1. Personal Data

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2. Executive Summary

The research project spins around a relevant manufacturing issue regarding how to design an efficient assembly line that can cope with a variety of products in a make to order environment.
The outcome of the project is a methodology that contains a number of guiding steps helping to achieving a beneficial assembly line design according to important performance objectives. The performance objectives in this method include: throughput, costs, flexibility, reliability and utilization. The methodology makes use of different tools and methods for product analyses – one of the more important ones is the Westinghouse Method.
The methodology has afterwards been tested on three products all members of a product family manufactured by a Japanese company named Daikin. Daikin is a big worldwide producer of air conditioners.

The Daikin-case study gave several indications of how difficult it is to design a unified assembly line mainly because of differences across the product family but also because of complications in the individual products structure.
The experiences lead to a discussion concerning issues as; synchronization of the assembly line and the external systems, workers conditions, product-quality, impact of business strategy and product re-design.

3. Travel Schedule

2005-09-04 Copenhagen – Amsterdam
Amsterdam - Osaka

2006-02-01 Osaka - Amsterdam
Amsterdam – Copenhagen

4. Research

All products, ranging from airplanes and television to desk lamps and electronic components have one specific characteristic in common. The characteristic is that the product itself consists of parts that must be joined together to manufacture the finished product. This is the case for all manufactured products regardless of differences in cost, complexity, production volume, function, or any other attribute.

With the growing trend for greater product variability and shorter life cycles, many companies are replacing the traditional mass production assembly lines. In many cases the lines follow a 'make-to-order' production policy, which reduces the customer lead-time, and results in a random arrival sequence of different model types to the assembly line. And because of the mixed assembly line, the tact times will vary within each model, and thus very difficult to unify. For a typical lot production, the tact times are constant and therefore easier to manage.
The benefits of the mixed assembly line, however, are greater, such as: reduced inventory and WIP, labor, reduced lead times, increased flexibility etc.

The design problem of mixed model assembly lines in a make-to-order environment is therefore to control the assembly line in order to achieve a lean and balanced assembly process as possible.
This research introduces a design methodology for an assembly line in a make-to-order environment. The methodology is divided in five main parts, each with subsets of analytical steps. The purpose of the methodology is to point out guidelines to the possibilities and constraints that appear when designing an assembly line for a product family.

Certain assumptions and limitations have been made prior to the methodology.
To begin with, it is assumed that the production takes place in a make to order environment. This means that the assembly line is a mixed assembly line, where the products arrive in a sequence determined by the customer demand and in batch sizes of one. The controlling of such a line is therefore significantly more difficult than controlling a single product line. Different cycle times for each operation will most likely appear, as well as new demands for equipment and worker skills will increase. Hence, the challenge lies in the coordination and levelling of the different parts and operations across the product family. However, as it is a product family, it is assumed that the products, which are to be assembled to a great extent, have advantageous similarities. There will thus be parts and operations which are shared by the different products, but at the same time deviating and additional parts which need special attention.
Another important statement is that this methodology regards a manual assembly line, which of course still can be assisted by machinery.

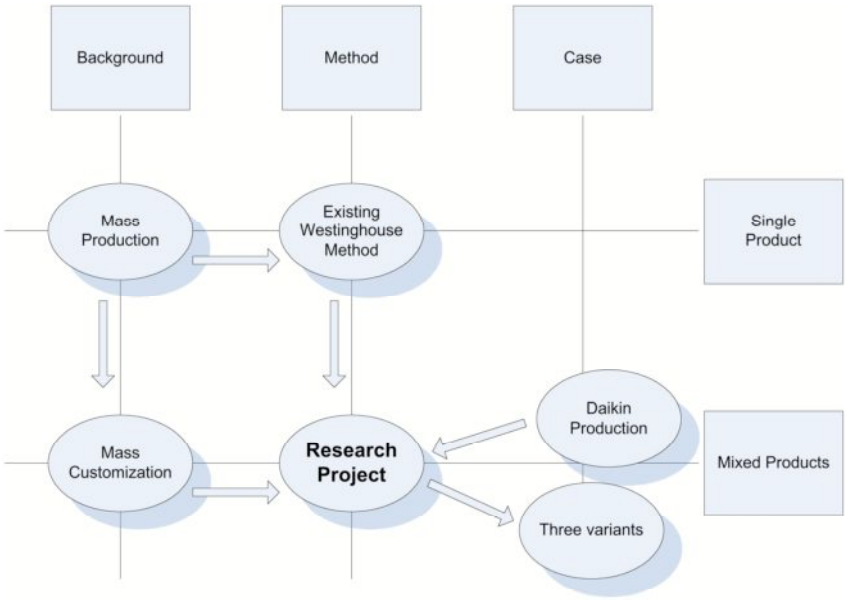
The term product family is often used in the methodology which is referred to as being the products that are desired to be assembled on the line. This means that even if, for ever reason, the products being dealt with in the methodology only are a part of a product family they will still be referred to as the product family. There will be no detailed description on how to choose the products desired to undergo the methodology, hence the product family is considered predetermined.

