Master’s Thesis

Analysis of impact of process complexity on unbalanced work in assembly process and methods to reduce it.

Project undertaken in Electrolux AB, Mariestad under guidance of SWERA IVF AB

Submitted by:
Kushal Lokhande
(kushal@kth.se)
Maheshwaran Gopalakrishnan
(mgop@kth.se)

Supervisor:
Kerstin Dencker
SWERA IVF, Stockholm.
Abstract

In the Manufacturing sector there are continual demands as regards to quality, cost, production volume, deliverability, enhanced efficiency and added flexibility. In addition now a day’s major challenge for industry is to achieve sustainability. Every company strives to put a lot of efforts in new product development and new process development. There are new products launched very frequently which increases the market presence of the company. The new product challenges the entire production value chain and thus increasing the complexity of products and thus processes and production.

The overall goal is to support management of dynamic production changes and added complexity, thus optimizing the use of production resources towards sustainability. In order to obtain competitive advantages, production systems in Sweden have to be slim, readily adjustable, and must meet the sustainability and environmental requirements. Sustainability refers to ecological as well as economical issues and social/human:

(1) Introducing new technology and processes in production meeting new environmental requirements;

(2) Achieving economical and ecological sustainability of process and operation;

(3) Improving work environment, ergonomics, and competence to manage new processes.

Sustainability thus sharpens requirements and makes optimization of production increasingly complex. In particular the flexibility is affected: there is need for handling rapid new “crash” programs that may severely change technology, process and products. Further, production realization process must handle increased complexity. For example, introduction of new engines (hybrid, electrical) in production of passenger cars is expected to lead to an acute increase of the number of components and variants in parallel. Increase in variants increases the complexity of the manufacturing processes.

In this thesis we have tried to reduce the complexity of the processes by mainly focusing on work content and layout for the assembly and logistics function in the Electrolux factory in Mariestad, Sweden. We used time studies for assembly station and Value Stream Mapping for the logistics section to break down work structure and differentiate balanced and unbalanced work. Then the focus was on determining the perceived complexity of the process by using Complexity Index. After analyzing the relation of unbalanced work with the perceived complexity, specific problems and difficulties on the assembly line and the material handling of Electrolux are addressed.

The thesis has resulted in understanding of the Complexity of Assembly stations and Material Handling section. With help of this complexity, the distributed unbalanced work is reduced using Lean techniques.

Key Words: Lean, Complexity, Production, Assembly, Logistics, Balanced work, Unbalanced work, Value Stream Mapping, Time Study, Complexity Index
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Kushal Lokhande
Maheshwaran Gopalakrishnan
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1. Frame of Reference

1.1 Assembly Process

According to the definition by assembly is a unit that contains the parts that make up a mechanism or a machine (K. K. Ramalingam, 2009) and the operation that makes up this mechanism or machine is called the assembly process. There are different types of Assembly processes in practice viz. Progressive assembly and Non-progressive assembly (V. S. Korsakov, 1974). Progressive assembly is accomplished on the conveyor and the assembler or the assembly operator carries out a single operation progressing from one station to the next. Progressive assembly is suitable for mass production. Non-progressive assembly is the carried out individually or in a small batch. The items to be assembled are taken near the base component and assembly operation is done.

The assembly process employed in the Electrolux factory is progressive. The cabinets travel on the conveyor and one single operation is performed on every station. There are in total 60 stations on the line B72.

1.2 Material Handling

Material handling generally centres on moving palletized, kitted, individually sorted and quantified material from the storage to the process (Clifford J. Weinpel). The methods to accomplishing this task breaks down into variety of processes.

In Electrolux these are done using the combination of mechanical conveyor, forklifts and the trucks. The mechanical conveyors transport the material from the storage to the kitting station. The heavy material that cannot be accommodated on conveyor they are handled by the forklifts and then transported to the assembly line through the truck.

1.3 The Kitting process

The kitting is the process of selecting the parts and grouping them and sending them to the place from where they are ordered viz. to the customer or the manufacturing unit. In Electrolux the parts are kitted for the manufacturing. The parts are selected and ordered from different stores and then kitted according to the predefined order.

Previously in the thesis study titled ‘The Analysis of the Kitting process at Electrolux Mariestad’ done by Daði Janusson and Vilhjálmur Alvar Þórarinsson. The results from the complexity analysis show how article and product complexity affect kitting. In the conclusion they have stated that more the different articles and product variants the more is the complexity. Their study has been beneficial for us to find out relation between the perceived complexity and the unbalanced work.
1.4 Assembly Line Balancing

Assembly line balancing is an effective tool to increase the output of the line. The major tasks involve matching the cycle times of the individual stations, removing bottlenecks, designing the batch sizes, reducing the balancing losses etc. The Line balancing is not a onetime task. Rebalancing of the assembly line is a continuous process which needs to be done regularly in order to ensure the smooth flow of the line. Rebalancing is done mainly due to the following factors:

a) New Products
b) New variants
c) New equipment
d) Operator skill
e) Waste identification

(Abhiram reddam, Emre ozugurel 2011)

In the thesis work done by Abhiram reddam and Emre ozugurel they have analysed the level of automation with particular focus on the cognitive aspect in order to make information more readily available, this is necessary for the smooth running of the plant. They also carried out the work on the rebalancing of the assembly line.

