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# Lean Production-Identification of essential KPIs in a medical production process and design of a visuel interface

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<i>Title and subtitle</i> <b>Lean Production – Identification of essential KPIs in a medical production process and design of a visual interface. (Lean Production – Identifiering av viktiga KPI:er för en medicinsk produktionsprocess samt utformning av ett visuellt gränssnitt)</b>			
<i>Abstract</i> <b>Introduction:</b> Rockwell Automation needs to understand how a lean company wants to visualize different KPIs. Ambu wants to see the value of using such visualization in their company and the effect it might have. Thus the two parts fulfill each other's needs and are the perfect match. <b>Purpose:</b> The purpose of the master thesis is to identify essential KPIs in a medical production process and design a visual interface. <b>Method:</b> The study was made in a case study approach and the data were treated in a qualitative approach. <b>Theory:</b> A theory study within the topic lean and KPI was done as a foundation to formulate the interview sessions. <b>Empirics:</b> The empirics were gathered through the interviews made with the respondents at Ambu. Those were then analyzed by the theory section. <b>General Conclusions:</b> <b>Advices to Rockwell Automation:</b> <ul style="list-style-type: none"> <li><input type="checkbox"/> It's easy to develop dashboards using VantagePoint</li> <li><input type="checkbox"/> Using animations, the KPIs are visualized in a very good way</li> <li><input type="checkbox"/> Perfect tool for lean companies</li> <li><input type="checkbox"/> Easy to drill down in each level and can be adapted to different roles</li> <li><input type="checkbox"/> Can be accessed through the web – worldwide connection</li> <li><input type="checkbox"/> Information can be shared between colleagues in different places in the world</li> <li><input type="checkbox"/> The cell phone – a future possibility</li> <li><input type="checkbox"/> Gantt Schemes must be made as a standard in VantagePoint</li> <li><input type="checkbox"/> In each drill level it's important to have a big overview</li> <li><input type="checkbox"/> Improvements in the heatmap graphic and making heatmaps a standard in VantagePoint</li> <li><input type="checkbox"/> Dashboards are mostly used in the tactical level &amp; down to the operational level</li> </ul> <b>Advices to Ambu:</b> <ul style="list-style-type: none"> <li><input type="checkbox"/> The dashboard implementation is an important element of building up a lean company</li> <li><input type="checkbox"/> Due to continuous improvement, the performance of different operations must be measured and visualized.</li> <li><input type="checkbox"/> Investment in such software makes difference, which must be seen in a long term manner</li> <li><input type="checkbox"/> KPIs are dynamic, thus investing in a dashboard it must be dynamic</li> <li><input type="checkbox"/> Investing in a dashboard will add value to the staff at Ambu</li> </ul>			
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# Preface

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*I want to dedicate this text to all participants who added value to my work!*

## *Thank You!*

*...Charlotta Johansson for introducing me to that thesis work, all help, the good advices, the wise suggestions & taking your time to read the report...*

*...Hans Nilsson for giving me the opportunity to make the thesis work at Rockwell Automation, pushing me forward through the project & the time you took to supervise me...*

*...Thomas Kongstad for taking me in to your Lean team at Ambu, helping me through the interviews & the time you took to manage all interviews with the respondents...*

*...All Respondents that took part of the interviews, for your time, the honest & valuable answers...*

*...The VantagePoint support team, for taking your time, the valuable help & the guidance through the different tasks:*

*...Lars Eyckmann...*

*...André Fliegen...*

*...Tino Jörgensen...*

*...My Family & Friends for their support & patience during the time...*

*Helsingborg, January 2011  
Mohamed A. Hamid*



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# 1. Introduction

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## 1.1 Background

This report presents a master thesis project focusing on lean production.

Lean Production is an ideology used in production in order to minimize all kinds of wastes that contribute to a bad performance. Waste can be e.g. overproduction, unnecessary transportation, and defected products. All kinds of wastes add time in the production and thus affect the company in a negative manner. To minimize waste, the people working in production should have a mentality that everything can be continuously improved. To support their way of working (meaning, in a lean way), they need different tools that simplify the identification and elimination of waste. One such tool is Visualization. By being visible it becomes easier to identify different wastes in production.

Rockwell is an automation company that also develops programs to make performance visible in a company by different animations. This makes it easy for a company to have control of different processes. Today there is a trend in Europe to be lean. So for Rockwell, to be competitive in the market they must adapt their visualization after the lean companies preferences. Thus, they must understand how a lean company thinks. Ambu is a medical company that focuses on the lean concepts and they therefore want to visualize different performance in production. The performance is measured through data output from the machines and combined into Key Performance Indicators (KPIs). A KPI is a digit, usually showed as a percentage, that presents a lot of information in a small space. The information given from a KPI is if an operation is doing good or bad and hence acts as a guidance for a manager to take different decisions.

In this master thesis, a case study was done together with Rockwell and Ambu, with the incentive to develop a visual interface of important KPIs. The result of the master thesis project is twofold; an example of a lean interface developed using Rockwell's product VantagePoint, and an opportunity for Ambu to see their KPIs presented in a different way than they're used to.

## 1.2 Rockwell Automation

Rockwell is a multinational company, which with its front edge competence within automation offers diverse solutions for different industries. Their product portfolio range all from hardware to software solutions.

Many of their products include software solutions that are flexible and have the opportunity to support lean production. VantagePoint is a product that has its focus on performance and visibility. The status of the production performance is viewed in real time on a speedometer and can be accessed via the web. VantagePoint in its nature is very flexible to connect to different machines and gather data. VantagePoint has even the feature to create web-based reports such as trends, x-y plots etc. The reports can then be used by operators, engineers, production managers, management etc. to have a better control on costs, quality, production, assets, resources etc.

## 1.3 Ambu

Ambu with its routes in Denmark, develops, produce and sales diagnose based and life supporting devices for hospital and emergency service. The areas concerned, are:

- Air Management
- Patient Monitoring & Diagnostics
- Emergency care

Almost 98% of their sales are export. This makes the distribution to an important component in Ambus supply chain, since it surely stands for the highest costs.

Ambu puts big energy on being lean and has the ambitions to deal with the requirements needed to be lean. One of the lean milestones is being visible<sup>1</sup>. To fulfil that, Ambu needs a system or software that makes it possible to visualize (on a screen) an overall performance view from the supply chain.

## 1.4 Problem formulation

Being lean gain the production effectiveness and as a result, reduces the costs (Womack, 1990). This is the driving force behind the trend, being lean, that many manufactures today are joining. Being lean affect the way people think and act, which results into behavioural changes. As an effect, this may change the manufacturer's needs. To retain competitive, Rockwell wants to understand those needs from a lean perspective and if needed adapt VantagePoint thereafter.

Ambu has many years of experience in lean and has many lean expertises in the company. They work hard to find ways to become more effective. Today Ambu are trying to visualize production performance on a screen as a KPI called OEE<sup>2</sup>. The screen is placed in the production area that shows the OEE as a graph. The graph might be a bit hard to understand, so Ambu wants to make it more pedagogical and visible for relevant people. Further work is to develop an interface containing performance overview from the whole supply chain.

In this case, Rockwell and Ambu is the perfect match. They both fulfil each other's needs. Rockwell wants to understand the needs of a lean thinking manufacturer and Ambu wants to make a pedagogic interface that can be accessed from a computer (via the web) and also connect it to a screen visible for everyone.

## 1.5 Purpose

The aim of this thesis work is to identify crucial KPIs and design a prototype interface for VantagePoint.

## 1.4 Delimitations

Delimitation has been made in the study, focusing on the production site when developing the dashboard. Further delimitation is made by having a focus on the OEE and not including other KPIs in the dashboard development within VantagePoint. That's due to the visualization today at Ambu, the OEE is viewed on a big screen. Developing a dashboard with the same constituents may depict the difference and hence the advantages of using a dashboard instead of a graph. Which also give a clear picture when viewing the same information but in a different way and hence one are comparing apples with apples. The other reason of delimitating to the OEE is due to its lean properties.

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<sup>1</sup> In a lean context, the word visible refers to many applications. See the Theory section **3.3.1 Visual Management** for more details on what visible, from a lean perspective, can mean.

<sup>2</sup> OEE - Overall Equipment Effectiveness, further reading in the Theory section **3.4.4 OEE**

# 2. Method

---

## 2.1 Approach<sup>3</sup>

The work is divided in 7 steps:

- Step 1: Define purpose
- Step 2: Study relevant theories
- Step 3: Interviews at Ambu
- Step 4: The software tool VantagePoint
- Step 5: Analysis
- Step 6: Prototyping
- Step 7: Result and discussions

Step 1: The first step in the project is to formulate the project. It is important that all parts involved in the project understands the project in the same way and that all parties have the same goal. The project formulation was done together with Hans Nilsson (Rockwell), Charlotta Johnsson (Lund Institute of Technology) and Thomas Kongstad (Ambu).

Step 2: The foundation of the project lies in the intersection of the three domains; automation, lean production and key performance Indicators (KPIs). In order to understand the three domains a literature study was done.

Step 3: To understand the lean culture and catch the overall idea in what kind of information that is relevant to visualize at Ambu, it was needed to do interviews. To get the overall opinion, all respondents had different roles in the company. Several of different questionnaires were designed to adapt to the different respondents, but all had the same core questions. The output from the interviews was used for two purposes. One, to understand lean and its principles and somehow analyze how Ambu applies lean as a whole. Second, to understand what kind of KPIs that is important to visualize for Ambu and how they should be visualized.

Step 4: Software tool VantagePoint

Step 5: Analysis

Step 6: A simple design of a prototype was done showing how to visualize KPIs. Simply done to give Rockwell and Ambu an overview of the output from the interviews. Getting feedback from them about the design was of big value. Once both parts agreed upon the simple prototype design, a design of a real prototype In VantagePoint was started.

Step 7: The real prototype in VantagePoint was done in accordance with the simple prototype.

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<sup>3</sup> Read this section simultaneously with **Appendix A.1**.

## 2.2 Study

### 2.2.1 Purpose of study

The purpose of making a study can vary and therefore affect the structure of it. Studies are classified in four different groups, as below (Lekvall & Wahlbin, 2001):

*Exploratory studies* – Are made, when there is lack of information about the current problem area. The study can be a first step to take in a research work with the purpose to precise which kind of questions that is relevant to ask.

*Descriptive studies* – Has the purpose to make a study in depth. To be able doing such study requires good prerequisites about the subject, so that right questions are asked to the right respondents.

*Explanatory studies* – Are aimed to give an explanation for different situations and/or problems. It requires a deep knowledge about the subject to understand the different couplings and relations.

*Predictive studies* – Making future assumptions may create opportunities and improve the actual status of a situation.

Because of the lack of information about lean and KPIs, as a first step, an exploratory study was made to get a brief idea about the subject. Thereafter, the relevant and most significant issues were studied in more detail as a descriptive study.

### 2.2.2 Study approach

A study approach can be either fixed or flexible (Lekvall & Wahlbin, 2001). In a fixed study, its structure and the kind of information to be gathered are decided in an early stage. The results from a fixed study are often given in a form of digits. Flexible studies have a structure that develops as information is collected and the results are given in words rather than digits.

Fix and flexible studies can be split into two dimensions each. The dimensions have different approach depending on whether the study is fix or flexible:

#### 1. How the study are made

**Flexible** – a case study approach. This approach is common in small-scale studies. Often, only one object is studied and the interest is directed toward details and depth. Compatible with certain exploratory studies, when details about a typical process are needed and not having any preferences on what's important to study and what's less important. An advantage is that a respondent can be contacted again and eventually complete the already given answers in more detail. A case study tends to answer on the question "how" and focuses on the present time.

**Fix** – a cross-sectional approach. Synoptically study to compare a bigger audience breadthways. Where statistical methods are of big importance. There are two types of a cross-sectional approach:

Survey approach – Is also called, mapping. Rather than having a depth in the study, the purpose here is to get a wide and a synoptic picture of it. Observations and registrations from reality are made passively without any activities, trying to affect it.

Experimental approach – An approach that many associates with elaborative approach. The studied environment are actively controlled and manipulated so that interesting parameters are clarified.

## 2. How the data are treated

**Flexible – Qualitative approach.** The data analyse is done with words and aims to give a detailed description of reality. The study is often affected by the involvement from the investigator.

**Fix – Quantitative approach.** The data analyse is done with digits, which with statistical methods makes it possible to study correlation and therefore compare different output. Here the investigator can't affect the study.

The selection between a fix and flexible study, rest on the method of analysing the data. This study made aims to analyse how Ambu wants to visualize KPIs and how they work. Since, the analyse can only be done with words and the study aims to give answer on the question; "how", the study are of a flexible type. So the study is made in a case study approach and the data are treated in a qualitative approach.

### **Selection method**

Next is to do a selection from the considered target group. The selection must be done very carefully so that the result can be representative from the target group. Planning a study, it's important to know how the respondents are selected. There are two types of selection method:

*Probability sample* – The chosen respondents represents a cross-section of the target population.

*Non-probability sample* – When not possible get data to do a statistical assessment of the target population. For a small population, it's of advantage to do a non-probability sample because a probability sample is time consuming. Further, a common type of a non-probability sample is:

Evaluation selection: The selection considers that the respondents attributes fulfils a certain criteria, those with such attributes are of highest priority to select.

To understand how lean are applied at Ambu and the kind of information to visualize, the respondents selected must have experience within lean and/or KPIs. Beyond that, respondents were chosen horizontally and vertically from the organisation, so that the general opinion was caught. Because Thomas Kongstad knows which respondents that fulfil those requirements, he made the selection. So the selection method used is an evaluation selection – a non-probability selection.

