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STUDY OF FACTORS IMPACTING ON-SITE OPERATIONS OF LARGE SCALE INDUSTRIAL AUTOMATION PROJECTS

Updated 12.03.2019

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M. Sc. (Tech.) Hannu Kailasvuo

ABSTRACT

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Study of factors impacting on-site operations of large scale industrial automation projects

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The goal of this research is to identify and evaluate key points and areas of a Cimcorp Oy project that affect on-site work (installation and commissioning) of large scale Factory automation projects. It has been noted that a key factor for successful project completion is identifying the areas that often affect each other and the final stages of the project, i.e. installation and commissioning.

In less than 10 years Cimcorp Oy has evolved from an automation company with 5-10 M€ projects to an international full factory automatization company with project sizes ranging 80 - 120M€. All project phases have not been able to follow this steep growth pattern.

In the past 5 years Cimcorp Oy has completed several medium and large scale factory automation projects that are the base for this work. Individuals working in the management positions prior and during the Installation and commissioning phase have been interviewed for this research study and questionnaires have been sent. Project documentation of these projects have been gathered together to locate critical areas that affect each other. From this data a project structure has been created with key areas of interest. This data has been put into a Design Structure Matrix, to see the cross reference of impacts on other key areas. From the data of the Matrix we will be able to see different factors impacting each other and site operations.

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Joel Kuusman

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Pori 12.03.2019

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LIST OF SYMBOLS AND ABBREVIATIONS (IF NEEDED)

BF	Brown Field project. An addition to an existing factory that does not contain existing equipment or machines.
CRT	Cathode Ray Tube.
DAP	Delivered At Place (DAP) (The seller is responsible for arranging carriage and for delivering the goods, ready for unloading from the arriving conveyance, at the named place).
DSM	Design Structure Matrix.
ETO	Engineered To Order.
FAT	Factory Acceptance Test.
GF	Green Field project. A new factory.
Handshake	Two separate instances, i.e. Equipment by the same or different vendor tie into each other mechanically, electrically or by software.
IJV	International Joint Venture.
JIT	Just In Time
MBR	Modular Basic Robot.
PCR	Passenger Car Radial (tire).
QHSE	Quality, Health, Safety, and Environment.
R&D	Research & Development.
RF	RetroFit project. New equipment that will replace old and existing equipment.
TBR	Truck and Bus Radial (tire).
WCS	Warehouse Control System.

1 INTRODUCTION

“Global projects are a rather new but pervasive phenomenon of today's business environment—yet they are relatively unexplored. In addition, the general way of organizing companies has changed, requiring fresh perspectives on the fundamentals of organization design” (Orr et al., 2011.)

“Cimcorp Group – part of Murata Machinery, Ltd. (Muratec) – is a leading global supplier of turnkey automation for intralogistics, using advanced robotics and software technologies. As well as being a manufacturer and integrator of pioneering material handling systems for the tire industry, Cimcorp Oy has developed unique robotic solutions for order fulfilment and storage that are being used in the food & beverage, retail, e-commerce, FMCG and postal services sectors. With locations in Finland, Canada, and the US, the group has around 400 employees and has delivered over 2,000 logistics automation solutions. Designed to reduce operating costs, ensure traceability and improve efficiency, these systems are used within manufacturing and distribution centers in 40 countries across six continents. Cimcorp Oy head office is in Ulvila, Finland.” (Cimcorp Oy marketing material.)

1.1 Cimcorp Project history

Cimcorp Oy history begins in 1975 as part of the Rosenlew toolfactory automation department. During this time they started projects in the television CRT (cathode ray tube) automated handling. This was the main line of projects up until the eve of modern televisions that no longer use the CRT technology. These types of projects were typically small scale equipment installations that were done during shutdowns, often working with a large workforce in a 24 hour per day rolling schedule.

Several ownership changes and name changes ended in the name Cimcorp Oy the first time in 1986. The current name Cimcorp Oy has been in existence since 2004. Around this time Cimcorp was getting a new foothold in the tire industry automation. These projects have been growing rapidly especially in the past 10 years from a big project being 1-2 M€ to now full scale factory product automated handling in the range of 50 to 80 M€ and above.

During its rapid growth in the past years it has been evident that larger projects require a different approach in the overall project handling mentality and organization. Starting with the sales contract and its obligations from engineering, shipping, subcontracting to installation and commissioning. A lot of this has been revised during the past years, but there is much to improve, and Cimcorp Oy is aware of this. During its rapid growth in the past years it has been evident that larger projects require a different approach in the overall project handling mentality and organization.

Often installation and commissioning (also referred as on-site work or site operations) is done in difficult conditions sometimes in locations far away from modern accommodations. Any changes in the preplanned work scope, lack of material or equipment. Changes in Cimcorp Oy, customers or other vendor’s time schedules can have a huge effect on the project outcome and success.

It has been recognized throughout Cimcorp Oy that a lot of the problems that are encountered during installation and commissioning have actually occurred in an earlier phase of the project. Some of these problems can also affect earlier stages of the project that then indirectly affect again site operations. During 2014 site operations and on-site work were reorganized with the implementation of Site managers, whose responsibility are all on-site operations. Despite good progress more effort has been decided to put into the project in the point of view of site operations. Site operations include installation and commissioning of Cimcorp Oy scope equipment including subcontracted work.

1.2 Review of past installation and commissioning problems

“International joint ventures (IJV) are difficult to manage due to their complex structures involving two or more entities often having different and competing objectives and strategies. Since each project is unique, project-specific factors are significant for the success of an IJV as well as the risks associated with the host country in which the IJV operates. Although some companies may cooperate with the same partner in several projects, IJVs in many industries are considered to be project-based rather than continuous collaborations.” (Ozorhon B. et al., 2007.)

In the recent years, project amounts and sizes have grown to previously unexperienced sizes. Almost all of Cimcorp Oy medium to larger scale projects can be considered IJV´s. This has increased the on-site issues both in amount and magnitude that come with these big IJV´s. Site operations is the time and phase of the project where all previous mistakes are generally noticed, if not caught and handled earlier. This does not mean other areas do not have their own set of growing pain, but on-site, far away from sometimes everything, this can cause a bigger issue as missing or wrong parts take time to come, personnel staying far away from home cannot find other things to do if they cannot work. If there are delays in shipment, changes in time schedule, disputes or uncertainties with customer or other vendors, they always cause financial loss at the end. From the method Cimcorp Oy handles projects and past project meetings, memos and installation diaries project key areas have been summed up to be the basis of this work and DSM. The DSM contains key areas of the whole Cimcorp Oy project scope from start to end.

1.3 Research goals and exclusions

This work will concentrate on the main aspects of a Cimcorp Oy project that directly affect each other and site operations to help the reader of this work understand the magnitude of the project variables. It will show how these interlink to other project phases and possibly end up affecting site operations. From interviewing Project managers, Site managers, other site key personnel, reading the site specific memos of these projects and technical agreements a summary of key areas that can affect installation and commissioning have been created. This information has been gathered into a DSM (Design Structure Matrix).

The goal is to set up a DSM for Cimcorp Oy to investigate and show the impact of different project phases on other phases. This basic DSM can be used in future projects to explain the relations of each separate phase and instance with its possible effects on other phases and instances.

2 DESIGN STRUCTURE MATRIX (DSM)

The tool selected to gather this information and to compare relations to other concerned areas is the DSM. Part of this work is to also see how well the DSM is suited for this type of information relation comparison.

Decomposition and integration of complex systems require proper tools for the systems engineering of products, processes and integrations. A DSM is such a tool that provides a simple compact and visual summary of such a complex system. It gives an innovative solution to the decomposition and integration problems. Advantages of a DSM visual and different approach to the system representation and analysis techniques have increased their use in a variety of contexts, including project management, project planning, product development, systems engineering and organization design. (Browning T. R. 2001, p. 4.)

“Typically a DSM is a square matrix whose rows and columns are identically labeled with the design tasks of a development process as shown in Figure 1. In its simpler form the non-zero cells of a DSM indicate the existence of an information requirement between two development activities. That is, a mark in cell (h,d) indicates a that task h needs information produced by task d in order to be completed. Hence by examining row h of a DSM managers can easily identify the other tasks that provide information to task h, and by examining column d, managers can easily determine which other tasks are using the information produced by task d. As a result the DSM captures in a compact and visual manner the web of activities that form a development process as determined by the development tasks and their dependencies.” (Kleindorfer P. R. et al., 2009.)

The DSM can be further adjusted to suite various uses highlighting different aspects of information and grouping data in sections of the table. In this case the DSM is shown that in cell (h,d) task h impacts task d to a certain extent. This will be added with a dimension where all information related to each other will be given a weight scale from 1 to 5 determined from further analysis of previous project information, occurrences and impacts. Value 1 will be indicating minimal impact on-site activities, cost or time schedule and value 5 will be indicating severe loss of time and money. So if the numerical value in cell (h,d) is value 3, the activity in row h has from previous cases and analyses caused column d´s activity a medium additional cost or delay in site work. (Eppinger S.D. & Browning T.R., 2012.)