1.5 Complexity in the Assembly

There are various factors which make an assembly process complicated. In our study we have made use of the research carried out at Chalmers University by Sandra Matsson. According to the study the following factors affect the complexity:

a) Number of variants
b) Work content
c) Layout
d) Work instructions
e) Tools and Support Tools

Using these factors the perceived complexity in the Assembly process can be found out.

1.6 Complexity in the Logistics

In logistics there are various factors which make the process complicated. They are as follows:

a) Maintaining the inventory level in the stores.
b) Ordering system from the kitting stations.
c) The two bin ordering system.
d) The number of components.
e) The schedule of the orders.
f) The movement of the trains and trucks.
2. Research process

2.1 Definitions

In order to identify and distribute the work we started off with defining the Balanced and Unbalanced work. This definition we came up with was accepted by the COMPLEXITY project group, therefore continues to use in this thesis and elsewhere.

Unbalanced work

The work or the task being done on the station which is not periodic and the method of doing it differs for each instance. There are alterations in every successive cycle and the alteration does not follow any pattern.

Balanced work:

The work or the task that is being performed on the station which is periodic, repetitive, can be recorded, monitored and its occurrence can be estimated. It is the direct work that adds value to the product considering all the customers downstream.

2.2 Station Level

2.2.1 Relation of Unbalanced work with the Complexity

As described in the earlier section the complexity index gives the complexity that is perceived by the line operators. In defining the relation of unbalanced work with the complexity we made the use of the time study and the work sequence followed by the operators and the one defined by Electrolux.

The time study charts made in excel sheet represents the list of the different tasks the line operator has to perform at each station. Different tasks are then segregated into Balanced and Unbalanced work.

E.g. For one Freezer variant the distribution of Balanced and Unbalanced work is found and depicted as follows:

As mentioned earlier the four stations of the line B72 are operational: Station 53, Station 55, Station 58 and Station 60. The above time study and work study is done for all the four stations of three Freezer variants and two Refrigerator variants.
Considering one station at a time the distribution at every station and the cumulative distribution for the entire freezer variants is calculated and depicted in the following pie chart.

The Station level analysis gives us the exact distribution of the balanced and unbalanced work at every station for the Freezers. In the later stages the distribution of the entire Freezer product line is calculated and depicted as follows:

![Figure 2.1: Example at Station 53](image)

In the similar way the all the three stages are performed for the Refrigerator Assembly and the distribution is found out at the three stages a) two variants and four stations at the Station Level b) cumulative balanced and unbalanced work for every station of refrigerator assembly c) Cumulative for the entire refrigerator product line.

![Figure 2.2: Work Distribution Freezer Assembly](image)
From the pie charts it is clear that the amount of unbalanced work is considerably high in both the Freezer and Refrigerator assembly. We compared the Balanced and Unbalanced work with the complexity interview results. The following were the results obtained:

![Balanced and Unbalanced work in Refrigerator Assembly](image)

**Figure 2.3: Work Distribution Refrigerator Assembly**

The stations with the highest complexity index had unbalanced work ranging between 56% and 61%. Comparing this with the individual complexity of each area in the CXI analysis it indicates that the station complexity is directly proportional to the unbalanced work. The complexity is high mainly in following areas:

![CXI Results of Assembly](image)

**Figure 2.4: CXI Results of Assembly**
a) Product variants

b) Work content

c) Layout

Therefore we decided to look into the above three areas and tried to find out ways to reduce the unbalanced work as it contributes more than 50%.

Analysis of the work sequences to find out the most prominent unbalanced work:

We listed all the unbalanced work for Freezer and Refrigerator of all the stations in the similar manner as shown below:

![Figure 2.5: List of Unbalanced Work](image)

### 2.2.2 Common unbalanced work

1) Rework

2) Repeated movement of the operator from the station to the material rack

3) Waiting time for the material

4) Waiting time for the coordinator

The suggestions that we came up with will assist in reducing the above unbalanced work.
2.3 Factory Level

2.3.1 Value Stream

The second part of the thesis was focused on factory level, in which the material handling section of Electrolux is considered. The logistics related to the 4 variant section of the assembly line alone is considered of all the material handling being carried out in Electrolux.

The value stream map below shows the overall idea of how materials are supplied to the 4 variant section of the assembly station from various parts of the factory’s storage and kit stations.

![Value Stream Map](image)

*Figure 2.6: VSM of Material Handling*

Value Stream (Individual)

The flow of materials to the variant section from each different place from the logistic section is identified. A Value stream is plotted for the same in order to identify the time taken in order to replenish a particular material to a particular station can be identified.
Trådhylla from Logistic Section:

For the trådhylla (metal shelf), the order is from the assembly line, the coordinator sends out the Kanban from empty bins to the pickup train drivers. They along with the Kanban also carry the empty box. The trådhylla are kept in the Kit Golv of Logistics section. For trådhylla, the replenishment method followed is showed in the value stream. The total time taken from order to delivery of a single box of trådhylla back to the station takes about 35 minutes, of which only 20 minutes are value adding and the other 15 minutes are non value adding time, mainly waiting times.

