DEPARTEMENT BEDRYFS- EN SISTEEMINGENIEURSWESE
DEPARTMENT OF INDUSTRIAL AND SYSTEMS ENGINEERING

FRONT PAGE FOR FINAL PROJECT DOCUMENT (BPJ 421) - 2011

Information with regards to the mini-dissertation	
fTitle	Consolidation of Production at Saab Electronic Defence Systems ZA
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Date	10/11/2011
Keywords	Lean manufacturing, Value stream mapping, Facility planning, Production consolidation
Abstract	This project looks at the current production facilities at SAAB EDS ZA using facility layout techniques and a lean manufacturing technique called value stream mapping. After analysis is done alternative layouts are designed for consolidating the production plant to a new building so that productivity is increased and materials handling decreased.
Category	Facilities Planning, Lean Manufacturing

Declaration

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3. Where other people's work has been used (either from a printed source, internet or any other source) this has been carefully acknowledged and referenced in accordance with departmental requirements
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EXECUTIVE SUMMARY

Saab Technologies is a world-class company that 'serves global market of governments, authorities and corporations with products, services and solutions ranging from military defence to civil security' (www.saabgroup.com). Saab Electronic Defence Systems (Saab EDS ZA) is a division of Saab Technologies that specialise in supplying customers with solutions for surveillance, threat detection and location, platform and force protection, as well as avionics.

Currently Saab EDS ZA's production is all done on one premise but in different areas of the premise. Hence, the productivity is not as efficient as it should be and a lot of strain is placed on the materials handling of the company. This project aims in consolidating the production departments and all their respective workstations into one production area. This will cause the productivity to increase and the workflow to be more continuous.

The current operations will be analysed using Industrial Engineering techniques, tools and methods. Value Stream Mapping will be utilised to look at the current flow of a product being produced at this company. This is a lean manufacturing tool that helps identifying and removing the 8 deadly wastes.

This project will include a facility layout design of the new production area using tools and techniques such as flow process charts, flow diagrams, relationship diagrams and spaghetti diagrams.

Both Value Stream Mapping and designing a new facility layout plan should help SAAB EDS ZA to get rid of a lot of wasteful activities. In the short run it might cost the company to implement new techniques, but if applied successfully and maintained well, the company is surely going to increase productivity and the cost of production will be reduced, thereby saving the company a lot of money.

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1 INTRODUCTION

1.1 COMPANY BACKGROUND

SAAB Electronic Defence Systems South Africa (from hereon referred to as SAAB) was originally established in the late 60's when the Grinaker family bought Racol (a military radio factory). It was first known as Grinaker Electronics and was part of the Anglovaal group until 1995 when Anglovaal unbundled and Grinaker Electronics was then known as Grintek Avitronics. The Avitronics name was established in 1988 when Electronic Warfare products became prominent in the company. In 1992 Grinaker Electronics also bought a company EM-lab, who specialised in Microwave components and antennas.

Their current facilities were built especially for the company and the then Grinaker Electronics Company moved into the facilities in 1993. When they moved, there was no real space for production and so parts were mainly produced in the development labs on the grounds. As time went by and their demand grew, they realised they required a formal production area which applies to all standards needed to make quality products. Yet, the company grew and the demand got even bigger that there was not enough space in the original production facilities. Hence more and more areas turned into production areas, all located in different parts of the premises, which inhibit a smooth production flow. In 1999 CelsiusTech, a Swedish military company bought 49% of Grintek Avitronics. Then in 2000 SAAB bought the whole of CelsiusTech and also kept on buying more and more military units in South Africa. In 2006 Grintek Avitronics became SAAB Avitronics and was now part of the SAAB Technologies group. Located on the same premises as SAAB EDS ZA there is another company belonging to the SAAB Technologies group under the division of SAAB Avionics called Radio and Monitoring (from hereon called R&M) company, previously known as AMS. R&M also already has its own production area and testing labs. Currently SAAB EDS has 2450 employees in 3 countries (Sweden, South Africa and Norway) and of those 415 are employed at the Centurion SAAB EDS ZA plant.

Due to the fact that the facilities are first of all not designed to host a production area and due to the fact that the company grew in the last 20 years, they have now decided that the production area of SAAB EDS ZA should be consolidated. All production areas and departments related to production and that are part of the production supply chain should be under one roof. These departments include stores, kitting, procurement, production, goods receiving and inspection, despatch and support and services.

1.2 PROBLEM STATEMENT

Currently a product being produced at SAAB EDS ZA is transported very far within the different areas of production and testing before it is in its final form. The company produce low volume, high value and high variety products. If any product or part of a product should be damaged while being handled, it can have a high financial impact on the company.

2 PROJECT AIM

The aim of this project will be to better the flow of production and also to decrease the amount of materials handling. The first step in achieving this goal is consolidating the production department - that is to bring all the areas of production into one big production area.

The facility layout of this new production area will be designed in this project. Before doing the facilities layout design, the production flow and material handling of a product at SAAB EDS ZA will be analysed. Although this analysis is only of one product, it should result in a general idea of how products are produced at the company. This understanding will aid the student in designing the new facilities. Values Stream Mapping will be also used in analysing the production and materials handling flow. This lean manufacturing technique will help to identify value-adding and essential non-value adding steps which both are essential in the production line. It will also aid to eliminate non-value adding steps, which are wastes and make the production line less efficient.

In effect consolidating all the production departments and designing a facilities layout of the area using Industrial Engineering techniques will reduce Saab's production cost and increase the safety of a product that is currently worked on.

3 PROJECT SCOPE

The parts that will be focused on in this project are:

1. Analyse the current production flow of one product using Value Stream Mapping
2. Analyse the current material handling of this product using Value Stream Mapping
3. Make alternative designs of new production area according to Saab's requirements taking into consideration optimum production flow and material handling
4. Analyse and decide which alternative will be the best to choose

3.1 DELIVERABLES

1. Analysis of current production flow:
    a. The drawings of the current production layouts have to be obtained
    b. Routing sheets of the selected product have to be obtained
    c. The production flow can be analysed from applying the routing sheet (how the product is built) to the current production set up. A value stream map will be made of this production flow.
    d. Speak to the line managers of production to see if the production flows like structured on the routing sheet
    e. Make a flow process chart of current production of the product
    f. Analyse if there is a recognisable production flow
2. Analyse current material handling
    a. From point 1 use the calculated production flow to measure how far a product travels before it is in it's final form
    b. Make a transportation map (string diagram) of the current materials handling flow
3. Make alternative designs of new production area according to Saab's requirements taking into consideration optimum production flow and material handling: According to Tompkins et al, Facilities Planning, 4th edition here are the steps to design a new facility:
    a. Use Saab's requirements to define the objective of the facility
    b. Specify the primary and support activities that must be performed to accomplish the objective
    c. Determine the interrelationship among all activities: Make use of a activity relationship chart and a relationship diagram
    d. Determine the space requirements for all activities: Also look at personnel requirements
    e. Generate alternative facilities plans
4. Analyse and decide which alternative to choose: According to Tompkins et al:
    a. Evaluate alternative facilities plan
    b. Select a facilities plan

4 PROJECT PLAN

4.1 ACTIVITIES AND TASKS

The activities and tasks will be divided into phases which are as follows:

- **Phase 1 - Project Proposal:** This phase is where the project aim, scope and deliverables are defined. The student will choose exactly how in depth to go into certain areas and what will be sufficient work that can be concluded in the time limit of the project
- **Phase 2 - Literature Study:** A preliminary literature study is part of the project proposal, yet the complete literature study should be completed before the actual project begins. According to Hart (1998), a literature study has the following purposes: Distinguish what has been done from what needs to be done; Discovering important variables to the topic; Synthesising and gaining a new perspective; Identifying relationships between ideas and practice; Establishing the context of the problem; Rationalising the significance of the problem; Enhancing and acquiring the subject vocabulary; Understanding the structure of a subject; Relating ideas and theory to applications; Identifying methodologies and techniques that have been used; Placing the research in a historical context to show familiarity with state-of-the-art developments.
- **Phase 3 - Data collection of current system and current products:** This is probably the most crucial phase of the project. The amount of data that can be collected and the way it will be processed will aid to produce the last 3 phases.
- **Phase 4 - Analysis of current production system:** After the data is collected the analysis of the current production and materials handling flow can be analysed. In this step Value Stream Mapping will be applied. Therefore the non-value adding activities will be found in this step which the new facilities will be designed without.
- **Phase 5 - Alternative designs of new facility:** One cannot just design one plan and be sure that this is the most effective and efficient plan of running a new production facility. Alternative facility layout designs will be produced in this phase. These will be preceded by various Industrial Engineering techniques which aid in deciding how to lay out the facilities.
- **Phase 6 - Evaluate and Choose new design:** This will be the final phase of the student's project but not of the total project. After the new design is chosen and applied, the idea should be reviewed every few months to see if what was designed in theory also works in practice.

4.2 RESOURCES

- Databases at SAAB EDS ZA (EB and Q-muzik)
- Staff at SAAB EDS ZA
- Niebel's Methods, Standards and Work Design, 12th ed
- Tompkin et al Facilities Planning, 4th ed
- Maynard's Industrial Engineering Handbook, 5th ed
- Transport to and from SAAB EDS ZA
- Internet and more textbooks
- Journal Articles

5 LITERATURE REVIEW

5.1 INTRODUCTION

The literature review will aid in getting to understand the lean manufacturing principles. Value Stream Mapping is a lean manufacturing technique and this will be the main focus under that heading. The review will also give insight to the field of facilities planning. Under this heading, the student will focus on production flow, material handling and techniques one can use to do effective facilities planning. Industrial Engineering methods, tools and techniques that can be used to solve Saab's problem will be identified and explained in this review. (Please note that this is only the preliminary literature review.)

5.2 LEAN MANUFACTURING

Lean manufacturing is a business philosophy that was introduced by Womack, et al., (1991) in the book *The Machine that Changed the World.* It has the motto 'doing more, with less'. Value Stream Mapping is a technique that one uses to apply Lean Manufacturing: By dividing all the operations of a production line into value-adding, essential non-value adding and non-essential non-value adding categories, one identifies wastes that one can eliminate in order to reduce production cost and decrease production time.

There are eight types of deadly wastes (in Japanese this is called *muda*) that have to be eliminated. They are:

1. overproduction;
2. waiting;
3. transport;
4. over-processing;

5. inventory;
6. motion;
7. defects; and
8. Under-utilisation of intelligence (only introduced in 2003 by *Womack).*

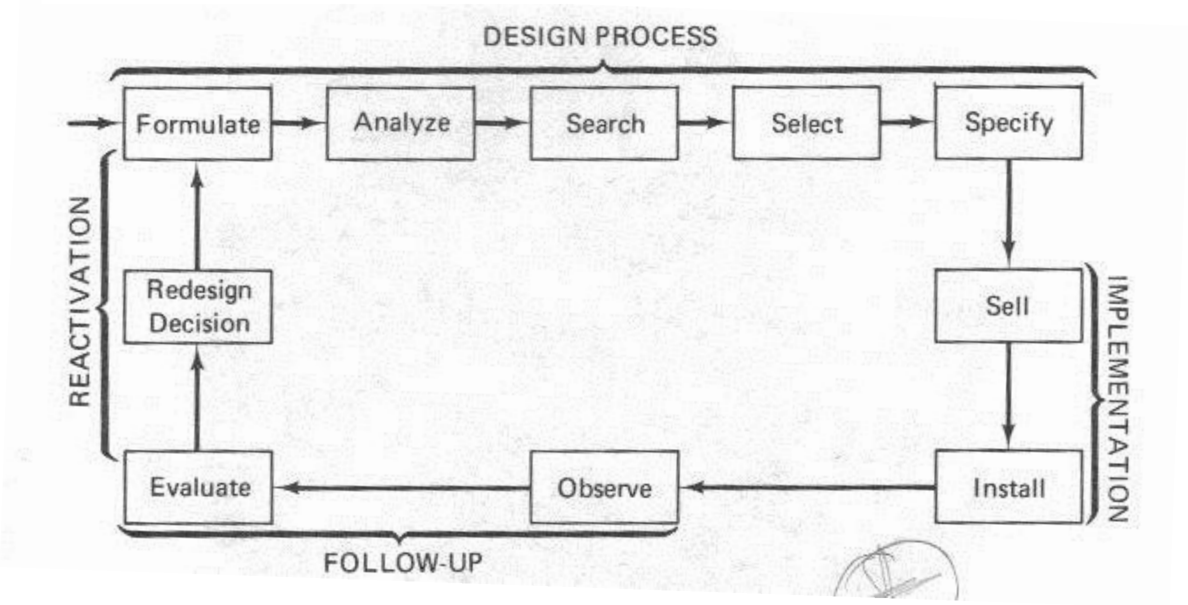
Value Stream Mapping can be used to map material flows and information flows. It is simply a way of transferring the current state value stream to a map. One then designs a future state map with all of the 8 deadly wastes removed which represents an ideal state of the production system. According to Rother and Shook (2003) the following 8 steps can be used to identify the 8 wastes in order to identify problems and create a future ideal value stream:

1. Calculate takt time and pitch: $T = T_a/T_d$ where T=takt time, T_a=Net time available to work and T_d=Time/customer demand. Pitch = Takt time * Pallet size
2. Determine if finished goods should go to a retailer or ship directly to customer
3. Identify where to use continuous flow processing
4. Determine where to use a pull mechanism
5. Determine the location of the pacemaker
6. Determine how to level the production mix at the pacemaker
7. Determine the increment of movement at the pacemaker
8. Identify improvements needed to achieve the future state

Value Stream Mapping could be a very good technique to apply at SAAB EDS ZA. The company already applied another lean manufacturing principle, the 5S principle at their production plant in the beginning of 2011.