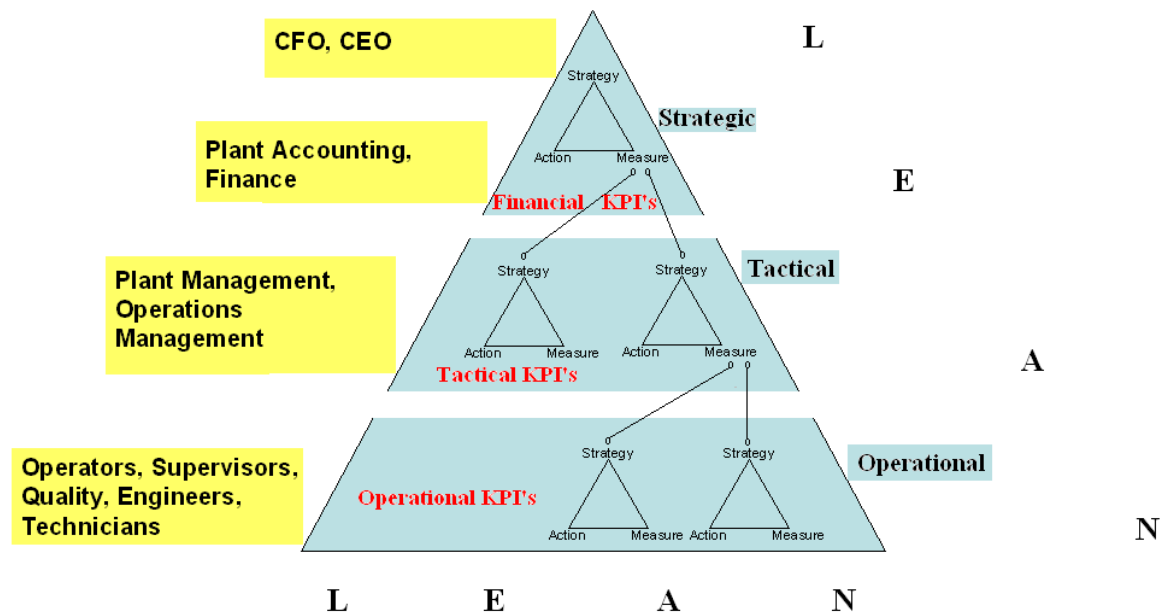
# 3. Theory

## 3.1 Disposition

The foundation of the project lies in the intersection of the three domains; lean production, key performance Indicators (KPIs) and strategic/tactic/operational decisions.

Introducing lean in a producing company, is not a short-term project. It's rather a mindset and a culture that deals with continuous improvement in the whole corporate, from top to down. In each level there are different roles and the common in between is that everybody has the same objective, namely to make continuous improvement. The decisions taken in each level can be categorized into a strategic, tactical and operational level. To take a decision in those levels, different performance measures are needed, so called Key Performance Indicators (KPIs). In the strategic level, financial KPI's are measured, in the tactical, tactical KPI's are measured and in the operational level, operational KPI's are measured.

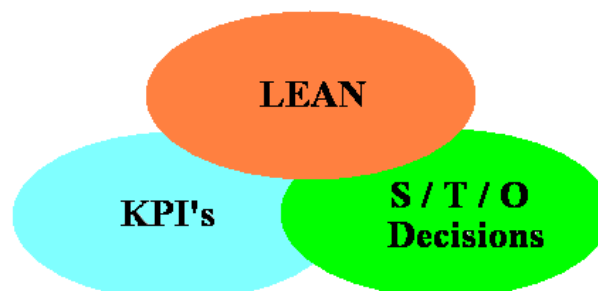
All those three parts are correlated and dependent on each other, see figure 1.



**Fig. 1.** Hierarchical Decision Levels in a Corporate with KPI measurements as a support. Lean thinking is embedded in all levels.

*Inspired and modified from: Metrics that Matter Guidebook & Framework © 2006 MESA International*

This chapter is structured according to these three domains, it also includes reflection on the correlation in between, see figure 2.



**Fig. 2.** The Disposition of the Theory chapter.

## 3.2 Strategic/Tactical/Operational Decisions

In a corporate there are different decision levels and hence different roles for each level. The decision hierarchy in a company is split up into three levels which consists of people with different roles, see figure 3. The highest level refers to decisions made in a long term basis, i.e. yearly basis. Those decisions are made as a plan of how to achieve different objectives, thus setting the ship course. Therefore, that level is called the strategic level. In the lower level, the decision made is in a short term basis, i.e. monthly basis. The goals set for the company must be achieved, so to avoid a big course deviation one must be ready for different kind of problems that might occur during the year, hence one must predict and be well prepared. Thus, if a problem occurs one are prepared so that the ship doesn't deviate from the course set in the strategic level. That level is called the tactical level. The third and hence, the lowest level – decisions are made in a direct order, i.e. hourly basis. Those decisions are made directly when a problem occurs, thus one are taking action in order to eliminate the problem at once. Referring to the ship scenario, if a storm occurs one must make fast decisions and hence adjust the course to be in alignment with the route set. That level is called the operational level.



Fig. 3. Hierarchical Decision Levels in a Corporate.

## 3.3 Lean Production

To fully understand lean one might go back to its origins, where it started and why.

The rise of lean one may say it was the fall of mass production (Womack, 1990). In 1913 Henry Ford started the world's first moving assembly line. This made it possible to assemble complex mechanical products at high speed and high throughput. At that time, the assembly line became the standard for mass production. Production volume seemed to be more important than quality where the focus was on making the day's production goal. If the quality wasn't perfect, the defects were covered by product warranty. So when the mass producer was focused on fixing problems the Japanese were focusing on making the perfect car in the first time (L. King, 2009).

The question now is why the Japanese worked differently than their western competitors and what external forces that pushed them toward it. This can be slightly explained in a few sentences:

- World War II – Japan suffered from a bad economy and small capital to invest with.
- No immigrant workforce was willing to make repetitive work.
- Small customer base – E.g. Toyota made fewer cars in a year than Ford did in a day.
- Meeting the wide variety of needs, flexibility was of high priority.

In other words, the resources for the Japanese manufactures were of minimum. That made them realize the value of the resources available and aware of using it. Toyota realized that more than other Asian manufactures and with Taiichi Ohno and Eiji Toyoda in the front edge they started to

identify crucial ways in eliminating waste<sup>4</sup>. With that in mind they developed the Toyota Production System<sup>5</sup> (TPS), today known as lean production. The term “lean production” was suggested by the IMVP survey leader, John Krafcik, using the word lean with the intention to describe that the TPS uses less of everything with comparison to mass production. In that context, Krafcik used lean as a description of less resource utilization. But to fully understand what lean is, one might look to the developer of the TPS, namely Taiichi Ohno who made the following statement: The basis of lean is the absolute elimination of waste (L. King, 2009).

### 3.3.1 Toyota Production System

*This section is about the TPS, also known as lean production. Understanding its components and the purpose of it might give a brief idea on what lean is.*

Referring to Ohno, the two pillars needed for eliminating waste are *just-in-time* and automation (automation with a human touch). Those pillars are components of the TPS and are often illustrated as a house, see figure 4.

The foundation for the TPS house are components that are strictly needed for building up the pillars that holds up the house. The component, visual management is the most important one. The intention with visual management is that everything on the work floor should be visual, see section 3.3.3 for further reading.

The left pillar is the just-in-time component and defined as, making just what the customer needs, whenever needed and in exactly the right amount. To fulfil that and make a waste-free flow, Ohno realized that the production rhythm should be in synchronization with customer demand. This is what the word takt (German word for rhythm) stands for.

The right pillar, built-in-quality, is the goal of Ohno’s automation. Eliminating waste is to stop all kind of rework. Having a high quality in the production is the way of stopping rework. And when a problem occurs, to get back to the root cause and eliminate it.

The door into the TPS house is the mentality of the whole company. The people must be highly motivated and keeping in mind that everything can be improved. The process, the way people work and everywhere in the company must be continuously improved for eliminating waste.

The roof of the TPS house is three elements which contribute for a successful business, Highest Quality to The Lowest Cost and Lead Time.

The TPS house is built to illustrate all components that might prevent waste and how they support each other in different levels. The TPS is an ideology on how to eliminate waste, containing different tools for that purpose. And this is exactly what lean is, an ideology that contain different tools to eliminate waste.

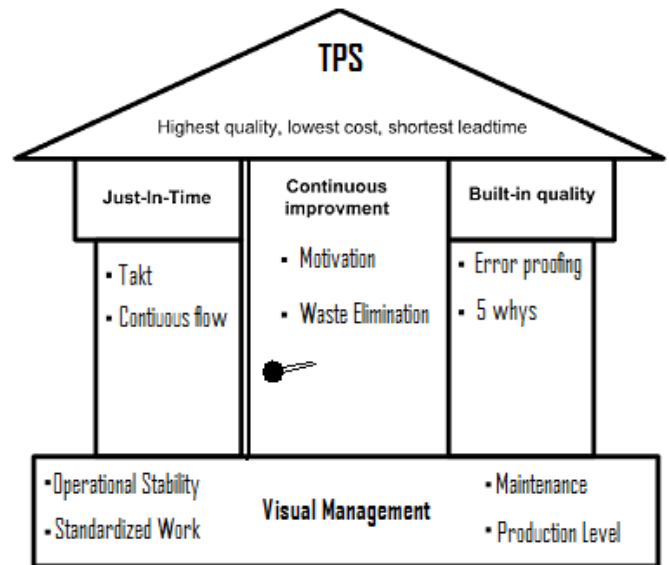


Fig. 4. The TPS House.

*Inspired and modified from: L. King, 2009*

<sup>4</sup>There are different types of waste, see section 3.3.2 Waste.

<sup>5</sup>For a description of the TPS

See section 3.3.1 Toyota Production System.



### 3.3.2 Waste

The essence of lean is to eliminate waste and the word has been mentioned so many times that we now are ready to explain it a bit more in detail.

Any activity that consumes resources (people, material, time) without creating value, as perceived by the customer which indeed exceed the costs, is waste (L. King, 2009), see also figure 5 for a more pedagogical view. There are several types of waste, which by Ohno are categorized in the following:

Overproduction – producing more than the customer order.

Waiting – time spent waiting for an activity to take action, e.g. operator waiting for material to arrive etc.

Transportation – moving materials within a manufacturing operation.

Overprocessing – building more value into the product than is required by the customer.

Inventory – all in-process inventory is waste due to transportation, which results of a non-continuous production flow.

Movement – Ohno refer to the motion that the employees perform when executing a task. Walking from one end of a machine to the other just for executing a task is a waste of time. In a lean environment all crucial needs should be placed in nearby so that the operator's motion is minimized.

Defect in products – the product properties fall outside of specifications or of customer expectations. This result in rework that consumes time and material!

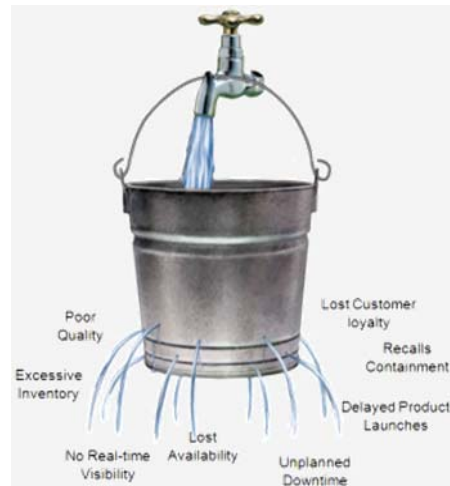
Human potential and creativity – the operators' ability to perform manual work.

Actually, time should also be added as one of the wastes listed above. But the observant reader realises that all eight types of waste add time to the process, hence including time as a ninth type of waste is not necessary.

In each any of those typical wastes, improvement should be done step by step and safely moving forward eliminating each of them, see figure 6. Having special events, gathering the whole staff to comment on what's bad and how it possibly could be improved, is necessary. Those events, also known as Kaizen (continuous improvement) events, should be done frequently. In that way one can be sure that the waste is continuously eliminated. Kaizen is one of the lean tools that are frequently used in any lean factory. Another tool concept that also is crucial and commonly used, is the way being visual. The topic of this thesis is to visualize different KPIs in a way that match the lean thinking, hence the lean tool "being visual" is further discussed in the next section.

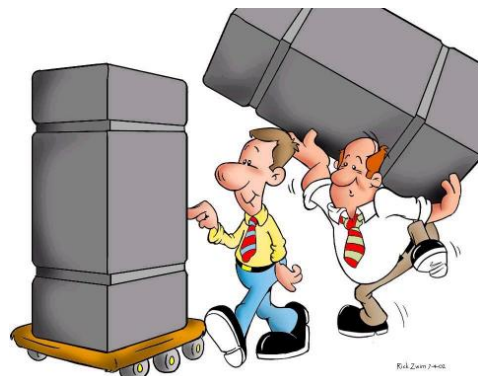
### 3.3.3 Visual Management

In a lean environment it's of big importance to be visual. It's necessary that different work areas are defined by typical signs, equipment is well organized and everybody knows what to do. The work



**Fig. 5.** The water is the resource which is consumed by the bucket and the waste is the water that is spilled without exceeding the water level, thus not adding any value as perceived by the one who's attending to use the water. Which lead to unexpected costs for refill and reparation of the bucket.

*Metrics that Matter Guidebook & Framework  
© 2006 MESA International*



**Fig. 6.** Improvement in transportation.

[www.strategosinc.com/kaizen\\_quick\\_easy.ht](http://www.strategosinc.com/kaizen_quick_easy.ht)

area should be managed in such a way so that a new person who's attending to the work can find everything needed without even asking anyone – the work floor should speak for itself. It's also very important that the work area isn't closed or isolated from the other so that the communication is smoothly done and shortening the feedback loop.

According to lean thinking, a visual management must fulfil six criteria's:

1. Clean, visual and well organized work area – 5S
2. Visual displays
3. Visual schedules
4. Display of relevant metrics (KPIs)
5. Management involved by using the information conveyed from the metrics
6. Open information floor – simplifying the communication through the whole manufactory

Those elements are crucial to build up a lean culture in the company and somehow make waste more visible.

A clean and well organized work area sets the foundation for the other practices. Defining the work area by sight make it easier to see abnormal situations and hence act on the problem. That's the key principle, no defects or problems are hidden. An effective way of achieving and maintaining a visible, visual work area is through the process called 5S. The term 5S come from the five Japanese words which refer to cleanliness, order and discipline, see figure 7. All terms begin with the letter S and that's why the process is called 5S.



**Fig.7.** The five terms from “5S” and their definition.

<http://unpocodetodoperu.blogspot.com/2009/01/resumen-de-las-5-ss-un-temita-en-moda.html>

The purpose of having visual displays is to define the area and the functions being performed. The signs must speak by them self and give as much information as possible about the production. People visiting the area should immediately know where they are, what part of the process they're seeing, what function each piece of equipment performs and how material flows to- and from it.