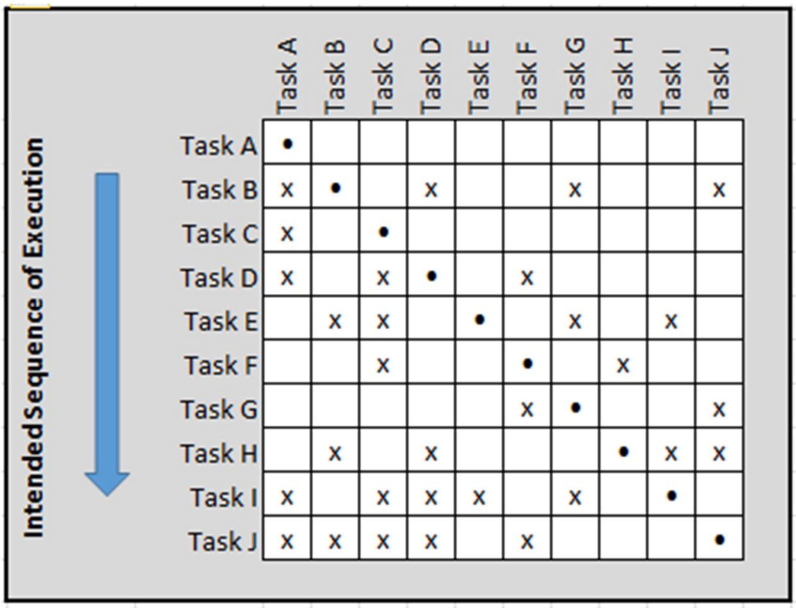

Figure 1. Example of a generic design structure matrix.

From the gathered known problem areas found and occurred during selected projects site operations a DSM has been created gathering main areas of importance affecting especially on-site installation and commissioning additionally showing the interlinkage of where a problem originated and what other areas of the project it has had effects on. The Cimcorp Oy DSM on factors impacting each other during a larger scale project is shown in Figure 2.

3 INITIAL DATA FROM PREVIOUS PROJECTS AND PERSONNEL

Cimcorp Oy can be defined as an ETO (Engineered To Order) project company. ETO sector companies are characterized by the complexity of engineered products and customer specific design, as well as by the distinctive nature of the engineered products. ETO components are produced often by separate fabrication shops, which sit squarely at the intersection of manufacturing and the installation and commissioning of the components. In traditional ETO supply chains, manufacturing processes are separate from the on-site installation and commissioning. This is emphasized by understanding that some suppliers produce and deliver their products directly to the site for assembly and installation. Importantly, because of often unreliable on-site execution planning, both by the customer or Cimcorp OY in addition with insufficient communication of on-site installation and off-site manufacturing, these are not scheduled in an optimal way. For this reason JIT (Just In Time) delivery of ETO components from manufacturing to the installation site is not often possible. (Matt D.T. et al., 2014)

Cimcorp Oy does not currently have a systematical ”lessons learned” protocol in use, where on-site occurrences are gathered and later reviewed after project is finished. Rather instances are recorded in various documents such as the site diary, and memos. This is something that could need more attention in the future, as it would help gather data and further improve the work in all aspects of on-site operations.

Data has been gathered from several large scale projects memos and on-site diaries and by interviewing key personnel of these projects. This was done to get a more versatile range of values and occurrences for the DSM through the whole Cimcorp Oy project. The five main categories, called phases, for the DSM project data are divided as is similar to most projects. These upper level categories have been further divided to subcategories that indicate certain important instances of the Cimcorp Oy main project phase. The five main phases and all their sub categories will be further explained for the reader to better understand them and their importance in a Cimcorp Oy project.

These categories are:

- System planning phase
    - Project scope
    - Project schedule
    - Obligations of the contractor & purchaser
    - Project type (GF, BF or RF)
    - Project location
    - Project risk assessment document
    - Standard equipment
- Project planning phase
    - Plant layout
    - Project acceptance plan
    - Resourcing
    - Non-standard equipment
    - Delivery plan & conditions
- Design phase
    - Procurement
    - Engineering
    - Manufacturing
    - Spare part plan
    - Machine Safety Risk Assessment
    - Equipment installation and commissioning schedule
    - Interface specifications
- Production and shipping phase
    - Site check done, ready to start installation
    - Site's risk assessment for work safety
    - Lifting plan
    - Installation and commissioning plan
    - Packing and hauling
- Installation and commissioning phase
    - Other contractor on-site work
    - Subcontractors
    - Installation equipment (lifts, cranes etc.)
    - On-site resource plan

4 RESULTING DSM

The created DSM, as seen in Figure 2 is divided into main sections and sub sections as described in previous chapter. This was sent out to be filled out by Cimcorp Oy key project personnel from all branches, whom are involved in any of the 5 main categories. The results have been compiled together. Authors note; There was in some areas high discrepancy in received individual DSM´s which this DSM was combined from.

PROJECT PHASES IMPACTING EACH OTHER ON CIMCORP OY LARGE SCALE INDUSTRIAL AUTOMATION PROJECTS	System planning phase	Project scope	Project schedule	Obligations of the contractor & purchaser	Project Type (GF, BF or RF)	Project location	Project Risk assesment document	Standard equipment	Project planning phase	Plant layout	Project acceptance plan	Resourcing	Non standard equipment	Delivery plan & conditions	Design phase	Procurement	Engineering	Manufacturing	Spare part plan	Machine Safety Risk Assessment	Interface specifications	Production and shipping phase	Site check done, ready to start installation	Site's risk assessment for work safety	Lifting plan	Installation and commissioning plan	Packing and hauling	Installation and comissioning phase	Other contractor onsite work	subontractors	Installation equipment (lifts, cranes etc.)	On site resource plan
System planning phase																																
Project scope			4	3	1	1	4	4		5	4	4	4	2		4	5	4	3	3	5		2	3	4	5	3		5	5	4	4
Project schedule		1		2	1	1	2	3		2	2	4	3	4		4	3	4	2	2	3		3	2	3	4	3		4	3	4	5
Obligations of the contractor & purchaser		1	4		1	1	1	4		1	3	3	1	2		1	1	1	1	2	3		4	5	3	5	1		3	2	5	4
Project Type (GF, BF or RF)		4	4	4		3	5	5		5	4	3	5	3		2	1	3	4	2	4		2	4	4	4	2		1	3	3	4
Project location		1	3	4	2		5	3		2	3	4	2	4		3	3	3	4	4	2		4	4	4	5	4		2	3	4	3
Project Risk assesment document		3	5	2	4	3		4		3	5	3	3	2		2	3	1	3	3	3		4	3	3	4	2		2	3	2	4
Standard equipment		3	2	3	1	1	3			2	4	3	5	3		4	3	4	3	4	3		3	2	4	4	4		4	3	3	3
Project planning phase																																
Plant layout		4	4	4	1	1	4	4			4	3	4	3		2	5	2	2	4	4		3	2	3	3	2		4	3	4	3
Project acceptance plan		2	2	1	1	1	3	4		2		3	2	2		1	3	2	1	4	3		1	1	2	4	2		4	2	2	3
Resourcing		1	3	1	1	1	4	1		1	3		1	3		2	2	3	1	1	1		1	2	3	4	2		2	5	4	4
Non standard equipment		2	4	1	1	1	4	4		4	3	3		1		5	5	5	5	5	5		2	1	3	4	3		3	4	3	3
Delivery plan & conditions		2	4	1	1	1	3	3		1	2	4	1			3	3	4	3	1	1		4	2	2	5	4		3	3	4	4
Design phase																																
Procurement		1	4	1	1	3	2	3		1	1	2	3	4			3	5	5	4	2		3	3	1	3	3		1	2	3	1
Engineering		1	4	1	1	1	3	3		3	1	1	5	2		5		5	4	4	5		1	4	4	4	4		3	4	5	4
Manufacturing		1	4	1	1	1	3	4		2	1	3	5	4		3	3		3	4	3		3	1	3	2	4		1	2	2	1
Spare part plan		2	1	2	1	1	1	2		1	4	1	3	2		4	2	4		2	4		1	1	2	4	3		3	3	3	3
Machine Safety Risk Assessment		2	2	1	1	1	3	4		3	4	2	5	3		3	5	3	3		4		1	2	3	3	2		4	3	3	1
Interface specifications		2	2	3	1	1	2	3		3	4	4	3	1		3	5	3	1	4			3	1	1	4	1		5	3	3	4
Production and shipping phase																																
Site check done, ready to start installation		1	5	2	1	1	3	1		1	4	3	1	5		1	1	2	1	1	1			4	3	5	3		5	4	4	5
Site's risk assessment for work safety		1	4	2	1	1	1	1		1	3	3	3	4		1	2	2	1	3	1		5		5	5	4		4	5	5	5
Lifting plan		2	3	4	1	1	1	3		3	2	4	2	3		1	3	1	2	2	1		2	5		3	4		4	3	5	3
Installation and commissioning plan		1	5	2	1	1	3	2		2	2	1	3	4		3	1	3	2	1	3		3	3	3		4		3	4	5	5
Packing and hauling		1	4	1	1	1	2	3		1	2	2	3	4		2	3	3	1	1	1		3	1	4	4			2	3	4	2
Installation and comissioning phase																																
Other contractor onsite work		3	3	2	1	1	3	3		4	4	3	3	2		2	1	2	2	3	4		4	5	3	5	2			3	4	4
subontractors		1	1	3	1	1	3	1		3	3	4	1	2		1	1	1	1	2	1		3	3	4	4	3		2		5	5
Installation equipment (lifts, cranes etc.)		2	2	1	1	1	2	3		2	1	2	1	3		2	2	2	1	1	1		2	2	5	5	4		3	2		4
On site resource plan		3	4	4	1	1	2	1		1	3	3	2	4		1	2	2	1	1	3		1	1	3	3	3		2	4	5	

Figure 2. Cimcorp Oy project matrix, showing factors that affect each other during a project. Values in cells indicate the following; 1 = no or minimal effect, 2 = can affect in uncommon cases, 3 = can affect but either typical or does not cause significant issue. 4 = has a significant affect, 5 = can affect critically.

From the DSM a simpler table can be made showing the averages of each main phase and its effects on another phase, as seen on Table 1. From these values, it can be seen that the most critical phase is the System planning phase, as it has the highest overall value of 3.23 and thus highest effect on other phases. Considering how a project is developed this is as it should be. However the highest affected area is the installation and site operations phase with an average of 3.38. This is 0.44 more than on the production and shipping phase that is the second heaviest area effected, a 14 % higher impact.

