Stockholm School of Economics
Department of Marketing and Strategy

Integration Flow Management (IFM):
Applying lean principles to complex airport logistics projects

Our research has two primary goals. The first one is to investigate to what extent the concepts of lean production are applicable to complex Siemens Airport Logistics (SAL) projects. With the example of Toyota we know, lean principles are very effective in a manufacturing environment. However, the SAL project environment is much more complex in its nature and many characteristics need to be considered that are different from those of manufacturing. We have chosen this topic because, so far, there has been little research done in dealing with this kind of issue. In addition to that SAL is very interested in this topic. As a result, Felix Grimm did a summer internship at Siemens, where he had access to first-hand information about SAL processes. In our analysis we studied various lean concepts that Toyota introduced and concluded that even though some limitations and obstacles exist, due to the difference in systems, those principles can in general be applied to SAL projects as well.

The second goal of our thesis (write either "thesis" or "paper" but not both) was to conclude, whether it would be possible to implement lean concepts at SAL from a procurement and logistics point of view. When we were comparing SAL's supply chain position with that of Toyota, major differences could be observed, and after a deeper analysis we concluded that an implementation of lean principles would not be feasible under current conditions. However, SAL has to some extend the capability to change this situation.

Key words: lean thinking, project management, integration flow management, implementation, logistics, procurement

Supervisor: **Professor Björn Axelsson**

Authors: **Felix Grimm**

Jelena Fedotova

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1 Introduction

1.1 Siemens Airport Logistics: Short insights into the business and the market

This thesis was conducted in cooperation with the Siemens Airport Logistics (SAL) division, which is a part of the Siemens Industrial Solutions group. SAL is providing all technical solutions that are needed to operate an airport (e.g. check-in desks, conveyor belts, scanning and screening devices, etc.). Almost all machinery, components and materials are procured from external companies, but in many cases SAL designs and patents form the technical basis, on which suppliers manufacture the goods needed by SAL. Some products from other Siemens divisions are used. In other words: The manufacturing of all material as well as installation services were outsourced whereas designing activities are still kept in-house in many cases. Hence, the actual business of SAL can be described as coordinating the integration of a large number of different hardware and software into a complex system. By offering the whole installation and integration to form a working system (excluding the construction of the building) SAL can be considered as being a turn-key provider. Their projects are of extremely high complexity and often quite high specificity. Fully automated solutions need to deal with extremely complex flow patterns in a very short time. This is easy to imagine if one looks at the number of planes that arrive at and leave from large airports, the number of baggage and cargo that needs to be sorted and transported, the time in which all this is supposed to happen, considering the safety and security measures and the amount of unforeseeable changes and interruptions that can occur every day. In addition to that investments into material and manpower to realize such a massive project are so high that only a financially strong company like Siemens can handle the risks involved. Despite these high market entry barriers the market for complete airport solutions is highly competitive. Continuous innovation, effective procurement and supply chain processes as well as outstanding project management are required to succeed in this environment. At the same time the very size of the projects to be performed and the different locations where they need to be carried out imply risks that are in many cases hard to forecast objectively.

1.2 Purpose

The analysis part as well as the conclusion of the thesis are divided into two parts. The purpose of the first part is to investigate in how far the principles that form the Toyota Production System (TPS = lean production) are applicable to the complex projects that SAL is carrying out. The very different environment of SAL compared to manufacturing companies like Toyota makes this a very interesting and relatively new field of investigation. In contrast to the rather general view of the first part, the focus of the second part will be on practical implementation issues. As the scope of this paper is restricted, we decided to go into depth only regarding one particular function of SAL. The choice for the main focus ended up to be on the procurement and logistic function. There were two main reasons for this selection. Firstly, Felix and his Siemens mentor as well as all interview partners at Siemens were convinced that the procurement and logistics function will be heavily affected by the implementation of lean concepts. Secondly, the operational part (flow optimization) on the construction site and the layout stage of the projects were already looked at quite carefully by other

Siemens internals and hence, a lot of optimization work has been done already. Furthermore, commenting on flow optimization in such an environment requires detailed technical knowledge and a high degree of experience that we don't possess. These considerations led to the following two research questions:

- ***Are the concepts of lean production applicable to SAL Projects?***
- ***Is an implementation feasible from a procurement and logistics point of view?***

This paper forms one part of a feasibility study that is currently carried out by SAL. Therefore, we also aim to conclude, whether (based on the insights gained from the study of the impacts on procurement and logistics combined with various other information collected) a "lean project" approach can potentially outperform the current processes at SAL. Hence, one important goal of this paper is to show not only the positive impacts that the implementation of lean concepts will have on SAL, but also the drawbacks that need to be considered if the traditional process approach is disestablished. In other words, an important goal of this paper is to provide a valuable part of the feasibility study for Siemens. Getting insights into the application of a famous management tool (lean thinking) to a wide spread business (plant engineering) should be of interest for anyone who is involved in project management in the large scale plant business and of course for anyone interested in the development of lean ideas. Furthermore, it is very likely that also managers from other project environments can find useful thoughts in this paper.

1.3 What is Integration-Flow-Management (IFM)?

The concept of IFM is very complex as it deals with a very complex business. The following paragraph briefly describes what it is about.

In the past SAL was facing major delays and other serious issues in their projects, which could only be resolved by very costly measures such as flying in additional material on an ad hoc basis and sending expensive top experts from all over the world to SAL construction sites. These experts form emergency teams, which consisted of people of different expertise. They turned out to be quite successful in solving the problems at hand. But this way of operating has also proved to be very expensive and hence contributes to a lower profitability of the business. The way SAL is currently handling delay issues is comparable to the expensive solutions that can be observed in car companies in mass production. Costly rework areas and rework staff are grouped behind the production line and supposed to quickly eliminate errors before the cars can be shipped.[1] One SAL project manager came up with the idea of using the cross-functional approach of the emergency team solution on a broader basis. As we will see later, this is an idea that is closely related to the multi-functional approach of Toyota's lean production principles. The result of his thoughts was a concept called Integration Flow Management (IFM). In general one can say that IFM is a tool to optimize processes by striving for earlier integration of all functions that work on a project. Hence, the basic concept already partly implies the use of lean concepts. Lean ideas are of course nothing new to managers. A lot of research has been done on this

[1] Womack, p.55

approach to production, especially in the various studies on the Toyota Production System (TPS). However, the approach to apply the concepts to complex unique projects rather than to product manufacturing, which is characterized by a more or less continuous flow, has not been researched extensively yet. So far some research has been done on the application of lean concepts in the construction industry. This kind of projects is only comparable to SAL projects to some extend. In other words, IFM is the attempt to apply the integral approach of the TPS to complex project tasks that differ from construction projects. The overall aim is to make people in the various processes realize how everything fits together as a whole and what implications this has for their actions in order to reach an optimal output. In practical terms the IFM approach aims to enforce coordination which in turn will reduce throughput time, cost and assets. To make the understanding of the terminology as easy as possible for the reader, IFM will be used as a synonym for “lean thinking in SAL projects” in the following. Hence, the initials “IFM” comprise the ideas that already existed when we started our work as well as all new lean principles applied to the SAL business.[2]

In order to give the reader a more comprehensive understanding of the business SAL is operating in and a better insight into the issues that led to the idea of implementing lean concepts (IFM), the following paragraph will give a more detailed description of the current situation. Although technically a section about SAL’s business environment would rather fit in the empirical part, the authors consider an early placement of this section as necessary for the reader to understand the context, in which this paper was written. However, none of the corresponding theory on the typical plant engineering project environment is brought forward. To not further compromise the regular structure the authors kept this part in the methodology section.

1.4 Some insights into the current situation of the layout, procurement and installation phase of the SAL projects and corresponding issues

In general one can say that the SAL business must be seen as consisting of two interdependent projects. The first project to undertake is the bid proposal, which implies preparing a basic layout. If SAL wins the bid a more detailed layout follows. As the layout design is the central part of the first phase it will be called the “layout phase” in this paper. The second project is the actual installation and integration of material on the construction site. As it is important for the reader to keep in mind that SAL is not involved in the construction industry, this phase will be called “installation phase” instead of a construction phase.

1.4.1 The current situation of the layout and installation phase

Under the current (traditional) approach, the various functions involved in the process are optimized separately with a rather low degree of coordination. This observation applies to both, the layout and the installation phase. To explain the issue in the layout

[2] To show the reader what our starting point, some material that was the basis for the thesis will be presented in the appendix (page 54-56). These materials already include the application of some lean ideas. By checking these materials it is easy to distinguish what documentation was already available and what are new thoughts contributed by us.

phase a simplified but quite realistic example is used, which is illustrated in Figure 1. In the example the function that is setting the basis for a layout is the mechanical department. As soon as the task is completed the layout is published for the following designing task on the intranet. The next step is typically the electrical department, followed by a department that is responsible for controller devices and a department that is in charge of integrating the whole system by implementing IT solutions.

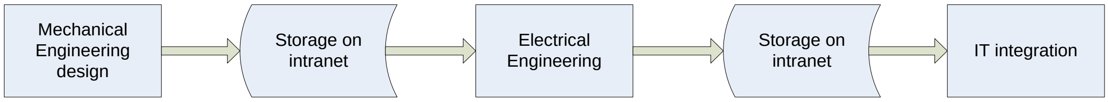

Figure 1: The layout design process (simplified)

Consequently a chain of designing tasks is created where the start of each task is dependent on the completion of the prior task. Each task is completed by specialized teams that ideally are not involved further and go on with the next project as soon as they have completed their part. Hence, this chain of tasks is characterized by short and intense (punctual) involvement of specialists. If the layout is completed, the project kicks off. This means that we now enter into the installation phase. This phase begins with the installation of a steel construction, which constitutes the framework for almost the whole system. After the steel workers have started to build the steel framework it is again the mechanical engineers, who are the first to enter the construction site. The other functions follow in the same order than in the layout preparation stage. Like in the layout stage there is a certain time off-set until a subsequent stage can follow; however, some tasks can be done in parallel. Again the IT specialists are in charge of integrating all solutions. The basic process is shown in a simplified way in the Figure 2.

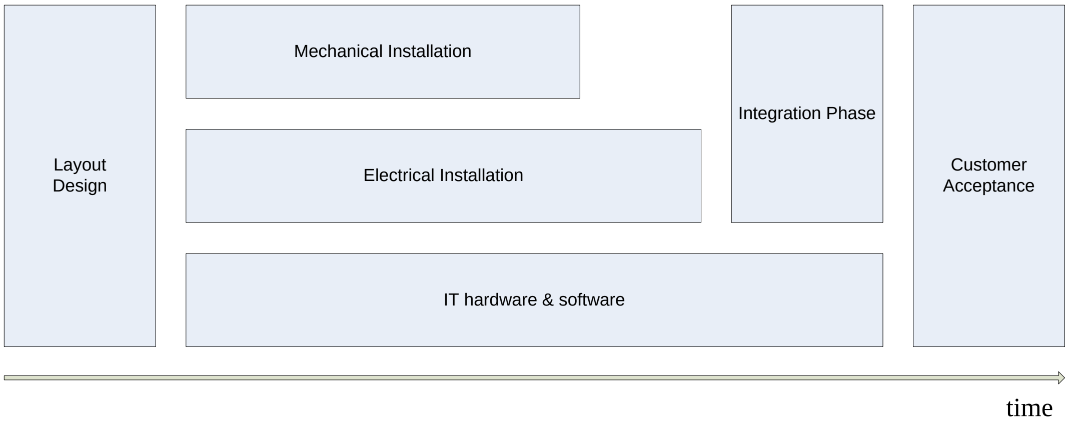

Figure 2: Installation phase (simplified)

Figure 2 displays the process as SAL shows it in their current documentation. It does not show that there are certain time off-sets, for example the electrical engineers start their work after the mechanical engineers, as do the software and IT specialists. But exactly like in the layout preparation stage short and intense (punctual) involvement of specialists that are ideally not further involved and go on with the next project as soon as they have completed their part could be observed. The figure does not show the intensity of involvement at the different points in time.

1.4.2 Corresponding problems

The traditional process structure has proven to make the chain vulnerable to interruptions in the past. If for example a layout blueprint has reached the IT department for completion of the design work and the first function (the mechanical department) needs to issue changes to the design, this will cause lengthy change phases in each subsequent stage. All in all this can lead to major delays in the completion of the final layout version. In the worst case, work on the construction site has already commenced.

Similar problems occur in the installation phase of a project. The integrators of the various systems (the IT specialists) are fully involved in the physical installation work only at a very late stage. Their involvement in the early phase is restricted to theoretical modeling of the project. However, the computer simulation model does not always meet the physical reality on the construction site. Hence, errors can occur that will only be identified when the IT solutions are physically implemented. As a result project managers often face a large number of problems in the integration phase. This phase is very close to the planned completion date, where any change tends to be extremely expensive and hard to realize without compromising contractual agreements with the customer.

To display these problems in the graphic of the process we revised Figure 2 to include some more information. As a result the current process can be displayed in a still simplified but more realistic way. Figure 3 comprises the time-offsets between the work commencement of the different functions and the fact that the integration function is involved only to a small extent in the beginning (computer simulations) and very intensely at the end of the project. To keep the figure simple and clear the other functions are assumed to have a stable level of involvement.

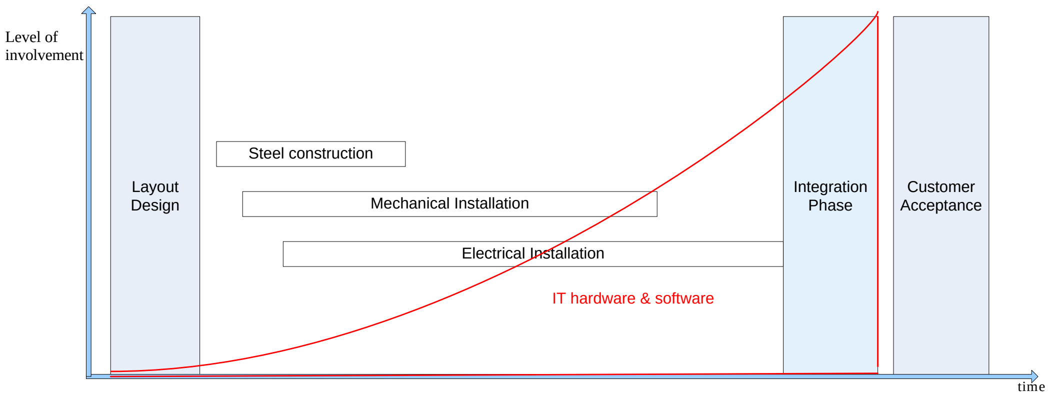

Figure 3: IT function involvement in the installation phase

The description of the current situation shows that completion of the tasks by specialists in separation from other functions can be considered a source of errors and also leads to the fact that those errors are often discovered very late in the process. The later a change needs to be done in a project, the more expensive it tends to be.[3]

[3] Slack, p.155

The separated specialist functions also lead to a lack of awareness of the whole picture of a project among people involved. This results in redundancies and non value adding activities, which increases overall costs.