By displaying the current status of the production, the task and the progress toward it makes everybody aligned with the same goal. It allows the area supervisors to manage much more

effectively by using the information displayed, problems that occur are no longer needed to be reported and that shortens the feedback loop. To make the displays useful and effective, the operators who are the primary users must be involved in their design. The best displays are ones that have been designed by a team including operators, supervisors, mechanics, lab technicians, production schedulers and anyone else whose involved in that part of the process (L. King, 2009). Such process is the perfect candidate for a kaizen event. Having a good display requires the following:

- Relevant to the operation
- Clear & understandable to all users
- Maximum use of symbols and graphics to minimize text
- Frequently updated

Using lights as a signal for the production performance gives much information in a small space. A commonly used configuration is referred to the traffic light, where green signifies that all is normal, yellow that there is a problem requiring attention and red as a signal that the line has stopped. Defining the colour is made by using metrics (KPIs), i.e. the light is green if the metric is above a specific value. Important metrics is those that show current production, deviations with reason, quality and trends (L. King, 2009). Visualizing trends makes people to have a sense for whether the performance is improving, stable or declining and that gives them the opportunity to take action. Such information given by metrics provides a basis for meaningful communication between supervisors and operators.

### 3.4 Key Performance Indicator

KPIs are defined as quantifiable and strategic measurements that reflects an organization's critical success factors (M. Brooks, 2005). Those are interpreted as result driven key factors and are used to measure performance and somehow control the company or some individuals to a specific goal (B. Catasús, 2001). The question is how the company will identify its success factors by measuring KPIs. There are two crucial aspects to take into account; the first key to success is to understand that there are no general success factors and the second key is to have courage to choose success factors and replace them if they don't lead to success (B. Catasús, 2001). Simply meaning is that the company must work dynamically with KPIs – which also can be linked to lean thinking.

One can ask what the purpose of using KPIs is and why KPIs do matter in a company. As listed in the journal from MESA International <sup>6</sup> one can understand why metrics do matter:

- KPIs improve performance of many correlated aspects of the business simultaneously
- It measures performance consistently across functions and departments
- The improvements must be concrete and visible to customers, shareholders and executive management
- KPIs support decision making at different levels in the company. At each level the decision differ in time to be implemented<sup>7</sup>
- Alignment with goals
- Prioritization of the investments

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<sup>6</sup> Metrics that matter Guidebook and Framework - MESA International, 2006

<sup>7</sup> See section **3.4.3 The KPI Pyramid** for further reading about KPIs in different levels.

To make improvements, the performance must be measured and visualised. As a psychological aspect one can interpret a KPI as follows, (MESA International, 2006):

***“Metrics drive behaviour, and behaviour drives metrics”***

### **3.4.1 KPI Pitfalls**

There is some pitfalls by using KPIs and therefore when developing a KPI one must have those in mind (B. Catasús, 2001).

- ✓ A KPI is a simplification of reality and there is a risk that some of the realities complexity fall apart. This can be solved by using several KPIs.
- ✓ When the use of a KPI becomes an overflow of information, which occurs when too many KPIs are used. The decision making in such situation tend to be worse. The information can be simplified by decreasing the number of KPIs. This solution stands to the opposite of the first problems solution, where the number of KPIs should be exceeded.
- ✓ The KPIs must be updated in synchronization with as the company’s strategy changes. Problem can occur when the changes result in marginal changes in an already existing KPI. Such a change may not be taken into account by the individuals when assessing the KPI. A solution is to use two KPIs in parallel under a period to simplify the transition for the company’s co-workers.
- ✓ An ideal KPI must fulfil some general requirements that defines a good KPI:
  - They can’t be too many
  - Easy to understand
  - Easy to understand how they can be improved
  - Easy to calculate
  - Hard to manipulate
  - Easy to gather data
  - Few side effects
  - Relevant for the activity

Those requirements are ingredients of an ideal KPI and can be very hard to fulfil in reality.

- ✓ The lack of information, incorrect information, weak interest from the co-workers and the use of too many KPIs may cause that the KPI not fulfilling its purpose. Having the co-workers aligned and working for a given goal, they must understand the meaning of the KPIs. Hence, the KPIs should be expressed, for the co-workers, in an appropriate way.

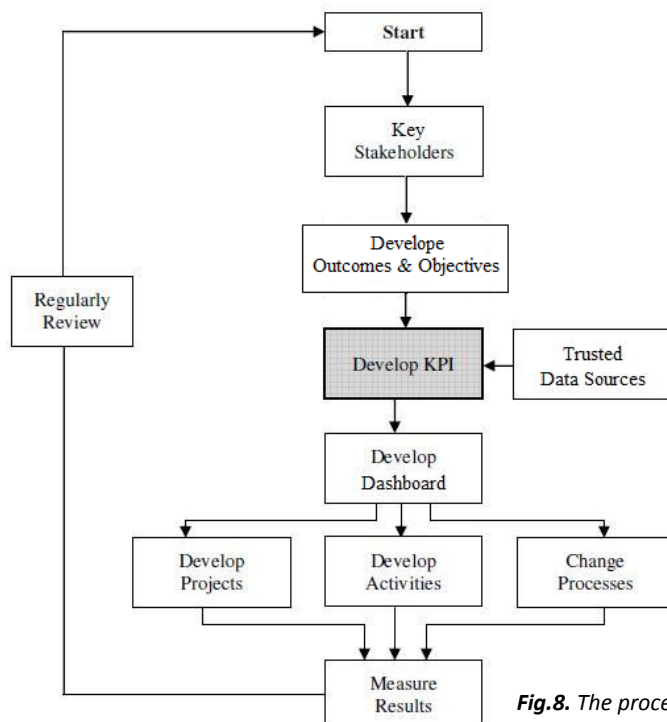
When choosing a KPI, with the problem around it into account, the most important thing is the awareness of that a KPI can’t be constant in time, it’s a dynamic parameter that changes slowly with the company’s vision and strategies.

### **3.4.2 The process for developing a KPI**

When developing a KPI it’s important to involve different departments in the process and not isolate them from each other (J. Davidson, 2006). Because a KPI might be effective for one part at the

company and just confusing for another, everybody must understand the goal of using the KPI and how it affects them. Traditionally, a KPI is developed to satisfy the management but the risk is that the purpose of the KPI is lost. That's because a KPI is also a metric which purpose is to direct the work staff through the path of success. When developing a KPI, the company should first start from what its key stakeholders think is critical, thus what they think is most crucial to improve and somehow what's preventing the company from achieving it. The company's business goals must be identified and that requires cooperation from all business units and individuals at the company. Many companies use only financial<sup>8</sup> KPIs and forget to take the internal and the external environment<sup>9</sup> into account. It's important to pick the right KPIs, i.e. a call-center might measure number of calls but avoid to measure the type of calls and how many calls that might lead to additional sales (M. Brooks, 2005). Next is to set a goal for the company to achieve some specific results, so-called expected outcomes. From the expected outcomes, the interval for the KPI is derived which gives the work staff fairly good information in how they are doing in according to achieve the goal and what might be done to achieve it, i.e. speed up the production rate. According to lean, the interval for the KPI should continuously be pushed to achieve greater result, thus making continuous improvement that result in higher efficiency. The data used as an input for the KPI's must be relevant and trusted as a source and can be very hard for companies to gather if they don't has the right material or technology. The last step is to develop a dashboard to visualize the KPIs so that each and any person at the company with clear and relevant information can follow the performance in contribution with the performance goals.

Finally, there should be continuous follow-up of the KPI. The company should periodically check what outcomes was expected, what they have achieved and if there is a difference them in between – ask the questions; Why? What changes can be done? Such process should be done periodically to get a more dynamic control instrument. See figure 8, for a brief overview on how the developing of a KPI can be done.



**Fig.8.** The process for developing a KPI.

*Inspired and modified from: J. Davidson, 2006*

<sup>8</sup> There is also Tactical and Operational KPIs  
See Section **3.4.3 The KPI Pyramid**.

<sup>9</sup> For definition of Internal & External Environment  
See **figure 8.** The KPI Pyramid

### 3.4.3 The KPI Pyramid

There are several types of different KPIs in a company and they are categorized into three different levels. The higher up in the company the more the KPIs become financial and the lower the more operational but some were in the middle in between there is tactical KPIs. Those three categories will be defined in more detail by the KPI pyramid, developed by Richard Lynch and Kelvin Cross in 1991. In this section some specific KPIs, that are an ISO-standard and widely approved, are also defined in more detail. Some of them were even used in the interviews made at Ambu.

The KPI pyramid divides the company in four different hierarchical levels containing specific KPIs for each level. The corporate vision is the top of the pyramid, which sets the base for the company's strategic path the following year/years. From the company's strategic objectives, the next level is defined by market and financial KPIs. The third level which acts as a linkage between the daily operational KPIs and the strategic KPIs, form the tactical ones. Those tactical KPIs, which give support for decisions in a monthly basis, are defined as the company's core business and are categorized into customer satisfaction, flexibility and productivity. The lowest level defines the operational KPIs and those are divided into quality, delivery, cycle time and waste, see figure 9. As seen in the figure, the company's objectives go from top to down and the KPI measures from down to top.

To be sure that everybody within the company works toward the same objectives, it's important that there is a linkage between the KPIs from the different levels, they must in somehow correlate with each other. That might be done by first breaking down the financial KPIs to tactical and so on, so called Top-Down strategy, (Andersen & Fagerhaug, 2006). See figure 10 for a brief overview in the next page.

Advantage: The KPIs are linked and aligned with the corporate strategy.

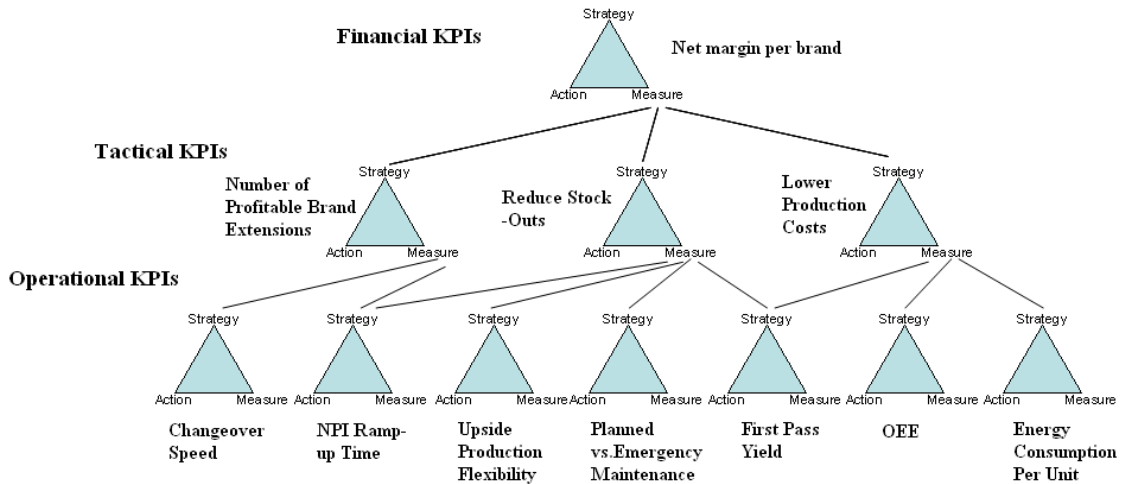
Disadvantage: Difficult that the work staff accept the KPIs since they haven't been involved in the development process.



**Fig.9. The KPI Pyramid.** As can be seen in the figure, the KPIs to the right form the corporate's internal efficiency and those to the left form the corporate's external effectiveness.

So it's very important that the employees at the operational level also are involved in the process and given the chance to develop KPIs that are valuable for their work.

Therefore it's recommended that a combination of a top-down and down-top strategy is used and the two approaches meet half-way. This is done by setting the strategy for each department or group so that they work in accordance with it when developing a KPI. During the development work it's also important to review the KPIs so that they're aligned and consisted with the corporate strategy.



**Fig.10. The KPI linkage.** Here is an example showing how a financial KPI is broken into tactical KPIs which further is broken into operational KPIs and the linkage them in between. This is a so called, top-down strategy. As seen, the strategy follows with the metric down to all levels.

Metrics that Matter Guidebook & Framework  
 © 2006 MESA International

To give a sense on what a KPI is, a definition of different KPIs must be exemplified. Those are lined up after category and level, see table 1.

ISO-standard KPIs
<b>Financial KPIs</b>
*Revenue Improvement: This Year Revenue/Last Year Revenue
<b>Tactical KPIs</b>
<b>Customer Related KPIs</b>
*Customer Quality Satisfaction: Good Quality/Delivered Products
<b>Flexibility Related KPIs</b>
*Ability To Deliver: Nr. of Short time Orders/Nr. of On Time Delivered Orders
<b>Productivity Related KPIs</b>
*Worker Productivity: Production Output/Hours Worked
<b>Operational KPIs</b>
<b>Quality Related KPIs</b>
Quality Rate: Good Quality/Produced Quantity
<b>Delivery Related KPIs</b>
*Delivery Speed: Order Time/Delivery Time
<b>Cycle Time Related KPIs</b>
*SMED-Single Minute Exchanged of Die (Lean KPI): Waste Time in Change Over
<b>Waste Related KPIs</b>
Wastage Ratio: Scrap Quantity/Produced Quantity

**Table 1.** Example of KPIs from different levels, with category included, in a company with definition.

**ISO – Definitions & descriptions of KPIs, \*Mohamed A. Hamid**



### 3.4.4 OEE

This KPI is one of the KPI listed in table 1 and as seen it's an operational KPI. This KPI got an own section because it's rarely used in a lean context and because it's the KPI chosen to work with when developing the prototype.

