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Title: Developments of production methods in the auto industry and its effects on other industries

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Subject: Developments of production methods in the auto industry and its effects on other industries

With Hendry Ford’s mass production and other developments, the auto industry has developed multiple production methods which are proven to be successful. Some of these developments are adopted by other industries. What has been the effect of the developments of production methods in the auto industry on other industries? To answer this question a historical overview of the developments of production methods in the auto industry has to be made. Also the topic why some of these developments failed in certain industries or some are widely applied in all sorts of industries will be discussed.

The report should comply with the guidelines of the section. Details can be found on the website.

The professor,

H.P.M. Veeke
Summary

The purpose of this literature assignment is to give a historical overview of developments of production methods in the auto industry and its effect on other industries. Multiple industries failed in adopting production methods of the auto industry and others succeed in widely applying all sorts of production methods.

Mass production and lean manufacturing are the biggest revolutions of production methods in the auto industry. In chapter 1 and 2 is described what was so new about mass production and lean manufacturing.

Henry Ford revolutionized the world with mass production: introducing assembly stands, shortening the tasks of workers and introducing the moving assembly line. When the stock market crashed in 1929 Ford became a popular employer as he paid his workers above average. Workers did not have to do heavy lifting, stooping or bending over. Also no special training required; there were jobs that almost anyone could do. On the other hand the tasks of workers were very repetitive.

Chapter 3 concentrates on the impact of the introduction of ‘mass production’ and its application during the WWII. In WWII the mass production techniques of Ford were applied to produce vehicles that were used in combat. Ships, airplanes, tanks and other vehicles were mass produced. The aviation industry had difficulties applying mass production because the airplanes were too complex machines to be mass-produced. They would also require more high precision components which were hard to produce with mass production. The Americans were successful in mass producing aircrafts during WWII by standardizing the aircrafts.

Chapter 4 describes the adoption of Lean Manufacturing in the aviation industry, process industry and in small versus large organizations. The best way to start off is to launch Lean pilots until lean is implemented. Lean manufacturing is adopted in a lot of industries and a lot of ‘guidebooks’ can be found on how to implement lean into a company. Lean capabilities are not firm-specific, but are plant specific. In the process industry there is a lack of flow and functional behavior and lean can provide financial, cultural and organizational benefits. Larger organizations are implementing lean for a longer time than smaller organizations. Larger organizations focus more on continuity and less on process mapping because larger processes are more complex.

The fifth chapter describes the future of the automobile industry with the use of new energy sources and the possible impact of the use of new energy sources on other industries. It is shown that 75-90% of a car’s energy consumed during the lifecycle is consumed during operation. Car manufacturers are searching for new energy sources, but a solution has not been found yet. Because of the size of the auto industry, changes of energy sources in the auto industry will have a big impact on other industries. Fast developments and benefits of economy of scale will let other industries benefit from the developments in the auto industry once again.
# Contents

Summary.............................................................................................................................................1-3  
Introduction........................................................................................................................................1-5  
1. **Ford: Mass production** .................................................................................................................1-6  
   1.1 Pre 1900 .........................................................................................................................................1-6  
   1.2 Henry Ford: mass production .........................................................................................................1-6  
   1.3 The conveyor belt ............................................................................................................................1-7  
   1.4 Pros and cons of mass production ....................................................................................................1-8  
2. **Toyota: Lean manufacturing** ..........................................................................................................2-10  
   2.1 The concept ......................................................................................................................................2-10  
   2.2 Push versus Pull and kanban ............................................................................................................2-12  
   2.3 The Lean worker ...............................................................................................................................2-12  
   2.4 Design process .................................................................................................................................2-13  
   2.5 Coordinating the supply chain .........................................................................................................2-13  
   2.6 What’s after lean? .............................................................................................................................2-16  
3. **Impact of Ford’s mass production on the other industries** ..........................................................3-18  
   3.1 Aviation industry ..............................................................................................................................3-18  
   3.2 Tank and ship industry ......................................................................................................................3-20  
4. **Impact of lean production on the other industries** ........................................................................4-21  
   4.1 Adapting Lean in the aviation industry .............................................................................................4-21  
   4.2 Process industry: ..............................................................................................................................4-22  
   4.3 Adopting lean: small versus larger organizations ..........................................................................4-23  
5. **Future of the auto industry: searching new energy sources** ......................................................5-25  
   5.1 Environmental reconnaissance and definition of goals ..................................................................5-25  
   5.2 Making policy .................................................................................................................................5-26  
Conclusion...............................................................................................................................................5-27  
References ..............................................................................................................................................5-28
Introduction