5.3 FACILITIES PLANNING

Figure 1: Design Cycle

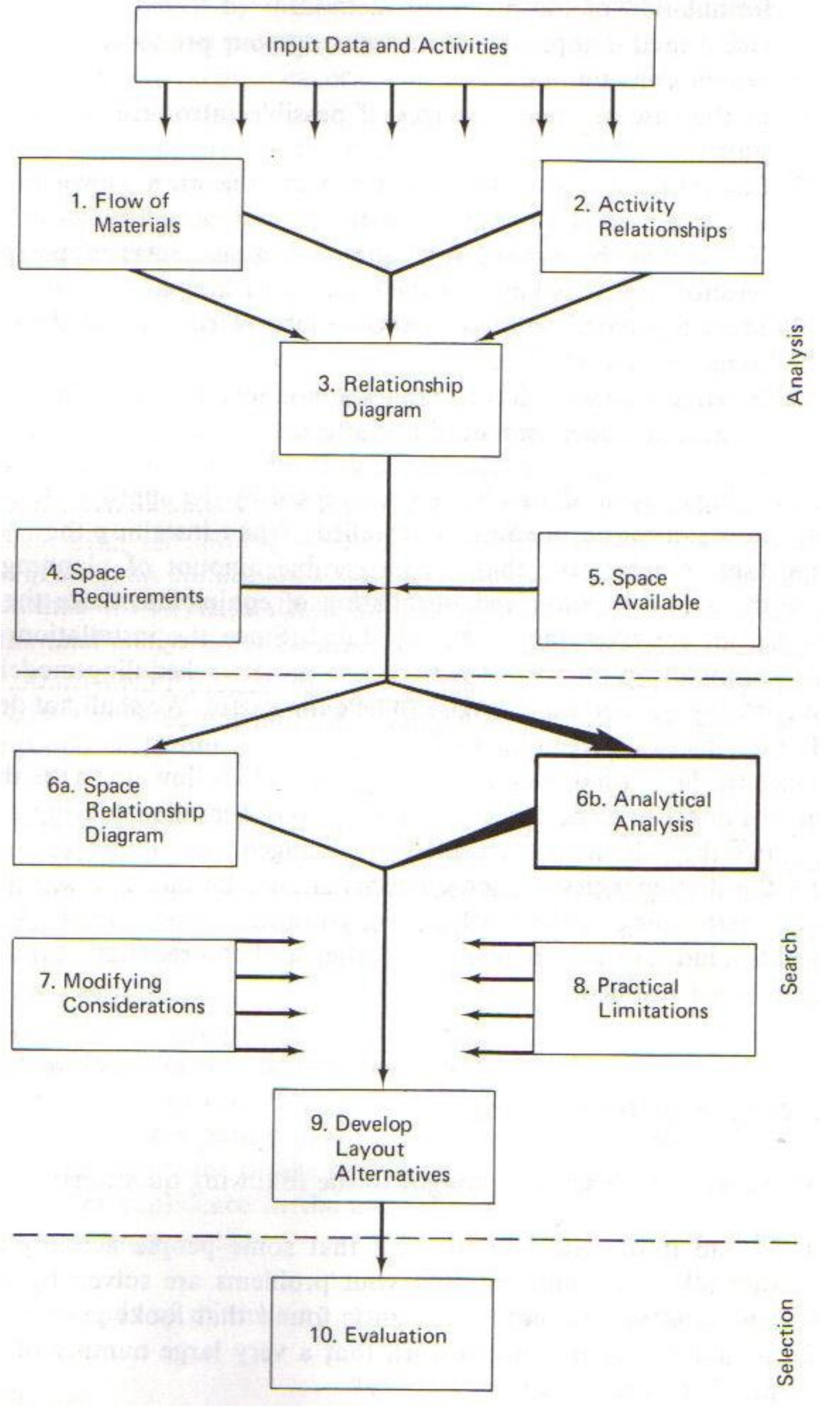


Facility planning is a relatively expensive, but very necessary tool and if applied continuously and done properly can save companies a lot of money. This is because facility planning, if done properly and strategically, will aid in getting rid of wastes, such as excessive materials handling, help manage a production plant and if designed properly will make a plant more sustainable.

Facility planning is a continuous plan (as shown on the figure on the previous page taken from (Francis and White 1974)) and will only effectively help a company save money if it is well maintained.

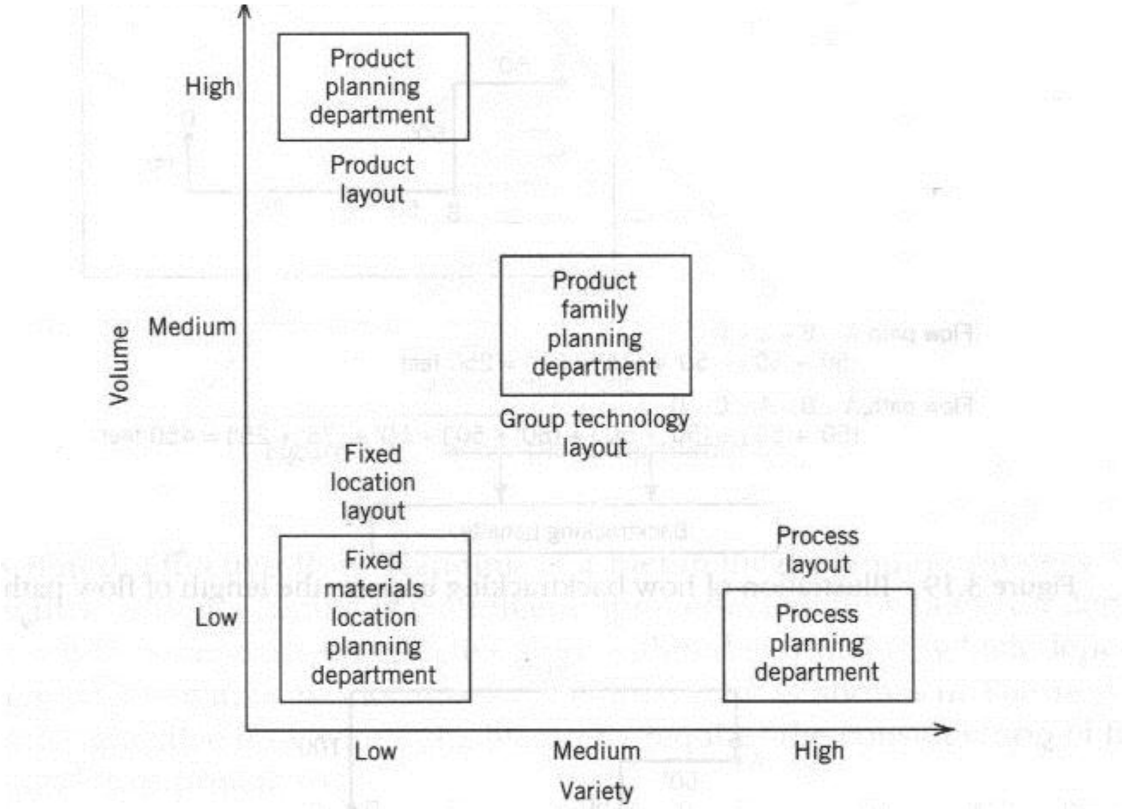
The figure on the next page shows a modified Systematic Layout Procedure (Francis and White 1974). This procedure shows the techniques one uses to design a new facility. First one has to gather the data that will influence the facility design. One typically finds information regarding the product structure and how it is assembled on routing sheets the company uses, production drawings, assembly charts if any exist, prototypes of the product, bill of materials and parts list.

Figure 2 Modified Systematic Layout Procedure



Then it is important to look at the flow of materials. First define the type of flow that is currently used and then decide which type of layout to design. As seen in Figure 3 (taken from (Tompkins et al. 2010)), a company (such as SAAB) that produces low volume, high variety products should have a process layout. This means that typically all operations of one kind (eg. all assembly operations) and all machines of one kind (eg. all the drills) will be together in their respective areas. A flow analysis can be done by using a flow process chart, multi-product process charts, flow diagram and from-to-chart.

Figure 3: Volume-Variety Layout



The next step is to make an activity-relationship chart and an activity relationship diagram. These will help deciding which departments should be closest to each other in the final design.

Following this step is determining the space requirements and availability. It is important to know how much and if enough space is available to make a new design as space can become a constraint. Important things to consider during this phase are production rate, equipment requirements and employee requirements. The manager of the production department at SAAB EDS ZA asked the student to especially look into the employee requirements, since most of the production workers at SAAB are manual labourers and do not have their own offices. This makes it important for the workers to have proper restrooms and tea rooms, where they can relax in their breaks. Another important factor when doing space requirements is the fact that all things produced have to be protected from electrostatic discharge (ESD).

After determining the space requirements, analysing the materials flow and relationships of the different departments, alternative facility layouts can be designed. One cannot expect that one design will be sufficient and the most effective idea. A space-relationship diagram is designed by taking the relationship diagram and space requirements into consideration. After analysing the practical limitations and the space relationship diagrams a number of block plans are made.

From these block plans one then develops alternative layout plans. One has to consider the possibility of future expansion of the facility and then make the design as flexible as possible. Once a number of layout plans have been designed, the best alternative has to be chosen. A number of factors, such as cost of installing the design, future cost, incremental cost but also production time, effective material handling layout, safety, working conditions, appearance and ease of supervision and control have to be considered. One technique one can use to analyse the alternative layouts is a factor analysis. In the book *Facility Layout and Location* this is described as follows: 'Each factor is assigned a numeric weight and then each alternative is ranked against each factor. The weighted rankings are totaled for each alternative, and the alternative having the best score is chosen.' (Francis and White 1974).

5.4 PARKINSON'S LAW

Parkinson's law states that things will expand to fill all parts of space that were left open during the design of the new facility which were supposed to create sufficient space (Tompkins et al. 2010) This complicates matter in the long term in facility design, because if a space is for example left open for future development of the production plant, and that development only happens later than the new facilities plan is implemented, there will most probably be no space left after a few hours, days or months to do that new development.

5.5 ADDITIONAL SELECTION OF APROPRIATE METHODS, TOOLS AND TECHNIQUES

5.5.1 Flow Process Chart

According to the book *Niebel's Methods, Standards and Work Design*, a flow process chart shows all the steps that a product goes through while being built. It has more detail than a company routing sheet. Even if the product is put on a storage rack to wait for further processing, this is indicated on the chart. The the name mentions the flow process – this indicates that one can analyse the materials handling flow when using this Industrial Engineering Tool. (Freivalds and Niebel 2009)

5.5.2 Flow Diagram

'Although the flow process chart gives most of the pertinent information related to a manufacturing process, it does not show a pictorial plan of the flow of work.' (Freivalds and Niebel 2009.) One uses a layout of the facilities and a flow process chart to draw exactly on the layout where a product travels when in production.

Together with the Flow Process Chart, Flow Diagrams could aid with the Value Stream Mapping technique and help getting rid of some of the 8 deadly wastes.

5.5.3 Spaghetti Diagram

A Spaghetti Diagram is another lean manufacturing tool that indicates the movement path of a person manufacturing a product in production. It is called a *Spaghetti* Diagram because of all the paths of the flow crossing and becoming intertwined. It is a good observation tool and will also help getting rid of the 8 deadly wastes.

5.5.4 From-to Charts

From-to-charts are used successfully when a process layout is present in the production plant. From-to charts are descriptive models that do not directly give a solution to a layout problem. It is more a handy method to reduce a lot of data into an easier workable form. They can show either the distances travelled between departments or the amount of trips between departments to build a product. They aid in analysing material movement and show the dependancy of the departments upon another. Once a from-to chart is developed, relationships among departments and work-centres become clearer and activity relationship charts can then be created. (Francis and White 1974)

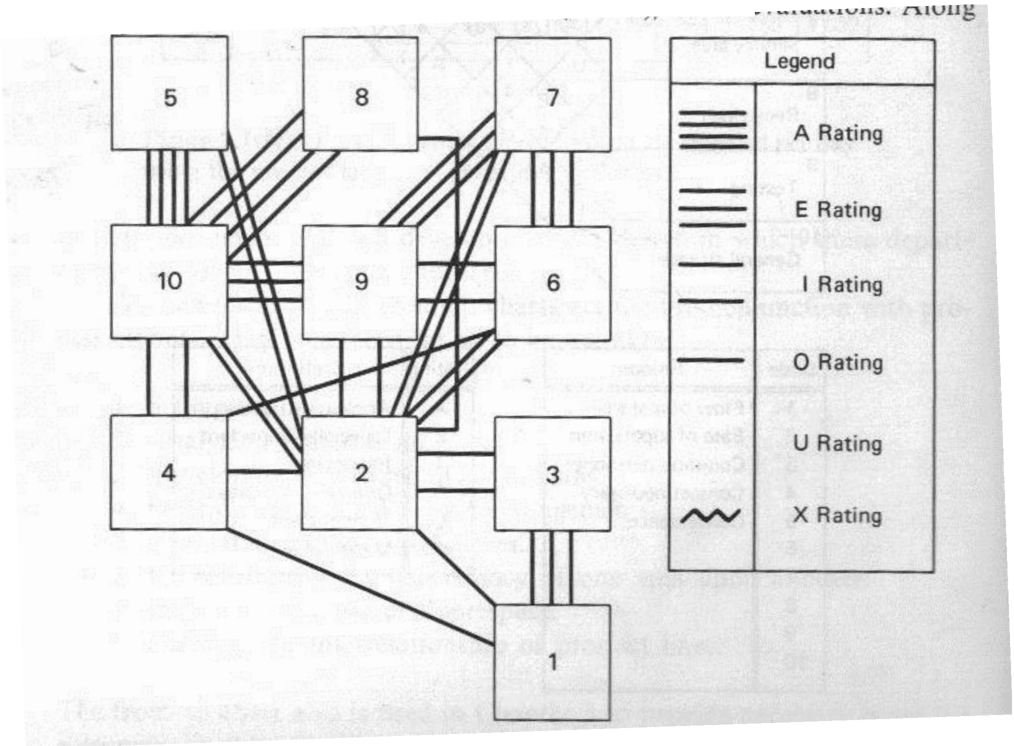
5.5.5 Activity Relationship Charts

Relationship Charts show the affiliation of the work stations by giving the relationship a closeness rating (A – absolutely necessary, E – Especially important, I – Important, O – Ordinary closeness OK, U – Unimportant, X – Undesirable). One also gives a reason as to why the closeness rating was chosen. This Chart also aids in deciding which departments or work stations should be closest to each other in the new facility layout design.