The KPI OEE is a widespread measure used to gauge effectiveness. Referring to the name **O**verall **E**quipment **E**ffectiveness, its popularity comes from that it in a single metric captures all factors that detract from optimum equipment performance (L. King, 2009). OEE is a product of three factors:

$$OEE = Availability \cdot Performance \cdot Quality \%$$

The **Availability** captures all downtime losses, maintenance and the time spent in setup or changeover. The formula for the availability is as follows:

$$Availability = \frac{Actual\ Operating\ Time}{Planned\ Operating\ Time} \%$$

The **Performance** captures the loss in productivity if the equipment must run at less than the design throughput rate because of some equipment defect. The formula for the performance is as follows:

$$Performance = \frac{Actual\ Throughput}{Rated\ Throughput} \%$$

The **Quality** captures the loss in equipment productivity when a product (being made) mismatch the specification, amount of scrap material is included and when rework of a material is made to meet specification. The formula for the availability is as follows:

$$Quality = \frac{Quantity\ of\ First\ Grade\ Material}{Total\ Quantity\ Produced} \%$$



# 4. Interviews at Ambu

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## 4.1. Design of interview guide

The interview guide has several designs to adapt to different respondents. But all have the same core questions evaluated from specific parameters. Those parameters deals with lean and KPI's:

Lean:

- Purpose
- Mentality
- Lean tools
- Visualisation
- Culture

KPI:

- Purpose
- Visualisation
- Important KPI's

See **Appendix A.2** for a look on a typical interview guide.

## 4.2. Current situation at Ambu

Before the interviews were made, an observation of the production was done. In that area Ambu has a big focus on lean. Ambu has a great portfolio of products, but in that production site, only electrodes (for EKG and neurophysiological use) are produced. The reason is to eliminate change over time and somehow reduce waste in the production. The production area was very clean and managed. Everything was on its place and very visible. There are three production lines set in parallel with each other, independent of one another. That is due to get higher material flow and if one machine is broken the other lines can continue producing without being affected. A quality test of the electrodes is done every two hours. The electrode consists of different layers which are attached together by glue. In the quality test, the amount of glue in each layer is of interest. If they are out of range of the accepted limits then action is taken (by reducing or increasing the glue added on the different layers) and a report is sent to the quality group. The electrode mentioned can be seen below in figure 11.

The raw materials are available in the production site, close to the machines. The raw material buffer is filled once a day from the stock which is situated close to the production area (6 meters to be more exactly).



**Fig.11. Ambu Blue Sensor L.** A 55 mm electrode with a decentralized connector. It has a high conductivity and a combination of a quick – and long term effect .It has a micro porous material which allows the skin to breath and the thin profile makes the electrode pleasant to wear even for a longer time.

Source: Ambu.se

## 4.3 Lean at Ambu

Lean was implemented in Ambu already in 1996.

“The lean implementation is a long-term process, nothing that you achieve in one day.”

**-Production Manager**

Thus, the lean culture and the lean mentality aren't as 15 years ago. There's a goal in mind, to eliminate waste and that's a lifetime project. Lean is used to eliminate waste, but in reality there will always be waste so one might work for the purpose of minimizing it. A clear strategy of being efficient is set, where different lean tools are somehow used to achieve it. Since lean was implemented, improvements have been achieved in productivity, delivery and Ambu has become more efficient.

“Value stream mapping is the most fantastic tool in the lean world. You can go out and measure with a paper and pen. Now we are making value and now we're not. The lead time was reduced from 85 to 5 days, thanks to the VMS.”

**-Production Manager**

This is a fantastic result, reducing the lead time with approximately 95% is something to be proud about. The activity that was not adding value and thus taking the most of the time was due to the place of the stock, which was far away from the production site. There was other kind of activities too which wasn't adding value in the production, but not to compare with the stock activity. This shows how meaningful lean can be in a production. By using the lean tool, Value Stream Mapping-go around in the production with just paper and pen and noting each non-adding value activity and the amount of time it consumes made such difference. This implies how powerful the lean tools are and how important they are to implement in the production. If efficiency is the goal in the production, then lean is the best way achieving it. The VMS was done and studied for several weeks and made difference in the end. This was done and achieved six years ago. Today, Ambu is more efficient and are pursuing for higher efficiency every day.

“Improvements has been achieved. Waste reduction as an example, we reduced the waste 1.5 million DKK in a year. We also achieved better processes and stability in the equipment.”

**-Lean Manager**

Improvements due to waste reduction with 1.5 million DKK only in one year gives big opportunities for Ambu. Such a result is a good feedback for the managers that they are doing things right and that they are on track. It motivates one to keep working the same way and fulfil the goals that are set. It gains energy to all the working staff.

### 4.3.1 Purpose

Knowing the purpose of why lean is implemented in the company is crucial and makes it easier to achieve different objectives. Thus some persons of different roles at Ambu have been asked what the purpose of implementing lean is.

“The purpose is to achieve efficiency and be more visible.”

-Production Manager

The production manager continues “... being efficient one must identify all non-adding value activities, thus all kind of waste must be identified and eliminated. To identify all kind of waste one must be visible so that all kind of waste are highlighted and easy to see.” Being visible is a general word, in that matter he mention the 5s and that they must be applied in a production area to become as visible as possible.

“The purpose of implementing lean is to give a smoother production, better quality, higher output, better flow through the production, less downtime on the equipment, better yield, less rework and scrap – generally, eliminate all kind of waste. As human aspect, improve the working place to achieve the perfect environment for the working staff.”

-Lean Manager

The lean manager has been working at Ambu for three years and he has experienced for each and every year a difference in the production. Having the lean thinking in mind and applying the tools it offers makes big difference. He means that thanks to lean the production has become smoother, with higher output (less stops and problems in the production) to better quality and less rework as a result. All kind of results achieved have one thing in common – they all are a type of waste. The lean manager means that, this is the purpose of lean – to eliminate waste, and so far it has fulfilled its purpose. The human aspect for him is very important, meaning that the work staff should feel comfortable in the production area, no dust, clean area, managed, visible and fresh so that the workers feel good when working and can focus 100% on their work and thus make a better work. A fresh work area motivates the workers to come to work and in the longer run they are healthy with less sick reports as a result. This is a different aspect in lean when focusing on the work staff and their environment, there is a thought behind the 5s, it’s not only for making scrap more visible. The lean manager thinks that there are many different purposes of implementing lean in a production and it differs from company to company how they adapt it, but all of them has the same main purpose, namely – eliminate waste. As an example, the lean concept can’t be adapted in the same way in an assembly production site as a process industry. Meaning, that in an assembly production (also called a discontinuous process), one collects different parts and put them together before one got the final product but in a process there’s a flow, it’s more continuous.

“We put big focus on high quality on the product so that it adds value to the customer and give something that satisfies their expectations, which might lead to fewer complaints, less backorders and thus less rework and by that we keep the costs down.”

-Lean Manager

### 4.3.2 Mentality

How is the lean mentality in the company? Is continuous improvement a standard thought, embedded in each person's mind? How is the work staff involved in that process? Does everybody know what lean is and what it deals with?

Each person interviewed talks about continuous improvement and how important it is to have it in mind in the daily work. It's a normal thought they have in mind and they are all aligned with the same thought that everything can be continuously improved. They have kaizen meetings once a month where everybody is free to reflect on own thoughts and new ideas. They are discussed and eventually, everyone agrees about a solution.

Everybody at Ambu is familiar with the word lean but the production manager and lean group are the specialists there. The lean group has educated the operators and technicians in how to be lean. A session was made to train them and give them a basic knowledge of what lean is. The session include, how lean started, Toyotas approaches, 5s, kaizen, 7 wastes etc. Some activities were made so that they understood it better. Everybody is involved in such way that they can come with ideas for improvement. This is not only done on the kaizen meetings, ideas are met on floor meetings and can be announced on a board made for that purpose.

"There's a lot of procedures where the operators comes with new ideas and the lean manager has weekly meetings to discuss new ideas for improvements."

-Production Manager

The operators are motivated through involvement. They are encouraged to take decisions and are well met for an open dialogue. The lean manager listens to their ideas and to motivate them even more, their ideas at the most time become real.

"The operators are free to come with their ideas and we have weekly meetings, kaizen. We motivate them to be lean by Bonus if improvement is achieved."

-Production Manager  
Xiamen, China

In China, there's no difference comparing to the lean thoughts in Denmark. The operators are educated in lean, sessions were made explaining what lean is and what the 5s is. The operators aren't self dependent and can't always take different decisions by them self as the operators in Denmark. They do exact what they have been told, not more or less. One reason is because the operators in China most of them hasn't graded 9<sup>th</sup> grade in school comparing with the operators in Denmark where most of them has graded high school. Another reason is because of the different cultures.

"I feel that I am well met when suggesting ideas for improvement in the production, the manager encourage us to do that. A continuous improvement meeting is held once a month and I feel very involved in my work."

-Operator

An operator from Denmark expresses how she's met when suggesting ideas for improvement and that the manager motivate her by encouragement and involvement in her daily work. She also says that, there's a routine in her work to keep the work area clean, visual and well organized.

The lean manager expresses himself about continuous improvement, what can be improved and can't and whether improvement ever can end, short and consist he says:

“Each and any activity in the production can be continuously improved. If you think lean, you must have in your mentality that continuous improvement never can end!”  
-Lean Manager

### 4.3.3 Culture

Visiting Ambu one can feel the lean culture. It's so managed, clean and visible. One can't feel that it's a production site. It's very calm and a comfortable place to be in. The work staff knows what to do and they have control on their task. No one is uncertain on how to handle different situations and they are confident. The operators seem to be well educated in how to handle the machines and lean has become something embedded in their daily work. Working the way lean require is normal for the work staff, the lean culture is spread all over the company. Everybody thinks in similar way and one can't feel different culture on different places at the company. Implementing lean in a company might contribute to a stressful environment, but that's not perceived at Ambu.

“We don't want to be lean, too much. It can be too stressful for the workers. The lean culture is affecting the company in a good way. But if we were strictly lean it would go the other way.”  
-Production Manager

The thought here is that if adapting the lean culture literally might affect the workers in a negative way. Lean of its nature contributes with stress, due to the pursuit of highest efficiency. But at Ambu one thinks that you can't adapt the lean culture too much because the people in this part of the world don't think or behave the same way as the people in Asia. You can't be strictly lean, you should adapt it to your culture and don't try to push it too much, it should melt in the company by itself.

“In Malaysia the operators work different, they have been working with lean a long time ago so the culture there is more a lean environment. The stress tolerance is higher.”  
-Production Manager

When introducing something new to a company which require a new way of working may affect the work staff psychologically. Some will be negative affected, they can't change a routine or adapt it to themselves. That kind of problems can occur when working on a change process.

“Today, lean is a part of the company culture. It took time to make it a part of the company culture, because some people had to change habits. It took the management two years for breaking down all the challenges. It was a huge task 5 years ago, it was a tough task for the management.”  
-Production Manager

Implementing a change process in general is a huge and very hard task for the management. There are many different challenges one need to go through before completing that kind of process.

At the interviews the respondent was asked two questions, one was how lean they are comparing with Toyota and the other was how lean they want to become, comparing with Toyota (in scale of 1-10). Toyota in that case is strictly lean.

So lean are Ambu today:

1.  2.  3.  4.  5.  6.  7.  8.  9.  10.

So lean are Ambu “tomorrow”:

1.  2.  3.  4.  5.  6.  7.  8.  9.  10.

The respondents asked were the production and lean manager. Their answer was identical.

#### 4.3.4 Lean tools

Lean got many different tools which might benefit the production. At Ambu they apply the 5s, one can see several pictures in different areas describing the 5s. Visiting the production area, the 5s can talk by itself – it’s managed, clean, clear, visible etc. The lean group are well aware of how important it is by educating the operators about the 5s, what kind of wastes there is and how they might solve a problem and prevent it to appear again. There might be bigger problems, those are studied and solved by the lean group. The easiest way of addressing and solving a problem is the 5 whys, this is commonly used by the operators.

“There are many different lean tools that I use in my daily work. When I try to identify the root cause of a problem, I ask the operator the 5 whys, I use Ishikawa – the fishbone method. Another tool is the 5m’s; look on the method, the material, the machine, all those tries to address the problem in a structure, to see what can go wrong with the problem concerning the machine, the process etc. To improve a process, the PDCA (Plan Do Check Act) is done. It’s a continuous improvement circle, which plans how to get the improvements through. For bigger problems the A3 tool is used to get an overview on the problem and how to deal with it, describe the problem and break down the problem, if you have different solutions and how to choose between them and make it as a standard => standardization tool to the operators. It’s a bit complex. Easy to work with and understand, one of the biggest advantages => you are guided through steps that you do every time.”

-Lean Manager

Kaizen is used frequently to improve the process. It’s also an open dialogue between the manager and the operator which allow the operators to come with ideas and reflect around different problems. The operator feels as a part of the process and that they can affect the production. When placing different tools in the production area, several sessions were made where the operators could also be there and affect it. First the 5s was studied and then it was practically made in the production. The purpose is to make the tools placed close to the machines and to be visible for the operators. Different marking as a tool contour and special places for different tools were set. The operators were free to come with ideas and decisions were made with respect to their opinion.

#### 4.3.5 Visualization

Today Ambu are taking the lean thoughts further, they want to be more visible by highlighting different problems occurring in time and somehow track the cause. They want to show the production performance to motivate the work staff and give the management better control over the process. In the production area, there’s a big screen showing a graph. This graph shows the

production performance during time. The OEE is chosen to be a measure for the production performance at Ambu.

“OEE is a good parameter to visualize. How big is the waste? If you know how big the waste is one can make something about it.”  
-Production Manager

The program used to visualize the graph is Excel. Thomas Kongstad perceives the program as an easy tool to handle and at an early stage very cheap way of visualizing data. The purpose is to see what such information can mean for the work staff in the production area and if it's of valuable meaning – thus adding value to their work. Thomas Kongstad has no problem with understanding the graph and analysing it, but concerns that the operators don't.

“In an early stage we are testing what difference a visualization of the production performance can make for the operators work and how it can gain us managers in our decisions. The graph might be hard for the operators to react upon and act thereafter so there's a need of something more pedagogical. But today we are settled with Excel instead of investing in an expensive system. But the question is; is Excel adding value, what do the work staff want, are they settled with the way information are visualized today, how do people at Ambu want information to be visualized, can it be made on Excel or do we need to invest in a system made for such purpose? For me, in the optimum world, there's a big screen with traffic lamps for each activity in the company, once everything is green you can go on with your work and if it's red somewhere you can easily track the cause and solve it.”  
-Thomas Kongstad

Thomas Kongstad thinks that it's of big value to have a big performance overview on all kind of activities at the company. He thinks also that it's very important that all activities are connected in some way, so one can see a route down to the root cause and that they should support information upwards in the company by highlighting the costs upcoming because of the problem occurring.