Table 1. Averages of each main phase's effect on each other including overall average effect on other phases and phase average effect.

	System planning phase	**Project planning phase**	**Design phase**	**Production and shipping phase**	**Installation and comissioning phase**	**AVERAGE effect on others**
System planning phase		3.20	2.90	3.43	3.39	**3.23**
Project planning phase	2.29		2.90	2.60	3.35	**2.79**
Design phase	1.95	2.70		2.50	2.79	**2.49**
Production and shipping phase	1.94	2.64	1.70		4.00	**2.57**
Installation and comissioning phase	1.96	2,55	1.67	3.25		**2.36**
Phase average effect	**2.04**	**2.77**	**2.30**	**2.94**	**3.38**	

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5 SYSTEM PLANNING PHASE

The System planning phase, also known as project sales phase is done during the pre-project. A lot of important information about the project is received from the customer. Decisions done during this time can affect the whole project outcome. By studying past projects, it can be noted that errors done here can have a large impact on all aspects of the project, including site operations. This phase is managed by a group of experienced key personnel who have the support of Cimcorp Oy staff in full. Cimcorp Oy implements a similar system during the system planning phase as shown in Figure 3.

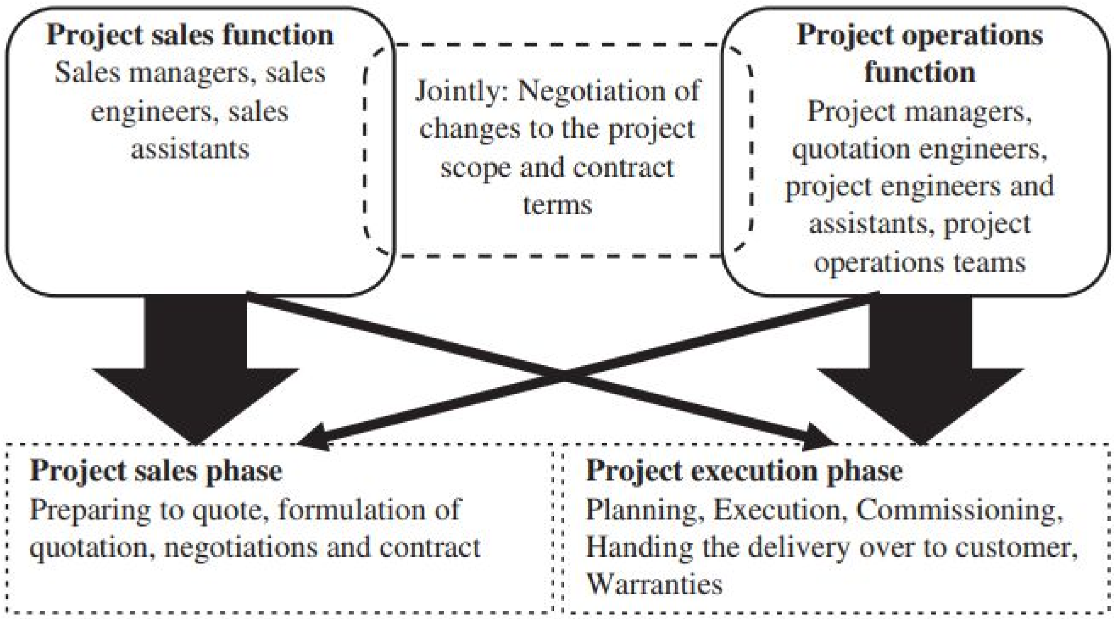


Figure 3. Integration of project sales and project operations functions in different project phases (Turkulainen V. et al., 2013.)

"Observations from projects suggest that the nature of the teams and meetings used to manage the system planning and operations interface changes over the course of projects. In the system planning phase, and especially at the end of the system planning phase, the teams involved managerial-level people and the focus of the teams and meetings was on matching customer requirements vs. delivery capabilities of the company. During the project execution phase, in contrast, the teams were more technical in nature, involving technical engineers. The discussion focused on technical interdependencies of the project solution, for which small changes in one part of the project might require significant compensating changes in other parts of the project. The use of cross-functional teams with both managerial and technical focus can be explained by the complexity of the projects, which is partly related to the project scope. Complexity relates to the number and innovativeness of technical components, their degree of reciprocal interdependency and the number of parties involved in delivering the project. These create information processing needs during the project due to the higher number of interface coordination issues to be solved. Formal mechanisms, especially liaison persons with no formal authority are also used during the project execution phase. In particular, sales managers were assigned as liaison persons during the project execution phase, although they had somewhat different roles in the different cases." (V. Turkulainen et al., 2013. p. 230.)

"While the project manager responsible for operations take the main responsibility for managing the customer interface. The sales manager, however, can act as a liaison between project sales and project operations to facilitate information processing from project sales to the project manager responsible for operations. The possible role of the sales manager as a liaison person in the project execution phase can be explained by dispersion as dispersion creates barriers between units, leading to a lack of understanding of customer requirements and delivery capabilities, and language barriers. All these increase the need for information processing between the project sales and project operations functions during the project execution phase. During the execution phase, dispersion creates information processing needs especially from the project sales function to the operations function. Such information exchange can be facilitated by assigning a liaison person from the sales function." (V. Turkulainen et al., 2013. p. 230.)

As can be suspected by anyone who has worked in an ETO project, the System planning i.e. Sales phase is the most critical phase affecting all other phases. This can be seen also by the DSM average effect on others score of 3.23 points out of a 5 total. This is by far the highest average effect on other areas from all five main phases as seen in Table 1. The highest area of impact is interestingly the production and shipping phase, with an effect score of 3.43 and after this the installation and commissioning phase with a score average of 3.39 points out of 5.

5.1 Project scope

"The Project scope definition is a process whereby a project is defined and prepared for execution. It helps to decide on whether or not to proceed with a specific project. An incomplete scope definition in early stages of a project's life cycle is a common source of difficulty in project development process. Meanwhile, the developing of the project can effect positively or negatively a variety of interests." (Fageha M. K. & Ajibade A. A., 2012)

The project scope determines what all is included in the Cimcorp Oy project scope and what is not. What equipment and solutions Cimcorp Oy will be offering and providing the customer, and what non-Cimcorp Oy scope equipment will be evident, for Cimcorp Oy equipment to tie into mechanically, electrically and by software. Also at this point it is determined who will act as the project integrator, who is responsible of making sure all equipment will function as specified together.

By studying the DSM, it seems that the project scope directly effects the Installation and commissioning phase significantly, more than any other stage under the System planning phase. For a person who has worked on projects this is true, but at the same time obvious. However there are several other instances during the Project life it has a significant effect also. The unanswered question is how much indirect effect a change in an already agreed project scope has on others after the System planning phase should be finalized.

By studying past projects some key points can be identified:

- Locking down non Cimcorp Oy equipment brands and types, with customer, whom Cimcorp Oy ties into, is critical to avoid re-engineering and changes in Cimcorp Oy offered equipment.
- Certain installation sequences for equipment should be already identified at this point.
- The safety aspects of areas where Cimcorp Oy and other vendor equipment handshake (tie into each other mechanically, electrically or by software communication) need to be more thoroughly agreed at this stage to avoid misunderstandings during engineering and site operations.

5.2 Project schedule

A peculiarity of construction is the high variability or unpredictability of future events. Cimcorp Oy projects can be related to construction work in many ways so, a static long time scheduling of on-site works cannot be used for coordinating the on-site operations and for aligning the manufacturing of ETO equipment. The concept presented combines the equipment scope to the working process (task list) on-site. Furthermore the planning of on-site operations and the sequencing of work is based on a Rolling-Forecast. The installation process of ETO work on-site should be planned in a daily granularity. At the end of the week an update of the planning is done by recording the effective realized tasks within the work scope, measuring in an accurate manner the progress on-site. In the concept, based on the detailed on-site progress a Look Ahead Planning of a minimum of 4 calendar weeks should be done. The Look Ahead Planning is done in a weekly time interval and is needed for triggering the delivery, installation and commissioning of components which are to be done. (Matt D.T. et al., 2014.)

At this point the schedule critical dates are making sure Cimcorp Oy has the capacity to manufacture required system to match this date and when facility for equipment is ready to receive equipment. However further along the project phase all other key operation dates including Installation and commissioning are integrated into this schedule. The DSM shows the project schedule has minimal effect inside the system planning phase, but more so in later phases, especially the Installation and commissioning phase. The Project schedule also effects the Design phase and Production and planning phase a little, this is mainly due to time required finalize these tasks. A little adjustment can be done by manpower adjustments, but only to a certain degree.

By studying past projects some key points can be identified:

- All data for engineering is not always received on time and customer often has not decided all other vendors or equipment for proper scheduling.
- Start date of site operations tends to move forward from agreed by customer, sometimes by months causing financial loss.
- Set key dates for non Cimcorp Oy scope critical equipment that interlink directly or indirectly to Cimcorp Oy system often are not controlled by customer causing financial loss to Cimcorp Oy.

5.3 Obligations of the contractor & purchaser

This Cimcorp Oy specific document is part of the contract separately agreed and signed by both parties. It holds a vast amount of detailed standard obligations concerning the project and items related to it. It includes for example the responsible party of arranging a local area network, facilities for workers, on-site electricity etc. From previous project history it is evident that it could be better emphasized to the customer to better fulfill their part of this document and agreement, in a timely manner.

The DSM shows that this important document and sub-phase contains information that is important to especially the production and shipping- and Installation and commissioning phases. It can have an effect on the original planned Equipment Installation and commissioning schedule possibly causing delays.