5.5.6 Activity Relationship Diagrams

These diagrams often follow after one has drawn up activity relationship charts. They show each activity as an equal-sized square and then the relationship can be drawn up between the activities by using the same closeness rating used in activity relationship charts. The closeness rating in an activity relationship diagram is represented by lines and not by letters. Figure 4 (taken from (Francis and White 1974)) shows an example of an activity relationship diagram.

Figure 4: Activity Relationship Diagram



6 DATA GATHERING AND ANALYSIS

6.1 CHOOSING A PRODUCT

SAAB EDS ZA recently introduced a new system to the company – an electronic routing and tracking system (from now on called ERTS). ERTS aims to reduce the amount of physical paper work at the company by using computers to show and sign routing sheets. This program helps line managers to see which products that are currently in production are of priority and to have track of where a product is in the production plant. For this program to run successfully, all part operations from the routing sheets have to be updated on Q-muzik, which is a planning tool that SAAB EDS ZA uses.

The student chose to analyse a product (from now on called Product A) that has been completely updated on Q-muzik. A flow diagram of the highest assembly of product A can be found in Appendix B.

6.2 VALUE STREAM MAPPING

6.2.1 Finding product families

Each of the assembly steps in the flow diagram of product A still have their own way of being built. Each of the steps has their own routing sheet. The first step before starting to design a current state Value Stream Map is to find product families. Even though the student is only looking at one product, there are still different product families in this product. The student chose only to look for assemblies that have more than 5 steps. The product family selection matrix can be found in Appendix C.

From this matrix it can be seen that all the A1-A7 PCB assemblies are part of one family, the A7A1 and A7A2 PCB assemblies are another product family and the detector and cover rear assemblies are each their own family.

6.2.2 Creating a Current-State Map

Value Stream Mapping is a paper and pencil tool. Hence the student first creates a map from doing a department walk-through, checking the steps with the routing sheets and then writing every little step of the assembly on post-it notes.

Figure 5: Manual Current-State Value Stream Map

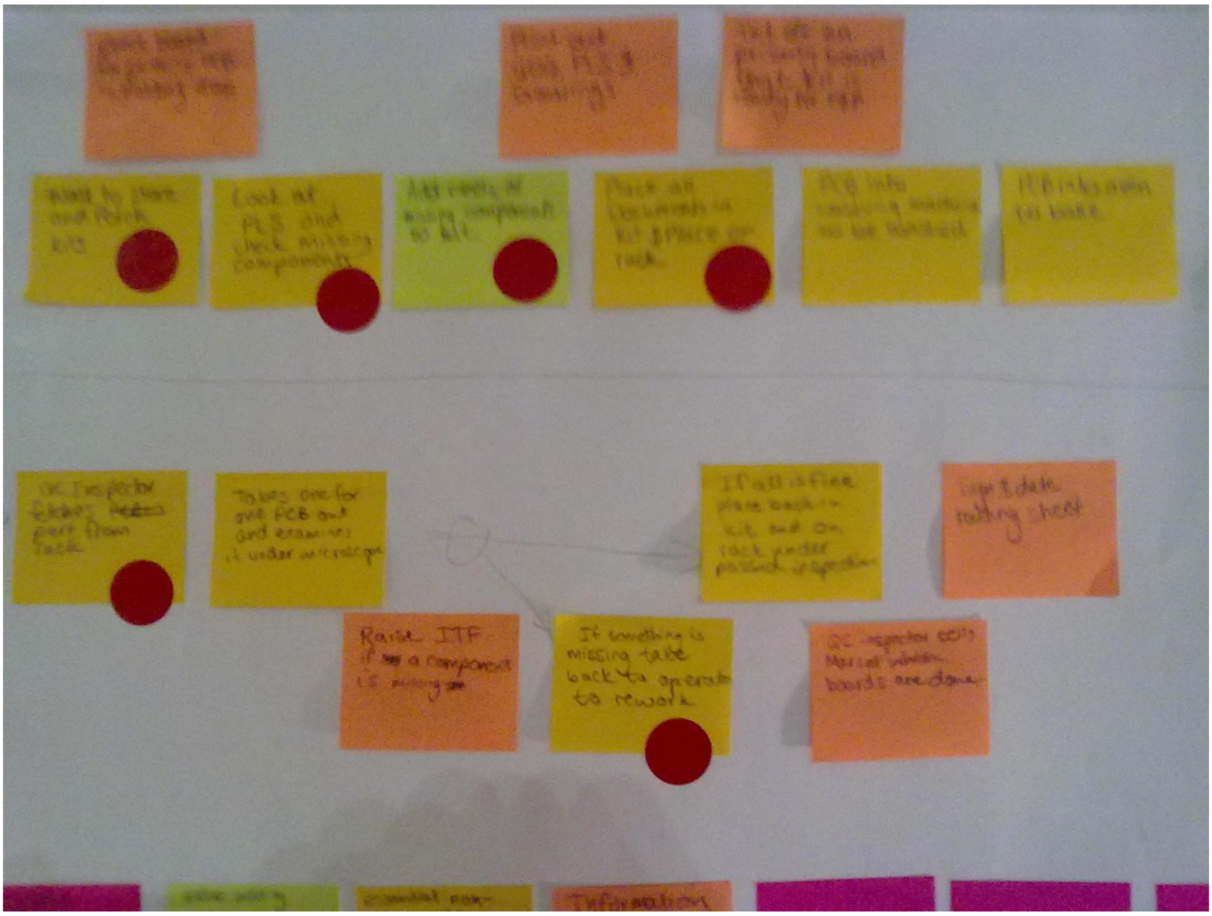
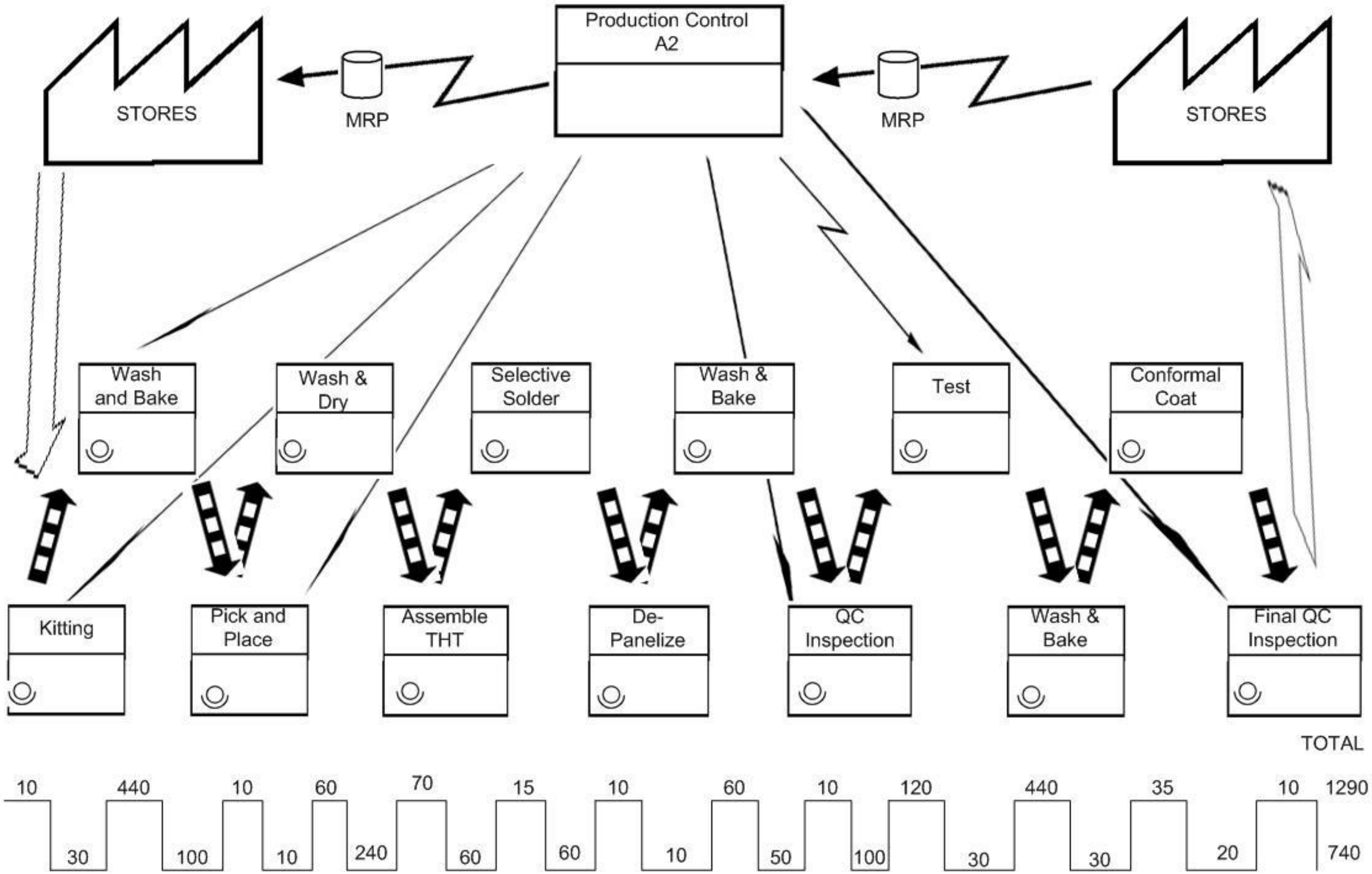


Figure 5 is a part of the manual current-state map that was drawn up. The yellow post-its represent essential non-value adding activities, the green post-its value-adding activities, the orange post-its are the information flows and the red stickers show which activities might be a waste.

From this manual current-state value stream map, another electronic version of the current-state map is then created using the value-stream mapping icons. A glossary of those icons (taken from Rother and Shook (2003)) can be found in Appendix D.

Figure 6 displays the electronic version of a value stream map. The value adding time (in minutes) is represented by the top line and the non-value adding time on the bottom line. Both the total times are at the end of the line.

Figure 6: Current-State Value Stream Map of A2 PCB Assembly



6.2.3 Wastes (muda) identified

Wastes that have been identified are:

- Transport: The kit gets transported very often between assemblies, wash and bakes, QC inspections and testing. Also the testing labs are located at quite a distance from the assembly lab. The storage area is also very far from the assembly lab – it is located in a different building on the premises. This all creates transportation waste.
- Waiting: The kit waits a lot in between assembly steps on racks. This constitutes for wasted time during production
- Defects: Sometimes QC inspection has to send back PCBs because the solder comes off or cables are scratched. This also adds extra time to production because the PCB's have to be re-worked.

6.3 FACILITIES PLANNING

6.3.1 Flow Process Chart

The first step in facilities planning is information gathering and then the analysis of the current facility layout. One of the techniques the student is using is a flow process chart. The flow process chart of one of the PCB assemblies of product A is shown in figure 7.

One can clearly deduce from this chart that the amounts of transportation and delays should be reduced drastically to improve productivity.

6.3.2 From-to Charts

Another way of analysing the flow of a production line is by using from-to charts. Three different products were looked at (called products A, B and C respectively from here on). The flow-process charts show the total number of material-handling trips between the respective work centres of the products to produce one such product.

The reason that some of the work centres differ between the different products is because the different products are tested at different work centres. The various from-to charts can be found in figures 8-10 on pages 16-17.

From these charts it can be deduced that most products move mostly between the assembly work centres and the products' respective testing areas. This will be taken into account when designing the new facilities layout.

Figure 7: Flow Process Chart

		Summary			
Location: Production at SAAB EDS		Event	Present	Proposed	Savings
Activity: A2 PCB Assembly		- Operation	11	11	0
Date: 31/08/2011		- Transport	10	5	5
Operator: Various	Analyst: NL Johannes	- Delay	10	4	6
Circle appropriate Method and Type		- Inspection	3	3	0
Method Present Proposed		- Storage	1	1	0
Type Worker Material Machine					

Event Description	Symbol	Time (min)	Dist (m)	Notes
Stores kitting		10	100	
Kit inspection		10	0	
Wash & Bake		440	5	
Transport to P & P and Wait		100	6	All the waiting times are
Pick & Place		10	5	variable
Wash & Dry		60	10	
Transport to Assembly & Wait		240	18	
THT & Prepare for selective soldering		70	5	
Transport To Selec Sold & Wait		60	15	
Selective Soldering		15	0	
Transport to Assembly & Wait		60	18	
De-panelize & fit serial nr		10	5	
Wash & Dry		60	18	
Transport To QC inspection & Wait		50	31	
QC Inspection		10	3	
Transport to Testing & Wait		100	11	
Test		120	4	
Transport to Wash & Bake		3	45	
Wash & Bake		440	0	
Transport to QC & Wait		30	31	
QC Inspection		10	3	
Transport to Conf Coat & Wait		5	26	
Conformal Coat		35	0	
Transport To QC inspection & Wait		20	26	
Final QC Inspection		10	3	
Book into Stores		10	0	
TOTAL:		1988	388	

Figure 8: From-to Chart Product A

	WCP 1	WCP 2	WCP 3	WCP 5	WCP 15	WCP 16	WCP 20	WCM 1	WCM 2	WCM 6	WCM 9
WCP 1		5	2		1			1			
WCP 2	3		9	1	8						
WCP 3	3	4			11						
WCP 5					1	17	3			1	
WCP 15		1	7				5				
WCP 16				4			3				
WCP 20		2	1	2	2	6					
WCM 1							1			3	1
WCM 2	1										
WCM 6				1				3			
WCM 9							1				

Figure 9: From-to Chart Product B

	WCP 1	WCP 2	WCP 3	WCP 5	WCP 15	WCP 16	WCP 24	WCP 10	WCP 26	WCP 11	WCM 1	WCM 2	WCM 3	WCM 4	WCM 6	WCM 9
WCP 1		3	1													
WCP 2			15		3											
WCP 3	1	2		1	19		1	1								
WCP 5			1			11	2									
WCP 15			7				5									
WCP 16							1	1	1							
WCP 24				1	5	3										
WCP 10						3			6							
WCP 26			1		1	1		5								
WCP 11					3											
WCM 1												2				
WCM 2											2					2
WCM 3																8
WCM 4															1	
WCM 6												1	8			
WCM 9														1		