Furthermore, the methodology and the different techniques presented discourages from analyzing every aspect of the assembly line thoroughly. It is intended as a general approach to the difficulties that surround the exercise of designing an assembly line for a product family, but the issues will mainly be seen from a product design perspective, meaning that the guidelines presented will emerge from data from the product characteristics. As a result of this, the methodology will not provide specific guidelines regarding affected areas such as manpower, inventory management and specific economical solutions. The areas will however be mentioned in the sense that they are somehow affected by the other decisions made during the design.

Because the parts and the characteristics of the products have such a considerable influence on the design of the assembly line, the communication between the design engineers and the manufacturing engineers is vital. The methodology should therefore also be seen as a basis for discussion between these two areas, and thereby attempt to accommodate obstacles that might occur.

As empirical material, three air condition units from the Japanese manufacturer Daikin Industries, Ltd. have been used. The models all belong to a product family, which shares the same assembly line at the Daikin Shiga plant, which we had the opportunity to visit during our research in Japan. In present report, the air conditioners have been used concurrently as an empirical case example, partly as methodology generation and partly to verify key issues of the methodology.

Before moving on with the review of the methodology it will be a good idea to sum up the background and objective of the research project, seen from a manufacturing point of view, with a figure. The figure below illustrates the movement from mass production (single product) to mass customization (mixed products). The DFA method Westinghouse is meant to handle single products, while the purpose of the present research project is to develop a methodology capable of handle mixed products. It's also possible to see that the method is tested through the Daikin-case.



Following is a quick review of the procedures and tools, which are presented in the steps in the methodology. The process is iterative.

The first step is to determine general manufacturing conditions which have to do with the size of the product family, production volume and limitations for the assembly system. Knowledge about the expectations of the output across the product mix and the limitations toward the assembly facility is vital to obtain before any design decisions can be made.

The second step is to gain knowledge about the given products in the product family. In this part general data and information about the products should be generated as a basis for the pending examination and development of the assembly line. The data is mainly collected through The Modified Westinghouse Method, which gives information about assembly times, insertion conditions and part characteristics for one product at a time.
With the basic knowledge at hand, the situation can be analyzed according to various issues.

The third step is the analysis which consists of a comprehensive comparison across the product family. This is necessary to determine the extent of similarities and differences in the product mix. The analysis section will explain how to prepare the comparison and what to compare. The first part of the analysis regards the

issues assembly structure, the assembly time and choice of reference model. In this part an assembly master diagram and sum of difference chart will be introduced as helpful tools to carry on the analysis.
The last part of the analysis concerns the conditions regarding operations and processes across the product mix, which has importance for the choice of equipment, workers conditions and skills. In this part a comparison chart is introduced, which list parameters such as handling condition, insertion direction and fastening type for each part and operation of the product.

After the analysis, the preliminary design of the line can take place, which is done in the fourth step called design considerations. In this part, there will first be looked at to what degree parts can be off-loaded from the line. Secondly, the possibilities for removing the deviating parts along with what to consider when the final line is to be designed will be reviewed.

The fifth step concerns the final design and will mainly look at the conditions regarding proper grouping of operations and thereby create the base for the line and workstation design. Latter mainly concerns the exercise of placing the workstations along the line in order to ease the flow of the different products. In addition to this, the workstation structure diagram is introduced.

The final step regards the evaluation of the design choice and will look into parameters as, throughput, costs, flexibility, reliability and efficiency of the assembly system.