5.4 Project Type (GF, BF or RF)

The type of project GF (Green field), BF (Brownfield) or RF (Retrofit) has a very large impact on several aspects of a project. Especially site operations need to take this into consideration. This can affect on-site activities as BR & RF projects can have more available accommodations and lunch rooms, whereas GF projects, being often in an undeveloped area and construction phase, do not have these facilities ready for personnel. Safety regulations are often more strict in GF projects due to construction hazards. If construction work is ongoing in the same area of installation work, this can cause safety issues and delays. On the other hand, by studying project documentation, BF and RF projects are often more limited in workspace and existing equipment can limit methods of work and require time consuming extra work with special tools, hoists and other installation equipment. Hauling material to work location can also be difficult due to existing machines and small corridors and openings. It is evident from past project information that it is important to do, whenever possible beforehand, a proper review of the on-site work. “According to Sanvido V. E. & Riggs L. S., 1993. The terms GF and BF originate from the building industry, where previously developed land is described as being BF and previously undeveloped land is described as being GF. In information technology, as with construction, BF deployments can be cost effective because the infrastructure to support the new installation is likely to be already in place. However, BF deployments can be complicated by the need to rectify dependencies between the new and current installations.” The main difference between a BF and RF is BF is adding new equipment typically an add-on to an existing system or facility. An RF project is the modification or conversion (not a complete replacement) of an existing process, or facility. A retrofit project involves an existing facility. Working in an existing facility imposes constraints on the owners, operators, designers, and constructors. This modification may involve additions, deletions, rearrangements or upgrades of one or more parts and equipment of a facility. All projects have constraints, but a retrofit project is unique because the degree of freedom available to all parties is limited. Appropriate management and technical methodologies might solve, mitigate, or circumvent problems caused by these constraints and thus reduce project costs, shorten schedules, and achieve other project objectives. There are many justifications for retrofit projects, such as expanding plant capacity, incorporating a new technology, reducing cost, increasing quality, meeting environmental requirements, and enhancing safety. (Sanvido V. E. & Riggs L. S., 1993.)

A Typical Cimcorp Oy retrofit project is replacing an existing old Cimcorp Oy or other vendor system to a modern more efficient Cimcorp Oy system. The Project type affects a lot of its other sub-phases inside the System planning phase and has the least effect on The Installation and commissioning phase of all System planning sub-phases. One reason for this is that it is one variable that does not change during the project life.

5.5 Project location

“The project location is in some studies considered one of the 10 most influential factors that need to be considered for modelling construction duration. It is reported that construction duration can be also influenced by the project location. This can directly effect the installation and commissioning of equipment. Findings confirm that this categorization is valid and location does effect construction and thus installation time and from this the overall investment. Different regression equations based on project location ought to be generated to model construction duration. In other words, pooled models do not provide reliable results for time–cost relationship models.” (Dursun O. & Stoy C., 2011. p. 98-99.)

The DSM shows the project location effects the Production and shipping phase in full.
This is because the project location has a significant effect on not only on-site activities, but also engineering rules and regulations, packing and shipping. Not mentioning overall cultural differences. Key issue that is clearly evident is has the customer prior experience in

this location and has Cimcorp Oy prior experience in this location. When considering this aspect from an on-site point of view the following critical aspects can be found by reviewing previous projects:

- On time delivery, longer distances can cause more uncertainty on delivery dates due to customs, and other rules & regulations
- Packing might be affected due to size limitations and other constraints. This can cause extra assembly work and extra on-site time.
- Transportation, accommodation and on-site work conditions are very important on-site issues.
- Work Visas for personnel can take a lot of time, maximum days allowed in country can be limited per person.
- Local work force availability and skill level.

5.6 Project risk assessment document

"According to Project Management Institute, Risk Management is one of the nine key areas of any project, which determines the degree of success or failure of any project. Within the currently accepted view of project management as a life cycle process, project risk management (PRM) can also be seen as a process that goes on in the project from its conception through its planning, execution and control phases up to its completion and closure." (PMI, 2008. p. 273.)

The DSM indicates that the Project risk assessment document has an even medium impact on all phases and least directly the Installation and commissioning phase. This can possibly be explained by the fact that all categories of the document should be assessed prior to this. Cimcorp Oy uses a detailed risk assessment document that gathers a lot of data, dividing it into 10 different categories, as shown in Figure 4. This document is created for every project during the system planning phase, but it is a document that continues its lifespan all along the project. It is periodically evaluated based on possible new information. This document helps to foretell possible risk areas that might affect also on-site operations.

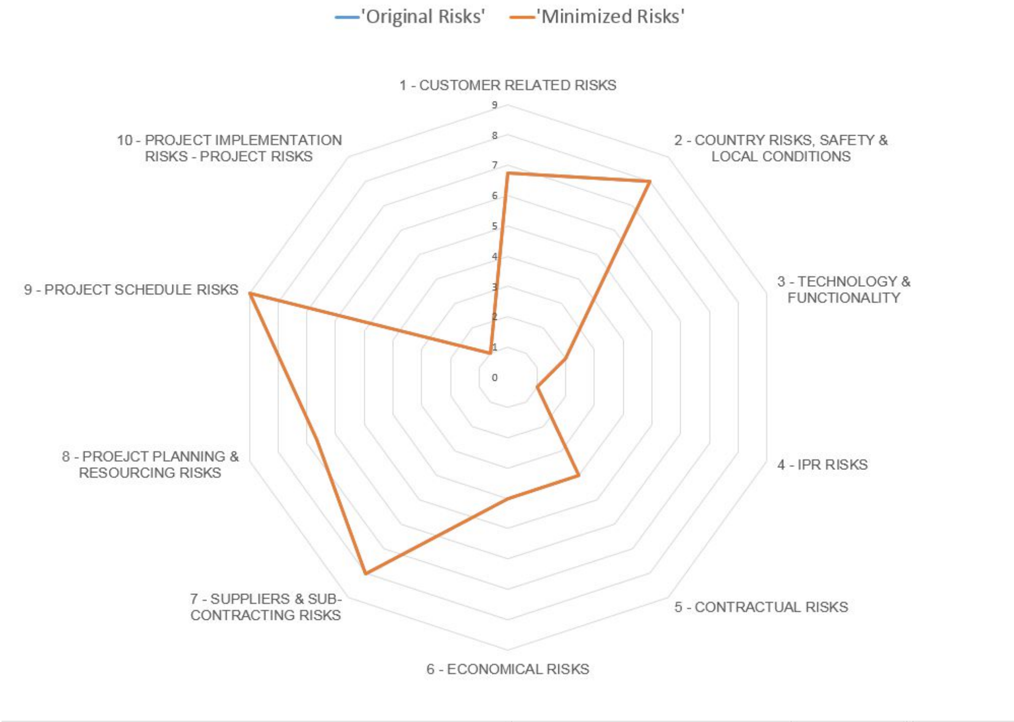


Figure 4. Example of Cimcorp Oy risk assessment graph.

5.7 Standard equipment

The equipment scope affects the project in full, from engineering, to project management to on-site operations. All schedules made are partially based on the amount of different equipment sold and their types. Equipment offered and sold can be divided into three categories. Cimcorp Oy standard equipment, Cimcorp Oy non-standard equipment and subcontracted equipment. Standard equipment is a unit that has been developed by our R&D department, engineered and tested and belongs as a commonly sold set of units that can work individually or as part of a larger system. An example of this is Cimcorp Oy MBR Gantry robot cell with a tire gripper attached. Non-standard unit is a unit that is either a modified standard Cimcorp Oy equipment to fit a specific purpose as for example MBR with a non-typical gripper attached to it, or a completely one of a kind unit like certain press infeed shuttles. Subcontracted equipment is anything bought, not manufactured by Cimcorp Oy. This can be for example support structures, conveyors or a general purpose autonomous robot not part of the Cimcorp Oy product line.

Based on previous projects the main risk is in the amount of non-standard equipment and subcontracted equipment and even equipment that Cimcorp Oy considers standard, that have non-standard modifications.

This section had the highest dispersion of given values from results ranging from a total score of 66 to 90. This was especially evident at the Design phase section. After some additional research, it can be determined that standard equipment itself have a minimal impact on other areas, but when there are minute changes to these Cimcorp Oy standard equipment, on any project they can have a significant impact on other areas. When evaluating this through on-site work, the score is 13/20 (65 %) it can be considered high, when it is on the median of 65%.

6 PROJECT PLANNING PHASE

"A project is a unique endeavor, a special task that has not been done before. Consequently, it is very difficult or even impossible to know precisely at the planning stage what are all the activities that need to be carried out in order to complete a project, and what their possible cost and duration parameters are. The issue is even more critical when the kind of activities that should be undertaken depend on the outcome of earlier activities or other vendors. The importance of the planning phase stands out relative to other phases in the project life cycle. In a recent study of development projects in Israel indicate that the planning phase, in which major decisions are made, such as deciding the project's objectives and planning the project's execution, has the most influence on the project's success." (Dvir D. et al., 2003. p. 90.)

This phase starts typically after the contract is signed by both parties. At the start of this phase a Cimcorp Oy project manager is selected with a team including a software manager and a mechanical manager. The detailed planning starts with the finalized specifications for the project. This phase is overall the second most critical of the five main phases This is partly due to a lot of the initial data still being agreed with the customer after the purchase order is signed. This phase has the second highest collected impact score with an average of 2.79 out of 5. This phase shows the third highest average effect directly to the Installation and commissioning phase with a value of 3.35 as is shown in Table 1.

6.1 Plant layout

Plant layout engineering is its own type of engineering requiring high skills and knowledge of also process engineering. There are a multitude of methods to approach layout engineering. Figure 5 shows the generalized plan layout engineering process. It combines the three different businesses using the knowledge about mechatronic units, their functionalities and use.

