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

Journey out:
Departure from Copenhagen airport, Sunday the 4th of September 2005 toward Osaka with one transit in Amsterdam airport. We arrived Monday morning the 5th of September in Kansai Airport, Osaka. We were picked up in the airport by assistant Prof. Yutaka Nomaguchi and were driven to our dormitory where we were settled.

Journey home:
Departure form Osaka, Kansai airport Wednesday the 1st of February 2006 toward Copenhagen with one transit in Amsterdam airport. We arrived Wednesday evening in Copenhagen Airport.
Airline both out and home - KLM.

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 leveling 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.

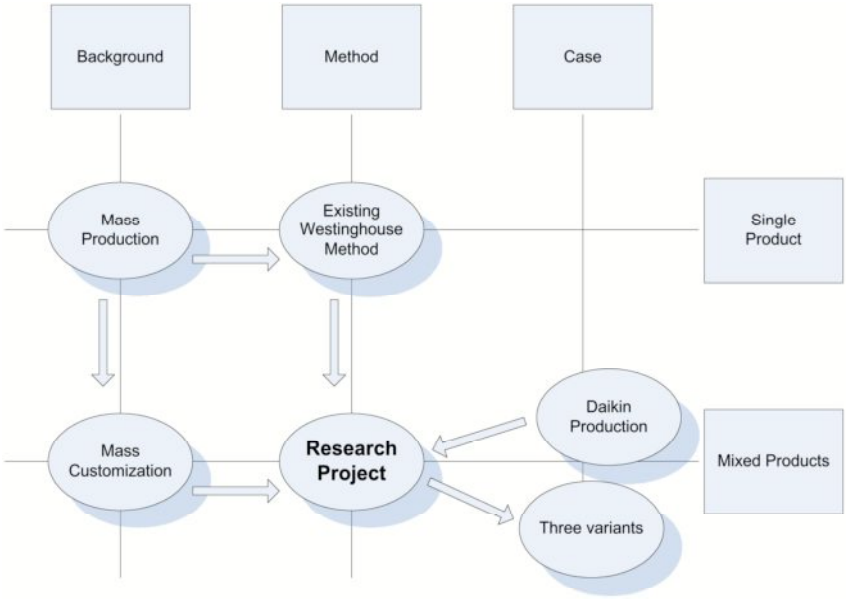
Furthermore, the methodology and the different techniques presented discourages from analyzing every aspect of the assembly line thoroughly. It is intended as a general approach to the difficulties that surround the exercise of designing an assembly line for a product family, but the issues will mainly 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

Most of the time in Japan was spend at the Suita campus, Osaka University. I used to meet around 9.00 in the morning at the laboratory where I had my breakfast. During the day my project partner (Martin) and I worked on the research project. Of course I needed some breaks during the day and evening, the larger ones were connected to lunch and dinner. The lunch and dinner was enjoyed at the school restaurant typically in company other lab students. I found the food there very good and nicely refreshing.

The laboratory which I was connected to was sheared by around 10 Japanese students all at different levels in their education. I had my desk next to two very kind second year master students who I had great fun talking to. There was a good atmosphere at the laboratory and the student and staffs were always helpful. We got support when we were to open a bank account and when we had to enter the public sector (paperwork etc.). Regarding the university I has been very instructive to be a part of a laboratory and see how things are done.

In the evening typically in the hours between 21.00 and 23.00 I went home to the dormitory where I had my room with a bed, closets, table and chair. The other DeMaMech students from Europe lived at the same dormitory which was good for the companionship. The dormitory was for myself not used for much else than to sleep and rest.

In the beginning of the stay I used public transportation when I had to get around. But a few weeks later I rented a bike from the manager of the dormitory. With a bike it was much easier and faster to get around and get acquainted to the Suita city. One of the good things about the city was that there was plenty of access to green areas; the old Expo Park is a good example. I remember one weekend in the first half of the stay, were we had a great afternoon in the park with great weather and plenty of time to relax.

It was meanly in the weekends that we had time to get familiar with the city and downtown Osaka. Riding with the Hankyu railway took about 25 min from Minami-Seri station (close to the dormitory) to Umeda station where there plenty of possibilities for shopping, sightseeing and dining. There was also a good night life in Osaka which we occasionally enjoyed, mostly with the other DeMaMech students.

I also got the chance to see other parts of Japan. I got family visit two times during my stay, which both resulted in some travel activities. Aside from Osaka I got the opportunity to visit Kyoto, Tokyo, Hiroshima, Kobe etc. This was of course all a very exiting experience which resulted in a more comprehensive understanding of Japanese history and culture. I was especially happy to witness the autumn where the leaves are changing colour and of course also to be in Japan during the New Year. This gave me a chance to see what religion means to the Japanese people. It was furthermore interesting to visit some of the many shrines and temples (mainly in Kyoto).

Another important element is the language. If I was going to stay in Japan for a longer time I would do some more language study. It’s a rather big handicap not to be able to speak the language.

6. Summary

In overall the exchange program has been a very good experience for me. I believe, I have learned a great deal seen both from an educational and professional point of view as well as for a personal a more human viewpoint. It has been rewarding to visit a remote location like Japan for a longer period (5 month). This has given me the opportunity to learn much about the Japanese people, culture, traditions and of course also the education system. It has furthermore been very interesting to visit a manufacturing company and thereby on close range get a glance at the Japanese production philosophies in action.

I very much hope that this collaboration program between Europe and Japan will continue, so that other students can get some of the same experiences in the future. Thank you for giving me the opportunity.