10.2 % of the total employment in the manufacturing sector in the EU is linked to production of automobiles. In the EU 12 million families depend on automotive industry with 2.3 million direct jobs and another 10.4 million jobs that are indirectly related to manufacturing and other sectors. (The Automotive Industry Pocket guide 2010). This illustrates the size and importance of the auto industry, and also the production and logistic challenges in the auto industry. During the 20th century there have been major developments in production methods in the auto industry. Other industries have been trying to adopt some of these production methods; some with more and some with less success.

The purpose of this literature assignment is to give a historical overview of developments of production methods in the auto industry. While adopting developments of the auto industry these production methods failed in certain industries or some are widely applied in all sorts of industries. The successful developments in the auto industry were adopted by industries as the aviation and other industries related to producing war machines during the WWII. Lean manufacturing has been widely adopted and has introduced a run to eliminate waste and restructure supply chains within an organization.

This assignment contains 5 chapters. In the first chapter the development of mass production by Henry Ford is described. The second chapter focusses on the popular Lean philosophy. Chapter 3 concentrates on the impact of the introduction of ‘mass production’ and its application in during the WWII. Chapter 4 describes the adoption of Lean Manufacturing in the aviation industry, process industry and in small versus bigger organizations. The fifth chapter describes the future of the automobile industry with the use of new energy sources and the possible impact of the use of new energy sources on other industries. At last the conclusion of the whole assignment is given.
1. Ford: Mass production

Paragraph 1.1 describes that before Henry Ford’s concept of mass production the manufacturing was done by craftsmen. Henry Ford developed his way of producing in three phases which are explained in paragraph 1.2. Paragraph 1.3 continues with the use of the conveyor belt in mass production. In paragraph 1.4 the pros and cons of mass production are described.

1.1 Pre 1900

Before Ford introduced ‘mass production’, craftsmen have been building cars only when there was an order for a car. A worker was highly skilled in design, machine operations and fitting. He would build one car from start to finish by using a full set of craft skills: the worker had to be an expert of the whole production process. This means the production of a car was a very slow and time consuming process. The organizations were very decentralized but concentrated in a single city for easier supply of parts. Most parts came from small machine shops and the supply was coordinated by the owner, who managed all involved parties.

In this period only very simple machinery and techniques were used like drilling and grinding of wood or metal. Upscaling production was almost impossible because more of these skilled craftsmen were needed. During the craftsmanship period a company produced at most 1000 or less vehicles per year of which a maximum of 50 were built to the same design. A car was an exclusive product and not available for ordinary people. A ride in a car was considered as a fun big excursion.

1.2 Henry Ford: mass production

Henry Ford was the founder of the Ford Motor Company and developer of the assembly line technique in mass production. With this technique he revolutionized the transportation of the American industry but also changed the way of most efficient producing from craftsmanship to mass production.

Source: ‘Ford model T Turns 100’ - http://www.fareastgizmos.com

Figure 1: Ford’s model T
In 1908 Ford changed the word’s industry with his Ford model T. Ford developed the 3 ‘phases’ of mass production. First he decides to not let one man built one car by himself, but he introduced assembly stands. At these assembly stands he let workers install bigger parts of the car, for example assemble the mechanical parts (wheels, springs, motor, and generator) on the chassis. This set of activities took a whole day and the workers could perform their activities at one place so unnecessary walking is avoided.