Cimcorp Oy approaches this in a mechatronic method optimized for Cimcorp Oy products and equipment. The three key factors of layout engineering are efficiency, economical usage, and safety. Used engineering processes are;

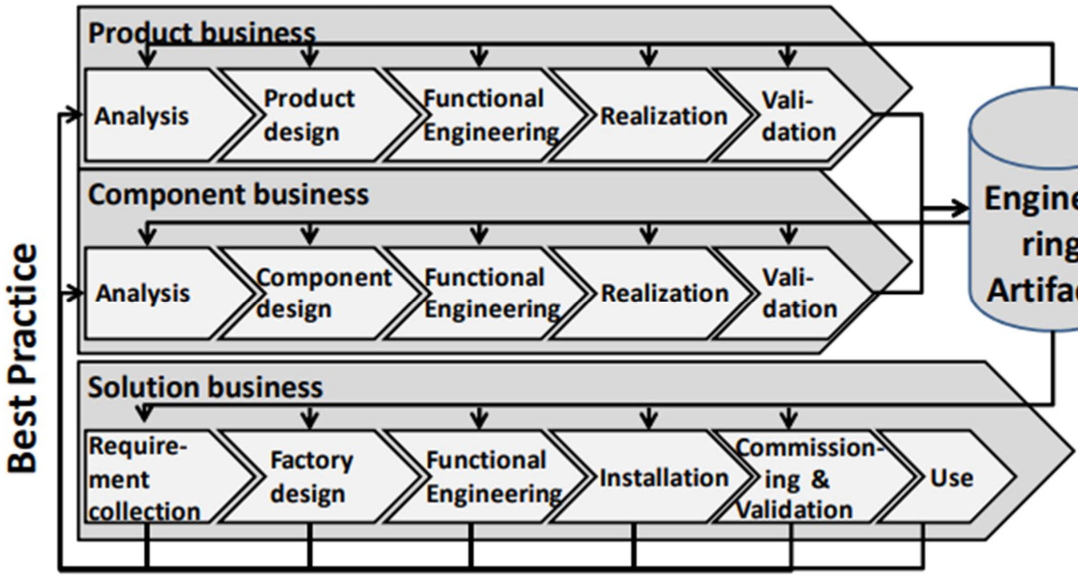


Figure 5. A generalized layout engineering process. (Lüder A. et al., 2011.)

The planned layout of the plant with Cimcorp Oy and other vendor equipment is frozen at the end of the system planning phase. It is not uncommon that changes and alterations occur after initial layout has been frozen and agreed upon all parties. This can be caused by change of previously agreed equipment, found mistakes in layout and other vendors. Typically customer or selected integrator is the main responsible party of master layout.

Major layout changes, especially at the end of the project planning phase can have a significant impact on the project planning phase and future phases. Lay-out changes are a result of iteration between multiple individual parties and seldom end up being an optimum solution due to financial constraints and customer decisions.

From the DSM it can be seen that this is the single largest sub-phase that can have an impact on the System planning phase in full. Any change to this after starting the Project planning phase can also have a significant setback where initial data from the System planning phase have to be reviewed and reconsidered. The plant layout effects Design phase especially via engineering. The layout and any changes in it can effect Installation and commissioning work significantly, the more lately a change in lay out has to be done the more critical the impact on-site operations.

6.2 Project acceptance plan

A quality plan does not only define the approach taken to ensure the level of quality for each result, but also the management processes required to influence the quality of the outcome, such as change, risk and management of problems. A risk plan lists all the anticipated risks of the project and presents some of the actions required to prevent any risk from happening and to reduce its impact if it happens. “Acceptance” is defined as getting approval from the client that the results produced from the project, meet the criteria set by the client. These criteria relate to the quality and cost of results and also the deadlines within which they are produced and can relate to the entire range of projects in industry, agriculture, services, infrastructure etc. (Kopani X., 2016.)

A production test and factory acceptance test plan is done for every Cimcorp Oy project. It includes the following information:

- Agreement that sets demands for project approval.
- Acceptance plan to clarify how project management verifies that approval demands are met at taking over and final acceptance phase.
- All device capacities and functionalities that are tested before shipping & FAT (Factory acceptance test).
- System capability, availability and functionality that are tested with customer according to agreed acceptance criteria.
- Final acceptance protocol, which is signed by customer after approval.

The DSM shows that overall this is one of the least effecting sub-phases. There are five key sub phases that the Project acceptance plan directly effects. These are;

- Standard equipment, due to these having already a very proven acceptance plan. If the equipment differs from standard, it will cause more work.
- Machine safety risk Assessment, as this has to be compiled completely new for any non-standard equipment.
- Equipment Installation and commissioning schedule is highly dependent on this plan.
- This plan is highly dependent on other site work, due to it often requiring other equipment from other vendors to tie in.

6.3 Resourcing

"A problem common for many high-technology companies is how can they balance the needs of project management as well as technologists in projects when both material and knowledge are needed for project success? The union between material and engineering knowledge in the form of projects within a company is viewed as a matching, and the established literature on matching is brought to bear on the issue. In particular, the project resourcing problem is related to the well-known "problem of stable marriage". A formal argument demonstrates that a range of potential choices for project resourcing exists and that such choices are anchored and routinized by the different organizational designs of the company. Efficient outcomes of project resource matching are related to several well-known organizational forms including the functional form, the project matrix, and the project-based organization. The project matrix organization can pay a heavy cost for its compromise between resource-preferable and knowledge-preferable projects." (Cunningham S. & Slinger J., 2014. p.1.)

Project resourcing and its risk are already taken into consideration to some extent in the Project Risk assessment document, as can be seen from the DSM. This is an ongoing iteration during the whole project lifespan. Despite the project needing resources during its whole lifespan the critical time and area is during the Installation and commissioning phase. Due to the vast growth of Cimcorp Oy over the past years, finding recourses for projects inside Cimcorp Oy who have enough time to invest in it is proven difficult and it is known that sometimes resources can be also double booked to more than one projects. Cimcorp Oy also uses out of the company help to cover peak times, but this does not take away the need of enough of Cimcorp Oy personnel, whom can concentrate on the assigned project from beginning to end. This is emphasized by the fact that many projects tend to extend over their originally agreed timelines due to reasons Cimcorp Oy has no control over.

6.4 Non-standard equipment

Standard equipment has been discussed previously and even though it would seem logical to have this non-standard equipment right after this in the System planning phase, It has been thought better to place it in this section. The basis of this is that even though it is already a subject acted on there, it has a heavier impact in this section.

Non-standard equipment is any Cimcorp Oy product line equipment that is engineered and manufactured from the start for a specific project and purpose or standard equipment with significant modifications. The amount of non-standard equipment engineered for a project during the design phase can have a high impact on a lot of other areas. This can be clearly noted from the compiled DMS by amount and high numbers.

For example:

- Engineering; More than standard man hours required.
- Procurement; Non-standard items purchasing and unknown delivery times
- Manufacturing; Unknown amount of man-hours required, uncertainty of on time parts delivery.
- Cimcorp Oy on-site work; Installation and commissioning man-hours unknown. Risk of errors greater than on standard equipment.

Typically subcontracted equipment is not considered non-standard equipment. For example conveyors, that is not part of the Cimcorp Oy product line.

Non-standard equipment also has an effect on Production and shipping- and Installation and commissioning phases. This is self-explanatory as non-standard equipment requires more time and is more difficult to preplan and predict. If proper testing has not been done prior to Installation and commissioning, this can cause problems and delays.

6.5 Delivery plan & conditions

“To acquire projects, companies tend to promise a delivery date that is as early as possible. This is too often done without sufficiently assessing the impact of these projects on the resource capacity, which typically leads to a serious overload of resources, thus having a devastating effect on the delivery, performance and the profitability of the production system and on-site operations as a whole. At the same time, if the quoted due date is not met, high delivery penalties may be charged.” (Hans E.W. et al., 2007. pp.570-571.)

A delivery plan is important especially for larger projects. It is important to try to get the right equipment to site on the right time, due to lack of extra storage areas. It made based on amount of equipment, location of work site and agreed delivery terms. Typically Cimcorp

Oy uses Incoterms DAP, but others are occasionally used. Equipment for overseas projects is packed into shipping containers on skids that can be easily unloaded. Equipment can also be manufactured in third countries, outside Finland or the country to be delivered to. Delivery of equipment can affect on-site schedule especially. There are many aspects that can cause delays of delivery that Cimcorp Oy does not have control over. For example customs, in countries Cimcorp Oy or customer has not had previous experience with. This is why location also affects delivery plan significantly. Also packing and hauling is directly related to the delivery plan.

The DSM shows that the Delivery plan sub phase is important for any schedules even in the Design phase. However more important for the Production and shipping phase, more precisely to the Installation and commissioning plan, that is done prior to start of site operations and packing and hauling. The Delivery plan is highly important also to the Installation and commissioning phase, especially actual installation and needed on-site resources.

7 DESIGN PHASE

This phase determines the details of the selected equipment while matching agreed and sold project scope during the system planning phase and project planning phase. Key areas that affect the design phase are project type, equipment sold, plant layout and amount of non-standard equipment. The design phase in return affects the project planning phase, production and shipping phase and Installation and commissioning phase.

The main causes of change in the design phase are unforeseen field conditions; correction of discrepancies, errors, or omission in contract documents; customer requested changes in scope; changes in building or lay-out; and changes in other vendor equipment and specifications. In addition, due to long lead times, too many design decisions have to be made at an early stage and based on vague understandings and assumptions, which often lead to less than optimal solutions, quality defects, and rework. (Elfving J. A. et al., 2005.)

The design phase overall has an average impact value of 2.49 on other main phases. It has the least impact on the Installation and commissioning phase with a quite large margin with an average value of 2.79. The Project planning phase is the second most affected with an average value of 2.70. From the DSM it is interesting to notice that the Design phase has the most internal effects of any phase in comparison. The Design phase also has a more than others effect on previous phases that can have in some cases a multiplicative effect on other instance re-effecting itself again.