Glashylla from L hall:

The glasshylla (glass shelf) are also ordered in the assembly line by the coordinator, similar to the trådhylla. The difference is that glasshylla are stored in L hall and the pickup of empty drawers is done by coordinate himself and in a place right outside G4 gate. Then the local forklift driver then replenishes it from the L hall. It takes a total time of 57 minutes of which only 17 minutes are value added.
Materials from Kit Station:

The materials which come from the Kit station are pre-orderd by the ERP. The orders are stored and given at right time by the ERP IT system. Once the order is available, the coordinator prints and keeps it ready for the kit station operator. The kit station operator kits the train and put it for the pickup by train drivers and delivery. It takes about 95 minutes for whole processes (from the order being available for the coordinator to print and replenishment of materials) out of which 60 minutes are non value adding.

Materials from 2-bin lappar – C hall:

The materials from the 2 bin lappar station are ordered from the assembly line only. This is a simple Kanban replacement technique. This is the shortest and the most efficient way of replenishing materials. Only selected materials which are pre kit by the suppliers can be used by this method. The lead time for replenishment of materials is about 15 minutes and there is no non value added time.
Materials from 2 bin Kit Station:

![Image](image.png)

Figure 2.11: VSM of 2-Bin Kit Station

The materials from the 2 bin kit station are ordered from the assembly line only. Similar to the 2 bin lappar station, 2 bin kit station works. The difference being the replenishment is done by a separate 2 bin kit station operator, whereas in 2 bin lappar the pickup train driver himself does it. It is efficient as 2 bin lappar kit station and takes about 15 minutes.

2.3.2 Relation of Unbalanced work with Complexity

CXI interviews are conducted to kit station operators and tåg drivers at 2 different times. The results below show the perceived complexity at different problem areas for both kit station operators and tåg drivers.

CXI measurements (set 1) - tåg & kit participants

![Image](image.png)

CXI measurements (set 2) - tåg participants

![Image](image.png)

Figure 2.12: Set 1 and 2 results of CXI of Material Handling
From the 2 sets of interview conducted, we can see that the problem areas which are most complex for both the kit station operators and tåg drivers are the

- Product variants
- Work content
- Layout

Balanced and Unbalanced work:

According to our definition of complexity we have figured the balanced and unbalanced work for the work done on factory level.

Balanced work:

- Materials from 2 bin kit station
- Materials from 2 bin lappar - C hall

Unbalanced work:

- Trådhylla from logistics section
- Glashylla from L hall
- Materials from kit station (B hall)

It’s not the replenishment process of trådhylla, glashylla and materials from kit station are itself unbalanced work but the in the process of replenishing these materials, a lot of unbalanced work are being carried out. The common unbalanced work being carried out is shown and solutions to reduce these unbalanced works were worked on.

2.3.3 Common Unbalanced Work

From the value streams the common unbalanced work are found to be,

- Too many places to pick up the materials for the train driver
- Excessive storage of materials
- Improper contact between coordinator and local forklift driver
- The materials are kept at a faraway place
3. Current Situation and Recommendation

3.1 Current Situation

Electrolux factory in Mariestad is a dedicated facility for the freezers and refrigerator assembly. The lines are independent for the different products but they are flexible to the extent that they can accommodate any variant of freezer and refrigerator except the battery cabinet assembly line. The freezer line can accommodate any type of refrigerator and the refrigerator can accommodate any variant of freezer.

The freezer assembly line uses lean techniques of assembly. The cabinets are pulled by the next stations to carry out the assembly operation. The cumulative of 60 stations are responsible for the construction of the fully operationally freezer. Last 10 stations of the line B72 are allotted for carrying out the variant assembly. As this thesis is concerned with the variant assembly section of the assembly line B72, we will discuss the current working of that particular section.

The variant assembly components are supplied from the various logistics sections viz.

a) Kit stations
b) C-Hallen
d) Kit Golv
e) L-Hallen

The materials sent from the kit station are ordered by the ERP system. The material from the C-Hallen, Kit golv and L-Hallen is replenished by using a simple Kanban system. The train drivers collect material from different locations and transport it to the assembly line and place them in the right shelves. The co-ordinator take the empty boxes and place them in the place assigned for them, the train driver delivers the material and then takes the empty boxes back to the stores. The co-ordinator checks weather the right material has reached the right station and whether the line operator can access it and use it for the assembly purpose.

3.2 Recommendations Station Level

3.2.1. Simplifying Parts Presentation

Current Situation:

The Line operator in the variant section waits for the cabinet to arrive to his station. Once it reaches the ramp the operator checks the skåpsbild i.e cabinet drawing pasted on the surface of the cabinet and picks the right material from the material rack and fixes it in the cabinet. The material involves different types of shelves, guides, locking pins, clamps, hinges, smörfacks(butter trays), dorracks(door trays) and the egg racks. The cabinet drawing
is a 2D cad drawing and has the labelling done on it. The operators read that and pick the right shelves and other components. As the operators in Electrolux are quite experienced they by now know which components are needed for which type of variant. As a usual practice they do not check the drawing in detail and make the use of their experience to select the right component.