“Today there is a performance overview in the production site but it's difficult to understand the graph.”

-Operator

“The production performance is measured by using OEE and visualized as a graph on a big screen. But there's a need to make workshops with the operators so that they can understand it.”

-Lean Manager

The operator has difficulties with understanding the graph and thinks that's very hard to react upon the information given. It could be done in a easier way so one could understand it and act upon a specified problem given on the screen.

“I want to have information in real-time that shows the amount that has been produced, what should be produced and how good the machine is performing, i.e. how much time is left until we reach the goal. Stop reasons and for how long such a stop was, show the most common stop reason and if we are producing better than the previous week.”

**-Operator**

The operator demands a simple picture that gives a good overview on the production, that is easy to understand and that makes it possible to react upon immediately.

“There should be one sheet for the technicians to see the main break down causes and the time consumed. For the operator, something very simple, visualizing green, yellow and red –lamps, referring to the production performance. Important is to also highlight how we are relating to target, the amount to produce.”

**-Lean Manager**

The lean manager wants different sheets for different roles. For the technicians something of more detailed information about stop causes so that it makes it easier to track a problem and fix it. For the operator he refers to an easier sheet that gives a good overview of the current production status so that action can be taken immediately if any problem occurs.

But what kind of information does the lean manager need to see and how does he want it to be visualized?

“The information I need to see is the production downtime and the production loss because of that downtime. It can be used to make improvement and see the benefit of making that improvement, i.e. before and after result. The production speed; how close are we to target, how much time do we have left to meet the goal? See how many stops in the total downtime, and when they occurred in time. And given a cause of why it stopped. That’s a good way to be able to make improvements, to have a overview of the production status etc.”

**-Lean Manager**

The lean manager needs to see big overview of the production and details of what’s causing different stops to improve the production performance. Information about time to meet the target so he can be ahead the schedule and thus have better control over the time the next batch will start to be produced and somehow to give better information to his superiors.



## 4.4 KPI

At Ambu the KPIs have been running for 5-6 years. The KPIs are reported in a monthly basis through their business intelligence program. OEE was implemented when Thomas Kongstad joined and it's the only KPI (which can be seen from an operational perspective) that is reported in real time. The higher up in the company, the more KPIs of a financial figure that is used and hence reported.

"All KPIs are measurement of financial figures. And improvements have been achieved during the last 4-5 years."

**-Global Operations**

Since the KPI reports started to be generated and were implemented in the system, improvements have been achieved due to the better overview on different costs that were occurring. The KPIs are dynamic and every year their limits are adjusted to be in compliance with the goals that are set.

"Once a year I have a meeting with my managers and set up goals for the year. Those goals push the KPI limits."

**-Global Operations**

The limit definition of what a good KPI might be, are changed each year to a stricter level and the tolerance of crossing the boundaries are lower. Ambu wants to make improvements and to be more efficient. Hence, pushing the KPI limits shows the path toward success.

"The CEO has a lot of information. So he only needs to know whether if; we are on track, there are any deviations, we are earning or losing money?"

**-Global Operations**

That statement implies that all different KPIs in the company eventually turns to only one KPI at the top of the corporate. The lower level in the company the more KPIs will appear. The KPI in the highest level is of a pure financial figure that defines whether the company is losing or earning money.

"All the KPIs should have some support upwards which should also satisfy the shareholders."

**-Supply Chain Manager**

It's of big importance to have control on the supply chain costs. It happens rarely often that the customer comes with short order time that requires a delivery within 24-48 hours. Due to on time delivery and the customer location, the air transportation become the main transport method. That kind of order drives up the costs as a result. Having a better overview on the supply chain might give a better control of the costs. A lot of the items today are produced to put in stock, that's due to be ready for short time orders and somehow reduce the transportation costs. But it's not the perfect solution, there must be a better way to handle it.

"In the optimum world, there's no extra item that is in stock."

**-Supply Chain Manager**

#### 4.4.1 Purpose

What is the purpose of using KPIs? Different respondents have answered that question and they are referred in the following:

“The purpose of using KPIs is to have control on the process and to report to management.”  
-Quality Manager

“The purpose is to know whether we are on track or not and take action thereafter.”  
-Global Operations

So with other words the purpose of using a KPI is to take control of different activities, have better overview and hence make better decisions.

#### 4.4.2 Visualization

The reports generated through the business intelligence program and the screen in the production stands for the KPI visualization at Ambu. Some are satisfied with that system and some are not. When representing KPIs at a higher level in the company- KPIs of a financial figure, it's not of interest to visualize them in another way than the reports generated from the business intelligence program.

“It's a mess for me to have a daily update about the production performance. I got monthly reports that contain KPIs of a financial figure and I'm satisfied with that.”  
-Global Operations

In a level between the financial and operational levels, the tactical KPIs appear. For that kind of KPIs, the interest is to have a daily update. For the operational KPIs, there's an interest for a more frequent update. The update for the operational managers should be in an hourly basis and in the lowest level where the operators appear the update should be continuous – along with the machine. Thus if a problem in the machine occur, the operator is updated with the latest information and has the current status visible. The supply chain managers are very interested of having a big monitor in a room that shows an overview of the supply chain performance.

“If everything is green one can just move on.”  
-Supply Chain Manager

It could be a place where everybody can meet and discuss i.e. over a break. It would be easier to track the problem. Having red and green lamps that refer to different KPIs makes it easy to track the root cause. Of course all KPIs should be linked together so one can follow a path to the source of the leak.

#### 4.4.3 Important KPIs

Below in table 2, different KPIs are listed that the respondents filled in after each interview. The respondents which were a part of that questionnaire session were two supply chain managers and the production manager. This questionnaire was handed out to the respondents in hope to understand what kind of KPIs that matters for each role. The other respondents that took part of the interviews weren't handed out the questionnaire of one reason; their role gave enough with

information about what kind of KPIs that matters to them. Thus the Global Operation was only interested of financial KPIs, the Quality Manager of Quality related KPIs, the operator only the status, the lean manager needed to see the downtime and the reason of it etc.

1. Grading from 1-5, how interest each KPI are to visualize. 1. <u>Not interesting at all</u> 3. <u>Neutral</u> 5. <u>Very interesting</u>	1	2	3	4	5	X
2. The 5 KPIs that are considered to be of most interest to visualize are picked out of each respondent. The respondents were agreed upon 3 KPIs to be the most interest.						
<b><u>Production related KPIs</u></b>						
1. Actual versus planned volume		■		■		
2. Throughput: Produced Quantity / Lead Time		■		■		
3. Production Efficiency: Production Time / Busy Time			■		■	
4. Machine Efficiency: Production Time / (Production Time + Delay Time)	■				■	
5. OEE Index: Availability * Effectiveness * Quality rate					■	■
6. Wastage Ratio: Scrap Quantity / Produced Quantity			■	■		
7. Reworking Ratio: Rework Quantity / Produced Quantity		■				
8. Production Lost Rate: Production Lost / Consumed Material		■				
<b><u>Inventory Related KPIs</u></b>						
9. Inventory Turns: Throughput / (Work in process Inv. + Finished goods Inv.)				■	■	■
<b><u>Quality Related KPIs</u></b>						
10. Quality Rate: Good Quantity / Produced Quantity		■			■	
11. Finished Goods Rate: Good Quantity / Consumed Material		■		■		
<b><u>Customer Related KPIs</u></b>						
12. Customer Quality Satisfaction: Good Quality/ Delivered Products		■			■	
13. Customer Delivery Satisfaction: Delivery Time / Customer D.T Expectation					■	■
<b><u>Supplier Related KPIs</u></b>						
14. Good Supplier Index: (Quality + Delivery speed + Price) / Max Grade				■	■	
15. <u>Another, own suggestion:</u> Supply Chain Costs					■	

Table 2. A Questionnaire handed out to each respondent to complete.

- Supply Chain Managers
- Production Manager
- The KPIs that the respondents agrees to be the most interest
- The Supply Chain Managers has the same opinion as the Production Manager

# 5. The software tool VantagePoint

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*This section describes the software tool Vantage Point that was used in the development of the real prototype.*

VantagePoint is a business intelligence software for manufacturing help. It focuses on performance and visibility and hence empower users at different level of an enterprise with information from web-based dashboards. It's possible to generate reports with KPIs and view different trends and x-y plots. Since the information is gathered from different machines and visualized in real time it supports managers to manage productivity in real time and hence make more insightful decisions such as product quality, equipment utilization etc. which helps to reduce costs. The data can be reported through a variety of tools, including Microsoft Excel.

VantagePoint is very flexible which has the ability to connect to multiple data sources that are; real time, historical etc. and hence makes it possible to access, aggregate and correlate information via the web browser.

There is a range of possibilities of what can be done with VantagePoint. Information can be viewed in a very simple manner and pedagogic point of view due to its features, i.e. animations of speedometers and other graphical interfaces. Information that could be viewed in a boring way, consisting of only digits that are not making any sense in the first sight can by animations and great graphic be perceived in better manner and hence any person will be able to interpret the information given.

It's easy to customize the interface after a specific users preferences and hence people of different role will access information in a different scale, i.e. some will be limited to only see the first slide and others might drill down and analyze different operations – of course there will be someone that has unlimited access to all kind of information (the administrator). VantagePoint is a dynamic tool in its nature, so once the interface to use is accomplished and ready to use one will be able to change in different parameters, i.e. the KPIs which are dynamic by nature and must be reviewed in a certain period can actually be modified whenever needed. Hence, the interface is not static and won't always look like as it did in the first time it was implemented, it's rather in the opposite – the interface implemented today will not be the same in the next year.

## Advantages

- Standard connectors to real-time data via FactoryTalk® Live Data (Logix, PLC/SLC, FactoryTalk® View, 3rd-party controllers, etc.) and historical data via FactoryTalk® Historian PLUS connectivity to other real-time and historical data sources.
- All manufacturing data is accessible in real-time.
- All you need is a web browser to view published reports, current dashboards, and real-time KPIs.
- Time-to-value: Pre-configured reports, trends and dashboards provide out-of-the-box functionality in hours; create your own on the first day of use.
- Published reports are always current – to maximize productivity and minimize cost.
- Drag-and-drop functionality lets you overlay equipment, line and plant trends for comparison and optimization.

*Producing relevant,  
timely and consistent  
manufacturing reports is hard  
... at least it used to be.*

*Now there's FactoryTalk®  
VantagePoint. Easier to  
install. Easier to use.  
Easier to own.*

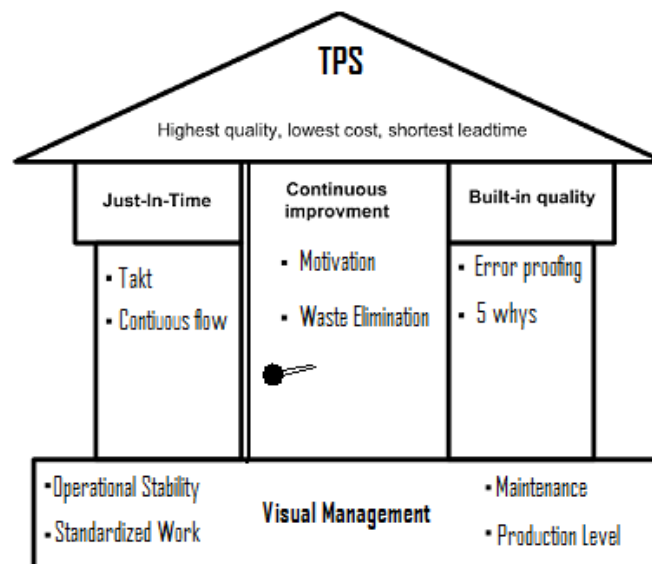
**Source:** Rockwell Automation

# 6. Analysis

*In this section, the empirics will be analyzed with support from the theory chapter. How are Ambu related to lean? Are they applying the concept of lean in their production? Are Ambu lean? How do Ambu build up a KPI? What kind of KPIs are used and how are they supporting the management? Such questions are of big importance to answer and understand.*

## 6.1 Lean

When analyzing the empirics due to lean, as a reference the TPS house is used. Thus the TPS house contains the whole lean ideology and it's easy to compare with. To be clear, the only manufacturer applying the TPS house ideology is Toyota themselves and they are strictly lean, thus being lean one may not fulfill all conditions stated in the TPS house. Each and any company apply lean in their own way, some lean ideas might be good for one company and bad for another one. Once again, the TPS house is stated below, see figure 12.



**Fig.12. The TPS House.**

As a foundation, the analyse is done due to the following parts of the TPS house:

- Continuous improvement – How are the lean mentality & culture adopted in the company?
- Visual management – Are Ambu aligned with the conditions of a visual management?
- Highest quality, lowest cost, shortest lead time – How are Ambu related to that statement?

The first thing to be analyzed is if the staff at Ambu understands the concept lean, this will be clarified in the following section.

### 6.1.1 Purpose

Referring to Taiichi Ohno:

“The basis of lean is the absolute elimination of waste”

That’s the big concept of lean, the totally elimination of waste. Some of the respondents answered the question; what is the purpose of implementing lean?

In the Empirics chapter, section **4.3.1 Purpose**, the production manager briefly answers: “... being efficient one must identify all non-adding value activities, thus all kind of waste must be identified and eliminated“. The lean manager share the same opinion as the production manager and asking any random person in the production site, they all seem to share the same knowledge about lean and what it deals with. Thus one can conclude that the lean concept is understood in Ambu as a whole and that the work staff is briefly educated in what lean is.

### 6.1.2 Continuous Improvement

#### 6.1.2.1 Mentality

The TPS house says the following about the lean mentality (referring to the theory section **3.2.1**):

...The door into the TPS house is the mentality of the whole company. The people must be highly motivated and keeping in mind that everything can be improved. The process, the way people work and everywhere in the company must be continuously improved for eliminating waste...

How is the lean mentality in Ambu? Do they have the required lean mentality?

At Ambu there are Kaizen sessions once a month and the operators are encouraged to make continuous improvement through involvement in different decisions. Everybody wants to achieve better performance in the production and they pursue the elimination of waste through continuous improvement.