7.1 Procurement

"Procurement has major impacts in project-based production, on other phases such as design and manufacturing. These impacts seem to be much greater than the industry has generally perceived and they hamper radical reduction in total lead time. It is demonstrated that the consequences of competitive bidding in project based production are not completely understood. The transaction cost for ETO product procurement is significant, but rarely considered. Competitive bidding forces the use of design and manufacturing methodologies that are poorly suited for a dynamic environment. Thus it considerably pushes design and manufacturing lead times and increases required resources." (Elfving J. A. et al., 2005. p.180.)

“In addition, competitive bidding can:

- Push engineered design further away from the real need, which increases the probability of changes and thus rework and cost.
- Increase batch sizes to meet the requirement to produce bid documents, which increases the probability of changes and thus rework and cost.
- Reduce incentives for cooperation and pursuit of common goals, so that system performance is sacrificed for local optimization. Prevents involving downstream players in the design process. The cost of not involving downstream players appears to exceed the potential savings from bidding. In spite of its shortcomings, competitive bidding is widely used practice in construction.”

(Elfving J. A. et al., 2005. p.180.)

Due to time schedules in Cimcorp Oy projects procurement has to order long term items at a very early stage. For standard equipment this is straight forward, but for non-standard equipment this can cause risk of delays in manufacturing, packing and hauling and from there the Installation and commissioning phase in general. This can be noted by studying the DSM. Procurement can affect overall project schedule at some points causing a snowball effect on other phases and sub-phases. However the more effected area is the Design phase and everything else inside this subcategory.

7.2 Engineering

Cimcorp Oy has high degree of variability in combination with highly dependent projects that can be encountered in ETO environments where there are several complex projects in parallel. These projects are often in a large percentage new to Cimcorp Oy, which results in a long engineering trajectory and many disruptions and adaptations. -As an example, because of specification changes from the customer. This type of project requires engineering and control approaches that are able to deal with both the organizational complexity and the variability, as well as with the complexity of the engineering problem.

Every product is engineered for a specific purpose. Therefore, every new product requires a long and intensive engineering process. Moreover, the customer may frequently require modifications of the design directly by request or indirectly by change of some other non

Cimcorp Oy scope equipment related to the Cimcorp Oy system. -Combining this with the complexity of the product results in an engineering environment with an extremely high degree of variability. (Hans E.W. et al., 2007.)

Engineering has a huge effect inside the Design phase it is a sub category of. This is obvious as engineering is directly effecting procurement and manufacturing especially. Cimcorp Oy has good protocols to handle this during this phase, to make sure engineering and changes are informed to these areas of effect. The engineering phase also has an impact on production and shipping. The reasons are simple, the more complicated the design, the more it effects production and often shipping too. The first area where possible engineering mistakes will be found, is during production and preassembly. In the Installation and commissioning phase, all possible errors and mistakes that might have been not noticed during manufacturing is found. Also engineering has a big impact on how the equipment will be installed and commissioned.

7.3 Manufacturing

Since supplier lead times are, for the most part much greater than the possible accurate foresight regarding work completion, JIT delivery of ETO components from production to the work site is not possible. The concept for aligning manufacturing to on-site work is very difficult due to typically having to rely on second hand information from customer. ETO components are released from the manufacturing within short time intervals. The last production process (assembly) sets the decoupling point from manufacturing to on-site installation. As soon as the site is ready for installation ETO components are released from production (assembly). This is done based on a detailed measuring of the construction progress on-site. Shipping time has to be also taken into consideration at this point. (Matt D.T. et al., 2014)

Project schedule, equipment, non-standard equipment amount and plant layout are items that affect the Cimcorp Oy manufacturing the most, based the DSM and Cimcorp Oy documentation. Manufacturing in return can directly and indirectly affect delivery plan, packing and hauling and the Installation and commissioning plan.

7.4 Spare part plan

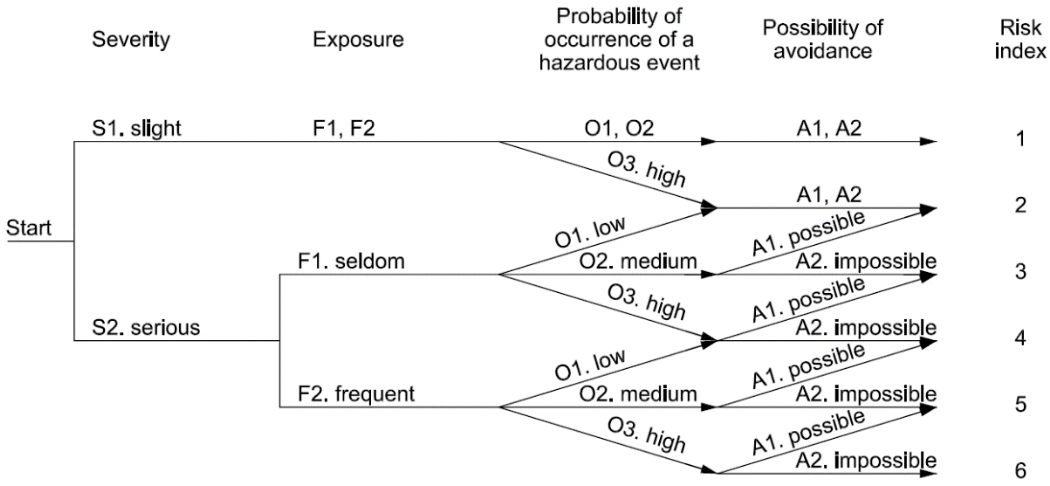
The most striking challenges of spare parts can be seen in the availability of the needed spare part(s), the ability to deploy the appropriately qualified service personnel, and the provision of required equipment, at the right place and the requested time. To meet these requirements, a well-organized planning of all tasks in spare parts supply chain is required.

The Spare part plan is often neglected by the customer and can have an impact on on-site work and the Installation and commissioning phase. If critical items for some reason are damaged during delivery or on-site work they often can be temporarily taken from the spare parts selection and afterwards replenished. This can save a lot of time during on-site works. The spare part plan is determined based on project scope, project type, project location, project risk assessment document, equipment, plant layout and amount of non-standard equipment. Cimcorp Oy offers several spare parts options for all project equipment showing long term high wear and tear items and critical items as higher priority as spare parts. However it is up to the customer to choose the spare part option that is best suitable for them.

7.5 Machine Safety Risk Assessment

The Cimcorp Oy machine safety risk assessment is done for all projects and devices. This document is managed by the QHSE (Quality, Health, Safety, and Environment) department. It is fulfilled together with various project technical personnel such as site managers, project managers and design engineers. Changes in engineering can have a significant impact on the machine risk assessment. The risk assessment is done based on a risk graph as shown in Figure 6. This Risk graph is a summary of a separate spreadsheet containing the Risk assessment with Risk reduction and Residual Risk information that has the following subsections:

- Mechanical hazards
- Electrical hazards
- Thermal hazards
- Noise hazards
- Radiation hazards
- Hazards caused by materials or substances
- Ergonomic hazards
- Environmental hazards



1 Risk reduction is not needed

2 Risk reduction measure: Training and Personal Protective Equipment (P.P.E.)

3 Actions for reducing the risk should be considered

4 Protective measures needed. Made as soon as possible.

5 Protective measures must be done urgently

6 Stop machine, protective measures must be done immediately

Figure 6. Risk graph used in Cimcorp Oy Risk assessment. (EN ISO 14121-2)

The Machine Safety Risk Assessment starts already earlier than it is depicted here, but this is the time it needs to be finalized. It can have an effect on already designed non-standard equipment in a way that something can have to be redesigned based on this sub phase. This is why both non-standard equipment and engineering are impacted on this especially. Site works can have some impact on this sub phase with additional safety equipment might have to be added, sometimes also effecting other on-site contractors with tie-ins to their system.

7.6 Equipment Installation and commissioning schedule

“The development of concise and accurate Installation and commissioning schedule of activities is very important not only to the overall loading of the project schedule, but the plan also becomes an excellent guide for the commissioning team in the correct prioritization and execution of various steps that make up the whole effort. Many projects are now being installed and commissioned to a very fast track schedule. This is typically demonstrated as new project commissioning build within the confines of an overhaul or turnaround of an existing asset. In these scenarios a very detailed hour by hour, procedure by procedure schedule will be invaluable as the duration of the schedule will be the principal driver to recommence production in an acceptable manner.” (Killcross M., 2012. pp.101-105)

The Installation and commissioning process of ETO equipment on-site is planned in a daily granularity. At the end of the week an update of the planning is done by recording the effective realized tasks within the construction and other installation sections. So, measuring in an accurate manner the overall site Installation and commissioning progress on-site becomes possible. In the concept, based on the detailed on-site progress a Look Ahead Planning for approximately 4 calendar weeks is done. The Look Ahead Planning is done in a weekly time interval and is needed for triggering the prefabrication of components. (Matt D.T. et al., 2014)

This Cimcorp Oy schedule is based on the initial project schedule, equipment scope and project type. Also delivery plan and amount of non-standard equipment and location can have an effect on it. This schedule is the basis of all on-site work and it is related to the lifting plan and installation equipment also. The installation schedule is heavily affected by the customer and other vendors. Their work and schedules can have a significant effect on the installation schedule. It is very common that this changes a lot during especially larger projects and if not taken into consideration can cause a negative financial affect.