1.5 Limitations of this paper

As the scope of the thesis only allows the closer study of one function among several that are involved in an SAL project, the conclusions of this thesis will not be enough to come to a final decision whether to implement the IFM approach or not. It must be seen as an important piece of the puzzle, against which other results (e.g. the implications of IFM on the design teams) must be balanced. One could argue that the conclusion of the thesis is not a fully developed contribution. It is rather one piece of the overall goal defined earlier in the text, namely to investigate, whether Toyota production principles can and should be applied to SAL projects. The fact that we try to come to a comprehensive conclusion by adding additional information to the argumentation does not fully resolve this issue. Furthermore, it is important to note that no explicit calculations were made that compare the actual monetary benefits of IFM with the specific costs it might cause. The paper is rather concerned with identifying the figures that need to be considered in such a calculation. The reason for this restriction is multifaceted. To begin with the time for the collection of the numbers that would be needed and the necessary models to be built would probably have more than doubled the scope of the paper. Secondly, as already mentioned before, IFM is only in a feasibility study stage so far. Hence, only very limited empirical data on the financial effect of IFM in practice was available. We would have needed to rely on observations of the usage of IFM ideas in practice that were not integrated in a standardized holistic application of the approach. In other words, sometimes project managers actually used concepts in parts of their projects on the basis of common sense. Hence, building a model under these conditions would have been interesting but rather speculative.

Some argumentations presented in this paper may not be significant from a scientific point of view. This is due to the fact that SAL is supposed to gain some benefit from this paper for their considerations in the feasibility study.

2 Methodology

In this section we describe the methodology used in this paper and motivate the choice of particular approaches. We also discuss the data sources for our research in this section

2.1 A Qualitative Research Method

According to Lundahl and Skärvard a qualitative approach is more suitable when the investigation is less structured, when the data is hard to communicate with short answers and when the number of respondents is relatively small. Moreover, a qualitative approach allows for a deeper analysis of our study object, namely SAL, while a quantitative approach should rather be used to gain superficial knowledge of many objects. Considering the above factors, we chose a qualitative research method for our thesis. [4] In our studies we were conducting interviews with a limited number of people, and the questions varied according to the position and field of expertise of the respondents.

2.2 Available literature on the topic

Available literature was limited to only very few previous attempts to study the application of lean concepts in project environments. Hence, general literature on project management as well as general literature on lean thinking and integration of processes was applied. Furthermore, a comprehensive research on the nature of SAL's business was conducted to be able to compare it to the environment of Toyota, the most famous successful implementer of lean principles.

2.3 Single Case Study as a Research Strategy

Yin defined several research strategies such as experiment, survey, archival analysis, case study and history. One should choose between those strategies based on the research questions of the paper. Siemens was at a pre-experiment stage when we started our studies, and since the "experiment" (implementation of IFM) is a very costly process, our goal was to make a pre-experimental research, analyzing how and to what extent it can be implemented. Therefore, we chose the case study as a strategy for our research. And since SAL represents a unique case, we can conclude that we perform a single case study.

Yin identifies six different sources of evidence for a case study: documents, interviews, direct observations, participant-observations, archival records and physical artefacts. In this thesis we mainly used interviews, which is our primary data source. However, documents and direct observations also played an important role and represent a secondary data source. This is in line with Yin's thoughts that interviews are one of the most important sources of case study information. This is especially true when event details cannot be observed directly, which is exactly the situation that we were facing at Siemens. IFM is not applied yet in practice, it is in a feasibility study stage.

2.4 Data Collection:

The main tool to get information about the issue at hand was the conducting of interviews with Siemens managers. During the study 23 interviews with managers from three areas of expertise were carried out. The interview partners were selected through a constructive discussion with Felix's supervisor at SAL. Among the interview partners were purchasing managers, engineers and project managers. The length of the interviews varied from one to three hours depending on the field of expertise and on how many additional issues besides the actual questions were discussed. The interviews with purchasing managers were very focused on supplier relations. We decided to focus on this field because supplier relations are a key driver of success regarding a lean strategy. The purpose of these interviews was to get an

[4] Holme & Solvang

understanding of SAL's up-stream supply chain, the power structure, situation on the supply markets and other issues regarding logistics, etc. Engineers and project managers were interviewed to get an understanding of the SAL project environment, their competitors and the behavior of customers. In addition to giving Felix access to interview partners, Siemens provided him with extensive amounts of material about their processes, contracts, cost structure, and company policies. Unfortunately (but not surprisingly) only very few of these documents can be included in the appendix of this paper. However, a selection from the vast pool of interview questions and answers to them can be made available.

2.4.1 Internal Validity

Internal validity deals with causal relationships and/or variables. However, our study is of explanatory and descriptive nature. Therefore, we believe that our thesis does not contain relationships that we should test. As a result tests for internal validity are not applicable to our study.

2.4.2 External Validity

External validity concerns with whether the findings of the thesis can be generalized beyond this specific case study. The projects of SAL are very special as they are massive and of high technical complexity. Therefore, any conclusion that would have stated that the results of this paper are applicable to any other kind of project could have been challenged quite easily. Even if the IFM approach turns out to be a good process approach for SAL this does not necessarily mean that the process is also good even for SAL's closest competitor. A generalization of the findings regarding project business or even the plant engineering branch is hence hardly possible. However, we still see some useful implications for other project environments too.

2.4.3 Reliability

According to Yin, the degree of reliability of the thesis is dependent on the ability of a future researcher, performing the same investigation and using the same procedures as we have, to achieve the same results and conclusions. The fewer errors and less bias are in the study, the better is its reliability. We have thoroughly controlled data gathering and selection of the sources. The interview processes are presented in the data collection section. We believe that the semi-structured interviews that we chose to conduct contribute to the reliability of the study. However, we have to admit that many of the questions were not specified in advance and were asked depending on the flow of the conversation. The reader can find the examples of interview questions in the Appendix.

2.5 Explaining terminology used in this thesis

Throughout this text "material" stands for all components and machinery needed on the SAL construction site.

A layout freeze is the point in time from which a layout is regarded as fixed. After that point it is not supposed to change anymore.

A bill of materials (BOM) comprises all parts that are needed to produce an output. It is hence an important document for the procurement function.

The critical path method is displaying all activities that delay the overall project if they are completed late.

3 Theoretical Frame of Reference

In the following two paragraphs some theory on the ideal type of the business environment of the kind SAL is operating in is presented. As this is only indirectly corresponding to the actual research questions the part is kept very short.

3.1 The ideal type of business environment for SAL's branch

According to Backhaus an industrial plant engineering company has its own manufacturing of parts and/or own installation service. They have the capacity to plan, process and manage huge and comprehensive projects.[5] The processing of a project consists of engineering, procurement, installation, transport and logistics.[6] The constructed plants are the output of the project. The plants have a high degree of specificity as a particular plant design has generally only one buyer on the market. The fact that the plants are highly specific does not necessarily imply that the projects to build them have a high degree of specificity. Resources that are used for one plant can often be used for other plants as well. Furthermore, some project processes can be reused. The degree of project specificity is hence dependent on how many new resources are needed and how many new processes need to be developed.[7] In other words the specificity of a project is dependent on the degree to which existing solutions can be applied. Risks in industrial plant engineering stem from changes due to miscalculations or decision problems on the part of the client, effects of environment changes (whether, etc.) that can not be forecasted and hardly be contracted as well as vague description of project assignments (e.g. if technical solutions need to be developed during the project).[8]

3.2 The specifics of projects and project teams in theory

A project is an organized endeavor aimed at accomplishing a specific non-routine and/or low-volume task. Projects differ from normal operations in their finite life, which is anticipated from the start.[9] Because projects are characterized by this "one time only" effort, learning is limited and most operations never become routine.[10]
A project can be considered as "complex" if it consists of a high number of interdependent subtasks. These subtasks are often carried out by a variety of parties. Often among them are the customer, subcontractors, consultants, government

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[5] Backhaus, p.233
[6] Zachau, p.11
[7] Zachau, p.12
[8] Zachau, p.12
[9] Shtub et al. p.1
[10] Shtub et al. p.6

institutions, etc.[11]The higher the complexity of a project the higher is the need for project internal coordination.[12]

The fact that teams are formed only for a limited amount of time complicates the flow of information and thus makes it harder to optimize communication and to coordinate the activities of the project participants.[13] After the project is terminated the teams usually disperse.[14]

3.3 The Toyota production system: Lean thinking

To answer the question to what extent and in what way lean ideas can be applied to SAL projects we need to take a close look at the basic lean principles. This will form the basis for later discussion.

Lean production is renowned for its focus on reduction of cost though the elimination of all kinds of waste. Waste is considered to be everything that does not add value to the product.[15] The concept became well known through its successful implementation by Toyota. However, the idea that waste elimination is important for increased productivity is older than the Toyota success story. Henry Ford denoted a paragraph to all sorts of waste in his book “My life and work” which was published in 1922. According to Ford each used article in the production process should be studied to find some way of eliminating the entirely useless parts. This applies to everything – a shoe, a house, etc. As useless parts are cut out and others are simplified, costs of production decrease. Nevertheless the mass production system introduced by Ford implied high levels of what can be considered waste of resources.

One reason for this fact is that no so called pull mechanism could be found in Ford’s concept. As a result the various stages in the production line in his car plants created high levels of inventory that were caused by overproduction. A pull mechanism triggers production only if a successive stage signals the need of a specific part. Thus, no or only minimal production to stock takes place. Ford’s production line was operated using a push mechanism where each stage of production was processing as much as possible to achieve high utilization of machines but without regard of what the successive stage is in need of. Among other revolutionary ideas a change from a push approach to a pull approach was added to Ford’s basic idea of waste elimination by Taiichi Ohno’s book “The Toyota Production System” (TPS), which was published in 1978. It describes how Toyota managed to advance from a small player to the biggest car company in the world and how lean ideas helped to achieve this. “The machine that changed the world” by James P. Womack, published in 1990, showed that lean thinking was not confined to the manufacturing function only. It gives a good overview of the principles of lean production and will hence be used as the basis for the following elaborations.

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[11] Funk, p.15 → Zachau, p.12
[12] Zachau, p.13
[13] Shtub et al. p.1
[14] Shtub et al. p.2
[15] Womack, p.61

As mentioned above the elimination of all waste is the essential part of the lean idea. Perhaps the most important source of waste is the inventory.[16] Keeping material or finished goods in stock does not add value to them. In a globalized world the customer is not willing to pay for the extra cost. In a manufacturing environment inventory in the form of work in progress is especially wasteful as it is not only costly but also tends to hide problems. This clearly shows that reducing work in progress has an effect that goes beyond the reduction of capital employed.[17] If inventory is to be reduced without interrupting the work flow, the reason for the existence of inventory must be removed first.[18] This can be accomplished by reducing down times of machinery, transportation and by reducing lot sizes in combination with shorter set-up times. Another source of waste is lack of quality. Defective output that needs to be reworked or scraped is obviously costs extra costs.

Besides the elimination of waste, the principle of continuous improvement of the production system is another essential principle of lean thinking. To achieve this, Toyota has implemented so called quality circles, which consist of groups of operators from different functions. Everyone is involved and responsible to come up with suggestions for improvements. In addition to that everyone is empowered to stop the production line if a mistake is discovered.[19] Regarding this matter Womack makes an important acknowledgement that this measure for improvement can only lead to real improvements if the product design is fully workable.[20] The organization of improvement activities can be arranged in different ways. Karlsson and Ahlström described three different stages of possible arrangements.[21] First, there might be no explicit organization and employees may implement system improvements in an informal and self responsible way. Second, a formal suggestion scheme may be implemented in a form of individual participation. The typical example for such an approach would be a suggestion box. The third method is Toyota's quality circle approach described above. At Toyota the groups formed to define improvements of the production process are supposed to work as multifunctional teams. This in turn helps employees gain a broad expertise instead of being specialized on just one specific task.[22] A task rotation within the team increases flexibility and hence, reduces vulnerability of the process and dependability on a single person. However, such organization of the labor force demands a high level of training, which is costly. Employees in a multifunctional team are expected to perform supervisory tasks. The team leading role changes over time (employees are taking turns), which allows a reduction of hierarchical levels.[23] At Toyota teams are organized along a so called cell based part of the product flow. Each team member needs to be able to perform all activities necessary in the process within the cell.[24] A cell layout is a form of process layout, in which all machinery and labor needed to process a product, is grouped together. An example of such a process layout is a large shopping mall with a high

[16] Ohno, p.83
[17] Hayes. P.67
[18] Ohno, p.84
[19] Ohno, p.69
[20] Womack, p.96
[21] Karlsson, p.29
[22] Ohno, p.
[23] Karlsson, p.36
[24] Karlsson, p.34

variety of stores.[25] In this cell the customer (in our example the customer is analog to the product that needs to be processed) can satisfy all his shopping needs in one spot. The multifunctional structure combined with empowerment ensures a high level of employee interest towards problem solving based on a grasp of the process as a whole.[26] Toyota's way to follow up on the problems that can occur is to "ask five times why" to get to the ultimate root of a problem. Their close relationship to all their suppliers allows them to involve all relevant players in the supply chain in this process.[27]

The principle of just-in-time (JIT) demands that each process should be provided with the right parts in the right amount at the exactly right point in time. An organization that is able to implement JIT can get close to zero inventories.[28] This implies that when only one part of the production system fails, the whole system can come to a stop. Ohno called this "a removal of all safety nets". The awareness of this is a motivating factor for all internal and external parties involved in the production of the final output.[29] To achieve zero inventories certain prerequisites need to be met that were already discussed in the paragraph on waste elimination. Lot sizes and the interrelated buffer stocks need to be reduced as well as lead times. Sequential JIT is the most elaborate form that can be reached. Here parts and materials are not only delivered in the right form, quantity and at the right time but also in the right sequence.[30] The change from push towards pull has been described already. At Toyota no stage of production is operated according to forward scheduling but on backward request. It is obvious that this approach is closely related to the JIT principle. Materials and parts are to be delivered according to a signal (at Toyota in form of a Kanban) from the successive to the preceding production stage. A Kanban is a note that comprises all information about the part that is needed and when and where it is needed.

Zero defect is the resulting aim of these principles to self production. But zero defect deliveries are also expected from suppliers. Fault free parts and materials are the prerequisite for a lean production system, hence zero defects denotes how a lean company works in order to attain quality.[31]

After extensive research on the benefits of lean concepts Womack identified two key organizational features that create a lean plant. In the plant the maximum number of tasks and responsibilities are transferred to those workers that are actually adding the value to the product. Secondly, the plant has in place a system for detecting defects quickly and traces the problem that caused the defect to its ultimate case.[32]

Finally it is also worth to mention at this point that it took Toyota more than twenty years of relentless effort to fully implement Kanban, which is a prerequisite for a

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[25] Slack, p.
[26] Karlsson, p.30
[27] Womack, p.155
[28] Ohno, p.30
[29] Womack, p.61
[30] Karlsson, p.32
[31] Karlsson, p.30
[32] Womack, p.99

working lean system.[33] Therefore, one can conclude that the Toyota production system is a powerful tool for flexible production, but it needs time to be implemented successfully. Another important fact to keep in mind is that Toyota granted their employees life-time employment in exchange for a commitment to flexibility and willingness to learn.[34] These facts will be important for our discussion in the analysis part when we will have a closer look at SAL's operations.