Problem statement:
To finish the work in the given takt time, occasionally they fail to recognise the right component and end up inserting the wrong component. We found that this is the problem of the part presentation which is not so much clear to the operator.

Recommendation:
The Skåpsbild or the cabinet drawing should have a 3 dimensional representation of the parts to be fitted in the cabinet as shown below.

![Current Skåpsbild](image1.png) ![Proposed Skåpsbild](image2.png)

*Figure 3.1: Skåpsbild*

### 3.2.2. Improving quality of the work – Workbench besides the material container

Current Situation:
Amongst the 8 variant stations only 4 are operational and different assembly operations are carried out in those. Every station has a space for material rack, two big containers for the shelves and one buffer space for the big container as shown in the figure (3.2).

Problem Statement:
The two containers contain two different types of shelves and they are fitted in different cabinets according to the cabinet drawings. The two containers standing at the station create a hindrance to the work of the operators and the operator gets less space to move in the station. One of the containers is unnecessarily standing at the station.
As a result the operator has to do the assembly of the shelf and the locking pins/hinges on the container as shown in the figure (3.2).
Recommendation:

There should be a workbench in front of the station and it should be placed between the material rack and the container. The workbench will facilitate the assembly of the shelves and will also hold assembled shelves which the operator keeps ready for the next upcoming
cabinets. The new layout will look like the figure (3.5). The cell level change is shown in the figure (3.6).

![Figure 3.5: Suggested Station Level Change](image)

In the proposed cell layout, the two containers should be movable so that after every batch the coordinator can interchange the positions. The existing stand on which the Glashylla (Glass shelves) containers are kept is a stationery stand. This stand should be replaced with the trolley as shown in the figure (3.8). This will help the operators to move it in the variant section.

![Figure 3.6: Suggested Station Level Change](image)
3.2.3. Reduce Line stoppages due to repair work at the repair station

Current situation:

The last station i.e. station 60 of the variant section is the inspection station. The assembled cabinets are inspected there for all the variant components and their fitments. The cabinets are even inspected for any defect related to the aesthetics of the interior or exterior. After the inspection the information is fed in the computer and then passed to the packaging section.

Problem Statement:

When some defect is found in the cabinet the line operator informs the coordinator and he then pulls the cabinet on to the repair ramp as shown in the figure (3.9).
When the cabinet is pushed back to the main line the conveyor stops. The sensors on the line have to sense the cabinets in sequence and if suddenly any cabinet leaves the main line and again enters and comes in proximity of the sensor it stops the conveyor.

![Figure 3.10: Current Setup](image)

When the conveyor stops the coordinator has to go all the back to the control panel and switch on the conveyor. The locations have been shown in the figure (3.11).

![Figure 3.11: Switch Location](image)

When the conveyor stops the assembly work in the station halts till the coordinator turns it on from the control switch.

Suggestion:

The conveyor has to be switched on from the control panel located far from the repair station so we suggest fixing a control switch near the repair station. This will enable the coordinator to have the control on the line itself and the line will never halt due to the repair work.

### 3.2.4. 1 minute Improvement walk

The work place should continuously change for betterment and this is the motive of Kaizen. To introduce kaizen philosophy in the working culture of the line operators we suggest this event called 1 minute walk.
In this every coordinator along with the team leader should think of some change in his particular section and should make efforts in implementing this change. This can be a minor or major change. Major change takes time so it should be communicated to the plant manager. The plant manager should visit every section everyday and spend 1 minute discussing the change with the coordinator. Plant manager should make sure the continuous improvement stays in the minds of the line operators.

3.2.5. Signaling System

Current situation:

The responsibility of the coordinator is to make sure that all the line operators in his particular section are getting the components in time and at the required time. The line operator has to call the coordinator on many occasions like the pallet becomes empty, when the trolley has to be moved, repair work, problem with the conveyor, conveyor stop etc. The coordinator is normally present in his section.

Problem statement:

The coordinator is responsible for the 8 variant assembly stations and 2 stations in the testing part, there is a cabinet drying unit in between variant assembly stations and the testing stations. When the operator is on the testing part the line operators needs some assistance on the assembly side they have to shout for him so that he can listen to them.

Suggestion:

Install a visual and audible signaling system in the variant section. Every station in the variant assembly section should have a switch and when it pressed the subsequent station number should be displayed on the screen mounted. We have marked some locations for the screen considering the best possible visible place. The following figures show the possible location.

Figure 3.12: End of the B72

Figure 3.13: Side wall of dryer (variant assembly side)
The signaling system will consist of the following:

- A switch at the station.
- Screens displaying the station number: At least 2, one on each side of the drying unit.
- A buzzer sound.

Effects:

The operators can easily communicate with the coordinator and coordinator can keep the work uninterrupted.