7.7 Interface specifications

Within the first phase, the system planning phase, the basic requirements of the intended system are developed. Based on this, the engineering phase designs the intended system.
Therefore, at first a raw planning including system decomposition and association of functions to the system components are made. Afterwards a detailed engineering will specify the system components regarding their behavior and interfaces. The system design is used in the project planning and phase as a system specification for system implementation. Thus, the system components and its interfaces are implemented by hard- and software and partially validated. Then the different system components are integrated resulting in the complete system. This is where an experienced system integrator, managing all this information is important. The complete system is validated in the Installation and commissioning phase. Therefore, the implemented system, its behavior, and its

functionalities are compared with the initially defined requirements. Finally, the implemented and tested system is used. (Lüder A. et al., 2011)

Interfaces are inevitable in any automation project; however, the number and complexity of them are dependent upon the project size and type. Interface specifications can be divided into three groups:

- Mechanical interface; any piece of equipment that is mechanically attached or aligned to a certain location, to function with another piece of equipment.
- Electrical interface; any wiring that comes from another piece of equipment. This can be electrical feed, safety or operational signals wiring.
- Software interface; any level operational program and safety communication to and from other equipment.

Cimcorp Oy has a ready set of basic interface specifications that are already discussed during the system planning phase. During the system planning phase an integrator might be selected. The main responsible party for setting interface specifications is the main integrator of any given project. Interface specifications are done in a very detailed level especially on the software side and agreed with customer and other vendors that Cimcorp Oy shares any interface with.

8 PRODUCTION AND SHIPPING PHASE

"In the early project stages, projects may vary significantly with respect to routings, material, tool requirements, or the work content of activities. In spite of the uncertain project characteristics, project accept/reject decisions must be made, and important milestones (such as the due date) must be set. It is common practice that companies accept as many projects as they can possibly acquire, although the impact of a decision on the operational performance of the production system is extremely hard to estimate." (Hans E.W. et al., 2007. p. 8.)

Any alterations to equipment, equipment scope and interface specifications can have a negative impact on the production and shipping phase. From studying previous project history the following critical examples can be brought into attention:

- Changes in project scope or sold equipment
- Changes in plant layout
- Non-standard equipment
- Machine Safety Risk Assessment
- Interface specifications

The Installation and commissioning phase is highly dependent on the production and shipping phase and delays that can occur in this phase. Delays during production and shipping are can cause financial and time problems during on-site work, especially if project end date(s) cannot be adjusted accordingly.

The Production and shipping phase is affected by previous phases and has the least effect on them. The average effect is 2.57, but this is the result of it directly effecting the Installation and commissioning phase directly the most by an average of 4.00. One reason for this is that they are often directly interlinked.

8.1 Site check done, ready to start installation

During all previous phases progress of especially GF projects, the site work is tightly followed. This is done by regular interval meetings and reports with photos from customers and when the start of on-site work starts a visit. This is to ensure that agreed schedules do not get out of sync. Cimcorp Oy follows this progress before and during installation by a selected steering group. It is this group that act as full in all major decisions concerning the project.

If site is not ready for Cimcorp Oy installation:

- Equipment has to be temporarily stored. This causes additional expenses. Worst situation is if material has already been shipped before delay is known and might have to be stored in inadequate conditions on-site.
- Reserved personnel, flights and accommodation can cause additional expenses.

Improvements to an installation process for an engineered system involve consolidation of the number of visits to a work site by field staff and/or particular work performed in a given site visit. A site visit manifest is generated to provide electronic documentation of pre-installation and/or installation activity. Various types of electronic information may be generated and collected in connection with any of multiple possible phases of a given installation at a particular work site for purposes of generating a site visit manifest. Additionally, different information components of a site visit manifest may be selectively viewed / accessed to facilitate one or more of review of the work performed, quality, productivity and / or cost assessments of same, and billing functions. (Nielsen F. et al., 2012)

A situation that Cimcorp Oy equipment arrives late to site installation can cause additional cost from possible penalty payments and if other vendor equipment has been installed it could affect Cimcorp Oy equipment installation. To avoid these issues, site checks are done on predetermined times. From these site checks and meetings with customer site readiness for installation is determined. As can see from the DSM this is a very crucial think that can affect the whole output of a specific project.

8.2 Site’s risk assessment for work safety

Risk assessment for work safety on-sites applies especially in certain high risk counties and especially GF sites. Cimcorp Oy has to be responsible for safe working conditions of all of its personnel and all Cimcorp Oy subcontractors working on-site. The first risk assessment for work safety is done prior to approving the start of any site operations. This assessment is done typically by project manager and site manager. Both have the right to stop already started work, if conditions change from original assessment.

Items that are known to affect the site´s risk assessment for work safety:

- Project type; Green Field projects, where there is still a lot of construction work going on simultaneously with equipment installation.
- Project Location; Different cultures have different standards for work safety
- Plant layout; Complicated layouts must be separately evaluated
- Non-standard equipment; Risk of installing and commissioning on-site must be also taken into consideration.

Site risk assessment can itself affect:

- Project risk assessment document
- Equipment Installation and commissioning schedule
- Lifting plan; more demanding or difficult lifting
- Installation and commissioning plan
- Other contractor on-site work
- Installation equipment; change of equipment might be necessary to install and commission certain equipment.

8.3 Lifting plan

All lifting operations must be properly planned, appropriately supervised and carried out to protect the safety of workers. This regulation places a legal duty on any employing organization to properly plan and appropriately supervise each and every lifting operation. (European Directive 2009/104/EC)

Cimcorp Oy work sites require a significant amount of lifting, as typical machinery operating height is 4.5m to 8.5m. Because of this a general lifting plan is done according to ISO 12480 for all sites separating all individual lifts. If a certain lift has the aspects of a demanding lift, then a separate lifting plan is done for this specific lift. Some Cimcorp Oy site managers have the ISO 23813 qualification of supervising demanding lifts.

From studying the Cimcorp Oy reports and compiled from them the DSM, the lifting plan can affect the following areas:

- Obligations of the contractor & purchaser; mainly determining the responsible party of doing lifting and arranging lifting equipment.
- Resourcing, sometimes special resources are required for more demanding lifts. Lifts also in general require 3-5 personnel depending on lift type.
- Site's risk assessment for work safety; a lifting plan is closely related to work safety and is tied into the risk assessment.
- Installation and commissioning plan; Planning lifting times can affect other site work, as certain lifting equipment might be available only on certain times and personnel might have to be pulled from other work to assist. Also other work near lifting area might have to be halted.
- Packing and hauling; how the item is delivered to site can have a significant impact on how it has to be lifted and installed.
- Other contractor on-site work; other work can have a significant impact on lifting and the lifting can also affect other contractors. In some cases lifting device has to be shared with other contractors.
- Installation equipment (lifts, cranes etc.); the plan determines type of equipment needed, depending also on availability of certain equipment. Often only a limited scope of equipment is available, and lifting plan has to be done based on availability of certain types of equipment.

The DSM shows that a lot of variables affect the lifting plan and this is a constant iteration up to the time of lifting, especially in more remote locations. Items that affect the lifting plan are the following: Project scope, Project type, Project location, Equipment, Engineering, Plant layout, Non-standard equipment, Equipment installation and commissioning schedule, Site risk assessment for work safety, Packing and hauling, Delivery conditions and Other on-site work.

8.4 Installation and commissioning plan

"A peculiarity of construction is the high variability or unpredictability of future events. So, a static long time scheduling of construction works cannot be used for coordinating the construction-site and for aligning the manufacturing of ETO components. The concept presented in this section combines the bill of material to the working process (task list) on-site. Furthermore the planning of construction works and the sequencing of part numbers is based on a Rolling-Forecast. The installation process of ETO components on-site is planned in a daily granularity. At the end of the week an update of the planning is done by recording the effective realized tasks within the construction sections. In the concept, based on the detailed construction progress a Look Ahead Planning for 4 calendar weeks is done. The Look Ahead Planning is done in a weekly time interval and is needed for triggering the prefabrication of components which are than stored in a supermarket." (Matt D.T. et al., 2014, p. 460)

Cimcorp Oy installation plan is a document managed by the project manager after the system planning phase. During the production and shipping phase this is reviewed with the site manager of the project and handed over to the site manager. Final review of this document before site operations begin is done after site risk assessment for work safety is completed and deemed acceptable. This document is viewed on a weekly basis during on-site work and from this a progress report is sent to Cimcorp Oy headquarters for project steering group meeting information. It is common that this document is updated based on-site activities, customer and other vendor progress. From past projects study it can be said that most of the projects previous key points affect this plan directly or indirectly. This separate plan is very important as this is where several different aspects from a project start tying into each other. Customer obligations must be fulfilled simultaneously to other contractors to match the Cimcorp Oy and original plans. That is why this is always separately planned in detail. There are a multitude of things that can cause changes in the Installation and commissioning plan and from there the overall project plan.

As the DSM shows, this individual plan can have a heavy effect on the overall project plan. This is the area that causes the most difficulties time schedule wise at the final stages of the project. This can also effect the delivery plan both prior to on-site work starting and during on-site work, as material might not be wanted on-site until certain other areas are complete.

The Installation and commissioning plan overall has an impact on the Installation and commissioning phase, i.e. on-site operations, as this dictates a lot of the on-site operations, what where and when.

8.5 Packing and hauling

Every package will undergo stress such as jolts, vibration, and pressure, as well as environmental influences such as moisture, dust, and dirt during transport. General standards should be seen as minimum requirements. Additional measures are often necessary to protect the packed goods. These can also be packed as agreed with the customer. As a matter of principle, packing will be implemented in such a way that the packaged goods and their packaging can be transported and stored without damage.