3.4 Toyota's supply chain and supplier relations

A very important factor for Toyota's success in applying their famous lean production concepts are their quite unique supplier relationships. According to Toyota these relationships must be characterized by the following four attributes to be considered acceptable[35]:

- Re-negotiations of contracts are never necessary
- Follow-ups after an order is placed are never necessary
- Administration and transaction cost are very low
- Quality monitoring of incoming deliveries is never necessary

Below we present some remarkable facts about Toyota's way of achieving good results from suppliers and summarize their extraordinary relationships. The facts below must be seen in the following context: Toyota has a very strong position in its supply chain.[36] As a result it can more easily impose demands on suppliers than smaller companies can. Two examples can clearly substantiate this view. Firstly, the cost of implementation of new concepts, such as the cost of a zero defect delivery performance, is fully financed by Toyota's suppliers themselves. Secondly, Toyota has forced their key suppliers to locate their production units within a radius of 30 kilometers around their own plants.[37]

Toyota's supplier relations can be characterized as a network rather than a sum of independent relationships. Toyota holds minority shares of its key suppliers and also (due to Toyota's influence) these suppliers have substantial cross-holdings in each other. Nevertheless, the suppliers are independent companies with separate books, which makes them real profit centers. Furthermore, Toyota is exchanging employees with their key suppliers on a regular basis, for example to provide help if suppliers have serious production problems. Toyota has built a network based on trust among its suppliers, which forces its suppliers to cooperate among each other. Knowledge is not seen as property of a single company in the supply chain but as property of the whole network.[38] However, this is only possible because Toyota is able to ensure that each supplier will make a reasonable return on their investments.[39] But there are also other reasons that make working with Toyota beneficial for suppliers. Through production smoothing (lowering prices in economically bad times and aggressive

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[33] Womack, p.62
[34] Womack, p.154
[35] Karlsson, p
[36] Womack, p.57-62
[37] Womack, p.83
[38] Dyer & Nobeoka, p.351
[39] Womack, p.157

selling practices) Toyota is able to guarantee their suppliers a steady volume of business. That way the suppliers can minimize their inventory buffers and can utilize employees and machinery more effectively than companies which are facing sudden changes in the volume and mix of orders at a very short notice.[40] All benefits (= improved margins) that stem from innovations by suppliers alone are fully granted to them. Toyota has also connected their information systems to enhance communication, which further improves efficiency. Their suppliers are usually involved in innovation processes at a very early stage. Often half of the engineering hours are transferred to the first tier suppliers.[41]

Another approach that could be observed at Toyota is the tiered supplier structure. It implies that the firm has a few first tier suppliers that provide it with sub-assembled units based on components from lower-tier suppliers. Thus the first-tier suppliers regulate the relationships with other suppliers themselves.[42]

This structure and these policies lead to an implicit culture of openness and mutual interdependence. The culture has proven to be successful in setting reasonable prices and enhancing innovation. But realization of these benefits goes hand in hand with a high level of dependence on the suppliers and requires a powerful player that influences the supply chain accordingly.

All in all this shows what extreme prerequisites are necessary to implement lean production to a full extend. Hence, to come to a conclusion whether SAL can successfully imitate the Toyota approach, we need to find out whether the procurement environment prerequisites can be established in a somewhat similar form.

It has become apparent that Toyota is very much relying on long-term relationships. However, also short-term relationships with suppliers can bring beneficial input to companies that should be utilized. According to Fredrik von Corwant such relationships leave ‘imprints’, for example for a new development project. Established processes and interfaces can often be reutilized with new partners. It can be seen that the utilization of the same product architecture (or at least certain interfaces) for other products enables component commonality and/ or ‘carry-over’.[43]

3.5 <u>Pros and Cons of Shielding Production (Ballard & Howell vs. Wischnewski):</u>

Ballard and Howell emphasize the importance of work assignment quality. Assignment quality is the quality of plans for future activities of all units that are involved in a project. According to Ballard and Howell the quality of an assignment depends on the following factors:

[40] Womack, p.154
[41] Womack, p.159
[42] Von Corswant p.11
[43] Corswant, p.224, 225

1. *Definition* of the assignment: Are assignments specific enough to assure that the right amount and type of material can be collected and that coordination among different functions is possible?
2. *Soundness* of the assignment: Is design complete and are materials at hand? Is prerequisite work completed?
3. *Sequence* of the assignment: Are assignments selected according to a sound constructability order? Is the selected order according to customer wishes?
4. *Size* of assignment: Is the assigned task achievable in a specific time frame?
5. *Learning* from experience: Are things that went wrong in an assignment documented and followed up?[44]

If any of these points is not fulfilled sufficiently, Ballard and Howell propose to stop the project work until the mistake is eliminated. This shows that in their view a construction project can in fact show analogies to the TPS. Their research has shown that high work assignment quality can shield the units that carry out a project (engineering squads, construction crews, etc.) from work flow uncertainty. Work flow uncertainty is the lack of guaranteed adequate design information, full availability of the right materials at the right time and/or completed prerequisite work. Ballard and Howells approach gives some useful insights for this paper as they address more or less the same problems as the IFM model, but in a construction project context. Regarding the solution for the problems addressed, they use an overall planning approach. Although this is time consuming and hence bears the risk of failing to meet the schedule dates and includes idle times of machinery and staff "on purpose", their research has shown that positive results regarding the overall length of projects can be achieved. The approach involves the issue of coordination only to a very small extent. The assignment is to be defined in a way that allows for coordination.

The IFM model takes up this particular point (coordination) as its starting point for improvement suggestions. Like the "assignment quality approach" IFM is a method to achieve higher planning reliability. It also uses lean concepts as a basis for argumentation and is trying to apply those concepts to a project environment. But IFM goes a bit further than the concept of Ballard and Howell. First of all it puts a higher emphasis on coordination among the various functions. Detailed planning can take place within each function (mechanics, software, etc.) independently, without any coordination. Hence, although assignment quality improvement has led to some overall improvements, the application of the concept does not guarantee coordination of functions in an SAL project environment. But coordination is especially important in an environment with many reciprocal processes where the number of interdepencies is high. Mutual adjustment is the most costly coordination form and therefore reciprocal activities are placed in the same adjacent units. Sequential tasks that can be coordinated to a lower cost by schedules are placed in less closely adjacent units; and rules are least costly and therefore tasks with pooled interdependence are placed in the least closely adjacent units.[45] Ballard and Howell are doing their research on construction projects. These projects are somewhat different from SAL projects. The two most important differences will be explained below. A project manager in the construction business has a higher level of certainty when it comes to

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[44] Ballard & Howell, p.13
[45] Von Corswant p.17, 18

planning. A layout freeze can be done much earlier and it is also much less likely to change. This implies that the bill of materials is less likely to be subject to changes. In addition to that the single modules that constitute a building are relatively independent on the functionality of other modules, which is not the case in airport systems. Small errors do not tend to let a building collapse. This is different in SAL projects. They are characterized by high computerization and high functional dependability among the parts that constitute the overall system.

Other authors, like Wischnewski, would strongly disagree with Ballard and Howell's approach. In their view planning is not the answer to everything. Instead the effective pursuit (checking of actual data) of the project is much more important to manage projects successfully. We selected two concepts of this actual data checking because they imply lean thinking.

According to Wischnewski one important tool for project management is a consecutive trend analysis, which is supposed to detect weak spots in the process as early as possible. Weak spots are errors in a work package that can cause problems for the project. The analysis should be done regarding deadlines and additional cost issues. [46] Anticipating errors is important because late detection is costly. A project consists of several parts that are interdependent in their functionality and need to be integrated. Errors and resulting changes in one part may hence have far reaching impacts on the other parts if they are detected at a late stage of the project.[47] Another important tool is the implementation of error statistics.[48] These statistics are based on the collection of information about errors, e.g. when and where errors occurred, what was the root of the problem and who is responsible for it. Besides being a good tool for project mangers to justify errors it can also be a valuable tool for a learning process for coming projects (systematic documentation of errors is the basis for the elimination of their roots). These two approaches clearly comprise thoughts about waste elimination, continuous learning and integrated control of work quality in a project management context. Thus, the applicability of these concepts to the SAL business is evaluated as a part of the attempt to find out to what extent lean principles can be implemented in SAL projects.

3.6 <u>The Kraljic purchasing portfolio analysis</u>

The purchasing portfolio analysis by Kraljic is a matrix that can be used to design commodity strategies.[49] Procured products are categorized according to their supply risk and the impact of purchasing on financial results. A high supply risk exists if there are very few appropriate suppliers, high costs of switching to another product, storage risks, etc. Impact of purchasing on the financial result refers to the profit impact of a given supply item (e.g. product cost as a percentage of total project cost). According to these two factors, components and materials can be placed into the following matrix[50]:

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[46] Wischnewski, p.134
[47] Wischnewski, p.135
[48] Wischnewski, p.165
[49] Van Weele, p.148
[50] Van Weele, p.150-151

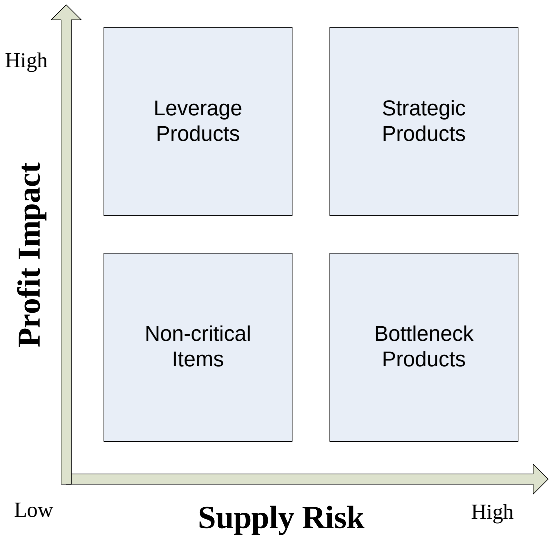

Figure 4: the Purchasing Portfolio Matrix

Strategic products are complex, high volume items, for which the supplier can only be switched at considerable cost. The power structure can potentially be in favor of both, buyer or supplier. A balanced power structure is also possible.[51]

Leverage products represent a relatively large share of the end product's cost price but they are available from several suitable suppliers under low switching cost. Generally the buyer is in a stronger position in sourcing negotiations for such a product.[52]

Bottleneck products represent a relatively small value in terms of money in relation to the overall project cost. However, there are very few suitable suppliers and the products are important for keeping the work on the project going. This leads to a power structure that is in favor of the supplier.[53]

Non-critical items have a small value per item and do not cause technical problems. A number of different suitable suppliers are available.[54]

Dependent on where each material is placed in the matrix an individual sourcing strategy can be defined. Each of the four categories imply a certain power structure in relation to the suppliers. Hence, the categorization allows the derivation of guidelines for the form of supplier relationship and contract forms that are favorable and realizable. For strategic products Van Weele suggests a performance based partnership whereas for leverage products competitive bidding is recommended. For bottleneck products continuity of supply must be secured in any possible way. The form of relationship will most likely be decided by the supplier in this case. For non-critical items administrative costs must be minimized e.g. by pursuing system contracts, e-procurement, etc.[55] As strategic products can imply very different power

[51] Van Weele, p.149
[52] Van Weele, p.151
[53] Van Weele, p.151
[54] Van Weele, p.151
[55] Van Weele, p.152-153

structures the interviewed buyers were asked to comment on them for the products they placed in that part of the matrix. This kind of analysis can give us an insight into what supplier relations currently exist and what relations are potentially achievable. As can be understood from this argumentation we do not want to use this tool for the development of differentiated procurement strategies but for the analysis of supplier relations. This is important for the purpose because supplier relations are one key factor to a lean project approach.

4 Analysis

As already mentioned earlier in the text SAL projects actually consist of two projects. We named them layout phase (which basically comprises all activities before commencement) and the installation phase. In the following the focus will be mostly on the installation phase as it implies much more potential for our discussion. This is due to the fact that the nature of a layout design process for SAL projects is not really much different from designing processes of a complex product. Moreover, the focus will be on the procurement and logistics function later on in the text. And (although strategic buyers are not happy about the situation) the task of this function is much more related to the actual installation needs than to the design of the products. To keep the text free from technical data, examples will refer to the work on the steel framework in most cases as this task does not imply extensive technical terminology.

4.1 Lean thinking applied to SAL projects

Installing and commissioning airport technology in a building that is constructed by another party is different from product manufacturing. Among other things the involvement of a higher number of external players in the installation phase and the project character distinguishes SAL projects from Toyota's business environment. This makes it necessary to re-think some of the lean principles to make them fit in a SAL project context. Therefore, some analogies between lean production theory and lean SAL project management are drawn in the following. Furthermore, potential benefits and drawbacks as well as implementation issues of a lean approach regarding the SAL business are discussed. Most lean concepts are interrelated to a certain degree. As we address them separately to allow for a clear structure, some argumentations might re-occur throughout the text.

The overall aim of the lean production approach is to lower cost by eliminating all kinds of waste. The resulting increase in customer value or profit margins is of course also an issue for SAL projects. A lot of inefficiencies were discovered in past and current projects that led to extra cost.

Just-in-time is one of the most important tools of the lean concept. Waste in the form of inventory is eliminated by delivery of the right components and materials to the assembly line exactly at the point in time when they are needed. In an SAL project context three different stages of JIT thinking could be applicable. The first and the second are quite similar to the Toyota case.

1. SAL could demand from their suppliers to deliver the parts they need for a certain period of time (monthly, weekly, daily) to the right place at the construction site. A first step towards implementing such an approach in an SAL project context could be to set delivery dates for materials in a different way. Material delivery dates should not be defined according to the date of the overall installation start on the construction site but to the exact point in time when each material is actually needed. In the case of SAL, setting of these dates is the project manager's responsibility. The feasibility of such an approach is dependent on whether the project manager is able to define early in the process what materials he will need at what point in time. It also depends on the on-time technical clearance by SAL's technical department. This implies that coordination between the project manager and the technical department regarding what materials need technical clearance first would be vital for the functioning of this kind of JIT approach. Another important issue in this context is transportation cost. Transporting parts and material from one location to another does not add value to the product nor to a project. In the best case transport activities should be eliminated. If that is not possible rationalization is the second best option.[56] SAL projects are carried out all over the world. Therefore, the length of transport ways and effort intensity for the logistics function (e.g. due to complex custom laws) differ from project to project. In one of the latest projects in Beijing a JIT solution like the one described above would not have been a good approach. For the long distances material needs to be bundled as much as possible to enable as few transports by ship or plane as possible. For airport projects like the one in Munich, which is close to the main first tier suppliers, the story is different. This is in line with Womack's findings. He showed that even Toyota increases its inventory level with the distance to the supplier.[57] In a project where SAL suppliers are located nearby, the direct delivery JIT is an option. Applying JIT in such a way could have a very positive financial effect for SAL. Scheduling material delivery to the construction site according to the point in time when they are needed, rather than scheduling delivery according to the project kick-off date will postpone the point in time when costs will actually accrue. In other words, the capital commitment can be reduced due to later ordering, production and delivery of materials. This is in line with the idea of creating flow. Each part should go directly from manufacturing over transportation to the installation process. The financial effect of this JIT approach is twofold: Firstly, the lower imputed interest increases profit; secondly, the discounted project costs will be lower. That means that without shortening the project time and without lowering prices paid for material, IFM (= a lean approach to SAL projects) can potentially increase profitability of a project by lowering capital commitment.[58] The advantages of this improved capital efficiency are obvious. If the same operating cash flows can be achieved by using less working capital or less physical capital, a company's free cash flow increases which is commonly reflected in a higher value of operations. One issue regarding realization of this approach is the fact that SAL cannot consistently guarantee the use of a certain level of suppliers' capacity. This implies that it will be hard for SAL to impose the implications of JIT deliveries onto their suppliers. These

[56] Karlsson, p.28
[57] Womack, p.83
[58] Zachau, p.37

relationships will be looked at in more detail later in the text. But it can already be pointed out at this stage that the Toyota story has shown the importance of continuity of trade with suppliers as a crucial factor for the success of the JIT approach. It is doubtful, whether JIT can be implemented successfully if it can only be realized once in a while over a restricted time horizon.