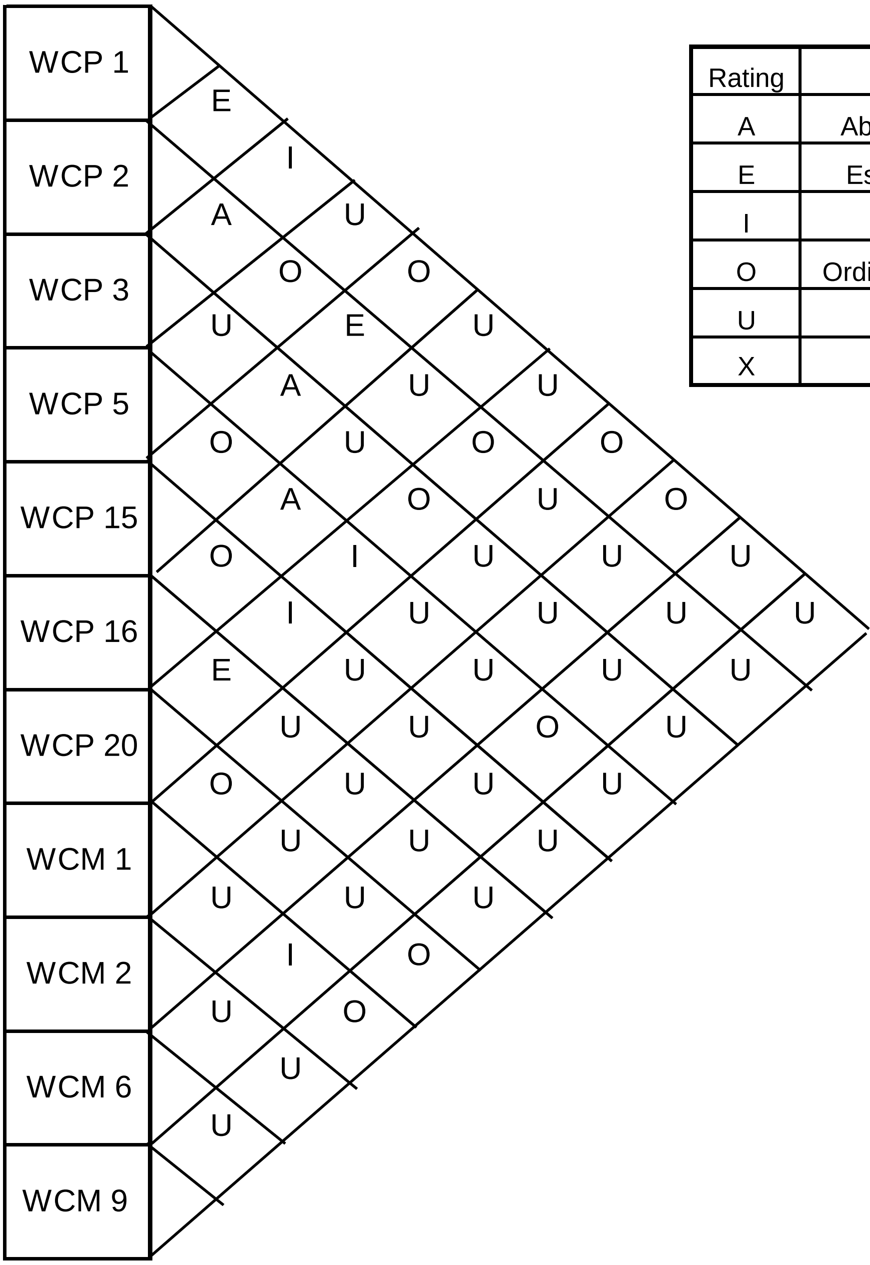
Figure 10: From-to Chart Product C

	WCP 1	WCP 2	WCP 3	WCP 5	WCP 15	WCP 16	WCP 30	WCP 31	WCM 1	WCM 3	WCM 6	WCM 9
WCP 1		2	3									
WCP 2			13		4		2					
WCP 3	6	4		2	8							
WCP 5						2	1	2				
WCP 15		4	4					2				
WCP 16							3	3				
WCP 30					1	9		4				
WCP 31				2	4	2	2					
WCM 1											2	
WCM 3											1	1
WCM 6												2
WCM 9												

6.3.3 Activity Relationship Charts

The activity relationship charts of products A,B and C are developed from the 'from-to charts' and can be found in figures 11, 12 and 13 respectively. The relationships between the material handling trips between the different work centres are displayed in these charts. The rating of the relationship is given in figure 11.

Figure 11: Activity Relationship Chart Product A



Rating	Definition
A	Absolutely necessary
E	Especially Important
I	Important
O	Ordinary closesness OK
U	Unimportant
X	Undesirable

Figure 12: Activity Relationship Chart Product B

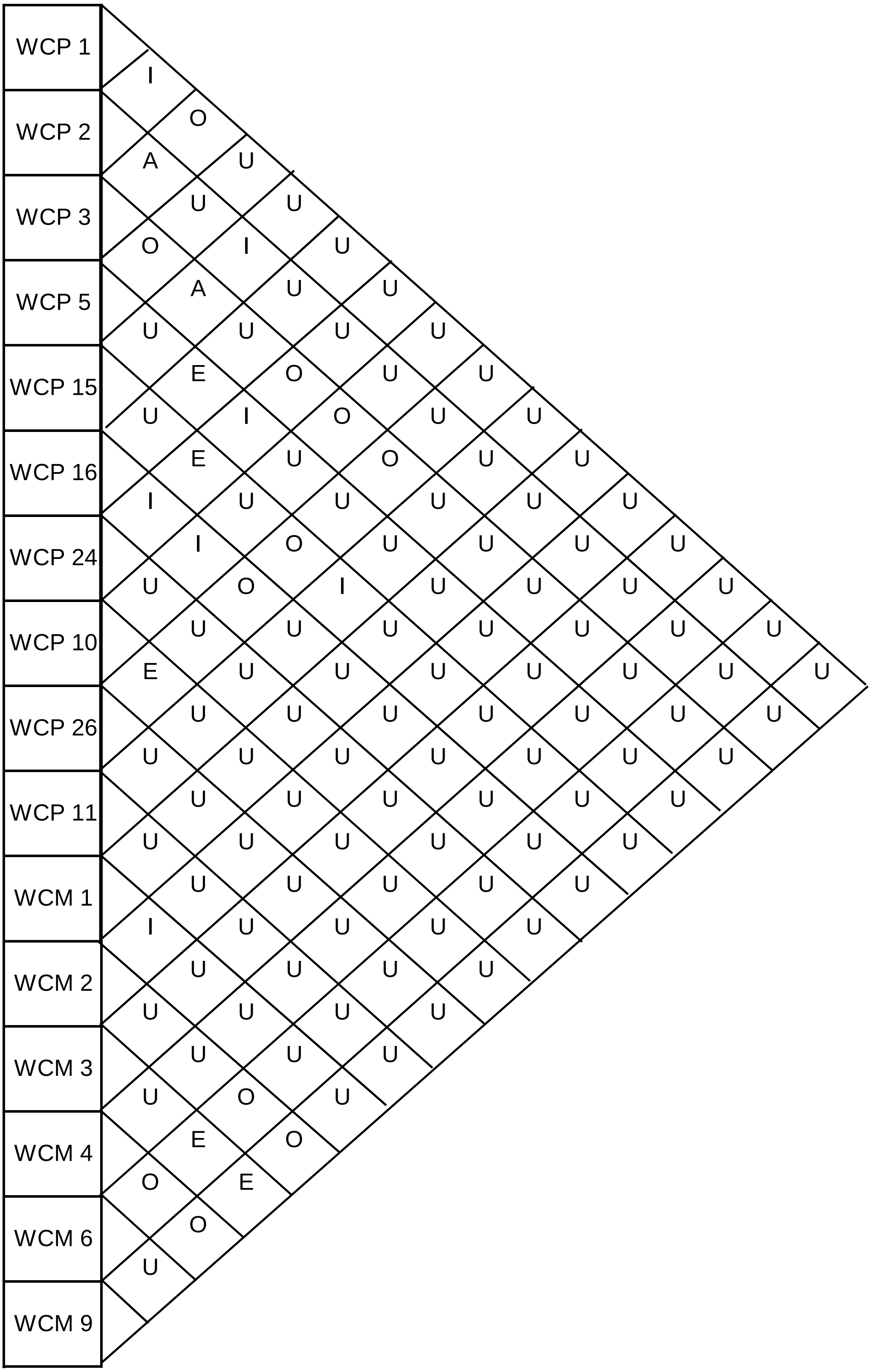
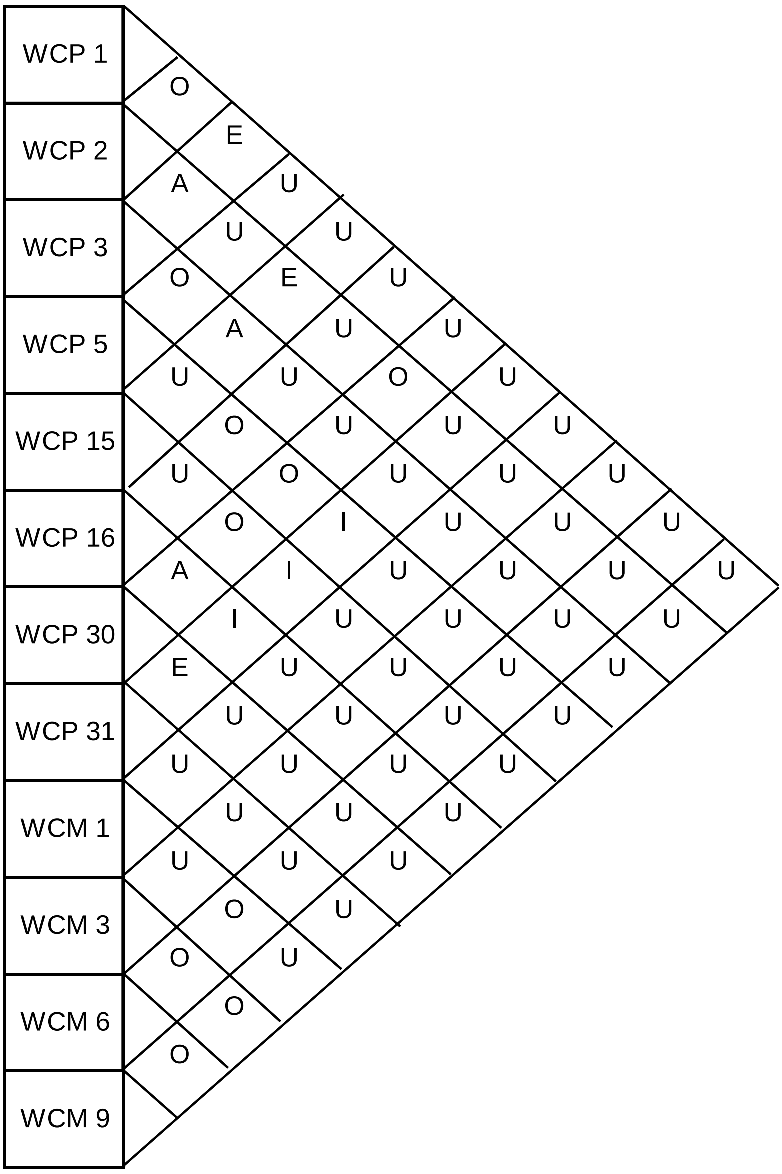


Figure 13: Activity Relationship Chart Product C

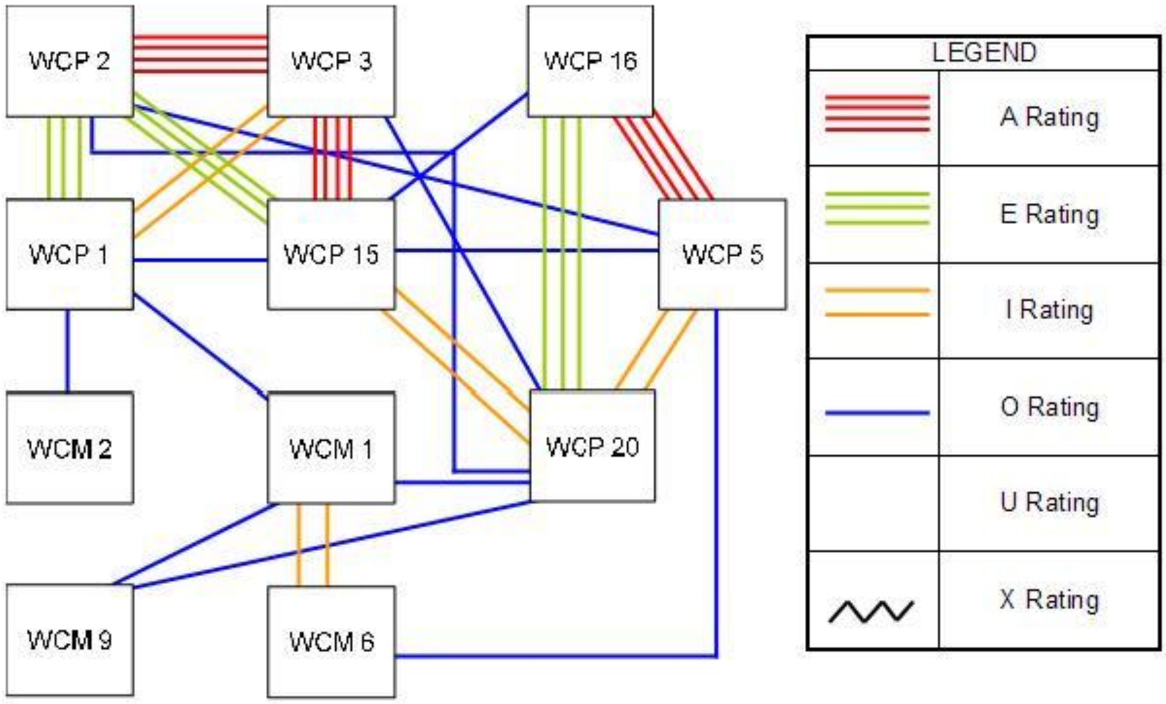


From this one can see that the only product where a relationship exists between the production work centres (WCP) and the microwave work centres (WCM) is product A. This fact will be taken into account when developing the activity relationship diagrams.