Referring to the empiric section **4.3.2 Mentality**, the lean manager stated the following:

*“Each and any activity in the production can be continuously improved. If you think lean, you must have in your mentality that continuous improvement never can end!”*

That’s exactly the lean mentality one must have to achieve the purpose of lean, namely eliminating all kind of waste in a process. The lean mentality seems to be embedded within the company and in all processes there are thoughts about how to make improvements and hence become more efficient.

If each respondent interviewed is graded from 1-10 due to their lean mentality including a weight for their role, one might get a weighted average of the staff mentality.

The people that has most significant role due to lean (people in the production site) has highest weight equal to 1 and those outside the production site has a weight equal to 0.5 & 0.1, see table 3.

People in the production site, **Weight: 1**

Role	Operator	Lean Manager	Lean Manager	Production Man. Denmark	Production. Man. China	Quality Man.
Grade	6	10	10	8	7	8

People above the production level, **Weight: 0.5**, Global Operations has a **Weight: 0.1**

Role	Supply Chain. Manager	Supply Chain. Manager	Global Operations
Grade	4	4	2

**Table 3.** Grade and Weight for each role in & outside the production site

$$\text{Weighted Average: } \frac{\sum \text{Weights} \cdot \text{Grade}}{\sum \text{Weights}} = \frac{6+10+10+8+7+8+0.5 \cdot 4+0.5 \cdot 4+0.1 \cdot 2}{1+1+1+1+1+1+0.5+0.5+0.1} = \frac{53.2}{7.1} = 7.5$$

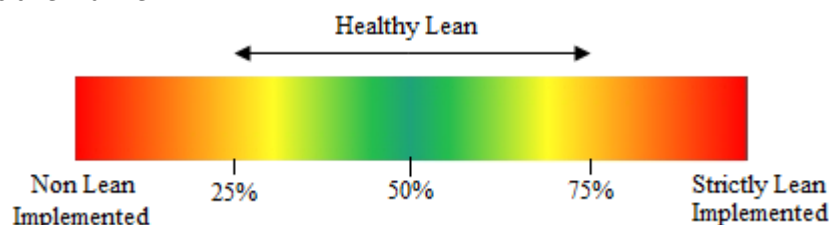
The higher up in the company the lower significant importance of a lean mentality (the weight goes to zero) and the lower the higher importance and since all lean managers are included here and one might think that all other operators have the same mentality; the average won't differ from 7.5 that much in the long run. Thus one might conclude that there is a rarely high lean mentality in the company.

### 6.1.2.2 Culture

Visiting the production site at Ambu one can feel the lean culture. It's managed, clean and very visible and the people think lean. Lean is such a process that is very hard to implement due to the different cultures between Japan and a European company in general. One might change habits and thus affect one psychologically in a negative way. At Ambu it was a very tough process to implement and now, 5 years later the project is accomplished and the lean culture and Ambus culture is united. But they don't want to be strictly lean at Ambu due to the stress it might contribute to the work staff. In the empiric section **4.3.3 Culture**; the production manager said the following:

*"We don't want to be lean, too much. It can be too stressful for the workers. The lean culture is affecting the company in a good way. But if we were strictly lean it would go the other way."*

In a strictly lean environment such Toyota's, the whole staff work very efficiently, everything is taken care of in the fastest way possible, no faults are accepted to show up. So the environment is very stressful in a strictly lean company, thus pursuing effectiveness even though it affects the work staff in a negative matter. That's one point that might be negative with lean as a human aspect. In Ambu such thing is not experienced, that's due to the different cultures between Japan and Denmark (or even Europe as a whole). In Japan the work staff does not seem to be negatively affected but if any company in Europe would apply it in their production site would affect the work staff in a negative way and cause psychological damages due to all stress and the unusual habit. As said earlier, each company apply lean in their own way and the way they feel the best. Hence, at Toyota, the work staff experiences a lot of stress and due to their efficiency the company is gaining positive effect. But in a European company, stress would cause an inefficient work staff and hence damage the company seriously. So applying to much lean in a European company may affect the company in a negative manner due to the stress it cause to the work staff. As a pedagogical picture of what's have been said, the following picture may depict a scale showing the affection of being, not lean at all and strictly lean (in comparison with Toyota) and where a suitable position is, that's positive for a European company to be, see figure 13. If lean is implemented in a smaller scale it would also affect the company negative, thus a healthy lean implementation should be situated between 25%-75%. Referring to the picture below, the more green the healthier as human aspect and thus gaining the company in a positive manner.



**Fig.13.** A color scale that shows the region of a healthy lean implementation for a European company – in comparison with Toyota.

Referring to the empiric section **4.3.3 Culture**, the respondents thinks that Ambu are 20% Lean in comparison with Toyota and as a goal they want to be mostly 70% lean. Looking on the scale in figure 13, Ambu thinks they are 20% lean and they are precisely situated in the healthy region. Their future

prospects are to be like 70% lean and thus will still be in the healthy region. They are aware of the negative parts, lean can contribute with and are handling it in a good way. They know where they are standing today and where they want to be tomorrow!

### 6.1.3 Visual Management

Referring to the theory section **3.3.1 Visual Management**, from a lean sight of view, there is six criteria's that must be fulfilled to be visual:

1. Clean, visual and well organized work area – 5S
2. Visual displays
3. Visual schedules
4. Display of relevant metrics (KPIs)
5. Management involved by using the information conveyed from the metrics
6. Open information floor – simplifying the communication through the whole manufactory

As visual management appear as the foundation for the TPS house, it's of big importance to fulfil the six criteria's stated above so one can keep building up the TPS house and complete it element by element until one achieve the full implementation of lean in the company. In Ambu all criteria's are fulfilled, except one, namely displaying relevant metrics. Today they are visualizing the OEE in the production site in a very low-tech view (viewed by excel) and the operators can't understand the graph or even react upon it. The management are aware of that and has only implemented the system as a prototype in an early stage. They are involving the operators in the development of a visual screen in the production area and their wish is to have a screen, showing the production status in real time and a reference of how they are performing in relation to schedule, see the empiric section **4.3.5 Visualization** for further information. The lean managers wants that the information displayed on the screen should be role dependent, thus there will be an overview picture that everybody have access to and drilling down is limited due to each role. From a lean aspect, the process for implementing a display of metrics is made totally in accordance with lean thinking, see the theory section **3.3.1 Visual Management**. In that section, it says that the operator's should be involved in the work of developing the design of the display, thus Ambu are aligned with that statement. Further on, a good display requires that the information depicted is relevant to the operation, clear & understandable to all users, maximum use of symbols and graphics to minimize text which also must be frequently updated. Today Ambu are not even close to those requirements, they must upgrade to a more advanced system to fulfil them. From a lean visualization point, Ambu are making good but they still miss an important component to achieve perfectness!

### 6.1.4 Roof of the TPS house

As stated in the roof of the TPS House:

*"Highest Quality to The Lowest Cost and Shortest Lead Time".*

According to lean, those three elements contribute for a successful business. In Ambu they work after that philosophy. They produce the products to the highest quality and in the same time pushing down the costs. As the lean manager, see the empiric section **4.3.1 Purpose**, said that they are producing the products to the highest quality and hence the result is fewer complaints and backorders and thus keeping the costs down. Further on, the production manager was talking about that the lead time was reduced from 85 to 5 days thanks to the VMS tool (see the empiric section **4.3 Lean at Ambu**). Ambu seems to work after the TPS model and are applying the tools in a good way and hence affecting the company in the positive direction.



## 6.2 KPI

Analyzing the KPI section in the empirics, the purpose is to understand the kind of strategy used when developing a KPI and the kind of KPIs that are interested to visualize in real time. The base for the analyze is the theory section **3.4 Key Performance Indicator**.

The definition of a KPI can be interpreted once again (from the theory section **3.4 KPI**), in the following:

“KPIs are defined as quantifiable and strategic measurements that reflects an organization’s critical success factors” (M. Brooks, 2005).

Due to some of the respondents’ definition of a KPI, it can be interpreted as following:

“The purpose of using a KPI is to take control of different activities, have better overview and hence make better decisions”. See the empiric section **4.4.1 Purpose**.

The purpose of why a KPI is used seems to be understood among all respondents.

Further on, it will be analyzed at which levels of the company it’s of interest to visualize KPIs using dashboards and whether if it is of high priority to have dashboards on those levels and the effect of having them there.

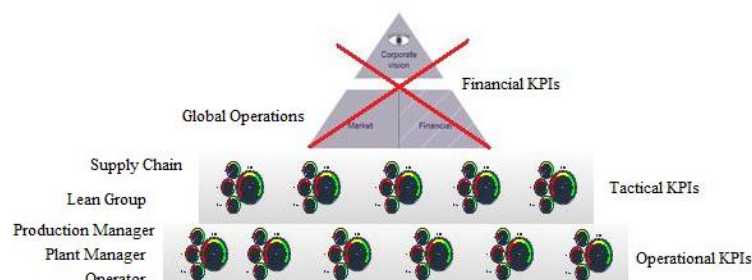
### 6.2.1 The development of a KPI

When developing a KPI at Ambu it’s made totally in accordance with figure 8 in the theory section **3.4.2 The process for developing a KPI**. That statement can be referred to the empirics, where it’s stated the following:

- ✓ The KPIs are developed in a sense to satisfy the shareholders
- ✓ Meeting once a year, setting up goals and hence pushing the KPI limits to a more strict tolerance
- ✓ The objectives are spread down using top-down strategy
- ✓ Involvement of the employees in the development process
- ✓ Involving all departments in the company in the development of dashboards

### 6.2.2 Review of the KPI Pyramid

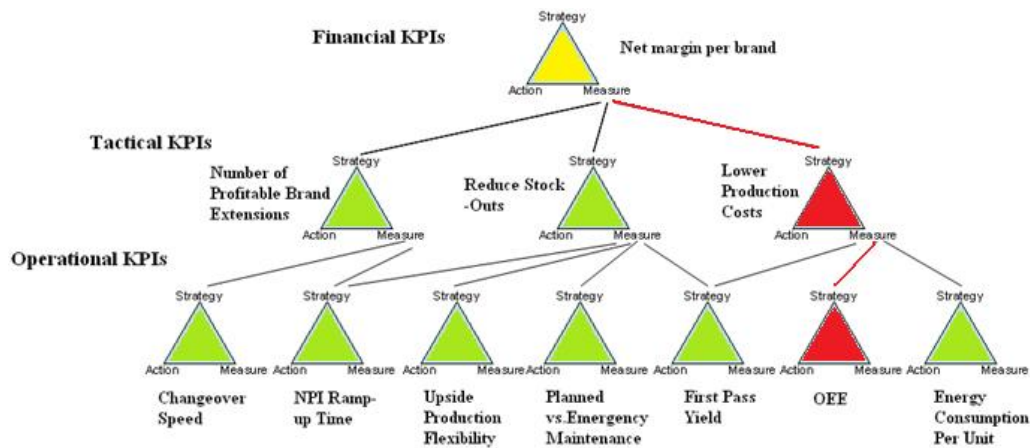
In the period when interview sessions were made at Ambu, it was in an early stage concluded what kind of KPIs that are of interest to visualize in a dashboard and hence in which levels of the corporate to implement those dashboards. Referring to the empiric section one might understand that in the higher part of the company, one are interest of financial KPI figures and that they are satisfied with the system of getting reports due to the months result. Thus, making further interviews in that part of the company was unnecessary and the completion of the interviews were made in a lower level. One can see that there is an interest of dashboards in the tactical and operational level of the company. The update frequency do of course differ in between the levels, i.e. daily update in the tactical level, hourly update for management in the operational level, continuous update for the operators etc. See figure 14, once again depicting the KPI pyramid but now including a picture of which levels at Ambu a dashboard should be included and for which roles.



**Fig.14.** Dashboards implementation in different levels.

Each and any respondent agrees upon the idea of having a big screen showing a big overview of all KPIs. The screen should include KPIs from the lowest level up to the highest level, which are of course connected in somehow. So if a KPI is red in a specific level it will affect the other KPIs it's connected to and one might see a path of where the leak is.

It's like a tree, everything starts in the roots and it continues upward till the top. If the roots aren't fed with water, this will be highlighted by the dead leaves falling on the ground which can be taken as a warning that tree needs water or else it will die and if everything is good, the tree continues to grow and the leaves retain green. This is exactly the same kind of process that occur at a company and which every company should highlight, see figure 15.



**Fig.15. The KPI Tree.**

*Green indicates good performance. Red indicate bad performance and hence, yellow indicates a warning that there's a problem that needs attention*

# 7. Prototype

In this chapter the prototype and the resulting dashboard will be presented. This is the outcome from the interviews on how a dashboard should look like and beyond that, lean thinking is behind the design. Before starting the work with VantagePoint and developing the dashboard, a pre version of the idea on how the dashboard should look like were handed out to the supervisors, once both parts agreed upon the design, the work started in VantagePoint – developing the real prototype. See the method flowchart in **Appendix A.1** for a better overview of the chapter disposition.

## 7.1 Concept Design of the Prototype

The idea is to visualize a big overview picture of the whole supply chain which offers the ability to drill down in each operation for details. The dashboard is intended to be used of people in the tactical level of the company and down to the operational level. The drill down access to each operation will be limited the lower level in the company, thus the access will depend on each role – but the big overall picture is viewed for everybody. In figure 16 below, the supply chain overview is depicted, containing several KPIs in each part. Of course one could also connect the KPIs to financial KPIs and build up a tree, but the focus will only be on the tactical due to the low interest for dashboards, from management in the strategic level. Since Ambu has a production site in Denmark, Malaysia and China – those will be visualized in the same picture.