In the second phase the variety of activities of the workers is shortened from one day to several minutes. The worker’s job is to execute only one task, like putting two nuts on two bolts or perhaps attach one wheel to the car. This led to a remarkable increase of productivity because the workers became familiar with their task and could perform their task faster and faster.

Ford noticed the problem that the workers had to walk from assembly stand to assembly stand. This took time and also caused jam-ups as the faster workers had their job done but the slower workers were still busy. This lead to the third phase of mass production: the moving assembly line.

### 1.3 The conveyor belt

The first conveyor belts were primitive and used since the 19th century. Thomas Robins developed the conveyor belt for carrying coals ores and other products. Sandvik improved the conveyor belt by inventing and producing conveyor belts of steel.

Henry Ford was in inspired by the moving assembly line of the meatpacking plants in Chicago. The idea came from an overhead trolley that the Chicago packers use in dressing beef. The job of one worker was split into twenty-nine operations to cut down the assembly time. In the same way Ford divided the work of one worker, assembling the motor, into eighty-four operations. The group of workers that were assembling the motor could now do the work where previously three times as much workers were needed. Soon after this finding Ford implemented this idea with the chassis and other components.

Henry Ford started to use the conveyor belt in his conveyor-belt assembly lines in his Ford Motor company’s Highland Park and boosted his productivity and let him finalize the 3rd phase of mass production. This innovation let Ford even cut the time of tasks of worker by half, now a little more than a minute.

In table 1 it is shown that Ford achieved a way lower assembly time with mass production than was possible with craft production.
Table 1: Craft production versus mass production in assembly hall

<table>
<thead>
<tr>
<th>Minutes to assemble</th>
<th>Late craft production fall 1913</th>
<th>Mass production spring 1914</th>
<th>Percent reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine</td>
<td>594</td>
<td>226</td>
<td>62</td>
</tr>
<tr>
<td>Magneto</td>
<td>20</td>
<td>5</td>
<td>75</td>
</tr>
<tr>
<td>Axle</td>
<td>150</td>
<td>26.5</td>
<td>83</td>
</tr>
<tr>
<td>Major components in a complete vehicle</td>
<td>750</td>
<td>93</td>
<td>88</td>
</tr>
</tbody>
</table>

Note: “Late craft production” already contained many of the elements of mass production, in particular consistently interchangeable parts and a minute division of labor. The big change from 1913 to 1914 was the transition from stationary to moving assembly.

Source: The machine that changed the world

1.4 Pros and cons of mass production

Ford created machines that had low setup-times, but could only do one task at a time. Previous machines could do multiple tasks, but needed a skilled craftsman to adjust the machine for the various tasks. So Ford needed less skilled workers which were easier to find. Ford’s salaries were pretty good compared to competitors so Ford became a popular employer, even though the tasks were simple and monotonous. When the moving assembly line was introduced all the workers had to work at the same speed, which could lead to problems with new versus experienced workers. At the end of the assembly line the ‘more skilled’ quality control team is looking for defects. If the cause of the defects was early in the production process, it could take a while before the feedback arrives at the point of cause. In Ford’s biography he tells the assembly line has to following benefits: Workers do no heavy lifting, no stooping or bending over, no special training required, there are jobs that almost anyone can do.

One of Ford’s strengths was using the advantages of economies of scale. Ford accomplished to reduce the production time from 12.5 hours to 93 minutes and more than 15 million pieces of the model T’s were produced, a true achievement. The famous statement of Ford about the color of the car was: ‘Any costumer can have a car painted any color that he wants so long as it is black’. Ford’s model T was of high quality compared to competitors and another important benefit was that users could easily repair the car themselves without special equipment. The tools needed to repair the car were supplied by Ford with the purchase of the car.