6.3.4 Activity Relationship Diagrams

The activity relationship diagrams display exactly what the activity relationship charts display, just in a more visual manner. When developing these diagrams one can already start thinking about where to place departments in the block layout. The work centres with a relationship A-rating should always be closest to another, while the work centres with a U-rating can be the furthest away from each other and the ones with an X-rating may not be next to one another. In products A, B and C there were no work centre relationships with X-Rating. The respective activity relationship diagrams are displayed in figures 14-16.

Figure 14: Activity Relationship Diagram Product A



As mentioned in point 6.3.2 the activity relationship diagrams of products B and C (figures 15 and 16) have been designed without the relationships between the production work centres (WCP) and the microwave work centres (WCM).

Figure 15: Activity Relationship Diagram Product B

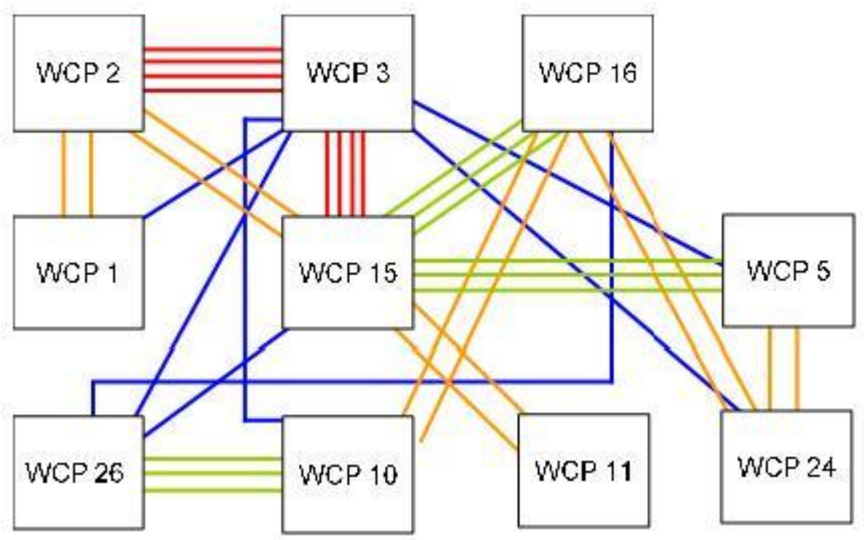
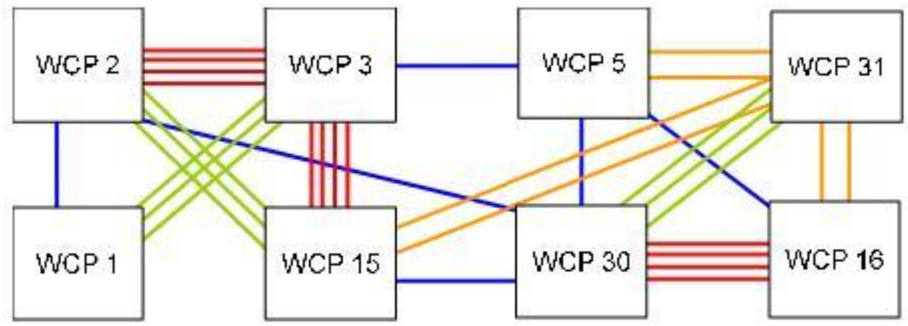


Figure 16: Activity Relationship Diagram Product C



From these diagrams one can immediately recognise that there is a very important relationship between WCP 2, WCP 3 and WCP 15 in all three products. There is also a significantly important relationship between WCP 16 and WCP 20 in product A, WCP 16 and WCP 24 in product B and WCP 16 and WCP 30 and 31 in product C. WCP 16 is a quality inspection (QC inspection) work station while WCP 20, 24, 30 and 31 are testing work centres.

6.3.5 Spaghetti Diagrams

The spaghetti diagrams of products A, B and C can be found in figures 17, 18 and 19 respectively.

Figure 17: Spaghetti Diagram Product A

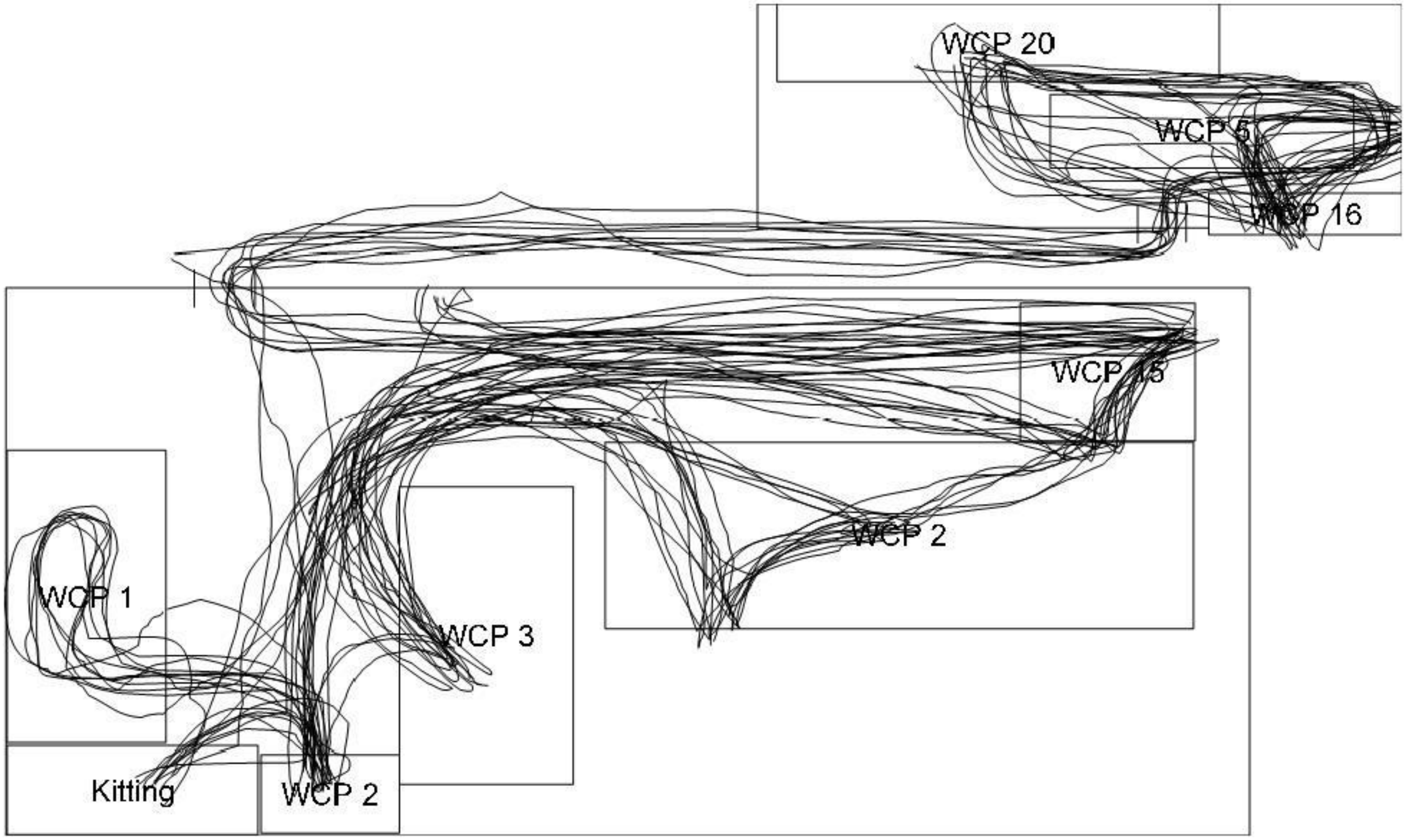


Figure 18: Spaghetti Diagram Product B

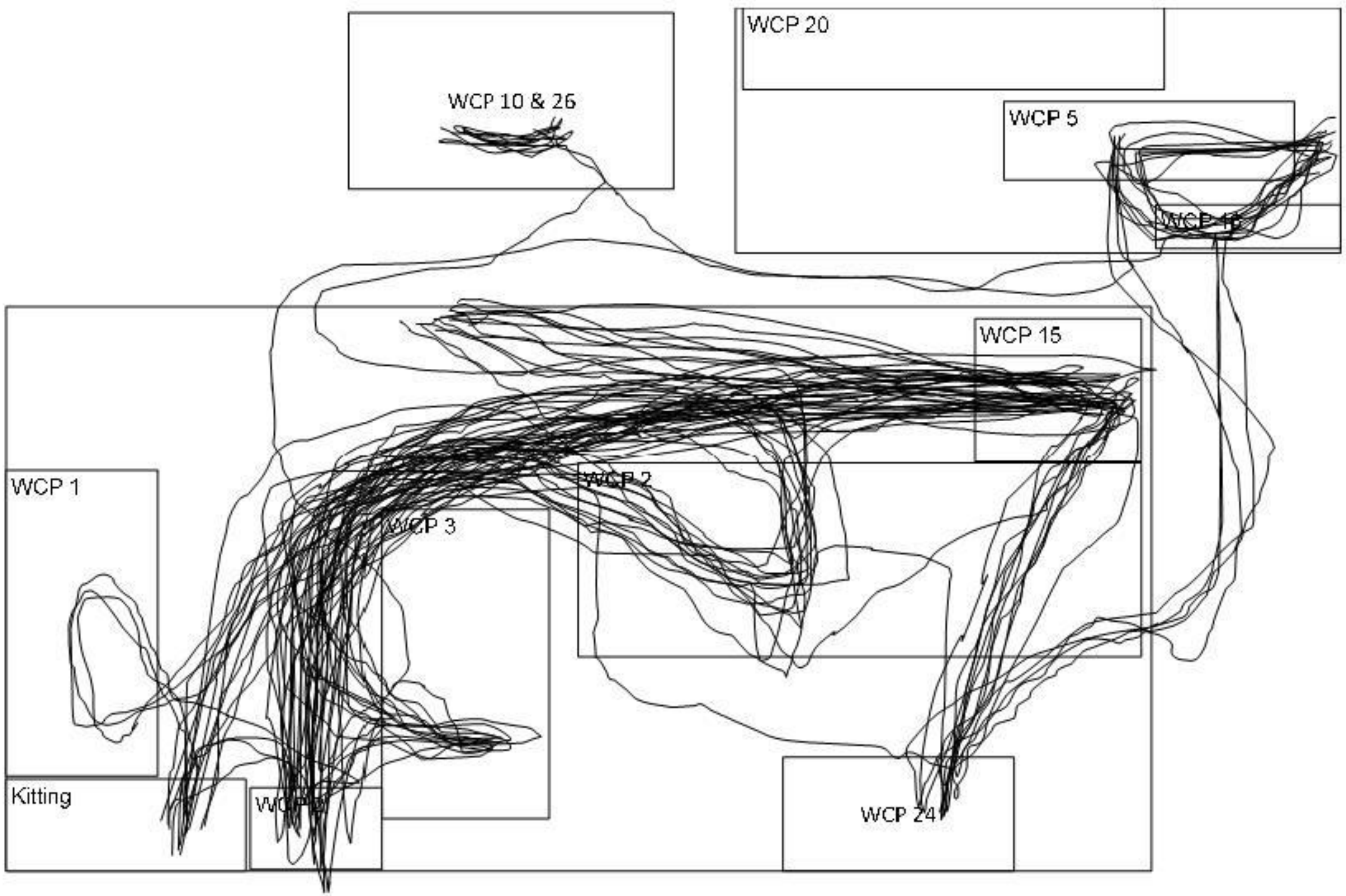
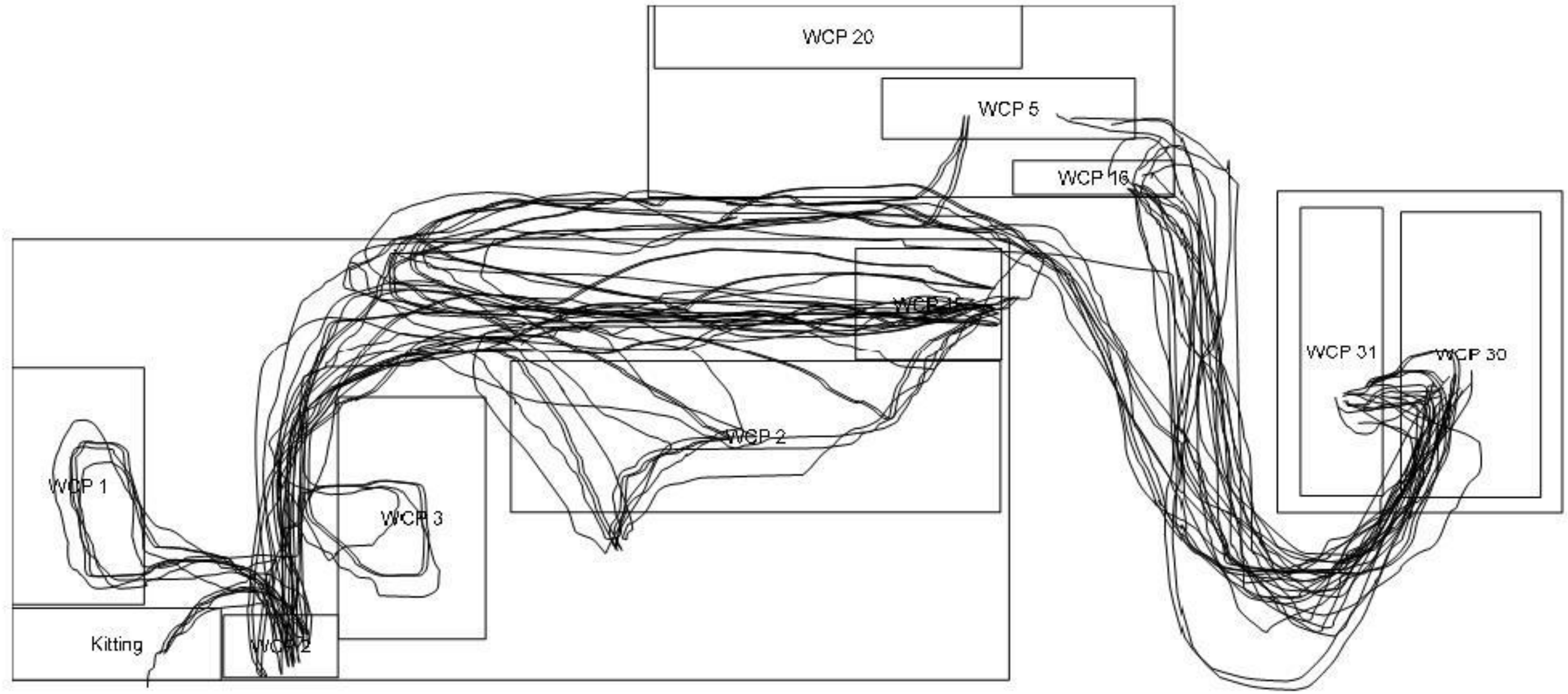


Figure 19: Spaghetti Diagram Product C



The Spaghetti Diagrams were developed from applying the movement of a product from work centre to work centre in the current production set up as it is notated on the product's routing sheet. From these diagrams one can visually identify where the most movement takes place in the manufacturing of the three different products. This helps in developing the block diagrams for the new facility layout.