2. SAL could keep on buying the material as soon as the purchasing department gets the clearance from the technical department and independently from the actual date it is needed. After order and delivery the material is then stored centrally near the construction site. From this storage material and components could be delivered just-in-time to the right place at the construction site instead of allowing workers to withdraw material whenever they want and stock-pile it somewhere else. Doing it this way storage costs are not eliminated, but at least material vanishing caused by human intervention could be minimized. This material vanishing must also be seen as a form of waste, which can be eliminated by delivering to the construction site only the amount of material that is needed momentarily and by assigning clear responsibilities for withdrawals.

3. The third stage of a JIT application is directly related to the installation of the SAL systems. As explained earlier in the text each function is dependent on the completion of the preceding task by the previous function. If each function is only building the part that is momentarily necessary (just-in-time) for the following functions this would potentially imply a high degree of waste elimination. Coordination between the functions would be enhanced, less material would be assembled, which in turn lowers the material in-stock needed (= asset cost) and the risk of restructuring due to late layout changes. A certain analogy can be drawn here to the reduction of lot sizes, which is considered an effective way to keep inventory down and achieve flexibility in lean theory.[59] For example, in the traditional SAL process approach steel frameworks are built according to the layout but independently of the progress status of subsequent functions. This implies that some parts of the steel framework stand for several months without being processed further. If changes in the layout occur, parts of the steel framework must be demolished and rebuilt. Similar problems occur regarding the other functions. If only the steel framework that is needed for the next integration step is installed, risk of costs due to layout changes as well as work in progress would be reduced.

A **zero defect** approach seems to be transferable to projects very easily. Of course it is important that material is delivered without default. In principle this approach can be implemented for SAL supplier relationships. But there is a special kind of defect in the context of SAL projects that is not dealt with in the Toyota approach. As a matter of fact layout changes can occur any time in SAL projects. Whereas in most cases regular products (like cars) are complete in their design before they go into production, layout changes after installation has commenced are the rule in SAL projects rather than the exception. One SAL buyer described the situation in the following way: “The layout can be considered complete when the project is finished and the result was accepted by the customer.” These layout changes are caused by

[59] Karlsson, p.28

circumstances that were not anticipated in simulations and forecasts. In most cases this leads to a change in requirements for materials. If for example inclination of a conveyor belt needs to be increased because changes in the construction of the building were necessary, the conveyor has to be longer and needs a stronger drive. Such a change can of course affect the subsequent installation layout. The result is that the material that was ordered (under the prerequisite that the layout is correct) suddenly does not fit anymore. In an SAL project context this must be interpreted as a defect. It is of course not a defect in a sense that the suppliers delivered a defect product. But without being responsible he delivered the wrong specifications, which has the same result for SAL than receiving a defect product. Often it is neither the fault of the engineer who designed the layout. In most cases changes occur due to actions of externals that could not be forecasted or due to bad coordination among the various players involved in building the airport.

The concept of **cross-functional teams** is in the heart of the IFM idea. Instead of specialists that work quite independent from each other a more integrated approach is the aim of IFM. Toyota implemented a multifunctional approach with employees that are able to perform several tasks in the production process, which increases flexibility and decreases vulnerability of the process. This way of organizing the labor force is an important component of Toyota's lean approach and is hence, considered to be indispensable for applying a lean approach to SAL projects. The question is whether this approach can be implemented successfully under the given conditions. As mentioned earlier on in the text SAL is only the integrator of systems that are manufactured by externals. This is also the case for most of the installation work. SAL is only providing the layout and the overall management of the project. The teams that are involved in the installation vary according to the location of the project. For example, the steel framework for the airport system in Beijing was built by a Chinese contractor, whereas for airport projects in Saudi Arabia a different contractor was selected. The restrictions that arise from this environment regarding multifunctional teams are highly visible. For example, to train steel workers on the issues of the subsequent functions (conveyor installation, electrical equipment and software) would be very time and cost intensive. Under the condition that the business relations are rather short-term and punctual at times when projects are carried out in a particular part of the world, it is hard to negotiate the question which side has to bear the cost of the training. This structure is in strong contrast to Toyota's life-long contracts with their employees. What makes the problem worse is the fact that the interaction between players in a project does not always involve SAL. Externals need to be coordinated with other externals in the completion of their work. It is doubtful whether under such conditions SAL can enforce the establishment of cross-functional teams and a mutual learning process. And even if they could, it is not guaranteed that they will have any benefit from the costly training sessions for contractors as they do not have long-term relations with them. As a matter of fact SAL is in some cases not able to choose their contractors freely. Often customers demand that service is sourced locally. For example the selection of a European company to build the steel framework would not have been acceptable for the ordering party of the airport in Beijing.

This limited applicability of mutual learning also restricts the applicability of Toyota's **empowerment** measures. Letting workers stop the installation process if an error occurs is not a recommended rule for SAL. In the beginning this approach leads to a massive number of costly production stops. Only in the long-run the benefits of the approach can be achieved. As project environments differ each time and the people who install the system also tend to change from project to project, it is doubtful whether SAL could ever evolve from this “stop intensive” beginning stage. In addition to that SAL would have to bear a risk of additional costs through extensive disruptions of the work as their contracts contain penalties for delayed completion of the project. Furthermore, it is doubtful whether such empowerment makes any sense under the precondition that in SAL projects the layout design is not stable. As Womack has shown, a stable design is the prerequisite for such a measure of improvement.[60] As long as design is not stable it is impossible for workers to clearly identify, whether what they see is an error or not.

At the design stage the situation is quite comparable to the Toyota environment. Engineers that are involved in the layout preparation are exclusively Siemens employees. Furthermore, the procurement function could be involved with their knowledge about lead times, the particularity of different supplier relations, etc. In this environment the cross-functional approach would work and should be promoted immediately.

The implementation of a **pull mechanism** is hard to imagine in a project context. At SAL the output is one unit (a unique project) compared to an output of several thousand units of one type in car manufacturing. By nature a project is only carried out on customer demand and not according to any forecasts. This also makes any form of overproduction hard to imagine. But within the project work an analogy could be seen. The IT department, which has to integrate all the installed parts into a workable system could be seen as analogy to the Toyota production line, which also integrates all parts into a workable car. This thought is illustrated below in Figure 4. According to this view the IT department would have to trigger a demand (based on the layout) that the other functions would have to fulfill.

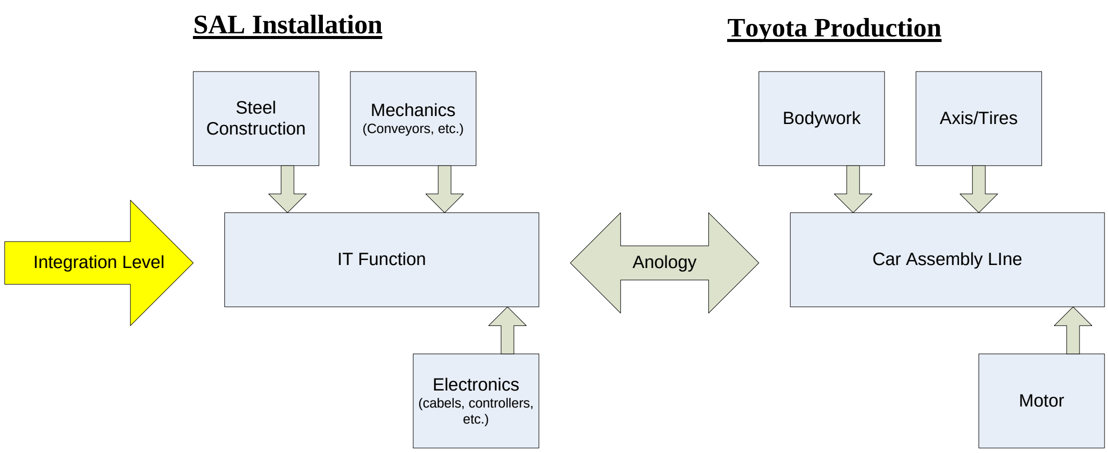

Figure 5: Analogy between SAL installation and Toyota production

[60] Womack, p.96

To make this approach work, a project cannot be organized as one single process. Instead, it must be split into separate workable sections as shown in figure 5. This is in line with the basic thoughts of IFM, with which we started out and the JIT consideration discussed above.

We can conclude that a pull approach is indeed an option for SAL projects. Of course the IFM process organization has its drawbacks. For example it can result in a substantial amount of idle time of workers, functions and/or machinery. In the TPS approach such idle time would be used to find improvement suggestions in quality circles. In theory this could also be done among the different functions involved in the SAL project. This is however not applicable to full extent, because of the problems with applying the concept of quality circles in SAL projects described above. The players that are involved in the installation work are mostly externals and hence, an integration of the work of these players is too costly and too hard to enforce for SAL.

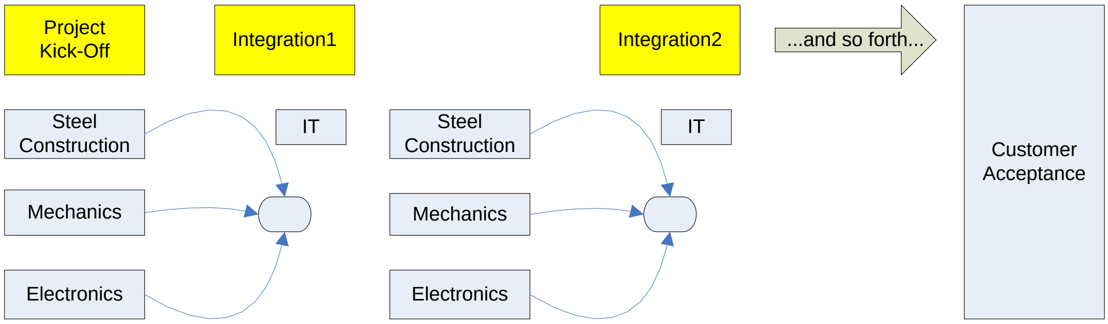

Figure 6: Installation process under IFM

In connection with the considerations about a pull mechanism the IFM approach implies some more benefits regarding waste elimination in SAL projects. Firstly, under the traditional approach there is overproduction, which leads to inventory in a form of work in progress as already discussed in the section on JIT. Secondly, quite often non-value adding work is carried out. If for example the conveyor installation team is not sure how exactly their parts need to be installed they just install it more or less randomly to get the section off their to-do-list. Later on in the process these parts need to be removed and built in differently in order to allow a sufficient calibration. Under IFM, the calibration is carried out much earlier, which reduces the level of uncertainty for conveyor installation. Thus, the level of unnecessary work can be reduced. In addition to that, it is quite likely that by implementing this process, earlier completion dates can be achieved. This is true because earlier integration guarantees an error free basis, on which the next installation step is based. This approach might make each separate function slower, but will speed up the overall completion. Again the argument for this is that the later an error is detected, the harder it is to correct it. Each alteration in one part of the system, which is the basis for the next part of the system, might cause a whole chain of necessary changes. Avoiding these lengthy alterations will save a lot of time. These assumptions are supported by the findings of Ballard & Howell in their studies on construction projects. Under most contracts earlier completion means earlier cash in-flow.[61] This implies that even if we assume (for simplification) that investment in a SAL project is the same regardless of the duration, the project value will be higher for the shorter project. The example below illustrates that:

Case	Item	Total	Year 1	Year 2	Year 3
Fast	Investment	5000	-2500	-2500	
	Return	10000			10000
	ROI	2			

Interest rate	5%	**Project value**	4189

Table 1 Financial impact of faster completion

Case	Item	Total	Year 1	Year 2	Year 3	Year 4
Slow	Investment	5000	-500	-500	-4000	
	Return	10000				10000
	ROI	2				

Interest rate	5%	**Project value**	4034

Table 2 Financial impact of faster completion

The two calculations show one project with higher capital invested in the beginning and shorter duration and another project with less capital invested in the beginning and longer duration. This illustrates in a simplified way the cash flow comparison between the IFM approach and the traditional approach. Even under the assumption that the biggest part of the necessary investment can be postponed to a very late stage of the project; the slower project generates less value. Note that the return of investment (ROI) figure is not affected by the change of approaches. Hence, if the key performance indicator (KPI) of SAL is ROI, the potential benefits of IFM might stay undetected. The project value is calculated in the following way:

$$-Investment_{year1} - \frac{Investment_{year\_n}}{(1+Interest\_rate)^n} + \frac{Cash\_Inflow}{(1+Interest\_rate)^n}$$

Reality is a bit more complex than the simplified example above. It can be expected that under IFM, installation will be shorter but also more expensive due to higher complexity of work organization and less economies of scale in installation. Economies of scale can be generated if each function can work on their task without consideration of the work of other specialists. E.g. installing 10 kilometers of steel framework at once will be cheaper for the service provider than installing 5 sections of 2 kilometers length each with idle time in between the building of the sections. Organizing the different groups around the one part of the system that is currently under construction demands very good management of the available space and machinery, which in turn is time consuming and costly. These are values that need to

[61] Leach, p.11

be charged against the benefits of earlier completion. On the other hand the completion of sections might allow the customer to operate parts of the project before overall completion is reached. This is especially applicable in an SAL project context. One terminal can easily be operated without the completion of another terminal. This might generate parts of the total cash-inflow at an earlier point in time, which in turn will enhance the project value. In addition, the assumption in the simplified example that the overall investment is the same in the shorter and the longer project is actually not realistic. Generally, one can assume that the longer the project takes the higher the overall amount that needs to be invested will be. Machinery needs to be rented longer; labor force needs to be hired longer, and so on. Unfortunately, the only way to find out whether the IFM approach is more profitable than the traditional approach is to try it out in practice and closely monitor the benefit to drawback relation by looking at the parameters described above.

However, through IFM the idea of a **continuous flow** with no interfaces in the process cannot be fully achieved in an SAL project context. Although the earlier stage of IT integration in the project brings us closer to a synchronized process, a full coordination is not achieved. The different functions can be expected to still carry out their tasks rather independently from each other. Putting them together physically in a cell layout of the process may enhance but not guarantee coordination. Hence, the only improvement SAL can be a 100% sure of is that an IFM implementation will lead to an earlier detection of errors that result from this lack of coordination, which reduces their negative impact. Therefore, an implicit system of error elimination and continuous flow is not necessarily achieved through IFM. As a result we can conclude that the earlier start of integration work by IT engineers is not the same as implicit integration across interfaces. This implicit integration could possibly be achieved by making use of the emergency teams concept described earlier in the text. Instead of involving a mixed specialist team only at the end of a project to solve the worst problems they could be involved in a continuous way throughout the project. Their job would be the supervision of each party involved in the installation work and to ensure that actions are well coordinated. One form of practical realization could be to appoint several project managers from different functions instead of just one leading project manager. All important decisions on the construction site would have to be made by the members of this group together. This method of enhancing integration could be combined with the different work break down structure of IFM or could also be seen as a top-down approach, which could form an alternative to the bottom-up strategy anticipated by IFM.

