimates progress, site manager approves (site)

Themes	Projects						
	Ewekoro	Hera	Humboldt	Kribi	Liberty	Suape II	Victoria C Extension
Perceived importance of schedule							
Project team focus on scheduling	High; mainly due to customer requirements, especially in progress follow-up	High; scheduling and control processes to facilitate management of the project	High; mainly due to customer requirements	High; mainly due to customer requirements	High; scheduling and control processes to facilitate management of the project	High; due to customer requirements and project size, scheduling and control processes to facilitate management of the project	High; pilot in project scheduling development
Role of schedule in project management	High; detailed schedules and progress follow-up, project control	High; schedule the most important tool to manage the project in execution	High; detailed schedules and progress follow-up, project control	Average; no need for detailed progress follow-up	High; schedule the most important tool to manage the project in execution	High; detailed schedule and progress follow-up, project control	Average; master for reporting, site important control tool
Schedule as a roadmap for the project	No; critical tool	No; critical tool	No; reporting and control tool	No; critical tool	No; critical tool	Yes; schedule used to manage the entire project	No; reporting and control tool

Results from the other issues

Issues	Project teams of selected projects				Other respondents		All respondents	
	Project managers		Project controllers					
	Number	Proportion (%)	Number	Proportion (%)	Number	Proportion (%)	Number	Proportion (%)
It is really important to focus more on project scheduling, and it is good that the subject is studied	5	**100%**	4	**80%**	6	**86%**	15	**88%**
Scheduling should always be done based on the project-specific needs and customer requirements	4	**80%**	4	**80%**	4	**57%**	12	**71%**
There is a clear need for common practice in project scheduling	4	**80%**	3	**60%**	5	**71%**	12	**71%**
Project scheduling competence should be improved in the whole organization, including the understanding of importance	3	**60%**	3	**60%**	6	**86%**	12	**71%**
Large EPC and otherwise complex projects require much more effort in scheduling than standard projects	5	**100%**	4	**80%**	2	**29%**	11	**65%**
Concentrating more on scheduling is not possible in project teams without additional resources with specific competence	3	**60%**	4	**80%**	4	**57%**	11	**65%**
Scheduling should always be done on a correct level, which should be determined on the basis of the need for control	4	**80%**	3	**60%**	3	**43%**	10	**59%**
Understanding and commitment to the project schedule are results from involvement	2	40%	1	20%	5	**71%**	8	**47%**
Development of detailed project schedules takes time, but the effort is rewarded in an easier control of the project	3	**60%**	3	**60%**	1	14%	7	**41%**
The development in project scheduling has recently concentrated on reporting, and not on how to manage projects successfully by effective practices	3	**60%**	2	**40%**	2	**29%**	7	**41%**
Schedule is an important document for communication with the project stakeholders	3	**60%**	2	**40%**	1	14%	6	35%
Project scheduling is always team work, but there should be one person mainly responsible, who has the required competence in the methods and tools	2	40%	2	**40%**	1	14%	5	29%
The baseline and actual information of the activities should be documented in as-built schedules to facilitate project scheduling	2	40%	1	20%	2	**29%**	5	29%
Schedule templates are not needed, but a common structure for schedules would be useful	1	20%		0%	4	**57%**	5	29%
Challenges and possibilities in project scheduling are especially in the site activities	1	20%	1	20%	2	**29%**	4	24%

Issues	Project teams of selected projects				Other respondents		All respondents	
	Project managers		Project controllers					
	Number	Proportion (%)	Number	Proportion (%)	Number	Proportion (%)	Number	Proportion (%)
Projects should have only one schedule to provide a good overall view and to enable dependency determination between all activities	1	20%	1	20%	2	**29%**	4	24%
Rolling wave planning should be utilized in project scheduling	2	40%		0%	2	**29%**	4	24%
Preliminary schedule should be developed in the sales phase to ensure that the project is executable within the agreed time frame	2	40%	1	20%		0%	3	18%
Project complexity should be assessed at initiation to determine the required level of effort and competence in project management		0%	1	20%	2	**29%**	3	18%
Scheduling of the site activities is challenging to the project team due to lack of required knowledge and experience	2	40%		0%	1	14%	3	18%
Dynamic schedules is the key to managing changes, requiring determination of all dependencies between the activities	2	40%		0%	1	14%	3	18%
Collection of parametric data on the actual durations of the activities, especially at site, would improve accuracy in scheduling	1	20%		0%	2	**29%**	3	18%
Subcontractors should develop their own schedules, in order to utilize the best available knowledge and to facilitate commitment to the schedule	1	20%		0%	2	**29%**	3	18%
Resources should be estimated for and assigned to the site activities	1	20%		0%	2	**29%**	3	18%
Progress for the activities is usually well-known, but more useful would be a reliable estimate of the completion		0%		0%	3	**43%**	3	18%
Scheduling is concentrated only on the project work activities, also the project management activities should be included to the schedule	1	20%	1	20%		0%	2	12%
Detailed schedule for the project should be developed at initiation, as it can be updated and elaborated during execution	1	20%	1	20%		0%	2	12%
Requirements for the project schedules are different from the customer and organization	2	40%		0%		0%	2	12%
Better integration of systems would reduce the need for routine manual work and release resources to more productive work	1	20%		0%		0%	1	6%
Scheduling of the commissioning activities is challenging for the project team due to lack of required knowledge and experience		0%		0%	1	14%	1	6%