6.4 SPACE REQUIREMENTS

The space requirements for every work centre of the three chosen products are calculated by taking the dimensions of every physical object in the respective work centre and then calculating how much space is needed to fit in all of the objects into the work centre. All of these calculations can be found in Appendix E.

From these calculations one can make a calculated estimation for the rest of the testing work centres that were not in the three products examined. This estimation is made as follows:

Table 1: Estimating the Surface Area of other test centres

WCP Testing Measured	Surface Area (m^2)
WCP 10&26	78
WCP 20	48
WCP 24	84
WCP 31	70
Average SA (m^2)	70

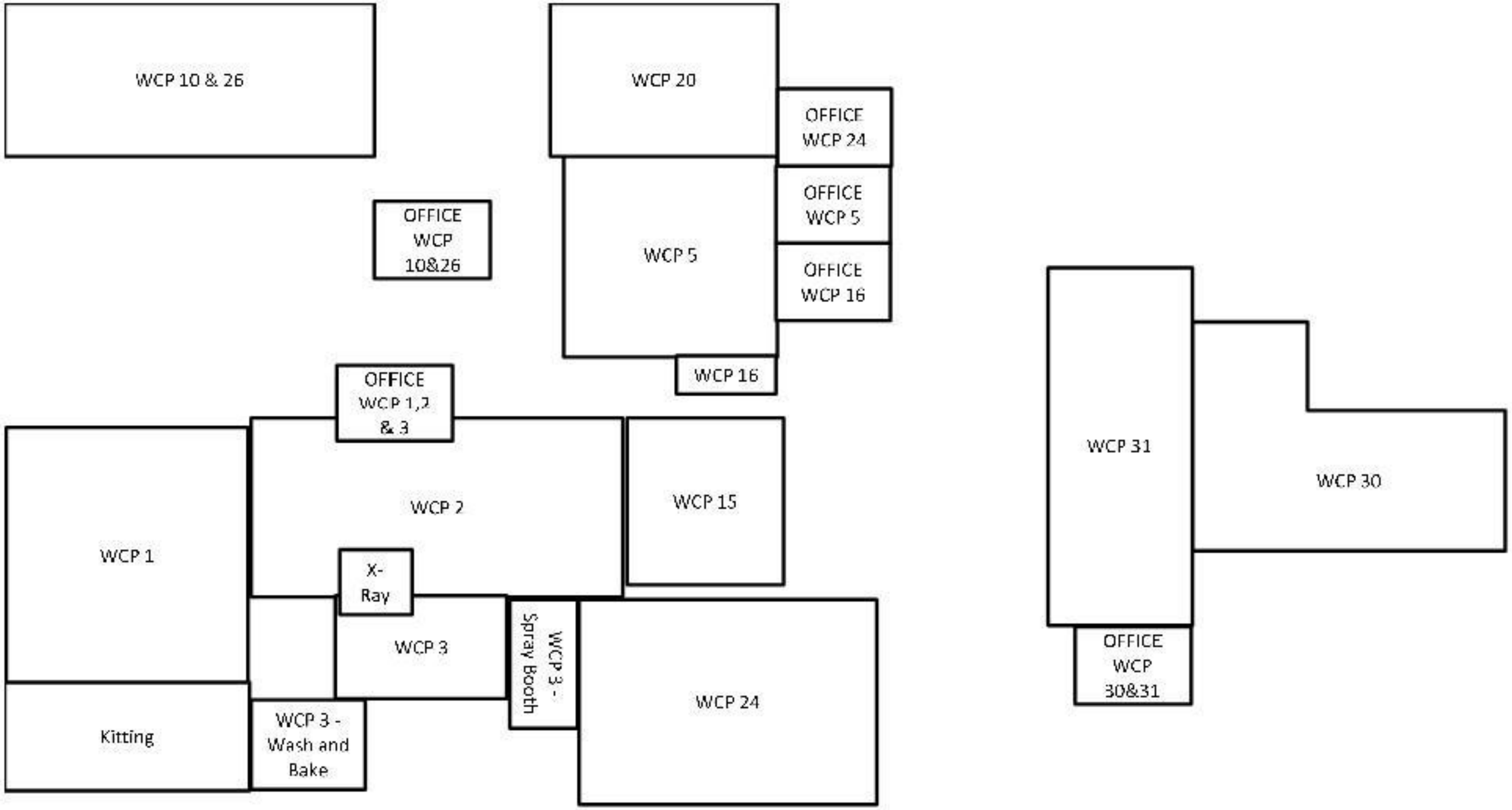
For the block diagrams, every other testing work centre at SAAB EDS ZA will now be estimated to have a surface area of 70 m^2.

6.5 CURRENT PRODUCTION LAYOUT WITH SPACE REQUIREMENTS

From the calculated space requirements a layout of the current production system is developed. Only the product A, B and C's work centres are taken into account. This layout can be found in figure 20.

The blocks in this layout will be used to develop block diagrams for the alternative layout designs.

Figure 20: Current production layout developed by using calculated space requirements



7 RESULTS AND COMPARISONS

7.1 DEVELOPMENT OF ALTERNATIVE LAYOUTS – BLOCK DIAGRAM

Two alternative block diagrams have been developed from the space requirements and current setup. They can be found in figures 21 and 22.

7.1.1 Alternative 1:

In this block diagram the offices are separated from the work centres. Preferably the offices should be upstairs from the production area. The line managers still have control over what enters and exits their work centre/s and are not disturbed easily anymore by the workers in their area.

The test centres evolve around the production area. Preferably, this setup will be open plan and workers will be cross-trained to learn how to test their colleagues' products. This will help in reducing time wasted when one employee is absent or even when one work centre has a higher workload than another work centre.

7.1.2 Alternative 2:

In this alternative the offices are located within the production area. This results in a bit more space being needed for the production area. The layout is once again a process layout because low volume, high variety products are being produced.

Instead of the test centres being all around the assembly area they are more in one area, closer to each other. This plan is not open plan, yet employees will still be cross-trained to help in other work centres when help is needed.

Figure 21: Block Diagram Alternative 1

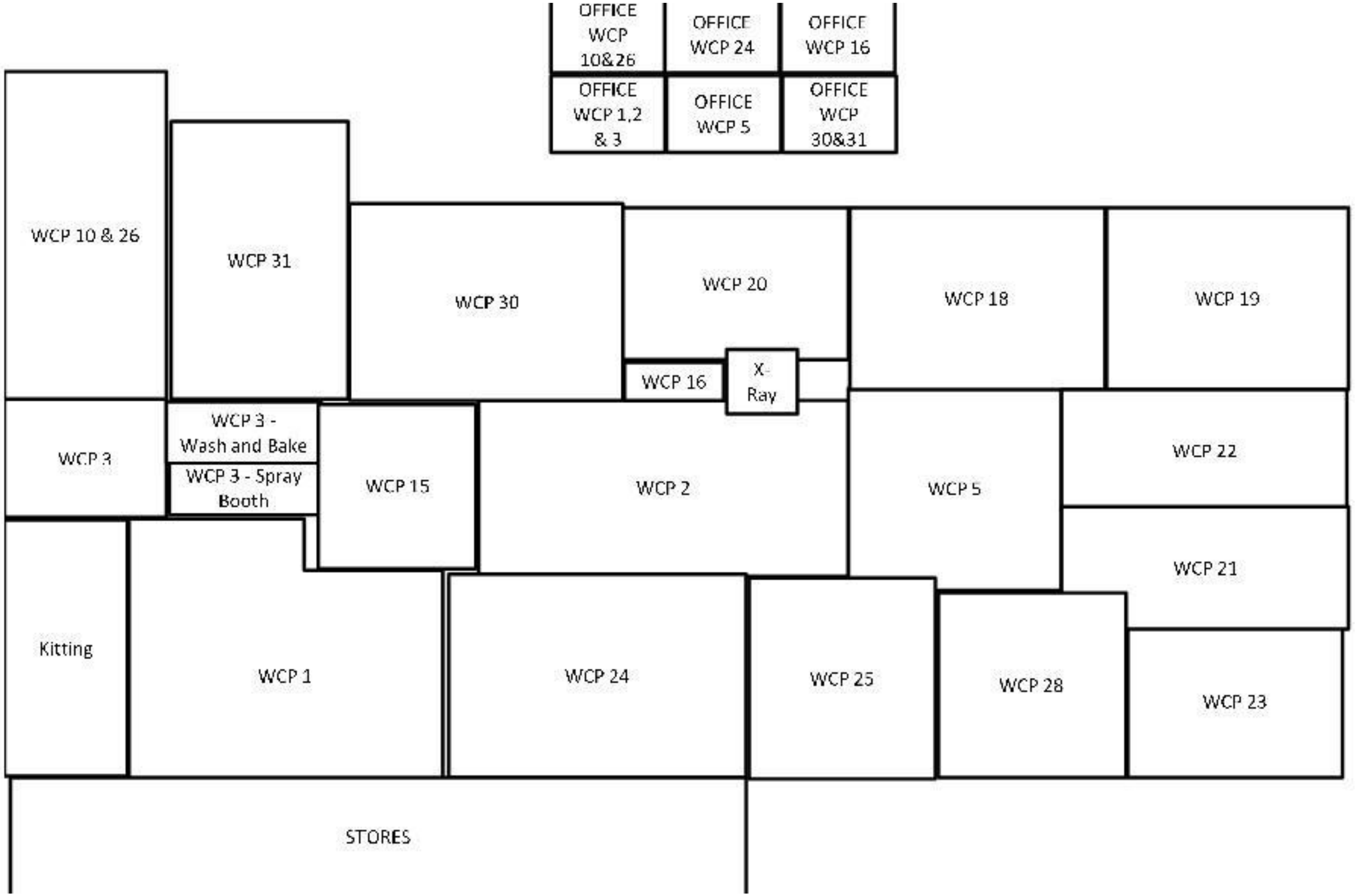
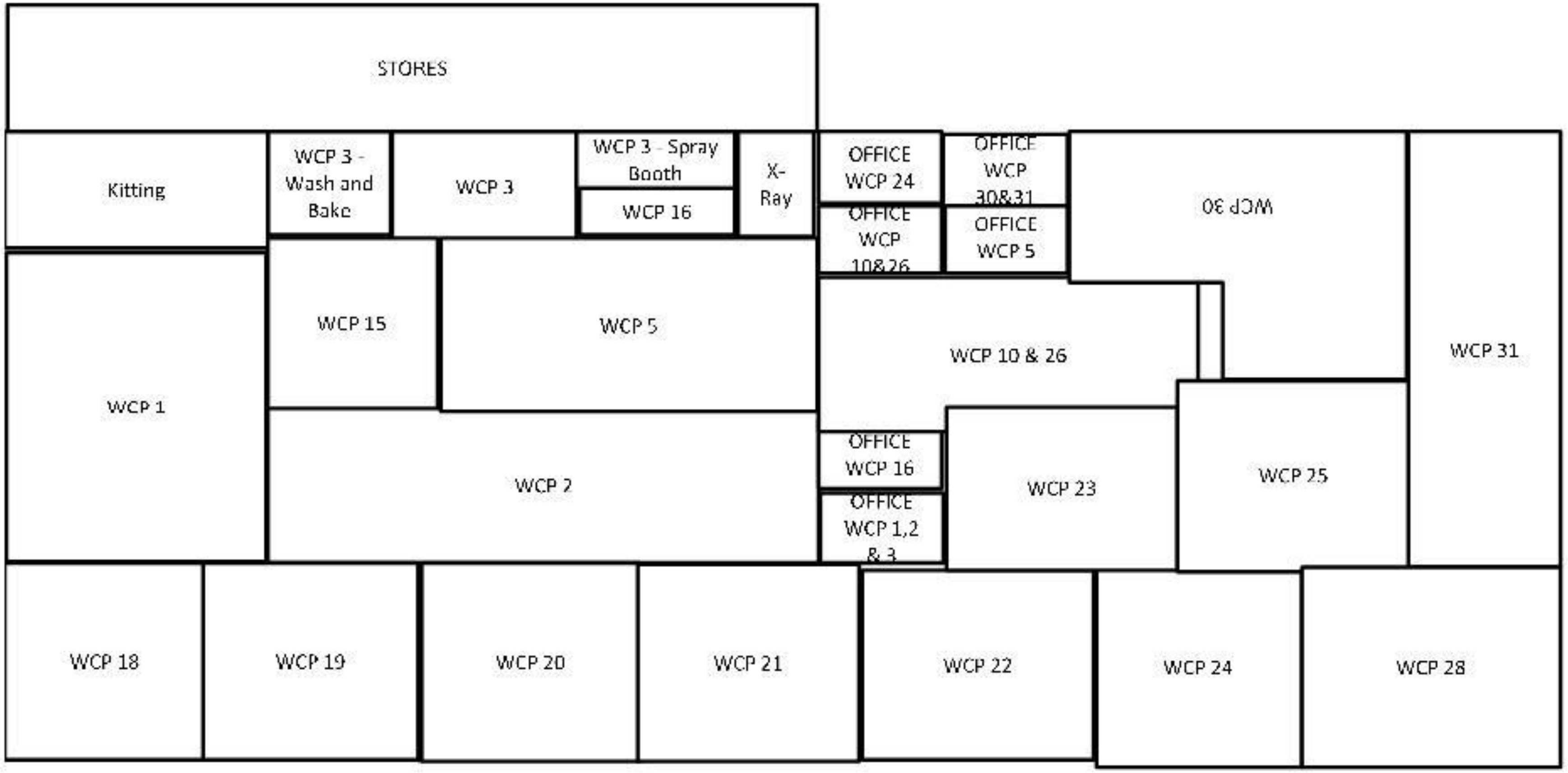


Figure 22: Block Diagram Alternative 2



7.1.3 Evaluating and Choosing a Layout

Table 2: Table to Evaluate Alternative Layouts

Criteria	Alternative 1 (out of 10)	Alternative 2 (out of 10)
Productivity	6.5	8
Realistic	7	6
Manager Convenience	5	9
Employee Convenience	7	6
Cross-training	9	8
Space Requirement	9	8
Production Flow	6	9
Total (out of 70)	49.5	54

Alternative 2 scored higher marks overall, therefore it will be the chosen layout.