The idea of **continuous learning and improvement** is a cornerstone of lean thinking. It is obvious that this is an approach that is important for SAL projects too. In the SAL business environment project managers (bear in mind that those managers are in charge of the installation phase on the construction site, but not for any layout design) need to deal with new challenges in each project they are responsible for. Therefore, a certain learning by doing effect is unavoidable. To make this learning process smoother and more efficient a knowledge data base could be a helpful tool. This would be in line with Wischnewski's proposal to make use of error statistics as a tool to achieve continuous improvement in projects. Currently problems that occurred and the way they were solved are reported, but not made available to other project managers. With a knowledge data base the efforts of continuous learning could be more concentrated on new solutions rather than re-inventing the wheel over and over again. After all, finding a solution that already existed cannot be regarded as a continuous learning and improvement process. The implementation of a knowledge data base could be seen as analog to the **suggestion box** solution with the addition that suggestions are accessible for all project managers.

Regarding the finding of solutions it is necessary to mention that the SAL business environment sometimes makes it hard to get to the bottom of a problem. This is especially true for the installation phase where a lot of externals are involved. Toyota's concept to "ask **five times why** to get to the root of a problem" as well as error statistics are hard to apply across organizational borders.[62] And in SAL projects quite a lot organizational borders may need to be crossed to get to the root of a problem. At the same time information about errors is held back by the parties involved to avoid any accountability for them. In SAL projects each external service provider may face claims for damage if he can be made responsible for an error. Hence, being responsible for an error is not only affecting reputation of a player as this is the case in the Toyota context, but can also have a very bad financial impact. The willingness of all parties involved to contribute to an objective solution to a problem can thus be seen as very restricted.

There are some other implementation issues that may not be disregarded. One prerequisite of an IFM implementation is a change of the incentive system. The incentive system under the traditional approach rewards fast installation of as much material as possible. The milestones that trigger the payments are rather related to quantity achievements than to functionality. This can again be illustrated by looking at the installation of the steel framework. If the customer enters the building and the whole steel framework has already been built, he feels that the project is making a good progress and is willing to accept that an important milestone is already reached. But although a finished steel construction might look impressive, it does not mean that the overall project is on track. If small integration steps are taken instead, the benefits must be "sold" to the customer because the progress in material quantity would be smaller. To not erode the financial benefits of IFM, its implementation may not cause a delay of milestone payments. Hence, to enable a successful implementation the culture of rewarding volume instead of functionality must be overcome. If the focus is to be on integration of the different functions, this kind of incentive system is highly counter productive.

[62] Toyota's ability to overcome this problem stems from the special relationships to their suppliers.

Practice	Description	Application at SAL	Critical Issues
Just-in-time	Delivery of the right material to the assembly line exactly at the point in time, when they are needed, postponing the point in time when the costs are accruing which improves the capital efficiency	Stage1: making suppliers deliver only parts SAL needs for the certain time (monthly, weekly, daily)	Ability of the project manager to define what is needed at what point of time The proximity between the supplier and delivery point is an issue
		Stage2: buying material independently from the date it is needed, storing it and delivering JIT from storage to construction	Storage costs are not eliminated, but material vanishing is reduced Clear accountability for withdrawals of material from the storage should be set
		Stage3: JIT approach to the installation process - each function is building the part that is currently needed by the following function	Higher risk of missing materials at the construction site
Zero defect	Material is delivered without default	Layout change is interpreted as a defect	Layout changes occur regularly and often due to issues with external and internals
Cross-functional teams	Multifunctional approach with employees able to perform several tasks - increases flexibility and decreases vulnerability of the process	Short-term relationships with workers that are often external contractors	Costly training and coordination
Empowerment	Letting workers stop the process if an error occurred	Approach will lead to a massive number of installation work stops	Changing people and environments from project to project causes the lack of learning needed for the TPS empowerment Instable design makes empowerment unfeasible, as workers might falsely identify a change as an error
Pull mechanism	Adapting the amount of output to the needs of the internal or external customer to avoid overproduction.	Not applicable to a project as a whole, as each project is unique and carried out on direct customer demand (no overproduction). However, can be applied within the project work with IT department as an integrator, triggering the demand that the other functions fulfill	Trade off between the benefits from earlier completion dates and costs from increased complexity and decreased economies of scale

Continuous flow	Full integration of interfaces in the process	Neither the current process approach nor IFM can create a continuous flow But the involvement of the emergency teams throughout the process could be a solution	Involvement of emergency teams is very costly
Continuous learning and improvement	Cornerstone of lean thinking, represented for example by "suggestion box" or "five times why" approach at Toyota	Continuous learning can be enhanced through creation of knowledge database available to all projects managers	"Culture of claims" erodes trust and promotes unwillingness of external parties to reveal the real cause of a problem, which makes it hard to implement "five times why"

Table 3 Summary of Lean Practices that could be potentially applied to SAL projects

Regarding the other (prior) part of a SAL project (the layout phase) lean theory would also suggest a different organization approach. As we have seen in Figure 1 the unfinished layout is moved from department to department, resembling a sort of production line, which leads from one end of the company to the other.[63] Instead of having totally different people working on it in each area the specialists should work closely together. This is important as the essential knowledge of a development team lies in the shared viewpoints.[64] Another reason for a combined team is the easier and faster communication to solve problems than in a sequential process.

4.2 SAL's procurement & logistics function and supplier relations

4.2.1 The importance of purchasing & logistics for the realization of IFM

After analyzing the applicability of lean production principles to the SAL project context the next step is to analyze to what extent the purchasing and logistics function could support the implementation of a lean approach. For clarification it must be pointed out that the aim of this paper is not to apply lean principles to the processes in the purchasing and logistics department. Although the application of the concept of lean procurement at SAL would be an interesting topic the focus of this paper is on the possible contribution of the procurement function to an overall lean project approach.

The particular importance of supplier relations and reliable supply for a lean approach were already mentioned. The following argumentation shows why SAL projects are especially dependent on reliable supply. Both the design stage that should result in a workable layout and the installation stage are characterized by a high degree of technical interdependence. This implies that many activities must be placed on the critical path. Without certain prerequisites in place and certain components at hand most tasks cannot be carried out. This in turn implies that a supply shortage of

[63] Womack, p.115
[64] Womack, p.116

material that leads to the delay of only one step can potentially stop large parts or even the whole work flow. In contrast to SAL projects other projects with only very few tasks on the critical path can potentially lack material for a longer time span without risk of delaying the overall project. A stop of work flow in a SAL project is costly. One day of having the required machinery and skilled work force on the construction site of a medium size project costs 15000€ on average. These remarks should make it clear that the procurement and logistic function needs to support any change in the installation process in order to make the change potentially feasible.

4.2.2 Technical clearance – Procurement – Delivery: The way of material to the SAL construction side

As already stated before, the focus of the paper is not the optimization of the procurement and logistic processes at SAL. However, to come to a conclusion whether the procurement and logistic function can potentially support a lean approach we considered it important to have a look at these processes and the most important current issues at hand. As a starting point the way of the material to the SAL construction site (from technical clearance over purchasing to delivery) will be explained. This is followed by the description of some issues the buyers at SAL are currently facing.

The first step towards getting the right material is to define the exact material specifications that are needed. These are defined by the technical department after the sales department has communicated the customer requirements. Based on a preliminary layout (normally complies with 85% of the final solution), lists of materials needed are sent to the purchasing department via SAP. Each component is again split into its sub-components, including the date of required delivery to the construction site. But before the purchasing department can place an order, clearance from the technical department is needed. This clearance is often given too late to meet the delivery date requirements specified in the list. As soon as clearance is given, material is ordered for each project separately. This implies that currently volume effects are not realized. Even if several parts of the same kind are needed for the overall project but technical clearance is only given for one piece, the single piece is ordered separately from the others. The ordered materials are either delivered directly to stock at the construction site or are exported by a specialized logistics service provider. This is sometimes necessary due to complex export regulations (e.g. for shipments to China) or if combined shipping of materials is efficient due to long distances. According to all interview partners from the purchasing department, the main problem is the very late setting of specifications by the technical department. This leads to a restriction of any strategic approach to purchasing and threatens the on time delivery to the construction site. The late involvement of the purchasing department by the technical department can be regarded as a communication problem that must be solved instantly. But there is another reason for the late forwarding of specifications. Although SAL is offering standard components customers tend to have special requirements, which (besides being costly) are time-consuming in their fulfillment. These special requirements add uncertainty to the layout designing stage. Layout uncertainty goes hand in hand with uncertainty of what specifications components need to have (e.g. the strength of drives, length of conveyors, etc.). This circumstance is highly problematic for the purchasing department. On one side they are challenged by project management to place the orders in due time and on the other side they experience material requirement changes at any stage of the project. In some cases even framework contracts with key suppliers were negotiated when design changes foiled the whole effort. Furthermore, the situation often doesn't allow for the search of alternative supply sources due to a lack of time. If a certain component is needed on a construction site under short notice as quickly as possible and lead times are long, the available time for offer evaluations is very restricted. The inconsistency of component requirements can have a fatal effect on the procurement of bottleneck and strategic products in particular. Both product categories are often not available under short notice or only at considerable additional cost. Frequent layout changes combined with strategic products that are affected by those changes bear the risk of cost overruns due to obsolete items that are already in stock.

4.2.3 SAL's supplier relations

In the following paragraphs information about the current situation of the SAL procurement environment is presented. These facts will form a part of the analysis whether or not a lean approach can be implemented successfully. The facts presented here reflect only a small part of the purchasing and logistic work done in SAL projects. However, we consider this part vital for the success of a lean approach. The overall issue is the own strategic position in the supply chain. Three main factors that determine this position are long-term contracts with suppliers (to involve them in the solution of problems, innovation work, etc.), the outsourcing decisions made by SAL and the power structure that determines the nature of the relationship with each supplier.

The fact that SAL has no own product manufacturing makes them even more dependent on the reliability and performance of externals than Toyota is. Furthermore, their rather unstable relations with their suppliers make SAL vulnerable to economic fluctuations. Long-term contracts including reserved capacities are missing, hence SAL tends to have problems to secure their supply if suppliers have a high utilization of their capacity. This is typically the case in times when economy is going well. After SAL realized that this situation is causing several problems, they came to the conclusion that better contracts are needed to control the performance of their suppliers and to guarantee reliable supply. The new framework contracts that were offered to all suppliers lately relate to technical standard items, services and solutions and contain new quality standards, delivery modalities, prices and purchase commitments. The purchase commitments are set according to a two year forecast of demand for each product. SAL commits to buy 15% of the two year forecast without setting a time limit. This means that the supplier has the guarantee that a certain batch will be purchased but no guarantee *when* this batch will actually be bought. The framework contracts were sent to the suppliers recently and it already has become apparent that a number of potential partners did not accept them. These rejections can be explained by looking at the fact that the vast majority of SAL's suppliers make a rather small annual turnover with SAL orders. For those suppliers it is often not even worth to read through the over a hundred pages strong framework contract that SAL has sent them. Furthermore, the contract makes suppliers accountable for any damage or delay their products cause during construction and after commissioning. Midsized companies would never be willing to sign such a contract as they would face bankruptcy if they were held accountable for a delay claim.

The inventor of lean principles considers the topic of outsourcing to be totally irrelevant. The real issue is whether the assembler and the supplier can work smoothly together, not the legal relationship they might have.[65] When looking at the previous description of Toyota's supplier relations, this statement is hardly surprising. However, the issue is discussed controversially among SAL managers. In contrast to Toyota the SAL project environment is strongly affected by the outsourcing decisions when it comes to the implementation of lean principles. The reason for this is simply the extremely different nature of the supplier relations. While Toyota can impose demands without owning any supplier, SAL is not able to control their suppliers in the same way without vertical integration. Since many SAL managers still do not regard the current level of outsourcing as a final solution, this is an important issue to consider. A change in this area could heavily affect the current supplier relations. At the moment there are intense internal discussions about whether product designs should still be developed in-house or whether all material should be ordered from externals. In the case of conveyor technology (which is a strategic item) the market price for comparable products is about 10% below the price of letting a manufacturer build conveyors according to SAL designs. On the other side some SAL managers argue that an in-house production would be favorable.

Purchasing Practice	Description	Application	Critical Issues
Technical clearance	Technical department defines specifications based on the information about customer's requirements, and forwards them to purchasing department	More efficient collection and treatment of information that occurs during the installation work Involving all functions in finding improvement measures	Customized requirements add uncertainty to layout stage - material requirements change
Procurement	Managing the external resources	Work towards increasing product standardization and modularization of the products It is necessary to choose whether to re-integrate conveyor manufacturing or to outsource conveyor business including design and supplier relations management	SAL is highly dependent on externals and has partly unstable relations with them SAL's orders constitute small part of their suppliers' turnover

[65] Womack, p.58

Delivery	Transport of material to the construction site	Either direct delivery from supplier or professional export by specialized service provider	Long distances often require bundling of material Transportation to some countries implies lengthy and complicated custom procedures

Table 4 Summary of Purchasing Practices

After having discussed some contractual issues we should now have a closer look at SAL's position in the supply chain and the interrelated relationships to their suppliers. To do so we use the purchasing portfolio matrix. The categorization is the result of interview sessions in which SAL managers were asked to place the products and services in the matrix. Results were discussed and reasons for their choice of placement were documented. In addition to that the results were compared to documentation on the cost structure of SAL projects, which gave a useful insight regarding the profit impact of each item.

Regarding SAL's position in the supply chain the following facts are important to keep in mind. No SAL supplier makes 50% or more of his turnover with SAL. This is in strong contrast to Toyota's position in their supply chain. The interview partners all pointed out that no supplier is really dependent on SAL. The only supplier that is to some extent dependent on SAL is a Siemens internal manufacturer of drives. However, without SAL as an internal customer for a special kind of drives the Automations and Drives group of Siemens would not loose in profitability. It is rather R&D issues that make the partnership with SAL important to them. Drives are part of the conveyor technology. The categorization of this part will be the start of the analysis below. In general one can say that a potential threat to a strong position in the supply chain could be a high number of bottleneck products and many strategic products in a supplier-dominated segment.