In 1915 Ford achieved vertical integration: producing all parts from raw materials himself. Ford had little trust in others and with his new idea of mass production he thought it would be better if he himself would start producing all the parts himself. He needed parts with closer tolerances and he wanted the parts to arrive at a tight schedule. Ford tried to control the supply chain from the mining of iron and coal to the finished product and he connected production facilities with a railroad.
attempted to mass produce everything: from food (trough tractor manufacture) to air transportation (producing the airplane-engine Ford Trimotor). With mass-producing all these products he wanted to reduce the costs of products and make 'the masses rich'. Ford himself actually had no idea how to organize a global business except for letting one person make all the decisions: himself. This nearly killed his business.

In the 1920’s there was a great growth for the auto industry and more and more people bought their first car. Many small car companies were started in the US, but the time of prosperity ended in 1929 when the stock market crashed the great depression started (see figure 3). Half of these new companies did not survive during the 1930’s. This economic difficulty resulted in people from all over the country tried to apply for work at the car factories. The car companies that were small and specialized disappeared and the big three: Ford, General Motor and Chrysler were rising.

![Unemployment during the 1930's in the US](https://en.wikipedia.org/wiki/Great_Depression)

**Figure 2: Unemployment during the 1930’s in the US**

In the 1940’s World War II helped the American emerge from the depression. The car factories were adjusted to produce vehicles and airplanes for the armed forces, which led to great technological advancements.


2. Toyota: Lean manufacturing

In paragraph 2.1 the way to lean manufacturing and the general concept is described. Important aspects of lean manufacturing are Push versus Pull and kanban, explained in paragraph 2.2. The role of the workers of lean manufacturing changed with respect to workers of mass production. This change is explained in paragraph 2.3. Paragraph 2.4 and 2.5 describe the design process and explain how to coordinate the supply chain with lean philosophy. Paragraph 2.6 is concentrated on the modern developments of lean.

2.1 The concept

The knife and wrench that could repair almost anything of the Ford T model were useless in the 1980's to repair an engine management computer or other electrical parts. Also there was a fragmentation of the market because people did not want one standard type of car, but they preferred reliable cars of different sizes with different options. In 1990 James Womack wrote a book called 'The machine that changed the world'. The book describes the history of the automobile combined with a comparative study of the American, European and Japanese auto industries. A new production practice 'Lean manufacturing' is explained. Lean manufacturing turns out to be a very popular management philosophy derived from the Toyota Production Systems.

In mass production a lot of waste and large inventories are noticed. The goal of Lean is to identify and eliminate everything that does not add value to the product, waste. Liker (2004) states eight different types of waste:

- **Overproduction**: Producing items earlier or in greater quantities than needed by the customer creates wastes, such as overstaffing, storage, and transportation costs because of excess inventory.
- **Waiting**: Workers who are serving as watch persons for an automated machine or having to stand around waiting for the next processing step, tool, supply, part, etc.
- **Unnecessary transportation**: Moving work in process from place to place in a process, even if it is only a short distance. Or having to move materials, parts, or finished goods into or out of storage or between processes.
- **Overprocessing or incorrect processing**: Having more steps in the process than necessary and also producing higher quality than needed. Inefficiently processing due to poor tool and product design, causing unnecessary motion and producing defects.
- **Excess inventory**: Excess raw material, Work in progress, or finished goods causing longer lead times, obsolescence, damaged goods, transportation and storage costs, and delay.
- **Unnecessary movement**: All motions workers have to do during their work that is not adding value to the part.

- **Defects**: The production of defect parts or correction. Repairing of rework, scrap, replacement production, and inspection means wasteful handling, time, and effort.

- **Unused employee creativity**: The loss of time, ideas, skills, improvements, and learning opportunities by not engaging or listening to your employees.

The lean mentality is to prevent problems to occur instead of fixing them afterwards. Where mass producers have finished products with defects, lean producers will try to deliver the perfect product right away. Workers can pull a cord if there is a problem so the production line is stopped to prevent to have the total series of products with the same defect. When for example a defect is noticed because a machine cannot hold its tolerance, the team will ask the five why’s: Why can’t this machine hold its tolerance? Because the worker who operates the machine is not trained properly. Why? Because employees that operate the machine keep quitting their jobs. Why? Because the work is noisy and unchallenging. Now the ultimate cause is discovered and the work process can be adjusted in order to fix the problem. The problem often turns out to be an organizational problem and once fixed it is very unlikely that the problem occurs again.