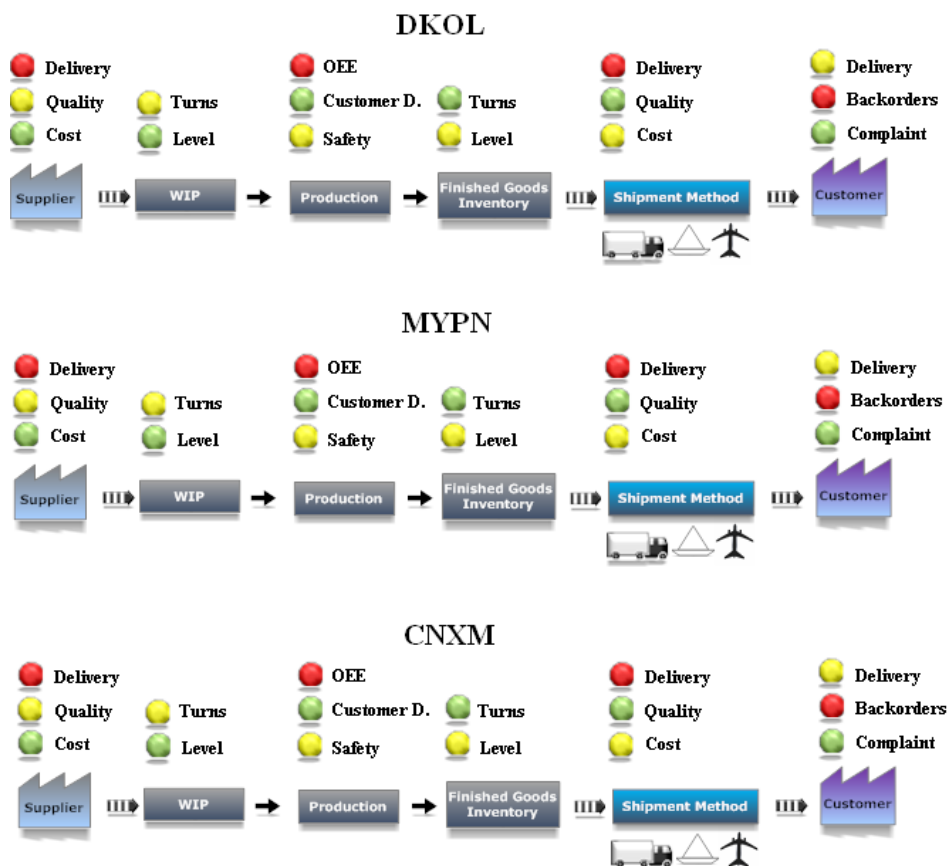


Fig.16. Supply Chain Overview.

Green indicates good performance. Red indicate bad performance and hence, yellow indicates a warning that there's a problem that needs attention.

DKOL – Denmark Ölstykke    MYPN – Malaysia Penang    CNXM – China Xiamen

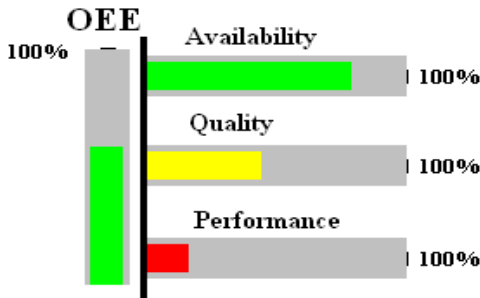
Since the biggest part of the project was spent in the production site, the focus for developing a drill down is made on the production part of the supply chain. Further on, there will only be a focus on the OEE KPI when developing a drill down in the production. That's due to the big interest from the lean managers about the downtime, causes for stop, trends and due to the implementation of the OEE overview in the production – here trying to show Ambu the benefit of showing the OEE in a different way than the graph depicted out in the production which isn't adding value at all to the operators. Since one got several different machines in the production, the OEE viewed in the overview picture is an average of all OEE for all machines. Hence, a drill down in the OEE will give an overview on all machines OEE (with the colors; red-orange-yellow-green, in chronological order showing a scale from bad to good) which will show specifically which machine who's having the worst OEE. The OEE for each machine is the total average for the last day, depicting an overview for the past week will result in an heat map were it will give a overview of where the leak is, see figure 17. The reason that it's only showing the day average is to simplify the analysis of which day and which machine that was worst which also meet the managers preferences, they don't want to watch how the OEE are changing in real time.

Day	1	2	3	4	5	6	7
M1	Orange	Green	Yellow	Orange	Yellow	Red	Orange
M2	Yellow	Orange	Yellow	Green	Light Green	Orange	Red
M3	Light Green	Red	Orange	Orange	Orange	Green	Yellow

**Fig.17. OEE Heatmap.**

Each color stands for a value of the OEE. A OEE equal to zero will depict a red color, close to zero will depict a orange color and so on until the color green, which might be met on 75%, those limits are set from the management preferences. Because a good OEE for them might be 50% and as the KPI is dynamic it will be pushed to harder limits and maybe after a specific period one might change the limit for a good OEE to 60% etc.

Being the manager now one might drill down in one of the machines for a certain day. Since the OEE is build by three different parameters, see the theory section 3.3.4 OEE for further details, drilling down gives the ability to study each part of the OEE and hence see more specific which parameter that's contributing with good or bad result, see figure 18.



**Fig.18. OEE.**

The OEE value with its constituents:  
Availability, Quality and Performance.

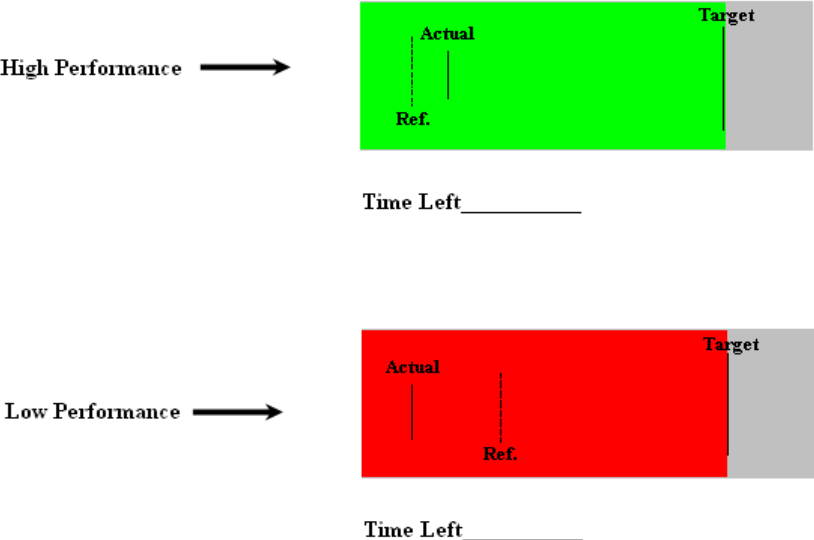
Further, if the manager is interested for more details, i.e. the machine downtime and causes for the specific day one might drill down in the Availability KPI. The drill down will result in a Gantt Scheme, showing an overview of the machine availability, when in time an downtime occurred, the amount of time the machine was down and the cause of it, see figure 19.



**Fig.19. Gantt Scheme.**

The Gantt Scheme contains an overall status that depicts the total availability of the day and when in time a downtime occurred and for how long. Standard causes are depicted to faster and easier recognize the reason of the downtime. If it was maintenance then it was a planned downtime and hence one can just go on.

That’s the complete overview one may get as a manager. But for the operator, there would be a big screen in the production site showing the machine performance, actual value (the amount produced), a reference value (the amount that should be produced) which must be met by the actual value. Hence one might finish the batch in time and meet the goals set and hence following the plan. The reference value is calculated due to the batch size and the planned time set for completion of that batch. Worth noting is if the production speed is too high, thus above the reference value one might produce to stock (which is not preferable) and if the actual speed is too low, thus below the reference value one might get a delay on delivery. So one should adjust the actual production speed so that the actual value is equal to the reference value. Instead of having an operator to control that task, this might be done automatically i.e. by a PID regulator. For a complete overview, the time left for completion of the batch is also depicted, calculated due to the actual production speed. To get the operators’ attention a colored box is highlighted, where red indicates a bad performance and green indicates good performance, see figure 20.

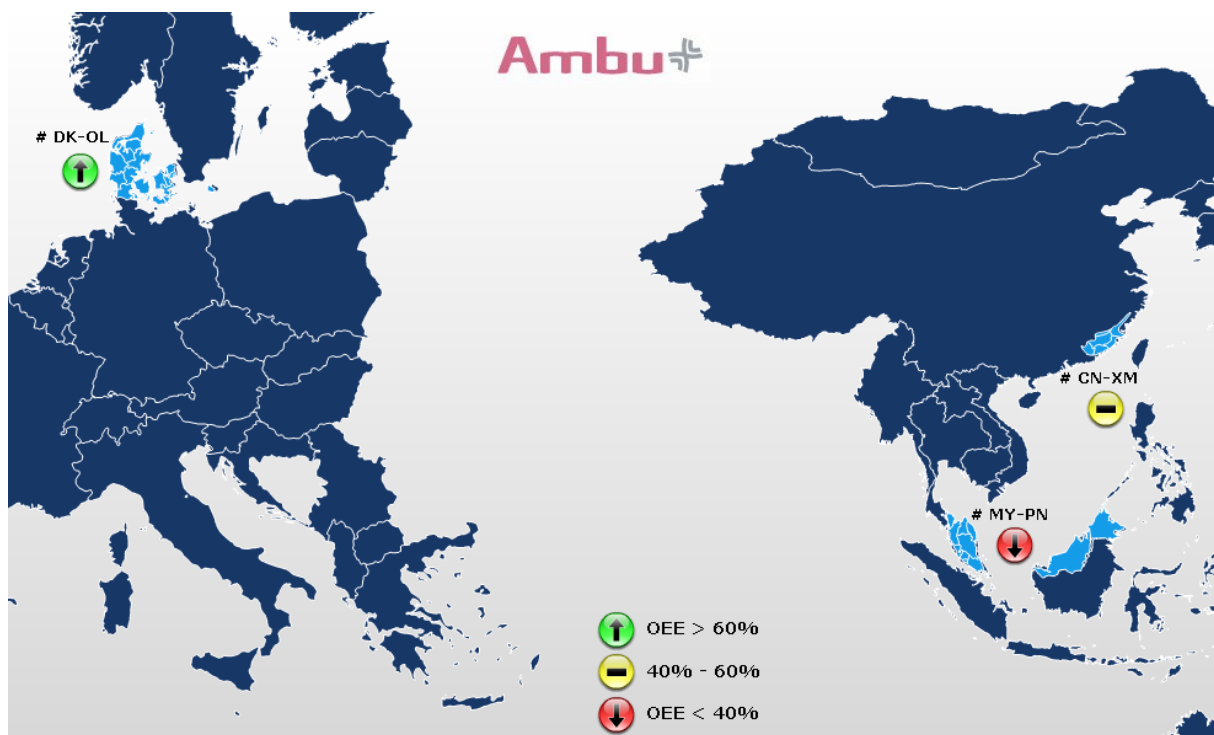


**Fig.20. Machine Performance in Real Time – Operator oriented.**

The above picture may depict how it looks like when the machine is performing well and the actual value is close to the reference value. The picture below shows a bad machine performance and hence an actual value far away from the reference value.

## 7.2 Real Prototype – a VantagePoint product

When designing the real prototype, focus was only made on the OEE when developing the supply chain overview. That's due to the delimitation made in the concept design and also because of the OEE's advantages making it easy to drill down and get a range of overview on the production. When developing the prototype, an advantage of VantagePoint was that it were a complete set of world maps. Then it was easier to depict the overview over Denmark, China and Malaysia. Hence one could make it more professional and it didn't took as much space as it did in the overview made in the concept prototype, see figure 16. So in that world map, only the OEE for the three countries is visualized, see figure 21. One may complete that map and build it up to a supply chain, locating the distributors, customers etc. in the map and showing different transports. This may give a complete overview and make it easier for the managers to track different problems.



**Fig.21. Ambu Supply Chain Overview.**

*The three areas are marked with a color of light blue. Each country got its own OEE. Note the difference in overview between this one and the one made in the concept prototype.*

The OEE lamps will alter in color depending on their value, which further depends on the pre defined limits stated as a tolerance for what might be highlighted as a good or bad performance. Further on if the manager wants to drill down in one of the OEEs stated, the next picture that will appear is the heatmap described earlier in the concept prototype. The advantage of VantagePoint is that one can use excel and connect them with each other. In excel heatmaps can be made as built in standard and the one developed can be seen in figure 22. It's very easy to create in excel and highlight it through VantagePoint and hence connect it to the net. If the manager wants to make a drill down in one of the machines for a specific day, the OEE and its constituents are visualized. In VantagePoint one can have the use of speedometers for a more pedagogical and a more fancy view. The development of those speedometers are done in alignment with the concept prototype, where focus was set on having a overview picture even though one are drilling down to a more specific and detailed information, this make it easy for the manager in each drill down to get a better picture of where the leak is. The OEE speedometers are highlighted in figure 23 and observe that the needles will move when connecting VantagePoint to a database that belongs to the company.

OEE Heatmap							
	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Machine 1	54	17	67	30	94	43	27
Machine 2	98	68	15	20	15	12	78
Machine 3	45	6	54	45	60	66	8
Machine 4	27	29	21	68	61	94	12
Machine 5	67	15	17	47	50	26	39
Machine 6	53	36	23	44	58	35	96
Machine 7	30	27	25	97	23	35	17
Machine 8	90	57	65	67	27	23	10
Machine 9	3	87	66	75	96	59	59
Machine 10	70	44	62	19	50	17	74

**Fig.22. OEE Heatmap.**

As earlier, the color depends on the OEE value which can be seen in the figure.



**Fig.23. OEE Speedometers.**

Depending on which values the different parameters will have, those will define the OEE value. Here can be seen the good overview of how the machine is performing and hence can track the leak, i.e. which parameter that is contributing to a low OEE. Let say that the OEE is equal to zero and hence is in the red region, the performance is excellent and so is the availability but the quality is zero, if only the OEE were visualized the manager would never know why the OEE is zero and would then be forced to get in to the system and search after the values for the OEE parameters.

The next drill down would be down to the Gantt Scheme, but since there was no Gantt Schemes built in as a standard it would require a bigger focus on that task and that wasn't of highest priority. The real prototype was aimed to prove the advantages of VantagePoint, so there was no need of completing the Gantt Scheme to make our statement clear. The overview of the machine performance aimed for the operators wasn't completed either for the same reasons. But it's worth noting, that the operator oriented machine overview stated in figure 20 is possible and easily made in VantagePoint, but since we had made our statement clear of what kind of tool VantagePoint is and how powerful it is, it wasn't necessary to complete it.