<u>Strategic product example</u>

Conveyor technology is one of the key technologies for an SAL system. Supply risk is high due to the very limited number of potential suppliers and due to long lead times in case of a short notice order. These short notice orders occur quite frequently due to layout changes during the projects. Obsolete conveyors cause high additional cost and realization of changes is not a fast process. The whole conveyor system amounts to about 60% of total purchasing costs and to about 40% of overall project costs. Hence, it is basically doubtless that it should be categorized as a strategic product. However, placing the item "conveyor technology" into the purchasing portfolio matrix is not as straight forward as it might seem at first sight. Among other things this is due to the special relationship SAL has with the supplier for all conveyor technology for straight movement (i.e. excluding curves, lifts, baggage claim carousels, etc.). For these conveyor parts SAL has one strategic partner who is building the conveyors on the basis of SAL's own designs. The expenditure for this particular conveyor technology amounts to about 20% of the whole purchasing volume and to about 14% of the overall project costs. SAL is responsible for the selection of suppliers for the conveyors and is also negotiating prices as well as purchasing the parts needed. In other words SAL is in charge of managing the relationship of their second tier supplier for their first tier supplier. Figure 6 shows the situation in a simplified way.

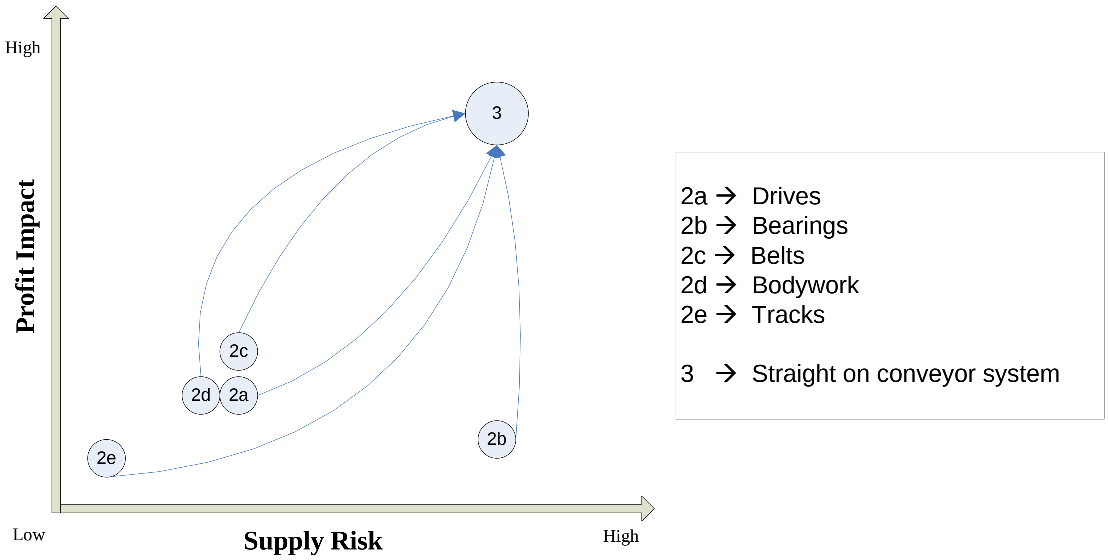

Figure 7: Placing conveyor technology in the Purchasing Portfolio Matrix

As one can see the decision to outsource the manufacturing of these conveyors resulted in a situation, in which the SAL procurement department is facing one item that must be classified as strategic instead of several non-critical items and few bottleneck products. As we have seen in the description of implications of the matrix, for strategic products the power structure can potentially be in favor of both, the buyer or the supplier. Therefore, we need to take a closer look at the situation. The second tier supplier selection and contracting processes as well as product design were kept in house to secure quality and to keep product know-how within the company. This is supposed to make SAL less dependent on the performance of the supplier and to make switching to another supplier easier. Regarding the conveyor business the supplier is fully dependent on SAL orders. However, the conveyor business forms only a very small part of the supplier's business portfolio. Although SAL owns the product know-how, switching to another supplier would be a rather lengthy process. Furthermore, the supplier is very appropriate for SAL. They know the conveyor business extremely well, have extensive technical know-how and are a quite solvent enterprise. All in all one can say that currently the level of SAL's dependence is quite high, which in turn implies a power structure that is rather in favor of the supplier.

For the other components of the conveyor system (curves, lifts, baggage claim carousels, etc.) the categorization in either leverage item or strategic item depends on the project size and partly on project manager and customer preferences. In large projects the technical requirements for conveyors can be higher than for smaller projects. For example higher throughput rates for baggage may be required. This limits the number of potential suppliers. Furthermore the call for tender or the preference of the project manager may already limit the supplier base. These are the reasons that often cause a categorization of these products as strategic items. All in all we decided to place the conveyor technology in between the two categories "strategic" and "leverage" item with a stronger tendency towards the strategic item category. The problem is that in the cases where conveyors need to be classified as strategic items the supplier is in a somewhat stronger position. This is true because if SAL is facing a restricted supplier base the suppliers tend to be well informed about this fact. We will now go on and have a look at some other important items that need to be procured and check on where they should be placed in the matrix.

<u>Leverage product examples</u>

IT hardware (controllers, etc.) is a typical leverage product. The financial impact of the item can be considered as quite high as the percentage of total purchase costs is quite high (about 26%). This implies that a small change in price has a relatively strong effect on the cost price of the overall project. At the same time there are various suppliers and switching costs are low. The same is true for the installation services SAL is buying. Together mechanical and electrical installation make up about 12% of overall project costs and 20% of purchase costs. Electrical installations tend to be technically more demanding than mechanical installations. Hence, the supplier base for those services is a bit more restricted, which increases the supply risk of electrical installations compared to mechanical installations. As already mentioned before, installation services are sourced locally for each project, which leads to high supplier fluctuation.

<u>Non-critical item example</u>

A typical example for a non-critical item is the steel framework. Although steel prices have been on the rise lately, the overall price for the steel framework including installation only amounts to about 11% of the purchasing volume and to about 7% of the overall project cost. Normally there are several suitable suppliers for the service and material can be procured easily.

<u>Bottleneck product examples</u>

For the sake of completeness two examples for bottleneck products in an SAL business context will be described below. SAL has developed a gear belt together with a midsized company as a partner. Today the whole know-how is in the supplier's hand and no attempt to break the monopoly has been successful so far. The amount spent on these components is rather small in relation to the overall project. But no SAL system is workable without these gear belts. In addition to this gear belt supplier another supplier has a strong position regarding bearings. The company has a monopoly on a certain kind of special bearings that are needed in large amounts for SAL projects. Currently their capacity is fully utilized, which makes availability an issue for SAL. The building up of new suppliers is pushed, but will take some more time. Again the amount spent is rather small compared to the overall value of a project but has nevertheless a big impact on the work flow. Both items are integrated in the conveyor technology, hence they will not be found separately in the final matrix below.

The research on SAL's supply base resulted in the following purchasing portfolio matrix.

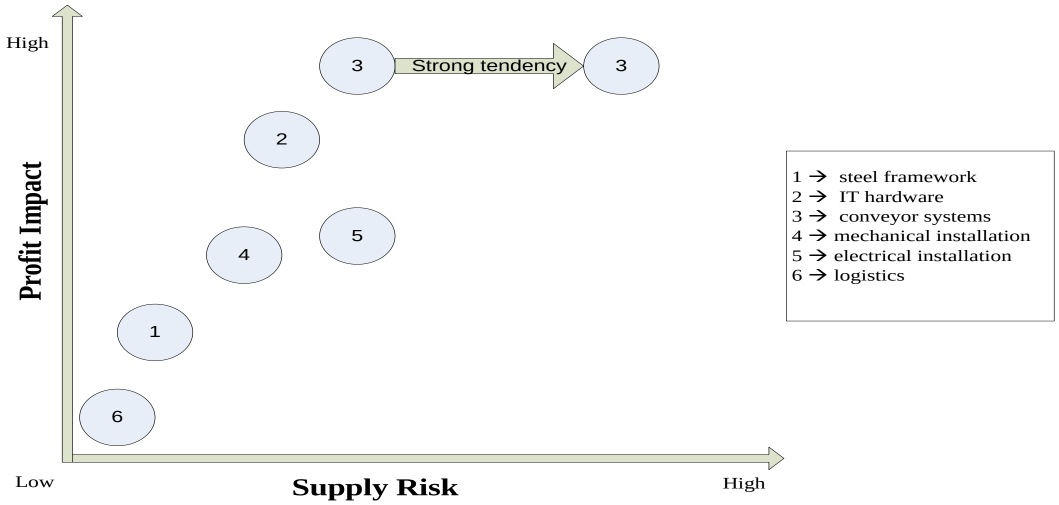

Figure 8: Final Purchasing Portfolio Matrix of subsystems

At first sight the balance of power in SAL's supply market looks quite favorable for the buyer's side. Most crafts have a rather low level of supply risk, which theoretically implies high bargaining power for the buyer. In addition Siemens is always attractive for suppliers as a reference customer. Furthermore, Siemens is an extremely solvent partner. For their suppliers the risk of not being paid for work performed according to contract agreements is practically zero. Hence, one could conclude that SAL should be able to strive for relations that allow for the implementation of lean principles (e.g. JIT delivery and zero defects). But unfortunately this is not the whole picture.

To begin with, one has to point out that the matrix above is displaying not single products or services but rather whole subsystems (crafts) of the project. Due to the limited scope of the paper a more detailed splitting was only carried out for the most important subsystem, the conveyor technology, which comprises over 60% of the project cost. Among all the subsystems no bottleneck item can be found. Yet within those subsystems a number of bottleneck products are hidden that can cause high costs, as the two bottleneck product examples above have shown. Furthermore, the nature of the SAL business limits the theoretical benefits that SAL's supplier structure as shown in Figure 6 has. SAL's demand can be regarded as quite volatile. In addition to that we have seen that they do not represent a high percentage of their suppliers' turnover. These two issues are of course interrelated. SAL is aware of the fact that they cannot guarantee their partners constant turnovers. Hence they do not strive for representing a high percentage of any supplier's turnover. If they would attain a financial dependence of a supplier on new contracts with SAL, they would risk the bankruptcy of this supplier. The argumentation above applies to both, suppliers of material and suppliers of installation services. As already mentioned before, the demand volatility issue is even worse for the relations with service providers. Installation services (mechanical as well as electrical) are sourced locally which results into pure spot market relations and substitution of suppliers from project to project. Therefore, long term relationships with the installation service providers that would allow a cross functional way of working and mutual learning is not feasible in most cases.

As a result suppliers often do not regard SAL as a premium customer that must be kept under all circumstances. Hence, SAL is in most cases not in the position to demand JIT and zero defect delivery without bearing the additional cost. As long as SAL will have to bear the cost, there is no incentive for suppliers to implement lean production in their own plants to meet these requirements without incurring additional cost. The interviews have shown that the criteria that Toyota has set up for a suitable supplier (no renegotiations, no follow ups, no quality monitoring needed and low administrative costs) are only met by very few suppliers of SAL. Among the suppliers of the main commodities no supplier can meet these requirements. It is only the suppliers of some side components (often they are suppliers of the Siemens concern in various different areas) can meet these standards. Furthermore, the lean principle of JIT delivery must be supported by transparency of the own demand for the suppliers. One tool to achieve this is an EDI connection that allows a supplier to check on the purchasing plans of his customer. No tool like this is established at SAL. On the contrary, they tend to often "surprise" their suppliers with their demand pattern.

It must be acknowledged at this point that supply shortage is often not a supplier relation issue. In many cases it is caused internally. One example is that project managers often have unrealistic conceptions of delivery times for certain components. The lack of coordination with the procurement function often leads to overhasty actions and late deliveries. This can be regarded as the reason for a lack of quality and suboptimal deals in monetary terms.

5 Conclusion

In this part we summarize the findings of the paper and derive conclusions to answer the two research questions. Regarding the SAL business environment it is important to keep in mind that the division is integrating numerous expensive and large systems into one airport system. SAL is partly providing the know-how for the parts that are used. They need to act in a complex project environment that often demands a high degree of specificity. Installation is done by externals. The layout design, system integration, IT solutions and project management is done by SAL internals (in-house). This structure is well in line with modern outsourcing principles (keep only core competences) but, as we will see, limits to some extent SAL possibilities to make use of lean principles.

5.1 Lean thinking for SAL projects, a feasible approach?

In the analysis part we started out by discussing whether lean production theory can potentially be fruitful for SAL's project business. We tried to modify implicit thoughts of the cornerstones of lean thinking in a way that enables us to apply them to the installation of an airport system. The point of departure was the new Integration Flow Management (IFM) process, which forms the basis for a large part of the discussion.

Applying IFM means breaking down a large project into a series of smaller projects. As a result the whole installation plan would turn into something similar to a cell layout. Workers from different functions would simultaneously process the same part of the overall system. This implies that the IFM process layout is an important step in order to enable a change from a **push to a pull** mechanism. Instead of letting the different functions install parts on the basis of an overall layout (which tends to change during the project) and in a more or less independent manner from the successive function (push), each function only installs the part that is needed for the integration step defined by the IT function. This procedure implies that each function is fully oriented towards the need of the internal customer and that installation begins only after a specific demand was triggered (pull). The installation process under IFM complies with the JIT concept. The fact that only parts that are necessary for the next integration step are installed reduces inventory in the form of work in progress. On the other hand some limitations were found regarding the **JIT** delivery of materials by suppliers. For certain projects the benefits from bundled, large volume deliveries may outweigh benefits from savings on storage cost and less tied up capital. This situation can occur if material needs to be transported over long distances and/or custom processes are lengthy. Therefore, the applicability of JIT delivery must be judged from case to case. But even in cases where JIT delivery from the supplier to the construction site is not regarded as a feasible option; merely JIT delivery of materials from the central storage to the construction site can already improve the current situation by reducing material vanishing.

In theory IFM allows the implementation of a **multi-functional** team approach, which would make the process of installation less vulnerable to errors through coordination default. If staff on SAL construction sites was multi-skilled as a long term result of cross-functional working, they could anticipate what impact their actions have on their internal customer and act accordingly. This would comply with the fact that the functions are technically interdependent. However, in practice the high level of external service provider involvement (remember that they are hired on a spot market basis rather than on the basis of long term relationships) limits the potential benefits quite a lot. The costs of training are high and hence a cross-functional approach can only be profitable for each party in a long term partnership. But in the current situation integration know-how can hardly be kept due to high (unavoidable) contractor fluctuation. And merely changing the organization chart to show “teams” or “quality circles” to improve the installation process is unlikely to make much of a difference. Therefore, the very successful bottom-up quality assurance approach of Toyota is out of reach for SAL. Our suggestion is to at least implement a knowledge data base that SAL project managers can use to transfer their knowledge from experience to other project managers. This is of course not comparable with Toyota’s quality circle approach. It is a top-down approach, which is rather comparable to the suggestion box principle. Nevertheless, it seems to be the more appropriate tool for quality assurance, continuous learning and improvement in a SAL context.

Another tool of the lean approach that can only be used to a very limited extent is the **“five-times-why”** approach. This concept represents Toyota’s way to solve problems once and for all and can also be regarded as an effective way to collect data for the error statistics that Wischnewski proposed. The tracking of the root of a problem will mostly lead across organizational borders. In an SAL installation environment being responsible for problems often means being a potential subject to claims. This implies a lack of incentives for objective problem solving.

However, regarding possible ways to **eliminate various sources of waste** IFM is offering some useful points of departure. This is true because it demands the earlier involvement of the IT function as an integrator. This in turn enhances an early detection of errors. The two figures display the current situation compared to the IFM process design.