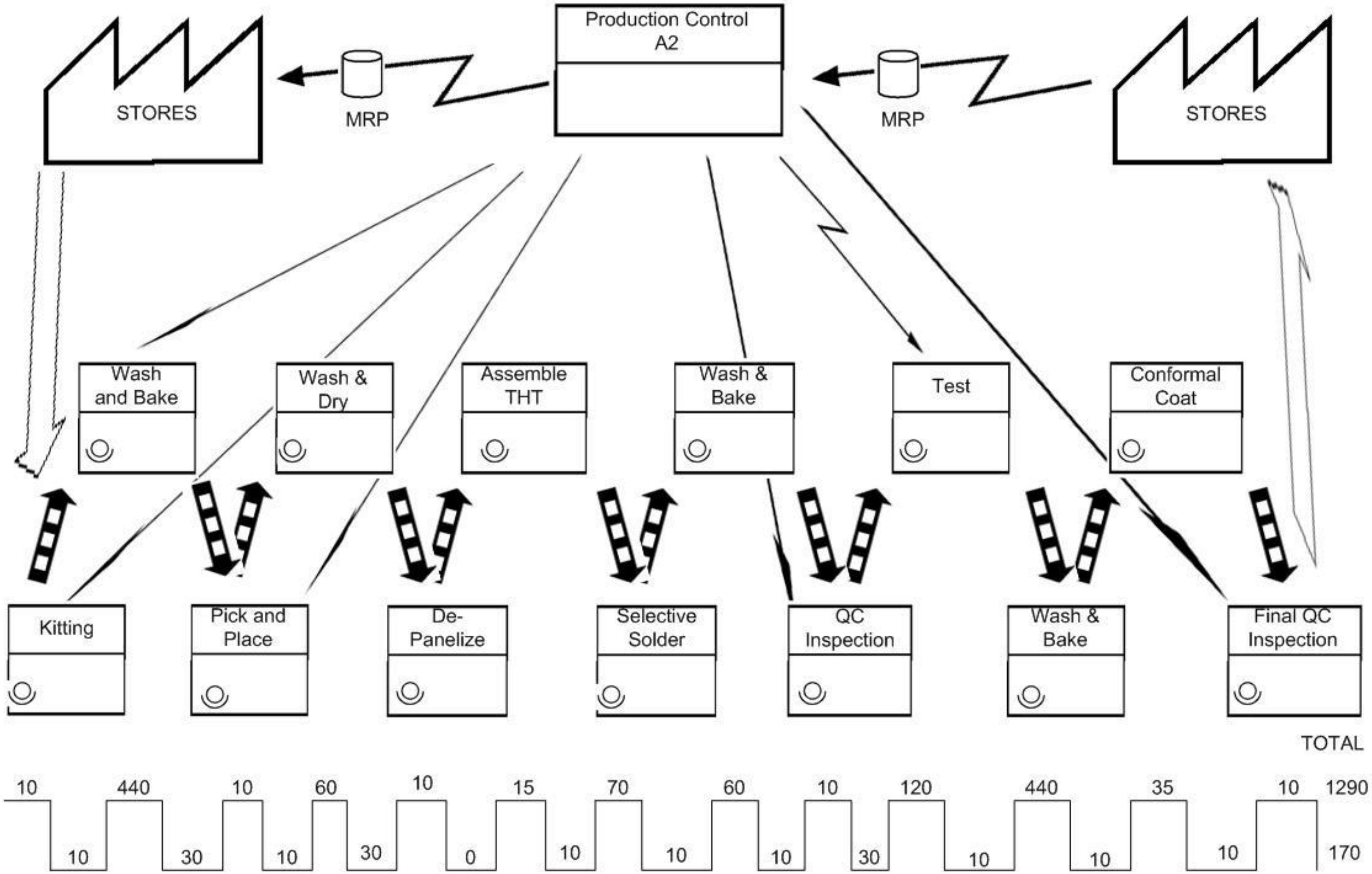
7.2 FUTURE STATE VALUE STREAM MAP

In the future-state value stream map the de-panelising of the PC-Board and the selective solder steps have been swapped around. This reduces two kinds of wastes: transportation and waiting time.

Furthermore, the waiting time has been reduced in the future-state value stream map, resulting in much less non-value adding time.

The future value stream map can be found in figure 23.

Figure 23: Future Value Stream Map



8 RECOMMENDATIONS AND CONCLUSION

It is clear from the current results of the Industrial Engineering tools and methods that have already been applied that there are a lot of wastes present during the production of the products at SAAB. If one implements solutions correctly and maintains them well, the productivity should increase and the cost of products will decrease.

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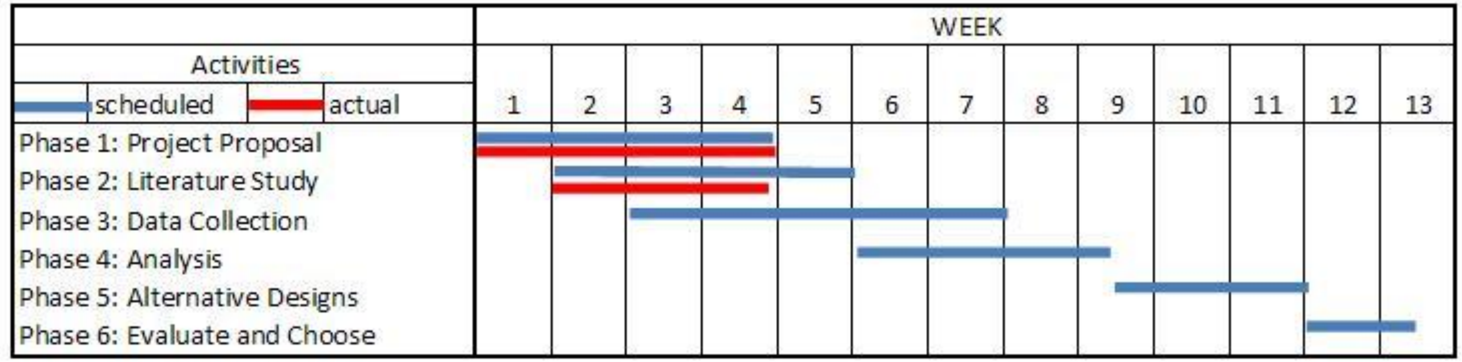
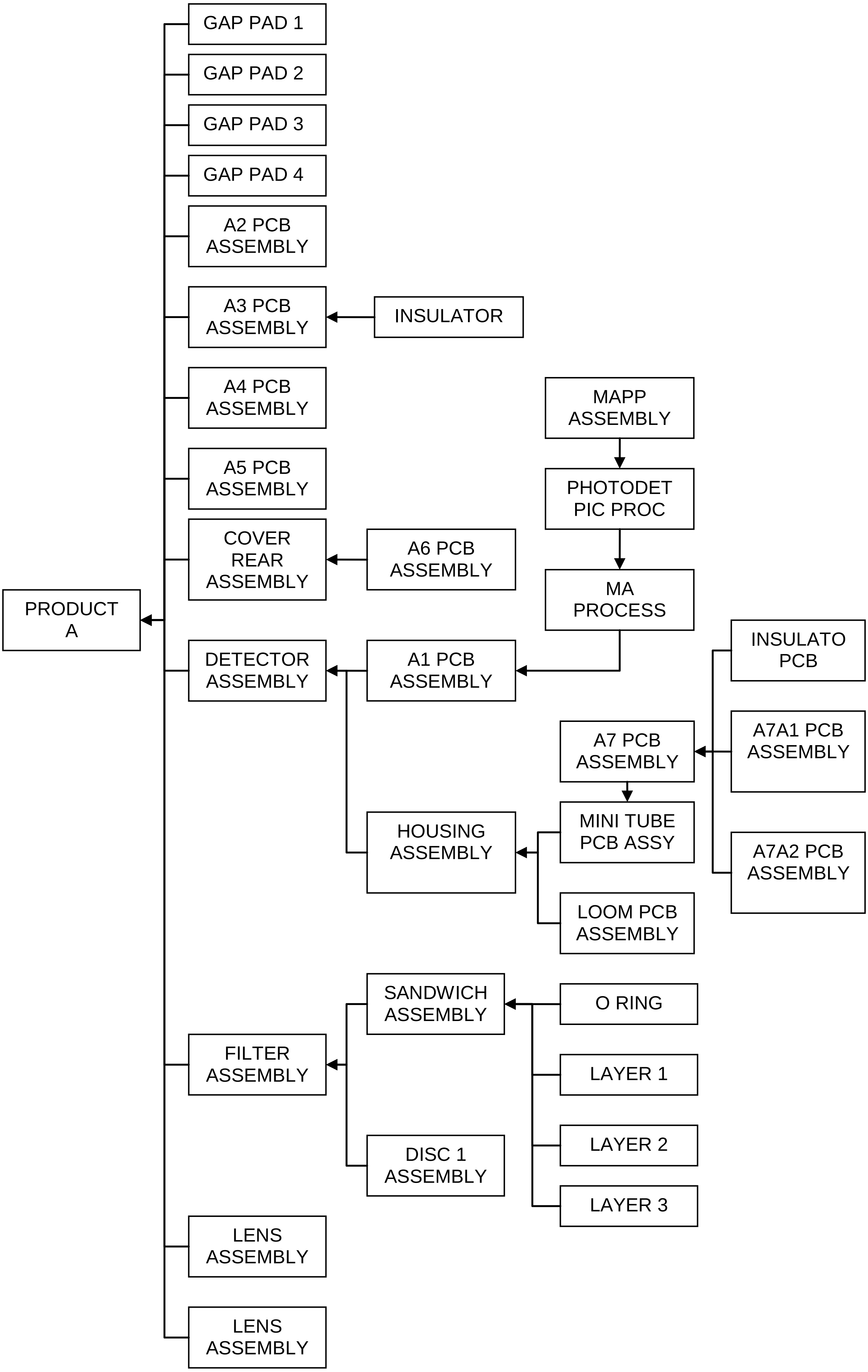
APPENDIX A – GANTT CHART



Week 1: 18-24 July 2011
Week 2: 25-31 July 2011
Week 3: 1-7 August 2011
Week 4: 8-14 August 2011
Week 5: 15-21 August 2011
Week 6: 22-28 August 2011
Week 7: 29 August-4 September 2011
Week 8: 5-11 September 2011
Week 9: 12-18 September 2011
Week 10: 19-25 September 2011
Week 11: 26 September-2 October 2011
Week 12: 3-9 October 2011
Week 13: 10-11 October 2011