3.3 Recommendations Factory Level

3.3.1 Placing all ōrdhylla containers in C hall

Current Situation:

There are 3 types of ōrdhylla that are currently used in B72 line. The ōrdhylla are used in big batches with each of it carrying 290, 120 and 200 pieces each. These 3 ōrdhylla big boxes are received from the suppliers in 3 different places in the company as inventories such as AMH, Kit Golv and Golv. Three different replenishment routes are used in order to replenish these ōrdhylla big boxes to the assembly line. The ōrdhylla boxes from the AMH, Kit Golv and Golv are internally replenished by the local pickup trucks using the Kanban which will be in the empty boxes kept by the pickup trains. The local pickup trucks remove the empty boxes and replenish them with a new ōrdhylla box so that the pickup trains replenish it to the assembly line.

Problem Statement:

Since there are 3 different routes to replenish the boxes from 3 different storage places, it takes a longer time in replenishing the ōrdhylla to the assembly lines. The other problem being, the work for the local fork lift driver in the logistics section in assisting the internal replenishment of the ōrdhylla boxes to the pickup trains which takes it to the assembly line.
Recommendation:

The suggestion we would like to imply here is to keep all the 3 trådhylla boxes at one place, ideally the C hall.

Figure 3.16: Space to accommodate Trådhylla – C Hall

Figure (3.16) suggests the place available in the C hall and the current trådhylla big boxes kept there (Golv and Kit Golv).

Effects:

By keeping the trådhylla box in the C hall, the variety of places in which the boxes are being replenished can be eliminated. The Golv and Kit Golv are the places in the C hall only; therefore the boxes in the AMH can be kept along with these in the C hall itself. By doing so, the work of the local fork lift drivers can be minimized to taking away only the empty boxes to the gates. The pickup train drivers himself can replenish the required trådhylla box from the C hall similar to the other materials that are kept in the C hall. They do the replenishing of other materials every 15 minutes. They can easily add this work to their schedule as it will be only very few times in one shift. This will considerably reduce the lead time in replenishing it to the assembly line.
3.3.2. Reducing the buffer in the assembly line

Current Situation:

![Current Buffer Space](image1)

The trådhylla and glashylla big boxes are currently placed in a buffer place right next to the variant section of the assembly line. The picture represents the buffer space used currently and the trådhylla and glashylla boxes could be seen. The space is used to store boxes more than what is required at one point of time. There coordinator is responsible for moving the boxes from this buffer place to in front of the individual assembly stations and also removing the empty boxes from there to the pickup points. The following table will show the distribution of trådhylla and glashylla used in each station in the variant section of the assembly line.

<table>
<thead>
<tr>
<th>Trådhylla Type No.</th>
<th>Quantity/box</th>
<th>Stations used in</th>
<th>Glashylla Type No.</th>
<th>Quantity/box</th>
<th>Stations used in</th>
</tr>
</thead>
<tbody>
<tr>
<td>208591601</td>
<td>290</td>
<td>53,55</td>
<td>208886922</td>
<td>500</td>
<td>58</td>
</tr>
<tr>
<td>243386601</td>
<td>120</td>
<td>58</td>
<td>208886903</td>
<td>500</td>
<td>55</td>
</tr>
<tr>
<td>243364801</td>
<td>200</td>
<td>55</td>
<td>208886901</td>
<td>500</td>
<td>53,55,58</td>
</tr>
</tbody>
</table>

![Trådhylla & Glashylla distribution](image2)

Problem Statement:

Since there is more than necessary trådhylla and glashylla boxes present in the buffer place next to the assembly line. It occupies a lot of shop floor space. There is a lot of potential to reduce this unnecessary storage of buffer and make it lean.

Recommendation:

Each station has 3 allotted places for keeping big boxes in front of the operator’s work space. 2 right next to the work place and 1 at the far end of the station. A proper arrangement
can be made in such a manner that a trådhylla and glashylla big box can be kept in 2 places close to the operator and the 3rd position can be used in replenishing the empty boxes. The picture below describes the arrangement.

![Figure 3.19: Proposed Change in front of Assembly Station](image)

From the table above, we can see that the trådhylla types 4801 and 6601 are used in the stations 55 and 58 alone. Similarly the glashylla 6903 and 6922 are used in the stations 55 and 58 alone. Therefore these 2 trådhylla and glashylla big boxes can be kept permanently in front of station 55 and 58. The trådhylla 1601 alone is used in stations 53 and 55. Similarly glashylla 6901 is used in stations 53, 54 and 55. Therefore these two big boxes can be kept in front of station 53 and a buffer of these boxes can be kept in the buffer space in case if it is needed in other stations. The movement of boxes is managed by the coordinator.

Effects:

The effect of this arrangement is that it saves a lot of unnecessary buffer space in front of the assembly stations and makes it lean. It also implements the concept of just in time replacement rather than piling up huge stocks beforehand.