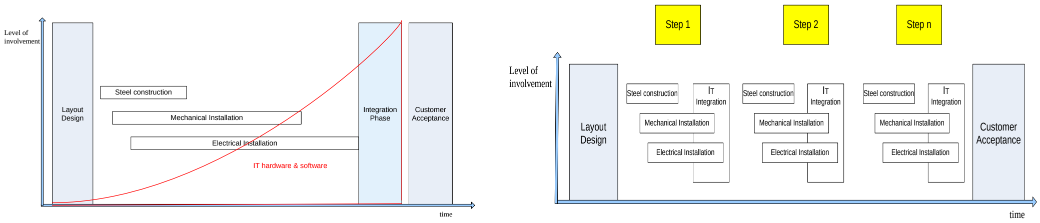

Figure 3 and Figure 9: Current installation process compared to IFM

To quickly review the potential of IFM to eliminate waste (in a form of overproduction of items that no one wants, and unnecessary processing, transport and movements) through an earlier involvement of the IT function, a small illustration follows below. It draws an analogy between a sailing trip and an SAL project. Imagine that the owner of a ship wants to undertake the project of sending it from Florida to London (the owner is analog to the SAL customer). The project begins by hiring a skipper, some seaman, a cook, etc. (analogy with SAL hiring external installation service). The captain of the ship has to integrate all these functions to reach the destination (hence the IT-function as the integrator in SAL projects can be seen as the captain). A good plan that comprises which route to take is given to the crew before the journey begins. This is a prerequisite for successful navigation (in an SAL context the navigation plan would comprise a workable layout). After sails are set the captain is not seen on deck for many days, doing theoretical studies in his comfortable cabin (analogy to the IT function not being involved on the construction site in the beginning of a project and instead only running theoretical models). When he finally comes back to check on the crew, the speed is excellent but the course is no longer towards London but towards Cape Town. As it turns out this is due to incidents involving a huge wale, pirates and some growlers (analogy to layout changes and coordination problems that lead to extensive problems due to late integration). London can only be reached (if at all) by correction of the course. This implies considerable extra time and cost since new food needs to be bought along the way (analogy to expensive solutions such as flying in additional material and establishing emergency teams). The second option the captain has is to decide that Cape Town is much nicer than London anyway. Unfortunately the owner of the ship might also have a say in this project (analogy to SAL having a workable plant that is not according to contract specifications).

Regarding the concept of **zero defects** our conclusion is that it is indeed an applicable principle to SAL projects. It is however, a more challenging issue than it is in the world of car manufacturing, because additional uncertainties need to be considered. For SAL a zero defect approach would be particularly challenging but also particularly beneficial regarding the design of the overall systems layout. As we have seen an ultimate layout freeze is hardly possible. Hence, “zero defects” in layout designing must be seen as a goal that SAL should strive for, although it might never be fully achieved. The findings on the feasibility of imposing a zero defect delivery standard on suppliers will be dealt with in the conclusion part about supplier relations.

Considering these comments it can be concluded that in general the answer to the first research question is “yes”. Although some concepts need to be rethought to fit into the SAL context and current practices of carrying out the projects imply some limitations, there is no doubt about the beneficial implications of lean concepts even in this complex environment.

To substantiate this conclusion we have shown some potential benefits of IFM. The most important ones are the reduction of costs through faster completion, less non value adding work and lower inventory in the form of work in progress. Depending on the location of a project even savings on inventory of materials could be realized. Especially the earlier completion of projects has a positive financial impact through the earlier realization of cash in-flows and lower imputed interest. Nevertheless, to come to a final decision, whether to put IFM into practice one may not disregard the apparent benefits of the traditional approach. Due to a lack of benefits from quality circles it will be hard to argue for a relinquishment of economies of scale (which are implicit in the traditional approach to material installation) in favor of a higher level of integration. Another issue that might limit the successful implementation of IFM is the current incentive system that rewards quantity of installed material instead of functionality. If SAL cannot manage to change these terms in their new contracts, the traditional approach may turn out to be the better solution.

5.2 Implementation of IFM, pros and cons from the procurement and logistics point of view

To implement a lean approach the concept must be supported by all functions inside and outside the organization. As Womack pointed out, many efforts to understand the implementation of lean concepts failed because no one looked further than the factory boundaries.[66] We have seen that the procurement and logistics function plays a vital role as it is their job to manage the up-stream supply chain relations. Due to the extensive outsourcing of SAL’s operations in recent years the tasks for the procurement and logistics function have developed from rather administrative issues to strategically important tasks for the overall business. But among the other functions involved this new situation has not been fully recognized. This leads to the fact that the procurement function does not have the position within SAL’s organization and information channels it would need to fulfill the role of a strategic decision maker.

As the research on SAL’s supplier relations including current contractual agreements has shown, it will be quite hard for SAL to put pressure on suppliers to implement production processes that allow JIT and zero defect delivery. In most cases SAL does not have the ability to impose effective economic sanctions. Withdrawing the business from the supplier does not hurt most of them very much. In addition, so far no long-term contracts and no tools for a more transparent communication with suppliers that

[66] Womack, p.3

would support lean principles are in place. The most important subsystem (conveyor technology), which represents about 60% of overall purchasing costs was classified as a strategic product with the supplier currently being in a stronger position. Furthermore, all other important commodity suppliers do not regard SAL as being a premium customer that must be kept under all circumstances. In our view these issues support the conclusion that SAL is not in powerful position in its supply chain. The contrasting of the factors has led us to the conclusion that under current conditions a lean approach cannot be supported by the procurement function.

Thus the second research question, whether an implementation of a lean approach is feasible from a procurement and logistics point of view, must be answered with a clear "no".

However, the activities which the procurement function is currently working on, could potentially change supplier relations to a standard that could enhance implementation of lean principles. In practice SAL is successfully striving for long-term relationships with all important commodity suppliers. The problems they have regarding quality and on time delivery are quite limited. Suppliers tend to be reliable and score well in the Siemens supplier evaluation. Furthermore, framework contracts with those key suppliers are expected to be closed as proposed by SAL. Hence, more stable relations are achievable in the near future. But it is important to note that the new contracts must be supported by the solution of internal issues. In our view the different (Siemens internal) parties involved in an SAL project mirror the two antagonistic views of Ballard/Howell and Wischnewski. Project managers and other functions involved in the installation phase would claim that their work should be shielded by assignment quality. They demand that layout designer and procurement managers should deliver zero defects. On the other hand the parties that are involved in the layout stage and the procurement and logistics function will stress the fact that comprehensive planning is not a realistic goal in this environment and hence cannot be the solution to the problems. They see the solution in a more efficient collection and treatment of information that occurs during the installation work. They will demand from functions in the installation phase to do trend analyses to detect weak spot as early as possible and to create error statistics to learn from things that went wrong. The basic IFM concept favors the second way of argumentation. The process is designed to deal with the problems that result from layout changes by detecting weak spots early. Thus, it accepts the fact that certain layout changes are unavoidable. We extended this concept to a comprehensive IFM approach, which includes all aspects of lean thinking. Such an approach would go further and involve all functions in finding improvement measures, including the people involved in the layout phase. Hence, it would be necessary to find out what each function can contribute to change the organization into a "lean friendly" one.

In this context the job of the procurement and logistics function would be to enhance transparency of SAL's demand for their suppliers. It is not realistic to demand reliable forecasts about what project tenders will be successful in the coming years. But within a project (which can take several years until completion) better demand forecasts are feasible. Let's take the conveyor technology as an example again. It will be very helpful for the supplier to know how many units SAL will buy in a given period, even if the exact technical specifications are not available yet. Information of this kind must be transferred faster from the technical department to the procurement function and to the supplier. IT tools such as SAP software were named as a way to put this into practice in an efficient way. Hence, one can conclude that the procurement function should create transparency for the suppliers, but can only achieve this goal if they are involved earlier on in the process. The lack of communication between the technical department and the procurement and logistics department is an issue that should receive the prior attention of the SAL management.

Furthermore, the sales department and the design engineers would have to take action. The degree of product standardization needs to be increased. This can be achieved by striving for modularization of the products needed in SAL projects and by influencing the demand towards accepting standardization and abstaining from customization. The first step to solve the root of the problem would be to make the extra cost of customization visible to the customers. If corresponding calculations on the basis of a total cost of ownership approach are made available, it would be the assignment of the sales department to present the saving potentials of standard solutions to the potential customers. This is of course only a workable approach if SAL can credibly threaten to add a price premium for customized solutions. In some tenders competition is so high that customization must be offered without demanding sufficient extra payment for it. In such a situation the argument that standard solutions allow cheaper installation and operation will hardly convince the customer. But although the sales department will face hard negotiations regarding this matter, they should at least try to always end up with standard products for the system in any contract.

We think that the above actions are prerequisites for a successful implementation of a lean concept at SAL. We also acknowledge that this conclusion is in some way a paradox. It is a paradox because in product manufacturing becoming a lean company implies striving for perfect customization i.e. endless product variety, which is the opposite of standardizing products.[67] But one can argue that in the SAL project environment the endless variety of outputs is already given by the nature of the business and it is important to implement ways to deal with that variety.

Last but not least there are also things the top management of SAL needs to do in order to support a lean approach. In contrast to Toyota, for SAL the outsourcing decision plays an important role regarding the implementation of lean principles. This is true because in SAL's case certain outsourcing decisions can heavily affect the power structure of their supply chain. Again the conveyor technology should be seen as the most important part regarding this decision. To get to a situation where the power structure is rather in favor of SAL two options are possible. The first would be to partly re-integrate conveyor manufacturing. A certain level of own production combined with purchased units when demand peaks occur would increase the pressure on suppliers to offer good prices in order to win part of the business. This would enhance the bargaining power compared to the current situation quite heavily. It is also in line with outsourcing guidelines to keep core competences in-house. In our view the fact that the designing activities are still kept in-house as well as the second tier supplier selection and contracting, clearly shows that SAL regards conveyor technology as one of its core competences. The second option would be to completely

[67] Womack, p.12

outsource the conveyor business including design and supplier relations management. This would create a pure leverage product with a high number of potential suppliers. Again the bargaining power of SAL would be increased. The implicit conclusion is that the current solution regarding the conveyor technology is a compromise between outsourcing and vertical integration that puts SAL in a quite weak position. A clear decision on whether conveyor technology must be regarded as a core competence or not should be made soon, including the interrelated make or buy decision. This is of course a tough choice as it also affects the decision about the degree of possible customization. However, not taking it and instead keeping a weak compromise alive cannot be regarded as a solution.

Together the new process concept to enhance the use of project information and the measures for improvement of the stability of the layout (work assignment) could potentially build a good basis for the implementation of a lean approach.

If SAL decides not to implement IFM the high inefficiencies that are caused by a lack of coordination will remain. However, other solutions are imaginable that demand a less radical change of the installation process. One example would be to involve the so called “emergency teams” (experts from different functions) to monitor the installation from commencement to completion. If they can achieve earlier completion through less integration issues this expenditure could be justified. The benefit of this approach is that it would be much easier to implement. A possible framework could be to appoint several project managers, one position for each important function. All decisions on the construction site must be made by the members of this group together. This could be seen as a top-down approach, which could form an alternative to the bottom-up strategy anticipated by IFM.

5.3 Further research

The paper has shown that the earlier completion of a project through IFM can have high financial benefits. As a next step SAL would have to take a close look on their cost structure to find out whether the benefits from earlier completion outweigh the additional costs caused by increased complexity of the installation work and a lower level of economies of scale. Due to the limited scope of this paper, no conclusion can be made on that. But analyzing the cost structure and estimating additional costs is definitely the next step that SAL should take in order to come to a conclusion whether IFM should be implemented or not.

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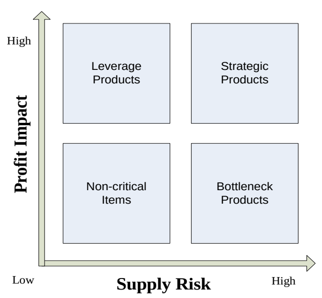
7 Appendix

7.1 Interview Questions Procurement & Logistics Managers

- Please describe the typical way of a product through a process starting with the finished layout and ending with installation on the construction side.

- What are the main reasons fort the problems described above?

- Please place all products bought for an SAL project in one of the following categories in the matrix:



- To what extend are frame contracts in use?

- How would you describe the balance of power between SAL and suppliers of strategic products?

- When looking at all cases in which goals were not reached on time during projects, in how many cases was the reason for this late or faulty deliveries from suppliers?

- How constant is the supply chain? How often are suppliers changed during and between projects? To what extend are long-term partnerships the type of supplier relationship established?

- What percentage of suppliers meet the following standards:

    - Negotiations after contractual agreements are not necessary.
    - Follow ups after ordering components/material is not necessary
    - Transaction costs are low.
    - Quality checks of incoming material are not necessary.

- In how many relationships is Siemens a customer who represents more than 50% of a supplier's overall turnover?

- To what extend are IT tools used for transactions?

- Who is carrying out the installation of the procured material under the supervision of SAL project managers? How long-term are the relationships with external installation service providers?

- Do you expect any interruptions/interferences in the supply chain in the near future?

7.2 <u>Interview Questions and Answers with Project Managers</u>

Q: Where do you see a lack of coordination among the functions that are involved in the construction and integration stage of a project?

A: It is not like the theoretical model you have drawn there. There is in fact some coordination among the different functions. But of course it could be improved. The new approach that you are talking about implies a higher emphasis on the IT-function, which is responsible for the integration of all the work steps that have been carried out.

Q: Let's start with the current situation: How is coordination working among functions during projects currently? What is suboptimal in your view?

A: After the layout fort he project is completed the different functions start doing their work more or less independently. Between the start of the different functions there is a certain time offset. Mechanics start building the steel framework. Only after this is partly completed the electrical engineers can start with their installations. Again some time after that the software specialists can start mounting controllers, etc. In the very end IT specialists have to integrate all the work completed so far and make the system as a whole workable according to customer wishes. In my view the IT function is involved much too late with practical matters of the project. While mechanics and electrical engineers are already working on the construction site, the IT specialists are only working on theoretical calculations, algorithms, interfaces and protocols. But the best simulations do not always meet the requirements of the physics in reality. This can lead to bad surprises towards the end of a project if for example a certain part of the construction is not workable like the simulations have shown. Than costly changes need to be implemented quickly. As you can imagine this may also lead to legal issues with the customer who is not always willing to accept changes that are not according to the contract. In other words: To a large extend the work of the IT function is on the critical path. That's why I think those guys should be on the construction site together with the testing engineers much earlier on.

Q: Besides the higher integration of the IT function, what else could be coordinated better?

A: There is room for improvement almost everywhere. Every function is complaining about the work of the preceding function. But then the project manager can just force them to proceed with their work. This works until the integration stage begins, the project seems to progress according to plan until the final stage. There all the mistakes that were not really followed up to the root need to be dealt with at a very awkward time of the project. But already earlier in the process coordination problems occur. Mechanics install conveyors just for getting the job off their to-do-list. But those conveyors can often not be aligned properly so that the electrical engineers have to dismount them again and do the installation all over again.

Q: Can you tell us something about problems that occur regarding the functionality of the construction?

A: Sometimes the steel construction is not fully stable and swings a bit. This affects of course the flow of the conveyor belts. A lot of small things that have worked out fine in simulations can go wrong. Trolleys can crash against the edge of a switch and fall of the track, etc. But these problems can be solved before the integration stage begins.