<table>
<thead>
<tr>
<th></th>
<th>GM Framingham</th>
<th>Toyota Takaoka</th>
<th>Nummi Fremont</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Assembly hours per</strong>&lt;br&gt; <strong>car</strong></td>
<td>31</td>
<td>16</td>
<td>19</td>
</tr>
<tr>
<td><strong>Assembly defects per</strong>&lt;br&gt; <strong>100 cars</strong></td>
<td>135</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td><strong>Assembly space per</strong>&lt;br&gt; <strong>car</strong></td>
<td>8.1</td>
<td>4.8</td>
<td>7.0</td>
</tr>
<tr>
<td><strong>Inventories of parts</strong>&lt;br&gt; <strong>(avg)</strong></td>
<td>2 weeks</td>
<td>2 hours</td>
<td>2 days</td>
</tr>
</tbody>
</table>

*Source: The machine that changed the world*

In table 2 the assembly and inventory characteristics of production plants of General Motors, Toyota and combined are displayed. The Nummi Fremont manufacturing plant in California is a joint venture between the classic mass producer General Motors and lean producer Toyota. General Motors decided that it could learn from Toyota and convinced them to provide the management for the plant and pretty fast the Toyota Production System was implemented.
2.2 Push versus Pull and kanban

When the buyers of cars became more demanding and were not satisfied with one type of car, dealerships in a mass production supply chain had serious problems. In order to keep the costumer happy they had to keep lots of different models in stock. Problem occurs when costumers only buy popular models and the less popular models do not sell. Of course the costumer’s demand is very fluctuating and to forecast the sales always ends up in chaos. Toyota had a solution for this issue. Toyota stopped producing in advance for unknown buyers and converted to a build-to-order system in which the dealer was the first step in the kanban system. Stock relatively small amounts of each product and restock the supermarket shelf frequently, based on what the customer actually takes away.

Kanban
Kanban literally means 'visual card'. It is used as one of the many methods to apply 'pull-based planning and control', a property of Just in Time, and is often mistaken as synonym of 'Just in Time'. Kanban can be expressed as visual signal to support flow by 'pulling' product through the manufacturing process as required by the customer. An example of this is the 'Two bin': two boxes of parts are used as storage. If the first box is empty the second box is used for parts and a signal is given to resupply the first box.

2.3 The Lean worker

Workers need a wide variety of skills so their work group can rotate tasks. For example workers need to acquire skills like simple machine repair, quality checking, housekeeping and material ordering. The workers need to have a pro-active mentality so they can solve minor issues before they become major issues. Therefore they are needed to be valued by the management team and the management team needs to delegate responsibility to the team. This was a big problem with Ford where workers had very narrow skilled tasks and have the mentality to achieve the dedicated target and just get the job done, with all its consequences: low quality and many production errors. Little teamwork took place. At Toyota salaries were built up via seniority instead of the same salary for everybody. Workers were working at Toyota for a longer time, so skills and to gain benefit of knowledge and experience became more and more important.

Opinions were divided about lean production, as the workers might have a higher stress level because the management is always looking to remove slack and continuously want to improve the production process. Another critique comes in a form of neocraftsmanship. Here the interval for the worker to repeat his actions is increased from minutes (in mass and lean production) to hours and workers can set their own pace and can choose to rotate jobs as they desire. This neocraftsmanship is supposed to create a work environment that is more humane.
2.4 Design process

At the head of the design process there is a large-project leader, called a ‘shusa’. This shusa will lead the design and engineering process of a new product and get it fully into production. The shusa assembles a small team of individuals who come from the following departments: marketing, product planning, styling, advanced engineering, detail engineering, production engineering and factory operations. The team members will be assigned to the development project for its life and also their career success depends on moving up their function specialty. The shusa has a clear control of the design process.