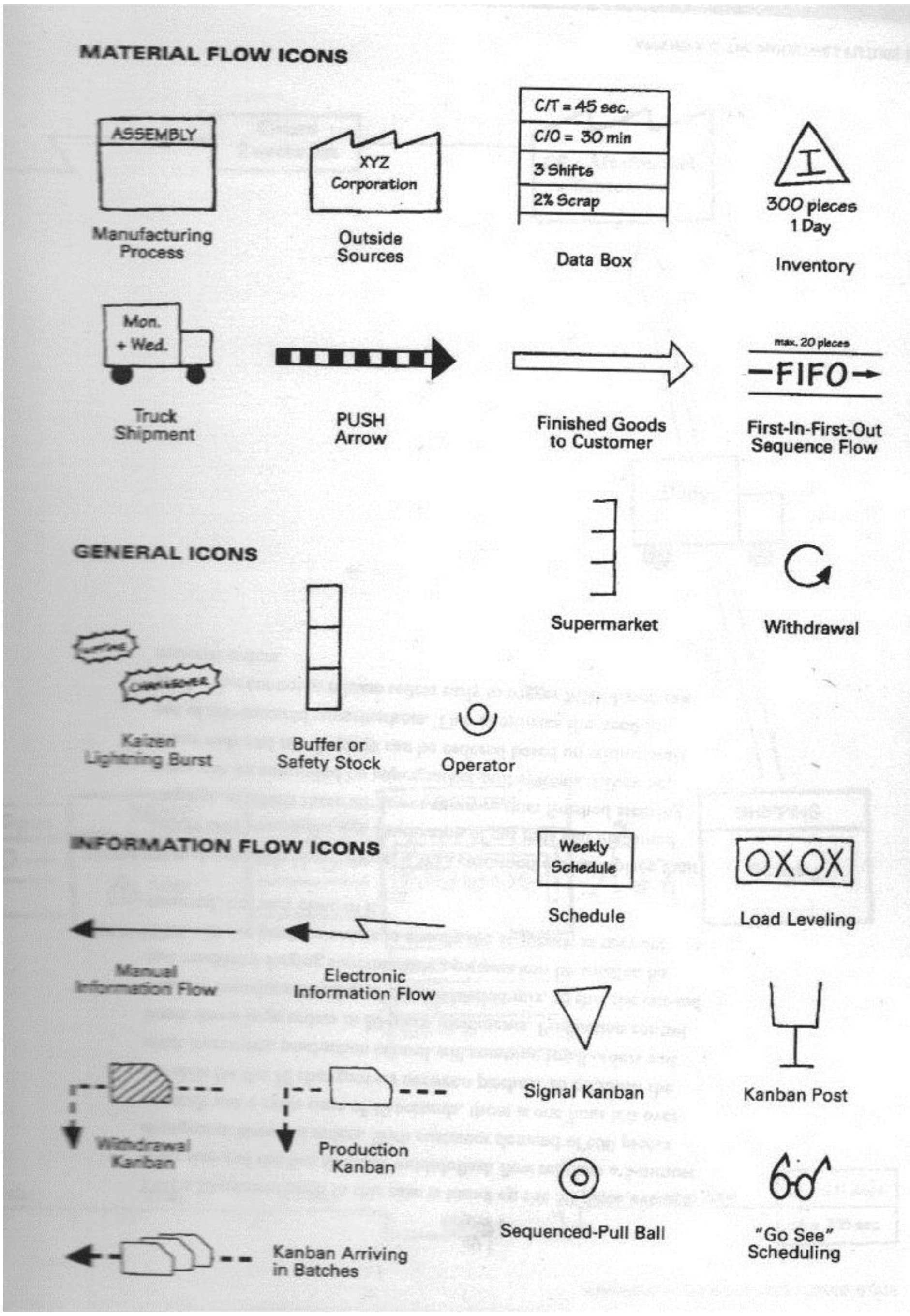
APPENDIX B – FLOW CHART OF PRODUCT A


GAP PAD 1
GAP PAD 2
GAP PAD 3
GAP PAD 4
A2 PCB ASSEMBLY
A3 PCB ASSEMBLY
INSULATOR
A4 PCB ASSEMBLY
MAPP ASSEMBLY
A5 PCB ASSEMBLY
PHOTODET PIC PROC
COVER REAR ASSEMBLY
A6 PCB ASSEMBLY
MA PROCESS
PRODUCT A
DETECTOR ASSEMBLY
A1 PCB ASSEMBLY
INSULATO PCB
A7 PCB ASSEMBLY
A7A1 PCB ASSEMBLY
HOUSING ASSEMBLY
MINI TUBE PCB ASSY
A7A2 PCB ASSEMBLY
LOOM PCB ASSEMBLY
SANDWICH ASSEMBLY
O RING
FILTER ASSEMBLY
LAYER 1
DISC 1 ASSEMBLY
LAYER 2
LAYER 3
LENS ASSEMBLY
LENS ASSEMBLY

APPENDIX C – PRODUCT FAMILIES

Products	Assembly Steps and Equipment														
	Kitting	W&B	P&P	Serial Nr	THT	Sel Sold	De-Pan	QC	Test	Con Coat	Integrate	Hand-Mount	Temp Cyc	Sil Coat	RTV
A2 PCB	x	x	x	x	x	x	x	x	x	x					
A3 PCB	x	x	x	x	x		x	x	x	x					
A4 PCB	x	x	x	x	x		x	x	x	x					
A5 PCB	x	x		x	x		x	x		x					
A6 PCB	x	x		x			x	x		x		x			
A1 PCB	x	x	x	x	x			x	x	x			x		
A7 PCB	x	x						x	x			x		x	
A7A1 PCB	x	x	x	x	x		x	x							x
A7A2 PCB	x	x	x	x	x		x	x							
DET ASSY	x							x	x			x	x		
CR ASSY	x							x			x				

APPENDIX D – VALUE STREAM MAPPING ICONS


MATERIAL FLOW ICONS
ASSEMBLY
Manufacturing Process
XYZ Corporation
Outside Sources
C/T = 45 sec.
C/O = 30 min
3 Shifts
2% Scrap
Data Box
I
300 pieces
1 Day
Inventory
Mon. + Wed.
Truck Shipment
PUSH Arrow
Finished Goods to Customer
max. 20 pieces
FIFO
First-In-First-Out Sequence Flow
GENERAL ICONS
Supermarket
Withdrawal
Kaizen Lightning Burst
Buffer or Safety Stock
Operator
INFORMATION FLOW ICONS
Weekly Schedule
Schedule
OXOX
Load Leveling
Manual Information Flow
Electronic Information Flow
Signal Kanban
Kanban Post
Withdrawal Kanban
Production Kanban
Sequenced-Pull Ball
"Go See" Scheduling
Kanban Arriving in Batches

APPENDIX E – SPACE REQUIREMENT CALCULATIONS

E1: WCP 1

Name	Quantitiy	Dimensions (cm)			Special Requirements
		Height	Length	Width	
Storage Rack	6	214	91	65	Access from front and back
Small Oven	1	130	250	90	Access on both sides, stands on table (incl. in height)
Tables	4	80	180	88	
Pick & Place Machine	1	150	110	270	These 3 are in a line assembly
Inspection Bench	1	130	95	110	
Oven 2	1	180	380	140	
Stencil Rack 1	1	210	640	82	
Stencil Rack 2	3	210	90	60	
Screen Printer	1	120	130	110	
Dry Storage	1	162	82	55	Stands on table (incl. in height)
Cabinet	1	180	90	45	
Large Workbench	1	161	165	81	

Space Required for Room:

Length	
Pick and Place length:	585
Dry Storage:	82
Stencil Rack:	82
Subtotal:	749
Aisle Space	251
Total:	1000
Width:	
Stencil Rack 1:	640
Storage Rack:	65
Subtotal:	705
Aisle Space:	145
Total:	850
Surface Area (m^2):	85

E2: WCP 2

Name	Quantitiy	Dimensions (cm)			Special Requirements
		Height	Length	Width	
Large Workbenches	8	161	165	81	
Storage Rack	5	214	91	65	
Rework Table	1	160	100	71	Space between benches for extractor = 46 cm
Cabinets	2	180	90	45	
WIP Table	1	80	300	50	
Priority Board	1	205	350	72	Visible at all times
Jig Table	1	82	205	85	
X-Ray Machine	1	196	160	103	Stand in own room
Office	1				Office for line manager
Rework Machine	1	80	205	85	Stands on table

Space Required for Room:

Length:	
Large Workbenches:	376
Storage Rack:	65
WIP Table:	50
Subtotal:	491
Aisle Space:	209
Total:	700
Width:	
Large Workbench:	324
WIP Table:	300
Rework Machine:	205
Aisle W/B:	300
Subtotal:	1129
Aisle Space:	171
Total:	1300
Surface Area (m^2):	91

E3: WCP 3

Name	Quantitiy	Dimensions (cm)			Special Requirements
		Height	Length	Width	
Workbenches	4	160	100	78	
Coating Machine	1	210	120	94	Next to PC
PC	1	210	80	94	Next to Coating Machine
Touch-up table	1	90	130	64	
Storage Rack	1	182	91	63	In Conformal Coat area
Large Cabinet	1	180	90	45	
Small Cabinet	1	134	90	60	
Spray Booth	1	110	140	110	In extra room - needs extractor
Table	1	80	180	88	In spray booth room
Storage Rack	1	182	91	83	In spray booth room
Cabinet	1	180	90	45	In spray booth room
Defluxing System	1	170	111	81	Needs water flow
Small Tables	2	90	100	70	
Basin	1	90	100	70	
Fridge	1	160	70	64	
Large Oven	1	140	80	75	
Small Oven	1	158	85	75	Stands on table (incl. in height)
Pressure Washer	1	170	150	55	Needs water flow

Space Required:	
Clean and Bake:	
Length:	
Workbenches:	200
Workbenches:	78
Coating Machine:	120
PC	80
Touch up-table:	130
Subtotal:	608
Width:	
Workbenches:	178
Aisle Space:	222
Total:	400
Surface Area (m^2):	24
Spray Booth:	
Length:	
Spray Booth:	140
Aisle Space:	100
Total:	240

Width:	
Spray Booth:	110
Table:	180
Rack:	91
Aisle Space:	119
Total:	500
Surface Area (m^2):	12
Wash and Bake:	
Length:	
Deflux:	111
Large Oven:	75
Basin:	70
Fridge:	64
Aisle Space:	30
Total:	350
Width:	
Pressure Washer:	150
Basin:	100
Deflux Machine:	81
Aisle Space:	69
Total:	400
Surface Area (m^2):	14

E4: WCP 5

Name	Quantitiy	Dimensions (cm)			Special Requirements
		Height	Length	Width	
Large Workbench	5	161	165	81	
Small Workbench	2	160	100	78	
Storage Rack	5	182	91	63	
Rework Bench	1	160	100	78	
Office	1				Office for line manager

Space Required:

Length:	
Workbenches:	430
Rack:	91
Rework Bench:	78
Subtotal:	599
Aisle Space:	151
Total:	750

Width:	
Workbenches:	162
Racks:	364
Rework Bench:	100
Subtotal:	626
Aisle Space:	174
Total:	800

Surface Area (m^2): 60

E5: WCP 15

Name	Quantitiy	Dimensions (cm)			Special Requirements
		Height	Length	Width	
Storage Rack	4	214	91	65	Access from both sides
Table	4	80	180	88	
UV light Table	1	160	100	75	Stands on table
Cabinet	1	180	90	45	

Space Required:

Length:	
Table:	360
Table:	88
Storage Rack:	44
Subtotal:	492
Aisle space:	158
Total:	650
Width:	
Tables:	360
UV Table:	100
Cabinet:	45
Subtotal:	505
Aisle Space:	45
Total:	550
Surface Area (m^2):	35.75

E6: WCP 16

Name	Quantitiy	Dimensions (cm)			Special Requirements
		Height	Length	Width	
Large Workbench	1	161	165	81	
Storage Rack	1	214	91	65	
Office	1				Office for Line Manager

Space Required:	
Length:	
Workbench:	165
Rack:	91
Subtotal:	256
Aisle Space:	94
Total:	350
Width:	
Rack:	65
Workbench:	81
Total:	146
Surface Area (m^2):	5.25

E7: WCP 20

Name	Quantitiy	Dimensions (cm)			Special Requirements
		Height	Length	Width	
Test Bench	2	170	170	155	
Workbench	3	180	200	120	
Large Test Bench	1	170	216	75	
Small Cabinet	2	134	90	60	

Space Required:	
Length:	
Workbenches:	600
Aisle Space:	200
Total:	800
Width:	
Workbenches:	120
Test Benches:	155
Cabinets:	180
Subtotal:	455
Aisle Space:	145
Total:	600
Surface Area (m^2):	48

E8: WCP 24

Name	Quantitiy	Dimensions (cm)			Special Requirements
		Height	Length	Width	
Large Workbench	3	160	200	100	
X-Large Workbench	1	160	200	130	
Testbench	1	200	420	238	Cannot stand against wall
Test Chamber	1	190	75	75	
Large Rack	1	230	180	60	
Storage Rack	3	214	91	65	
Cabinet	1	180	90	45	
Office	1				Office for Manager

Space Required:

Length:	
Workbench:	330
Test Bench:	238
Test Chamber:	75
Storage Rack:	65
Cabinet:	45
Subtotal:	753
Aisle Space:	297
Total	1050
Width:	
Workbench:	100
Testbench:	420
Test Chamber:	75
Subtotal:	595
Aisle Space:	205
Total:	800
Surface Area (m^2):	84

E9: WCP 10&26

Name	Quantitiy	Dimensions (cm)			Special Requirements
		Height	Length	Width	
Standard Workbench	7	180	200	120	
Test Chamber	5	190	75	100	
Test Rack	1	180	60	80	
Inspection Table	1	75	120	75	
Mini Oven	1	80	80	70	
Test Bench	1	195	75	120	
Table	2	80	180	88	
Cabinet	3	180	90	45	
Locker	2	180	45	45	
Filing Cabinet	2	90	61	80	
Table for PC	1	80	120	75	
Office	1				Office for Manager

Space Required:

Length:	
Workbench:	600
Mini Oven:	70
Workbench:	200
Subtotal:	870
Aisle Space:	430
Total:	1300
Width:	
Workbench:	200
Cabinet:	180
Locker:	90
Subtotal:	470
Aisle Space:	130
Total:	600
Surface Area (m^2):	78

E10: WCP 30

Name	Quantitiy	Dimensions (cm)			Special Requirements
		Height	Length	Width	
Standard Workbench	13	161	165	81	
Small Workbench	2	160	100	78	
Storage Rack	13	214	91	65	
Cabinet	3	180	90	45	
Fridge	1	120	55	50	
Testbench	2	170	170	155	
Office	1				Office for line Manager

(L-shape)
Space Required:
Vertical:
Length:

Workbenches:	346
Storage Racks:	78
Subtotal:	424
Aisle Space:	176
Total:	600

Width

Racks:	546
Fridge:	50
Workbench:	81
Subtotal:	677
Aisle Space:	223
Total:	900

Horizontal:
Length:

Testbenches:	340
Racks:	265
Workbenches:	495
Total:	1100

Width:

Testbenches:	155
Workbenches:	81
Subtotal:	236
Aisle Space:	164
Total:	400

Surface Area (m^2): 98

E11: WCP 31

Name	Quantitiy	Dimensions (cm)			Special Requirements
		Height	Length	Width	
Test Chamber	7	210	130	140	
Test Bench	5	195	75	120	
Table	2	80	180	88	
Cabinet	1	180	90	45	
Shaker	1	95	55	75	
Office	1				Office for Manager

Space Required:

Length:	
Chamber:	140
Bench:	120
Shaker:	75
Subtotal:	335
Aisle Space:	165
Total:	500
Width:	
Chamber:	910
Table:	180
Cabinet:	90
Subtotal:	1180
Aisle Space:	220
Total:	1400
Surface Area (m^2):	70

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DEPARTEMENT BEDRYFS- EN SISTEEMINGENIEURSWESE
DEPARTMENT OF INDUSTRIAL AND SYSTEMS ENGINEERING

FRONT PAGE FOR FINAL PROJECT DOCUMENT (BPJ 421) - 2011	
Information with regards to the mini-dissertation	
fTitle	Consolidation of Production at Saab Electronic Defence Systems ZA
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Date	10/11/2011
Keywords	Lean manufacturing, Value stream mapping, Facility planning, Production consolidation
Abstract	This project looks at the current production facilities at SAAB EDS ZA using facility layout techniques and a lean manufacturing technique called value stream mapping. After analysis is done alternative layouts are designed for consolidating the production plant to a new building so that productivity is increased and materials handling decreased.
Category	Facilities Planning, Lean Manufacturing
Declaration	
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