The methodology has a final verification been used at the three Daikin air condition units. Each step has been examined as related to the methodology, which resulted in a comprehensive analysis of the products. As one proposal four larger subassemblies was made. This resulted in:

A reduced through put time on the main line (while the assembly master has gone from 45 steps to 30 assembly steps).
The difference in assembly time has been reduced.

The analysis mainly emphasizes on the time concept for the assembly of the air conditioners. There are of course, several other performance objectives, to which this part of the analysis could be hold against. Objectives like inventory, manpower and throughput are also important and highly relevant issues in this matter. This is done in the final step through the evaluation matrix. It should be noted that the analysis to a large degree is theoretical. However, al though the results are theoretical, they are useful in the further work and as an empirical foundation.

Conclusion
By implying the methodology to the case study a list of statements and questions emerges. Some of the points are listed below and are in the thesis commented and discussed deeper.

- Obtaining high utilization of a mixed assembly line is one of the main concerns.
- Deviations across the product mix course troubles
- The reference assembly sequence and time distribution also has a major impact (where is the bottleneck?)
- Removing parts from the line might just push the problem to the external systems.
- Further breakdown of processes can be necessary (but where are the limits?)
- Where is the limit of part removal/relocation (to many external systems)?
- How much can be required of the worker regarding variations in the operations and processes (dealing with off sets)?
- Redesign of selected parts can be a possibility (in the long run necessary)
- The weighting of the points in the list will vary according to the type of products, the degree of variation, manufacturing conditions, marked conditions, strategic decisions etc.

5. Exchange student life

The exchange student life in Osaka, and Japan, is full of opportunities. The university has an international student organisation, who organizes various events for the broad range of international students at the university. The organisation can be a good forum to meet other students and participate in arrangements such as sightseeing and sport events.

As a research student at a Japanese university, one is situated at a laboratory together with other Japanese students. The laboratory is managed by a professor from the department. Being at a laboratory gives one the opportunity to meet and interact with local students and also get at first hand impression on how the student life in Japan is. Ten students were studying at the Design Engineering Laboratory, where I was enrolled. The students were very friendly and helpful, especially in situations where the language could cause communication problems, such as alien registration and social security. During the stay, several social activities were arranged by the laboratory, such as dining and parties. Altogether, the environment was very positive and friendly, and gave many good experiences.

I stayed at an international dormitory where most of the inhabitants were from China. The dormitory and the rooms were in quite poor condition but since most of the inhabitants, including the managers, spoke almost no English the circumstances invited to very few social activities at the dormitory. The life outside the university has therefore mostly been with other DeMaMech students and students from the Oussep exchange programme.

Osaka is a modern city with an interesting history and culture, and there are many things to see and do. The entertainment and food scene in Osaka is very good with a big variety of restaurants, bars and sights. Historically, Osaka is also very interesting, with the Osaka castle, as an impressive and historic building in the middle of the city.

The people in Osaka is said to be more outgoing and friendly, which certainly shows in many ways. People are very friendly and the life in Osaka is usually bursting with life every day at the week. The nightlife is also quite entertaining with possibilities of all kinds. Unfortunately the dormitory was located outside the centre of the city (25 minutes by train), and closed the doors between 1 am and 5 am, which implied some limitations when going out at night.

Because of its rather central location on the Honshu Island, Osaka offers great possibilities for travelling. I am very glad that I found the time and possibility to visit the very interesting and beautiful cities like Kyoto, Nara, Kobe (all three are very close to Osaka) and Hiroshima. Tokyo is also a very impressive city and definitely worth a visit. Unfortunately the project took up a lot of time, especially in the end, which meant that there was very little time for further sightseeing. However, my impression of Japan is extremely positive and I hope to come back one day and experience more of the many sides the country has to offer.

6. Summary

Staying in Japan for 5 months has definitely been a positive experience, personally as well as professional. The DeMaMech exchange programme has given me the opportunity to experience a very different country and culture, and meet new people from many parts of the world.
Japan is a very interesting country, and as an engineering student is has been very rewarding to study at a Japanese University for five month. The academic guidance from the professor and daily being among Japanese students have all resulted in an experience, which I believe will be of great use in the future.
I'm very glad to have had this opportunity, and I would recommend other people to do the same.