Team members sign formal pledges so everybody knows which aspects have priority and conflicts occur at the beginning of the process. The shusa will have to force the group to confront all the trade-offs they will have to make. In mass production the amount of people involved grows to a peak close to the end of the project while in lean production the people involved drops as some specialties like marketing and product planning are not needed anymore. This matches the lean mentality of dealing with problems as soon as possible and eliminating the slack.

Another technique used is simultaneous development. In order to speed up the project, pre-work for more expensive and slower process is done. This requires intense communication between team members and clever scheduling of the use of machines. In mass production orientated companies there is often a lack of day-to-day contact between the thinkers in the research center and the implementers in product development. Lean production orientated companies let their entry-level engineers spend their first few months at the assembly line and after that the marketing department.

2.5 Coordinating the supply chain

The supplier must share a substantial part of its proprietary information about costs and production techniques. The assembler and supplier will work together and go over every detail of the supplier’s production process. They will search for ways to eliminate waste and improve the process. In return of the openness of the supplier, the assembler must respect the supplier to make a reasonable profit.

Another lean attitude is that lean assemblers assume that the price for the first year’s production is a reasonable estimate of the supplier. Mass producers assume that bidders are selling below cost to get the contract and raise their prices year by year. When the lean producer and supplier find ways to reduce costs together, they will share profits. If the supplier comes up with an innovation by himself that also reduces costs, the profit will be for the supplier. In this way, both parties can co-operate to make a good quality product for a low price and keep improving the production process.

An important aspect of the co-operation of the assembler and the supplier is the just-in-time principle. The supplier will supply parts directly to the assembly line often hourly, multiple times a day, without inspection of the parts. The assembler will give empty part boxes back to the supplier as a signal to deliver more parts.
Classic mass producers encounter the following problem with their suppliers: certain components of cars consist of a lot of parts and thus loads of different suppliers are involved. With so many different suppliers there occur problems with the alignment between parts such as tolerance errors or different material behavior of parts. This can lead to failure of components when the car is in use by the consumer and this especially occurs if suppliers keep their production process as a secret for the assembler. The lean producers manage their suppliers in a different way: they order already assembled components at first-tier suppliers. These first-tier suppliers order the parts for the components at other suppliers: the second-tier suppliers. Figure 4 shows a simple car assembly model and it is visible where the first tier suppliers are positioned. See figure 5 for the lean supply system. For example the first tier supplier can be a supplier of a chair for a Toyota model. The second tier supplier can deliver the leather or foam for the chair, and so on. Between these suppliers there is interaction in designing new production concepts and innovations. With the distrust between mass producer and supplier this would not be possible.
What if the quality or reliability arrangements are not met by the supplier? The mass producer would stop their relationship with the supplier, but lean producers have found another way to punish the supplier. They supplier is punished by shifting a fraction of the business to another partner, which can have massive impact on scale advantages and profit margins.

**Quantifying the lean value network system**

With the 'lean' supply chain more leverage of adding value comes towards the suppliers. The Original Equipment manufacturers (OEM’s) are forced to transform into a Large Scale System Integrator (LSSI). W.W.A. Beelaerts van Blokland et al. (2006) has done research on the indicators that measure value-leverage and illustrates that LSSI companies have a value-leverage capability.
The value-leverage capability let LSSI’s generate value by producing a part of the total demand value and lever the value on supply chain. Creating profitable value requires a balance between what the customer wants the company’s value contribution and the suppliers. The LSSI company leverages value between the suppliers and the costumers, shown in figure 6.