Q: Who is involved in the fire-fighting teams that have to rescue a project if its completion is in danger?

A: That pretty much depends on the stage of completion. As I said before some problems can be solved before integration takes place. If we have reached the stage of integration it is mostly software and IT specialists who are involved in those tasks. Mechanics or electrical stuff is either removed or changed slightly, so those engineers are rather not involved in finding emergency solutions. In most cases mistakes in the layout are discovered by IT specialists when they test the system on site.

Q: What do you think about using cross-functional teams all through the process instead of just using them as a fire-fighting unit towards the end of a project?

A: Well, in the current system that is pretty much based on specialist teams this would not make much sense. An electrical engineer has not really much to do at a stage where mechanics start building a steel construction. What would make sense though is to involve a cross-functional team to evaluate the layout of a project as a whole carefully before construction begins. This could help to find some of the mistakes at an earlier stage which would in turn ease the integration stage. In my view a workable and stable layout is the most important thing to avoid problems during construction.

Q: What if we would change the process? For example instead of building the steel framework as a whole, a step-by-step approach of finishing parts of the total project could be applied. Workable partial solution could be delivered. That would allow for a cross-functional approach all-through the process.

A: This could be a good approach if parts of the whole projects can already be used by the customer before the project as a whole is finished. I also see potentials to identify and solve problems earlier. But the classical approach has its benefits as well. Resources can be used efficiently if for example the whole steel framework can be build at once. Mechanics can do their job without being disturbed in their work flow by other functions. Utilization of machinery is also very good, idle time can be minimized. The working in cross-functional teams on parts of the project would also require a lot more organizational effort. Certain functions can not work side by side for technical reasons. For example a welder can not work at the same time and the same spot as a software engineer. So the coordination effort, also regarding security issues would be massive. Regarding safety I see some problems. If we split the project into parts and put them in operation step by step instead of building the whole thing at once and put it in operation as a whole, part of the already operating system will cross the way of other parts of the system that are still under construction. This can be dangerous for the workers at the construction side as the operated part is already energized. In airport logistics systems a lot of loops cross each other, so I really see a problem there. All these factors will have to be considered when preparing the layout. We hardly have these problems with the classical approach of carrying out a project. Again, I think there are some interesting points in what the new approach offers, but the most crucial point is a workable layout. No approach can work without this prerequisite.

Q: But don't you think that the IFM approach based on CFT could deal better with any problems occurring due to imperfect layouts?

A: I agree, the iterative process would work in a better and faster way.

Q: If management would decide to implement the IFM approach, what problems do you see?

A: Well, first of all the site supervisor on any construction site is a mechanical engineer. Those guys are mostly focused on how much quantity was built in what time. They like to see the whole building filled with the complete steel framework construction as quickly as possible. They will not be happy about the step by step approach, as building complete functional parts of an overall project would fill the halls slower and on first sight this would look like slower progress. By the way, we would have the same problem with the customers. They want to see as much physical work completed as quickly as possible. If they enter a hall with the complete steel construction already installed they are impressed, whereas if only the basic complete functional system is installed they might ask us what we are doing all day and why progress is so slow. But I think this is a problem we need to overcome quickly. In the end it is more important to deliver the final project on time and according to the specifications in the contract than satisfying the non-objective view of our customer in an early stage of a project. After all those are two very different levels of pressure. A massive problem might occur if we are paid according to progress in the project and progress is measured on the basis of the hardware that has been installed. In other words we would have to take a look at our contracts before a change in processes is implemented. Another problem is that we would have to break up our current working cycle. Mechanics are the first who have completed their work on a construction site and are free for the next project, whereas IT specialists are fully occupied with integrating the whole solutions for quite some time. So starting out a new project with cross-functional teams from the start might be not realizable. I also see a cultural problem. If we integrate IT specialists earlier in the process, which means we are putting them together with mechanical and electrical engineers, they have to deal with the physics of reality early on in their work. I can already tell you now that most of them won't like that very much. Those guys basically "fear" reality and love working with their computer models. In essence this new approach would imply a shift of power from mechanical engineers to IT specialists. You can imagine that there will be a lot of people that are not happy about such a development.

7.3 <u>IFM – SWOT Analysis</u>

The SWOT analysis is a tool to determine the current position of a program or project. Hence the author uses it to summarize the facts that speak in favor or against an implementation of IFM from an organization internal point of view as well as regarding the factors in SAL's environment that are likely to support or restrict a successful implementation.

<u>Strengths</u>

- In some cases working parts of the project can be put into operation by the customer before the project as a whole is finished → earlier payments might be possible

- Mistakes in the layout are discovered in an earlier stage of the project → lower cost because changes occur earlier

- Stock will be reduced → Step-by-step construction of fully functional parts of the project → JIT delivery for each part (next step) of the project → lower degree of capital commitment

- Specialized functions will learn about the needs of other functions by their involvement in CFT → process will get even smoother over time as coordination is enhanced

Weaknesses

- Utilization of workers may decrease, idle time of machinery may increase
    - If all work of e.g. mechanics is carried out as a whole economies of scale can be realized → the classical approach makes use of this instance

- If smaller quantities are to be delivered just-in-time to the construction site transportation cost will increase massively. The further away the construction site is the worse the impact will be. Environmental issues might also be considered here.

- Difficult implementation: More practical work and responsibility for IT specialists who actually prefer working with simulation models instead of taking care of the actual physics at the construction site - Mechanical engineers need to change their way of working a lot and also loose some influence → resistance!!

- More complex planning and layouts will be required → coordination of different functions that need to work side by side instead of working in sequence is more complex

- Benefits of an implementation might not be visible in a monetary way. A faster and more reliable processes will not necessarily be transferable into a profit plus.[68]

Opportunities

- The practical test of the model in airport logistics projects may serve as an example for other plant construction projects at Siemens and may hence get the support of Siemens top management.

- The benefits of lean principles for suppliers are commonly known. Hence the support of the supply base for the realization of IFM can probably be obtained.

Threats

- Some external players that need to be involved and have high bargaining power might refuse to work according to the new process idea → limited supplier base

- Purchasing smaller quantities and have them delivered JIT might directly or indirectly increase prices for materials and services → impact is dependent on power structure in the SC

- Customers might not accept milestones according to functionality instead of installation volume → later cash-inflow

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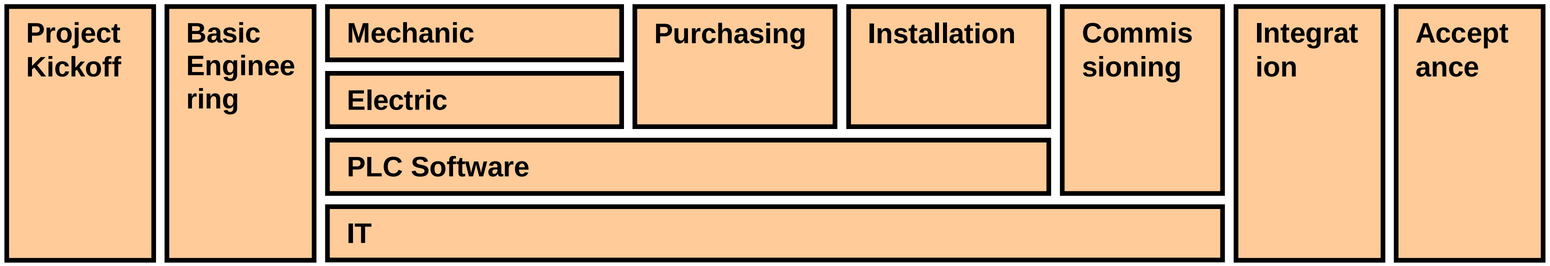
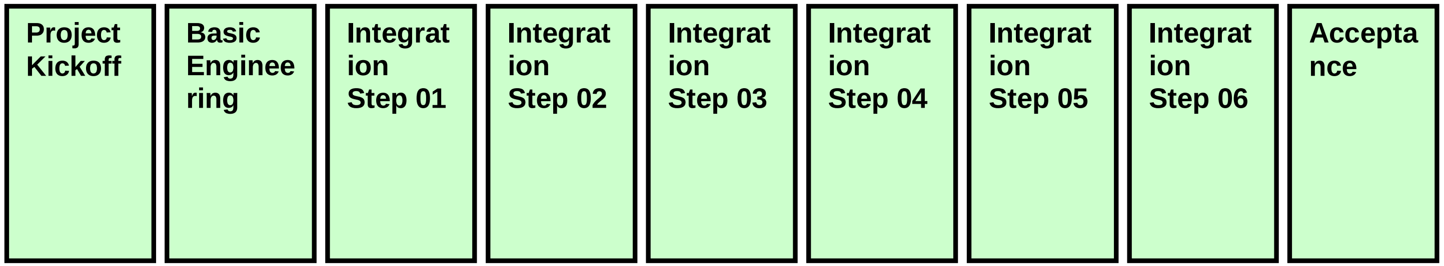
[68] Zachau, p.23

Integration Flow Management
Normal schedule vs. IFM schedule

Normal schedule is organized by disciplines working independently and integrating at the end.

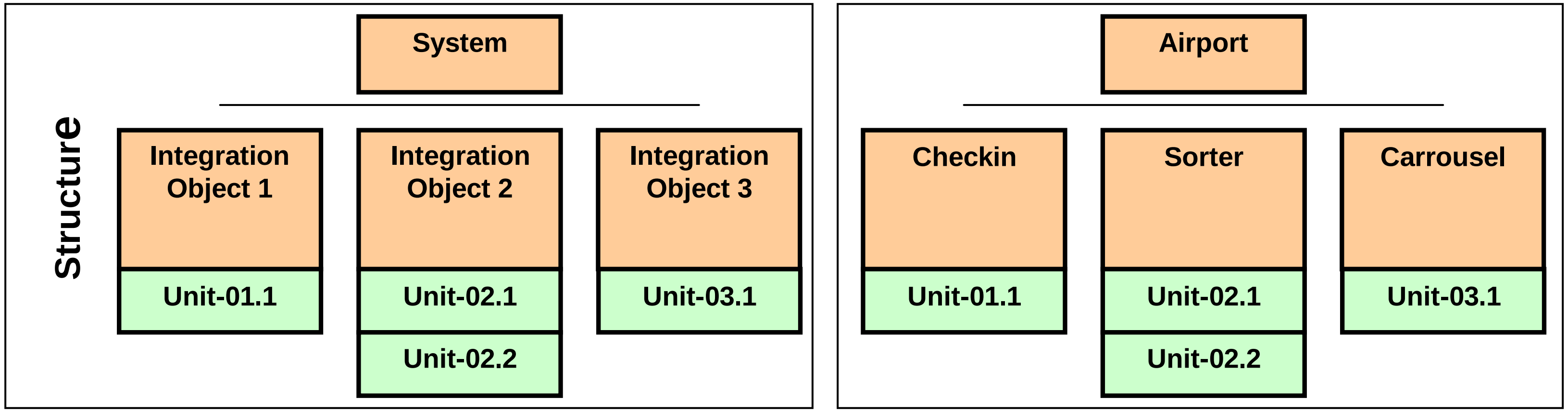


IFM schedule is organized by integration steps which are done by integration teams.



Integration Flow Management

How to design the integration objects and units



Objects and units have to be designed by the system architect in the early offer phase. Their design reflects the system structure.

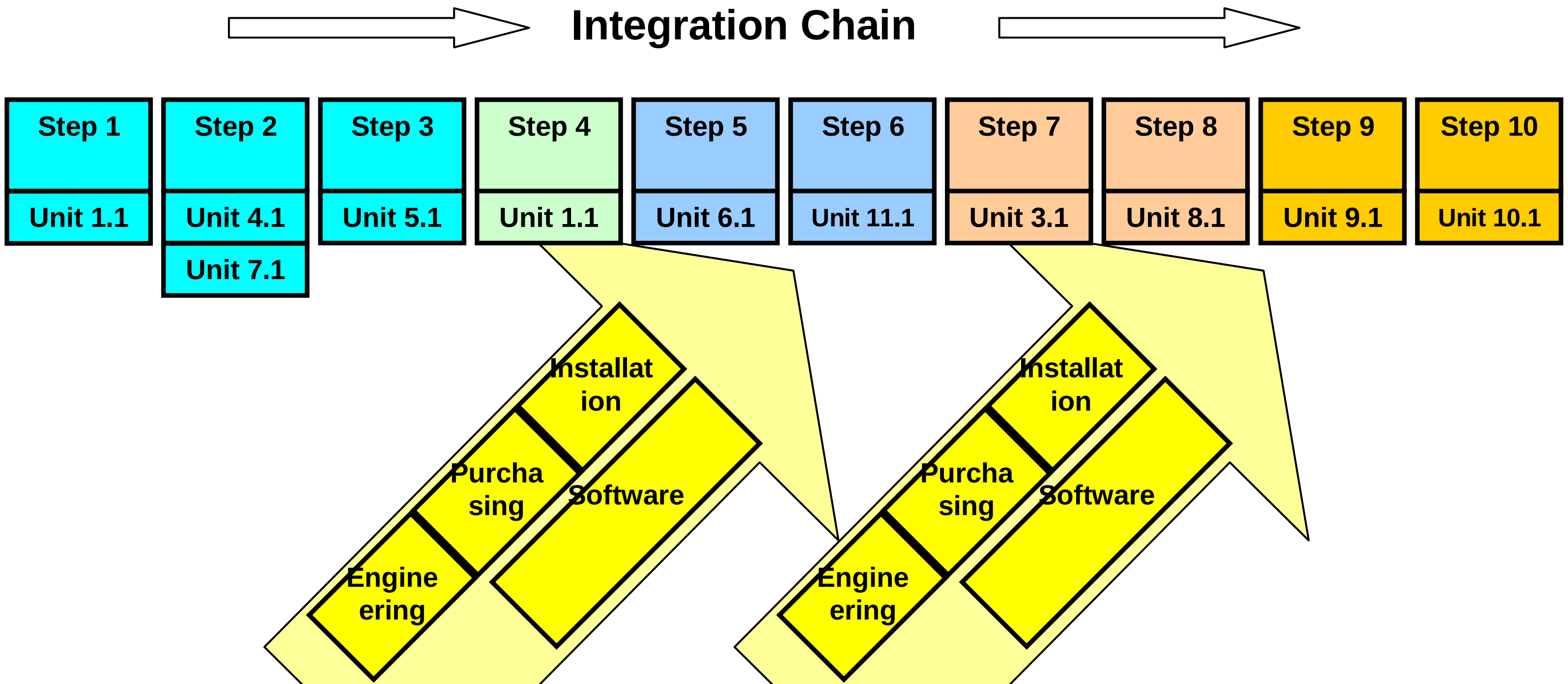
Integration objects are parts of the system.

A system should be composed out of pre-integrated solutions. An integration object is an parameterized instance of such a solution. (e.g. Checkin-Counter Subsystem for an airport)

Integration units are needed to split the requirements of an object into manageable pieces. The split needs an understanding of dependencies.

Integration Flow Management

Integration chain



Every subproject schedule is derived backwards from the ideal integration strategy.

All project members have to deliver just in sequence to the integration