## 8. Result and Discussion

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There was two core-questions stated in the interviews made at Ambu, the first one is if Ambu is a lean company and the second is how Ambu wants to visualize different information. Due to the analyzes made, Ambu are committed to the lean ideology. They adapt the lean thinking and there's the required lean mentality. The lean culture is implemented in a healthy manner, i.e. the negative side-effects of being too lean isn't perceived at Ambu – simply meaning, the staff aren't affected of the hard stress lean might contribute with. Due to a clean, uncluttered and managed work area, Ambu is fulfilling the lean thinking behind that up to 100%! Actually, the production area isn't perceived as a work area at all, one can't believe that there's something being produced – silent, clean, managed and open work area that makes it easy to communicate. The only missing element in the production area so that Ambu can be completely lean and aligned with the TPS ideology is the use of dashboards. It's something that would add a lot of value to the whole corporate and hence support management to take different decisions easier and faster. Seeing information in real time and having a tool that enable fast report generation and simply analyzing the information really save a lot of time. Doing that manually, it's very hard and require a lot of time – one must; pull out the right data from various manufacturing systems, to put it into a spreadsheet, rationalize, correlate, calculate, formatting and finally deliver. It really takes a lot of time and time in a lean context is waste and being lean is to minimize waste. So while you're sitting there and putting a lot of energy on gathering, analyzing and generating the data a dashboard user has already made the correct decision at the same time you're gathering the data. So, to be lean and really be committed to the ideology – each and any company that perceives themselves as a lean company, there is a solution for that; implement dashboards. Manufacturing reporting must not be so hard or difficult and time consuming – in contrary, it must be easy and letting you to focus on how to solve the problem and not spending time with focusing on the wrong task, i.e. gathering the data or calculating different parameters.

Due to the software tool VantagePoint, it can be easily adapted in a lean company and it works well as a support for decision making. It can be easily connected to different manufactory systems and are not dependent of only Rockwell manufactory systems. It's dynamic in its nature and hence gives the ability to the user to change the parameters for the KPIs used after a certain period – which is in alignment with the lean ideology of being dynamic. The interface viewed can be easily used by any person and has a range of drill down opportunities. The information can be viewed in a pedagogic way that makes it easy for the user to interpret the information visualized. A big advantage with VantagePoint, as I perceived it; any kind of interface that you might have in mind can be built up in VantagePoint – there's no limitation on what can be done, let your fantasy decide and see it becoming true.

# 9. Conclusion

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*Here will be given conclusions and recommendations to Rockwell Automation and Ambu. It will be concluded whether VantagePoint is a tool that can support lean companies or not. Further recommendations will be given on what may make VantagePoint better from a lean point of view. For Ambu one might conclude if they are lean or not and what might be the weak link in the company. Further recommendations of what they should improve to become more lean and hence eliminate the weak link will be given.*

## 9.1 Rockwell Automation

- It's very easy to develop dashboards in VantagePoint, since there are many standard tools ready to use.
- VantagePoint has the ability to visualize KPIs in a very good way with animations etc.
- By having the ability to show an overall status, it's the perfect tool for lean companies.
- Easy to drill down in each level and can be adapted after different roles.
- It's easy to access through the web, which allows a worldwide connection in any time.
- The web connection makes it easy to share information between colleagues in different places in the world.
- A future possibility is to connect VantagePoint to the cell phone.
- To adapt VantagePoint to a lean company's preferences it's important to make Gantt Schemes as a standard in VantagePoint toolbar.
- In a future work with a lean company, it's important to have in mind to visualize an overall status in each drill level. Having a good overview makes it easy to identify where the leak is. Leak in that context is interpreted as waste. Having a good tool that shows a big overview makes it easy to trace the waste and hence eliminate it – which is the purpose of lean.
- Heatmap's can be easily made in Excel and thereafter connect it with VantagePoint. It's not of the best graphic, thus an improvement in the graphics and the use of it may be of big importance. Nowadays, heatmaps are used fluently in different branches, i.e. overview of all stocks – by color defining how the stock has performed for a certain day and hence gives the ability in an easy way to analyse a specific stock in relation with other.
- The dashboard use may only be developed for people in the tactical level down to the operational level, but it doesn't exclude the opportunity to use in the strategic level. It's also good to have in mind when developing the dashboard, that the different KPIs for each operation may support KPIs in a higher level and eventually all the way up to the financial KPIs.

## 9.2 Ambu

- A conclusion may be made that Ambu are a lean company, but that there is an important element missing. That element is a very important tool in lean. It's the use of dashboards for a better overview on different processes and hence identify waste easier.
- To make continuous improvement, the performance of different operations must be measured and visualized. You can't improve what you can't measure and hence, you can't measure what you can't see!
- Thus making an investment in such software that gives the ability to measure and visualize the performance makes a difference. Remember, lean is not a short-term project, hence making an investment in such tool must be seen from a long term manner.
- KPIs are dynamic, so investing in a dashboard it must be dynamic. Thus it gives the ability to access each KPI and change different parameters.
- In Ambu, the interest of having a dashboard is in the tactical level and down to the operational level.
- The information must be viewed in an easy way. The visualization used today doesn't add any value to the staff working at Ambu.

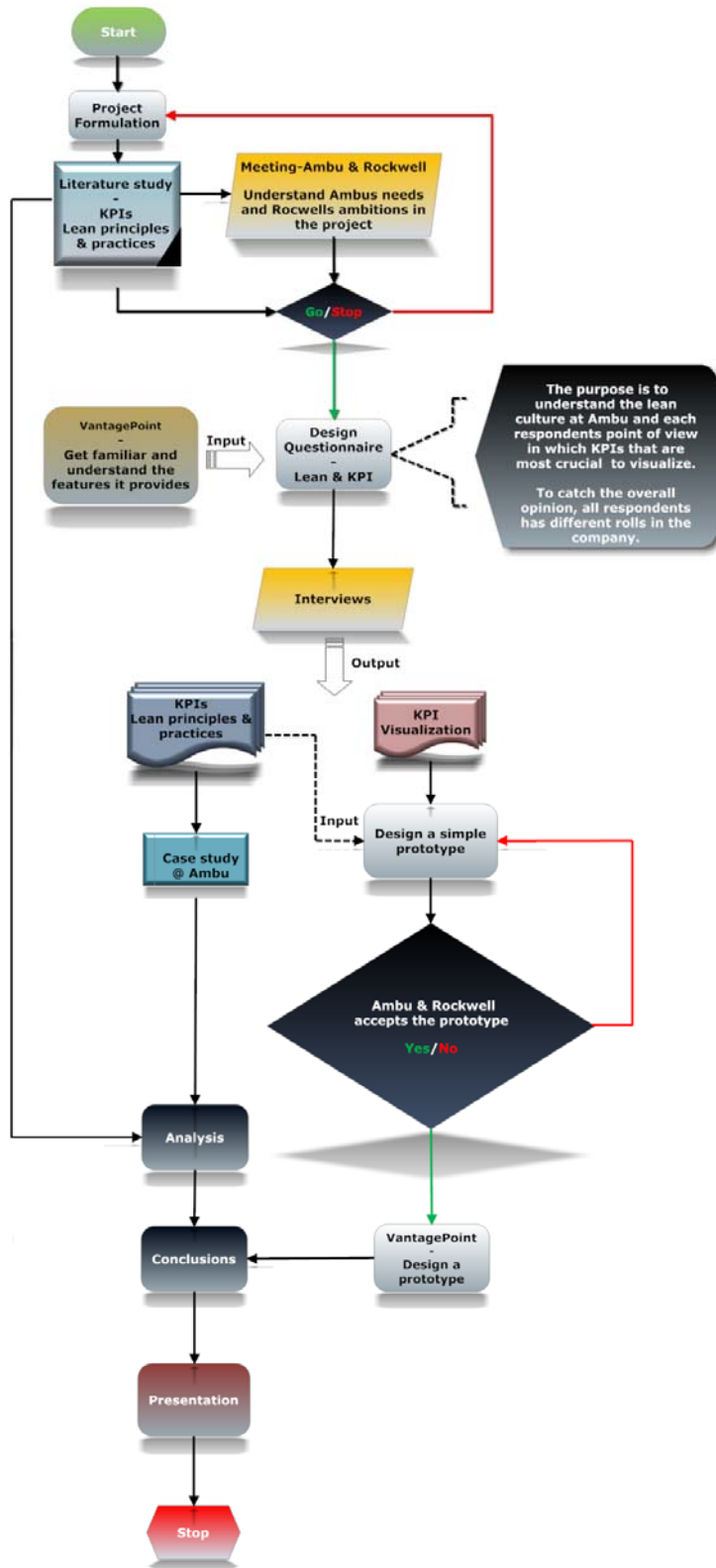
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# Appendix A

## A.1 Method Flowchart



## A.2 Interview Guide

**Position:**[\_\_\_\_\_] **Experience within the company (Year):**[\_\_\_\_\_]

### **Introduction**

In the beginning I'll start with general questions about lean culture in the production and how you use its tools. And thereafter continue with questions about a specific tool in lean, namely KPI (Key Performance Indicator). This key ratio is used very frequently in several process companies to visualize performance. The purpose with the whole interview is to get a deeper knowledge about those KPI that is of most interest for you and how you will visualize them. To visualize data and being agreed upon its meaning is a crucial ingredient in a company's lean culture. The objective is that after the interviews to design an interface that demonstrate the most important KPIs in an informative and pedagogical way as possible. This interview takes approximately 1 hour, your name is treated confidentially – it's your position that is of interest. The interview consists of a question time and in the end, completing a simple questionnaire.

1. The respondent will (and has the opportunity not to) answer the following questions by grading from 1-5.

<b>Lean</b>						
<u>1.Very bad</u> <u>2.Quite bad</u> <u>3.Neither good nor bad</u> <u>4.Quite good</u> <u>5.Very good</u>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	No Answer
1. How good or bad are lean adapted in the production as a whole?						
2. How good or bad is the lean culture adapted in the production?						
3. How good or bad are lean tools used in the production?						
4. How good or bad is waste identified in the production?						
5. How good or bad are waste prevented in the production?						
6. How good or bad are performance measured in the production?						
<b>Visualization</b>						
<u>1.Not important at all</u> <u>3.Neutral</u> <u>5.Very important</u>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	No Answer
1. How important is it to measure production performance?						
2. How important is it to visualize production performance?						
3. How important is it to visualize an overall status of the production?						
4. How important is it to visualize production speed?						
5. How important is it to visualize if the production rate is too slow or too fast?						
6. How important is it to visualize the current produced quantity relative to the planned quantity to produce?						

2. Next, the respondent is free to reflect and discuss own thoughts around the questions being asked.

## Lean

1. When did the implementation of lean start in the company?

2. What is the purpose?

3. What kind of improvements have you achieved? In:

Lead Time     Inventory     Service Grade     Other \_\_\_\_\_

4. How lean are you today in a scale of 1-10, comparing with Toyota?

1.     2.     3.     4.     5.     6.     7.     8.     9.     10.

5. How lean do you want to become in a scale of 1-10, comparing with Toyota?

1.     2.     3.     4.     5.     6.     7.     8.     9.     10.

6. Is there a process for continuous improvement of the production?

7. Can all the activities in the production be continuously improved?

8. Will continuous improvement reduce or eliminate non-value-adding activities?

9. Is there any end of improvement?

10. How do you involve the operators in that work? (Are they free to come with ideas for Improvement?)

11. Are they educated in how to be lean and what it deals with being lean?

12. How do you motivate them to be lean?

13. Are their work standardized?

14. How much of the production time is setup-time/preparation-time?



15. Are changeovers smoothly done?
16. How do you identify the root cause of a problem? Do you use the “5 whys”-technique?
17. When the error is identified, how do you prevent it to occur in the future?
18. Do you make value stream mapping to identify waste?
19. When waste is identified, can it be fully eliminated?
20. How is the machines placed?
21. How is equipment and tools placed relative to the machines? Are they easy to find and close?
22. So what I’m really asking is there a strategic “lean” thought behind the layout of the work floor today?
23. What is the main reason that is slowing down the lead-time?
25. How are you working to eliminate that cause?
26. How do you measure production performance?
27. How do you want it to be visualized?
28. What kind of information do you need to see?

## KPI

1. What is the purpose of using KPIs?
2. What kind of KPIs do you deal with in your daily work?
3. How are they visualized?
4. What is bad, visualizing them in that way?
5. Would you prefer to have them visualized in another way?
6. What do you need to make it better?
8. Would you like to visualize the KPIs in real time?
7. Are you working for continuous improvement of those KPIs and the way they are visualized?
8. Have you achieved any improvements due to the use of KPIs?
9. How do you involve KPIs in your daily work, i.e. when taking a decision?
10. How do they support your work?

3. This is the ending part of the interview. Here, the respondent is asked to complete a questionnaire. First, the task is to grade from 1-5 in how interest different KPIs are for the respondent to visualize. And thereafter, the task is to pick out the 5 KPIs that are of most interest for the respondent to visualize.

### Questionnaire

<p>1. <b>Grade from 1-5, how interest each KPI are for you to visualize.</b>          1. <u>Not interesting at all</u>      3. <u>Neutral</u>      5. <u>Very interest ing</u></p> <p>2. <b>Pick out the 5 KPIs you consider to be of most interest to visualize. Mark with a cross "X".</b></p>	1	2	3	4	5	X
<b><u>Production related KPIs</u></b>						
1. Actual versus planned volume						
2. Throughput: Produced Quantity / Lead Time						
3. Production Efficiency: Production Time / Busy Time						
4. Machine Efficiency: Production Time / (Production Time + Delay Time)						
5. OEE Index: Availability * Effectiveness * Quality rate						
6. Wastage Ratio: Scrap Quantity / Produced Quantity						
7. Reworking Ratio: Rework Quantity / Produced Quantity						
8. Production Lost Rate: Production Lost / Consumed Material						
<b><u>Inventory Related KPIs</u></b>						
9. Inventory Turns: Throughput / (Work in process Inv. + Finished goods Inv.)						
<b><u>Quality Related KPIs</u></b>						
10. Quality Rate: Good Quantity / Produced Quantity						
11. Finished Goods Rate: Good Quantity / Consumed Material						
<b><u>Customer Related KPIs</u></b>						
12. Customer Quality Satisfaction: Good Quality/ Delivered Products						
13. Customer Delivery Satisfaction: Delivery Time / Customer D.T Expectation						
<b><u>Supplier Related KPIs</u></b>						
14. Good Supplier Index: (Quality + Delivery speed + Price) / Max Grade						
15. <b><u>Another, own suggestion:</u></b>						