### 3.3.3. Replacing big boxes to small boxes for trådhylla

**Current Scenario:**

![Figure 3.20: Trådhylla Big Box](image)
In the current situation, huge boxes of trådhylla are used. These big boxes are stored more than what is required at one particular point of time. Moreover the amount of trådhyllas each boxes contain is huge. The details are in the table below,

<table>
<thead>
<tr>
<th>Trådhylla</th>
<th>Quantity/box</th>
<th>Stations used in</th>
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</thead>
<tbody>
<tr>
<td>208991601</td>
<td>290</td>
<td>53,55</td>
</tr>
<tr>
<td>243386601</td>
<td>120</td>
<td>58</td>
</tr>
<tr>
<td>243364801</td>
<td>200</td>
<td>55</td>
</tr>
</tbody>
</table>

Figure 3.21: Trådhylla Distribution

The coordinator is responsible for arranging the big boxes of trådhylla from the buffer inventory space to the place in front of each station. The replenishing of trådhyllas through Kanban is also handled by coordinator by handing out the Kanban to the pickup drivers and receiving the replenished big boxes from them.

Problem Statement:

Since all big boxes are used in front of each assembly station, the space for the operators in the station is much reduced thereby restricting their space of movement.

Recommendation:

The solution that can be used in order to solve this situation is by using small boxes in place of big boxes, i.e. using small batches of trådhyllas. Since a big box of trådhylla can contain from 120 to 290 trådhylla there can be many small batches if a small box is used. In order to find out, a scenario is assumed for full capacity and just one type of freezer.

Scenario Calculation:

Allowed weight one can carry in industries in Sweden 12 kg

Weight of empty small drawer = 1840g

Weight of one trådhylla = 600g

Therefore a small drawer can hold up to 16 trådhylla (which will be 11.4kg)

One full big box of each trådhylla will be accommodated by,

<table>
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<tr>
<th>Type No</th>
<th>Quantity/small box</th>
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<tr>
<td>208991601</td>
<td>19</td>
</tr>
<tr>
<td>243386601</td>
<td>8</td>
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<tr>
<td>243364801</td>
<td>13</td>
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</tbody>
</table>
• Assuming 420 pieces of one variant of freezer in a day,

• One station will need **14 small boxes/day**

• Therefore the entire variant section will need **42 small boxes/day in total**

• The material rack in the assembly line itself can accommodate the small boxes

• All the small boxes can be kept alongside doorfack and smörfack in C hall

• The pickup trucks which replenishes using simple kanban now can take up this work as well

• The truck right now are not running in full capacity, therefore they can accommodate this boxes too without increasing the number of trains

**Limitations**

• The size of the small box currently used does not apply for all 3 types of trådhylla

• The space for keeping as many boxes needed in C hall

• The cost constrains of pre-kitting it into small boxes by suppliers

**Effects:**

Though it may increase the number of boxes used at the station, which in turn occupies a lot of space in the material rack in front of each work station, it reduces the huge unused inventory waiting in front of each station and in the buffer inventory space. It will introduce and implement the concept of just in time replenishment.

### 3.3.4. Replacing glasshylle from L hall to vacant space in front of G4

**Current Scenario:**

In the current scenario, the glasshylle big boxes are kept in the L hall (which is present in far away from the production plant). The value stream of replenishment of a box of glasshylle is represented below.

![Image: VSM of Glasshylle from L hall](image)

*Figure 3.22: VSM of Glasshylle from L hall*
The currently used space in L hall looks like,

![Image 1](image1.png)

**Figure 3.23: Glashylla boxes in L hall**

Problem Statement:

The current method takes about 40 minutes on stoppage time of kanban sent out and replenished material taken back both put together. There is no communication between coordinator and the local fork lift driver who replenishes the boxes.

Sometimes when materials are needed urgently, the coordinator used to call the team leader of logistics and the team leader informs the fork-lift driver through walkie-talkie, who then replenishes.

Recommendation:

The entire of glashylla big boxes can be kept in the vacant space in front of G4, instead of just using that space for replenishments. This will eliminate the use of work from the local fork lift driver. Thereby it eliminates the problem of 30 minutes of waiting time between pick up and replenishment. The coordinator himself can replenish glashylla big box and it becomes a simple Kanban replenishment technique. The space in front of gate G4 resembles,

![Image 2](image2.png)

**Figure 3.24: Available space in front of G4**
Limitations:

- Space has to be managed between the materials already there
- A shed to protect things have to be made during winters

Effects:

There will be a huge reduction in replenishment time, from 40 minutes to about 10 minutes. The buffer inventory in front of the assembly can be completely eliminated and all replenishments can be made from G4 gate.
4. Discussions and Conclusion

4.1 Discussions

The thesis was done at Electrolux Mariestad when a lot of changes and improvements were taking place. Just about a year back (by early 2011), the entire assembly line was re-laid and the entire production process was changed and there was still lot of small changes taking place each and every day. We as per our thesis suggested a few changes in order to assist Electrolux in their newly changed assembly line and for its material handling. After the thesis is completed, it was presented to the Electrolux’s higher officials and department heads for its feasibility and discussions. A few important suggestions were made from the discussion and it’s published below,

1. Many of the recommendation with respect to the variant section of the assembly line have included the work of the coordinator as an integral part of it. But from the discussions conducted, it is to be noted that the work of the coordinator is not defined and he is not ideally a part of the variant section of the assembly line. He is present to fill in the short comings of the line, but since there are a lot of short comings like, replacing someone if he or she is absent/needs a break, he is in charge of materials being replenished at the right time from the nearby buffer inventory, he is responsible for the small per assemblies and repairs in the variants if any.