In the process, it should also be ensured that the packaging can withstand multiple transshipments during transport. In the selection of the shipment packaging and pallets, attention must be paid to the correct size (shipment contents plus padding) and to sufficient stability. For very heavy products packaging made are of wood (crates) or components of wood (wood stacking frames) are normally used. In the use of wooden packaging, care should be taken that any import regulations or requirements of the recipient country are fulfilled and that any shipping documents necessary for import or certificates in accordance with applicable law are accessible. Cimcorp Oy has permission to stamp its own packing wood. Also all items are also plastic covered to withstand some rain, however storing without cover is always prohibited by agreed shipping contract. Cimcorp Oy generally packs all of its material and equipment in containers with a detailed predetermined packing plan. This is done by a Cimcorp Oy packing division, whom specialize in this area of shipping.

Packing and hauling can affect the project schedule and delivery plan and conditions and from there possibly the Installation and commissioning plan, if problems are found during the packing and hauling phase. These problems can be difficulties in hauling routes and times or packing to a certain project requirement specification there also is always a risk of oversized crates in container, due to packing at origin facility does not match on-site conditions. Packing and hauling also can have an effect on needed installation equipment. In most cases the material comes in standard 40 foot containers. This requires a small enough forklift to fit in there with enough lifting capacity the get the material from the container. In some cases unloading might have to be done from container/truck to ground without unloading platform. This may require more than normal amount of equipment and special equipment with a long reach etc.

9 INSTALLATION AND COMISSIONING PHASE

Installation and commissioning is an important phase of the project, covering installation, commissioning, and trial operation, the various stages of completion and acceptance, and ultimately fully functional operational and finished work site. The primary objective of the implementation of a project is structuring and rationalizing the installation and commissioning process. Most of the non-value-adding activities (like waiting times) are caused by an interruption of installation due to a lack possibility to continue installation by various non Cimcorp Oy related activities. In usual project supply chains, economic benefits of a project reached through scale effects in previous phases, are lost due an inefficient installation process on-site.

The Installation and commissioning phase, being the last phase of any project has very little effect on the previous phases with an average effect on others score on table 1 of 2.36. The only phase it has some effect on is the Production and shipping phase as the DSM shows. The main reason why there is interaction between these phases is that especially in larger projects the on-site work starts prior to all material being ready and shipped.

9.1 Other contractor on-site work

Push systems are those where production jobs are scheduled, whereas Pull systems are those where the start of a new part or phase of on-site work is triggered by the completion of another. Often these pull systems that affect Cimcorp Oy scope are from other on-site contractors not working under Cimcorp Oy. Cimcorp Oy has too often work in the same areas of the main contractor, building the facility, with their sub-contractors and other contractors installing their own equipment. Everyone has their own schedules and interests. Installing everything just on time, before some parties and after others is very difficult and requires a lot of cooperation with all parties. It helps if there is an experienced overall coordinator and system integrator handling all of this on a weekly and daily basis.

Other contractor on-site work can have an effect as early as the plant layout and project acceptance plan during the project planning phase. This is when it is finalized what company and specific equipment Cimcorp Oy equipment ties into and how. It is important to notice that a lot of the later phases do already interact in some level with earlier phases and this needs to be taken into consideration. Other contractor's on-site work effects the most in full the production and shipping phase, with an impact on the site check, sue to knowing that other required installations from other vendors are on agreed schedule, site risk assessment for work safety and Installation and commissioning plan. This can also have an impact on the Installation and commissioning phase with amount of lifting equipment needed on certain times, especially if schedules do not sync. The same thing applies to the on-site resource plan for the same reasons.

9.2 Subcontractors

Subcontracting has considerable importance to Installation and commissioning of a project because using in-house resources is often costlier than outsourcing. In this context, international subcontracting as a production strategy is common also by other international project entities.

Cimcorp Oy subcontractors can be divided into two categories subcontractors for work only and subcontractors that install their own equipment Cimcorp Oy has purchased for the project, like for example conveyors. Cimcorp Oy uses both Finnish and local subcontractors. Often Finnish contractors are personnel highly experienced with Cimcorp Oy equipment and during Installation and commissioning they are considered part of Cimcorp Oy personnel. All site works are balance between Cimcorp Oy key personnel and subcontractors with a ratio ranging from 1 to 3 up to 1 to 8, with the Site manager always being a well-qualified Cimcorp Oy personnel. In today's competitive business environment, subcontracting arrangements are an important practice in international construction projects. The selection of Cimcorp Oy subcontractors starts at the project planning phase, but is not finalized until a later. The final decision is done by the Cimcorp Oy project steering group.

The DSM shows subcontractors affect the overall resourcing plan in the project planning phase. Especially if Cimcorp Oy can use a subcontractor used prior helps make the lifting plan and on Installation and commissioning plan with minimal risk of changes after on-site work starts. Inside the Installation and commissioning phase subcontractors can have an effect on installation equipment needed, as some contractors will be used with their own equipment and also certain subcontractor have personnel that can operate certain special lifting equipment. The on-site resource plan is of course effected, based on used subcontractor and their agreed work scope.

9.3 Installation equipment (lifts, cranes etc.)

The decision of needed installation equipment is predetermined during the Project planning phase. It is then worked on up until the start of the Installation and commissioning phase when the final lifting plan is done. Things that determine selected installation equipment are the following; project size, layout amount of personnel reserved for on-site activities, is the project only on one floor or multiple stories and openings for hauling, how material will be delivered to site, lifting height of installed Cimcorp Oy equipment and what type of equipment are available in vicinity of work site. Sometimes this is arranged via customer or local subcontractor, but more commonly by Cimcorp Oy.

The DSM shows that the Installation equipment selected and locally available can affect the Lifting plan significantly and from this also the Installation and commissioning plan and even the packing and hauling of equipment. This is why this should be known as early as possible prior to Installation and commissioning starting. As mentioned this can also affect the on-site resource plan.

9.4 On-site resource plan

The on-site resource plan is an adaptation of the overall project plan with more daily and weekly details. This is originally compiled also during the Project planning phase and evolves during the project. The On-site resource plan is also monitored and edited during on-site work in progress. Areas and tasks completed are also marked on this, so personnel off-site can follow progress. The DSM shows that this can affect the project schedule, just as the project schedule can effect this. It can also effect the obligations of contractor and purchaser. Inside the Installation and commissioning phase, this can directly affect the subcontractor selection and quantity and also required installation equipment and their durations on-site.

10 SUMMARY AND PLAN OF ACTIONS

The main summary of this work is that no effort should be spared in the any stage of a project to properly define and further distribute any changes in any phase of the project including the individual phase requirements. This task cannot be fully achieved without the whole project personnel involvement in the process and knowledge distribution. Involvement of all parties should start at the initial phase of the project and continue until its successful end. Special importance is full project involvement until the freezing of all end-product specifications and personnel from the end of the project phases participating in the early phases of the project, to supervise areas and issues that do not directly affect other phases. A certain level of information sharing tools and standard procedures are also important but what kind of tools is of no importance, as long as they are used companywide through all phases. Furthermore, formal planning is in the hands of the project manager while the development of requirements, specification and actions is dependent on tight cooperation with personnel of all phases of the project.

The compiled DSM was a very affective and visual way for showing interactions of different project phases and the magnitude of importance and gathered a lot of interest already while being compiled in Cimcorp Oy. After gathering the initial data for the DSM it was evaluated by Cimcorp Oy personnel, then sent to selected personnel to be filled. Despite having people from different branches of Cimcorp Oy fill the matrix in, the individual results indicated surprising similarity. The compiled matrix is an average of these results. The text in Chapter 2 was sent as instructions of how to fill the matrix in, to minimize the possibility of errors understanding this variation of the DSM. It has been noted during this work that some of these high impact value areas and phases could benefit by undergoing further investigation on what causes the high impact on other areas and investigate possibilities to try to lower this impact number on other effected areas.

During this work it was noticed that Cimcorp Oy uses many KPI´s, to follow several different project phases and aspects, but none that specifically monitor on-site work effectiveness. It is suggested that Cimcorp Oy try to find suitable KPI´s to use for on-site work effectiveness monitoring that are suitable to be used for the basis of on-site man hours per scale of project. One of these could be a balanced score card KPI, that the author has noticed while looking for information for this work.

It is also suggested that key personnel involved directly in site operations is involved when project is evaluated in system planning phase. This helps getting personnel from this phase involved in the project at an early stage and it can be argued that their input could be beneficial for successful project accomplishment.

11 CONCLUSION

The biggest task of this study was trying to keep the scope of work in reasonable limits, and focus on on-site operations. To fully understand issues that affect the factors impacting on-site operations of large scale industrial automation projects, properly one must understand the project structure in full and be able to correctly find all key elements in a way that it can be understandably explained to the reader. Summarizing the vast amount of information of all phases has the risk of losing valuable information for this study, but the author believes this is enough to understand the importance of the DSM and its outcome about the importance of on-site operations. The selected DSM method worked well when showing the effect of different project phases on other phases with the scale value of importance. The difficulty is explaining that despite the order in the DSM the particular original information for a specific phase might be originally from a previous phase and it is showed at the particular phase, as it is considered more important and possibly a time when it must be finalized. Thus there is a certain amount of iteration during the project lifespan and the phases on the DSM are gone through several times during a project lifespan to various degrees. Handling all this information is one of the more important tasks of the Project Manager. An important thing to notice is that something changing can cause a chain reaction. For example if something significant changes in the Engineering sub-phase, it can effect some or all of the following; project schedule, resourcing, possibly everything else in the Design phase and then multiply from those to other areas. This is the main area where the communication through all phases is important. The longer the chain the higher the risk of it not following through properly.

Due to time constraints of the author and key personnel, with Cimcorp Oy current workload, the results of this work are based on the input of 7 individuals involved in different phases of 6 individual projects that were studied, 4 Greenfield and 2 Brownfield. To get more reliable and accurate data and results the author of this work recommends that Cimcorp Oy to extend this study with more detailed phases for individual project types. However even with the limited amount of participants the DSM shows how the different phases have certain critical areas and that focus is that Installation and commissioning are the main areas of final affect.

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