2. With respect to the recommendation of replacing all the trådhylla big boxes at the C hall, it is not possible because the C hall is currently not under the material handling section if Electrolux. Therefore replacing them in C hall will largely increase the cost of storing goods.

3. With respect to the recommendation of replacing trådhylla big boxes to small box, apart from the fact that not all 3 types of trådhylla can be accommodated by the current small box available at Electrolux, the management in Electrolux are planning at replacing the big boxes of glashylla into small boxes. This idea was not considered because the supplier was from a very far distance.

4. With respect to the recommendation of replacing glashylla in space front of gate G4, it is absolutely not possible because the space in front of gate G4 has an underground passage forklifts to move and the weight of each box of glashylla is about 1 tonne. Therefore when considerable amount of boxes when kept, it won’t hold and it will break.
4.2 Conclusion

From this master thesis and its results and discussion it is evident that there is a lot of scope for improvement in the assembly line as well as the material handling section of Electrolux. A lot of continuous improvement techniques are required at the assembly line and there is immense scope for aggressive improvement. With the material handling section, there is a lot of unnecessary movement of trains and forklifts at the moment. The material mix in which replenishment are done to the assembly line can also be improved.

This master thesis, a part of COMPLEXITY project which is aimed at identifying the “unbalanced work” at station level and factory level was defined and analyzed. By definition and with help of time study the unbalanced work at station level is segregated. Similarly in the factory level, using the same definition and with help of Values Stream Map the unbalanced work is segregated.

The questionnaire made by Sandra (Appendix 1) in order to find out the CXi (Complexity Index) at each station and further determining the CXi value at each problem area was very useful in connecting the unbalanced work at each station to the complexity level of the station. The focus on problem areas in the CXi gave a detailed insight on where exactly lies the unbalanced work, thereby reducing it.

Finally, the results of this Master Thesis gives an idea about the percentage division of balanced and unbalanced work in a particular station and factory as a whole. The work done on reducing the unbalanced work, thereby reducing complexity gained importance for the management of Electrolux as it helped in improving the process and quality of the system that is being put to work at the moment.
5. Future Scope

This analysis can be used in a company where there is a high complexity due to more number of variants. For the study we have done analysis of the unbalanced work in the variant section of the assembly line.

In the future scope this can be done for all the sections of the assembly station. The work and work responsibilities in the logistics section are very diverse and also the tâg participants have to take care of the different routes hence the analysis of the unbalanced work in logistics can itself be a indigenous research topic.

While conduction CXI interviews, we got comments from the line operators and the logistics operators. As the complexity study focuses on quantifying the perceived complexity it is very important to have comments from the operators about the working of the systems and how they can be improved. The following comments can be used in the further work to make the necessary changes in the systems.

CXI findings for Assembly:

• Support system for instruction.

The operators feel they would like to have electronic support system for assembly, currently they are using instructions printed in paper.

• Use of vacuum suction to collect the plastic covers. Reuse of plastic covers.

The assembly operators feel that removal of plastic covers for fixing of each tray in the cabinet occupies a lot of time. The bin to collect these covers also gets filled soon and it is the job of the operator to empty it. They feel a vacuum suction arrangement in front of each station which assembles trays would be useful in collecting these plastic covers. Also that the plastic covers do not have any damage and are directly recycled. This covers can be resent to the supplier for reuse.

CXI findings for Logistics:

• Ergonomics for the train driver

The train driver has the common compliant of leg pain, since he/she has to stand in the train throughout the day while driving it.

• Lack of space when they turn the trains
There is very limited space for the trains to take turns inside the assembly area. It takes immense skill of the train driver to negotiate each time when they are taking turns.

- Improve the signal for the train

  The train drivers feel they need more proper communication for the trains, meaning improving the signals for the train.

- Some routes are difficult to handle

  The train drivers feel some routes are difficult to handle, they tend to miss replenishing a few boxes because of improper replenishing order.

- Some materials are difficult to handle

  Some materials are too big, heavy and are not in a shape which will give aid to carry easily. Therefore few materials are difficult to handle.
6. References

Liker, Jeffrey K, “The Toyota way: 14 management principles from the world’s greatest manufacturer”, McGraw-Hill, 2004


Claesson, T. “Implementing Lean Production”, Chalmers University of Technology, Gothenburg, 2011


Andersson, L. Björnelund, M. “Complexity is affected by the Level of Automation in a Production System – A Case Study brought out at Electrolux”, The Royal Institute of Technology, Stockholm, 2010.


Oriz, C. A. “Kaizen Assembly - Designing, Construction and managing a Lean Assembly Line.” 2009


www.electrolux.com
7. Appendix
Appendix 1:

Hej

Den här enkäten har utformats för att hitta lösningar som kan underlätta och förbättra ditt arbete. Enkäten är anonym.

När du fyller i enkäten är det viktigt att du tänker på en utvald station.

Utvald station: ________________
Antal år inom montering: ______år

Enkäten tar upp: produktvarianter, arbetsinnehåll, layout, verktyg och stödverktyg samt arbetsinstruktioner.

Tack för din medverkan!

Med vänliga hälsningar

Sandra Mattsson, Tommy Fässberg, Åsa Fasth och Johan Stahre från Chalmers
Ulrika Harlin, Gunnar Bäckstrand och Per Gallander från Swerea IVF och
Anna Davidsson från Volvo Car Corporation
Bedöm hur väl påståendena stämmer för det arbete du utfört under den senaste månaden vid denna station/station. Bedömningsskalans är 1-5 där 1 är instämmer inte alls och 5 är instämmer helt.

### A. Produktvarianter

1. Det finns många olika typer av varianter vid denna station

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2. Många varianter liknar varandra i karaktär och/eller utseende vid denna station

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3. Det finns varianter som återkommer väldigt sällan vid denna station

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4. Varianterna vid denna station kräver olika monteringssätt (tex ordning, svårighet, olika många moment)

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<td>Instämmer inte alls (precis samma monteringssätt)</td>
<td>Instämmer helt (helt olika monteringssätt)</td>
<td>Vet ej /ej relevant</td>
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5. Komponenterna som tillhör de olika varianterna är väldigt lika vid denna station

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**B. Arbetsinnehåll**

6. När jag arbetar på denna station vet jag vad jag ska göra

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7. Jag känner oftast att jag hinner med arbetet vid denna station

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8. Jag har många andra arbetsuppgifter utöver monteringsarbete vid denna station (t ex emballagehantering, 5S, dokumentation etc)

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9. Mitt arbete vid denna station påverkas ofta av oplanerade förändringar/avvikelse (t ex ändrade planer, nya instruktioner/varianter, eller maskinstörningar)

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</table>
10. Jag är med och påverkar förändringar som berör denna station

1 2 3 4 5
Instämmer inte alls Instämmer helt Vet ej /ej relevant

C. Layout

11. Denna station är bra utformad gällande åtkomlighet

1 2 3 4 5
Instämmer inte alls Instämmer helt Vet ej /ej relevant

12. Denna station är bra utformad gällande tunga lyft i monteringsarbetet

1 2 3 4 5
Instämmer inte alls Instämmer helt Vet ej /ej relevant

13. Denna station är bra utformad gällande materialfasaden (t ex med avseende på emballage-typ, placering, enkelhet att plocka och sekvensmaterial)

1 2 3 4 5
Instämmer inte alls Instämmer helt Vet ej /ej relevant

14. Placeringen av verktyg, fixturer och delar är generellt satt bra vid denna station

1 2 3 4 5
Instämmer inte alls Instämmer helt Vet ej /ej relevant
D. Verktyg och stödverktyg

15. Verktygen/fixturerna som används vid denna station är väl anpassade efter de arbetsuppgifter jag har

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16. Monteringen av olika varianter vid denna station kräver olika typer av verktyg

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17. Vilka stödsystem finns vid denna station?

- Pick-by-light (lampor som tänds vid rätt del)
- Streckkoder och scanners
- RFID system
- Feedback från skärmar
- Feedback från verktyg (t ex rätt dragmoment och rätt bits)
- Checkpoints (feedback i monteringsarbetet)
- Övriga ________

18. Ovanstående nämnda stödverktyg hjälper mig att utföra arbetet vid denna station

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E. Arbetsinstruktioner

19. Jag läser ofta (dagligen) de arbetsinstruktioner som finns vid denna station

1 2 3 4 5
Instämmer Instämmer Instämmer Instämmer Instämmer Vet ej
inte alls helt helt helt /ej relevant

20. Arbetsinstruktionerna vid denna station är enkla att förstå

1 2 3 4 5
Instämmer Instämmer Instämmer Instämmer Instämmer Vet ej
inte alls helt helt helt /ej relevant

21. Arbetsinstruktionerna vid denna station förenklar mitt arbete

1 2 3 4 5
Instämmer Instämmer Instämmer Instämmer Instämmer Vet ej
inte alls helt helt helt /ej relevant

F. Övrigt

22. Det är lång upplärningstid vid denna station (jämfört med andra stationer/stationer inom mitt lagområde)

1 2 3 4 5
Instämmer Instämmer Instämmer Instämmer Instämmer Vet ej
inte alls helt helt helt /ej relevant
23. Som helhet tycker jag att denna station är bra utformad

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24. Kommentar (t ex möjlighet till förbättring, förändring av stationen/stationen, arbetssätt, stöd eller dylikt)

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Tack för att du tagit dig tid att besvara den här enkäten!
Dina svar är värdefulla för oss

Med vänliga hälsningar

Sandra Mattsson, Tommy Fässberg, Åsa Fasth och Johan Stahre från Chalmers

Ulrika Harlin, Gunnar Bäckstrand och Per Gallandr från Swerea IVF och

Anna Davidsson från Volvo Car Corporation


För mer info kontakta Sandra Mattsson tel 031-772 44 46,
mobil 070-5855981, email: sandra.mattsson@chalmers.se