W.W.A. Beelaerts van Blokland et al. (2006) has found the following indicators to express value-leverage: turnover per employee (T/E), R&D per employee (R&D/E) and profit per employee (P/E). Turnover per employee indicates the ability of a company to leverage its assets and resources on the supply chain and is used to measure the configuration of the supply chain. R&D per employee provides information about the focus on innovation of the organization. Profit per employee is the indicator for the ability of a LSSI to attract the market demand for products and goods that are integrated. A relationship by statistical significance is proven between the indicators continuation, conception and configurations. It can be concluded that the aerospace OEM industry has become increasingly value-leveraged over the measured period (’96 – ’09) with respect to the three indicators continuation, configuration and conception and their relationship.

**2.6 What’s after lean?**

The Lean way of thinking was introduced in the western world by Womack & Jones with their book “Lean thinking: Banish waste and create health in your corporation”. Here the five phases are described to make your organization lean: Value, value stream, flow, pull and perfection (Figure 7). Now many industries adapted this lean way of thinking. With supply chain partners and distributors, lean manufacturers are seeking to build partnerships. These are based on finding common ground for mutually reducing costs and increasing productivity.

![Figure 6: 5 phases to make your company lean](www.lean.org)

Now many companies are looking for the next step, what is coming after lean? Some companies search their solution in an extension of lean initiatives. Others are looking to the costumer and try to deliver new value-adding tactics, differentiation and innovation. Market leaders will try to redefine and upgrade the costumer experience with the product. The after-sales experience is becoming of greater
importance as bad experiences with products will spread fast with the current social media. Bad reviews will give the brand a bad name and can be fatal. Manufactures will restructure their distributor supply chains to have more control the added value of the supply chain. In this way they can upgrade the customer experience and effectively represent the manufacture’s products. Others try to expand their role in the supply chain by offer packing and shipping services and offering after-sales support.
3. Impact of Ford’s mass production on the other industries

After Ford managed to produce a high number of automobiles for the average citizen this way of mass producing was adopted by other industries. Paragraph 3.1 shows how Ford and others tried to apply mass production in the aviation industry. Paragraph 3.2 describes how mass production was used during WWII at the tank and ship industry.

3.1 Aviation industry

By the end of WW I Ford’s production techniques were applied in other industries, but not in the aviation industry. However several countries produced a large number of airplanes this was still done via de craftsmanship method. The airplanes were considered to be too complex machines to be mass-produced and they would require high precision. As the cars were mostly made of steel, airplanes were mostly fabricated by wood and fabrics.

Use of assembly line in the aviation industry

Just as other car companies Henry Ford decided to expand his business to the aviation industry during World War I by building Liberty engines. In 1925 Ford started Ford Air Transport Service to transport mail and passengers using a fleet of six Stout 2-AT aircrafts. Ford started to produce the Ford 4AT Trimotor and in 1927 he was the first to use an assembly line in the aircraft production. The term mass production was not correct as a total of 199 Trimotors were built. In 1933 the sales lagged as the depression (Figure 3) started and the Ford airplane division was shut down.

Americans

Ford played a big part in the peak of war production of the Americans. He constructed the 40,000 workers one-mile long ‘Willow Run Bomber Plant’ where Liberator bombers were produced. Ford started with producing a couple of airplanes and saw he needed to redesign the aircraft for the ease of manufacture. Ford knew how to deal with this problem and used his trick again: divide the work in smaller sections. This was not an easy task as this process took about two years to achieve a reasonable production output. Multiple problems were encountered and the plant was nicknamed ‘will it run’. This showed that mass-producing aircrafts is not as easy as mass-producing cars.
## Table 3: Estimation of aircraft production during WWII

<table>
<thead>
<tr>
<th>Country</th>
<th>1939</th>
<th>1940</th>
<th>1941</th>
<th>1942</th>
<th>1943</th>
<th>1944</th>
<th>1945</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.</td>
<td>2,141</td>
<td>6,086</td>
<td>19,433</td>
<td>47,836</td>
<td>85,898</td>
<td>96,318</td>
<td>46,001</td>
<td>303,713</td>
</tr>
<tr>
<td>Germany</td>
<td>8,295</td>
<td>10,826</td>
<td>12,401</td>
<td>15,409</td>
<td>24,807</td>
<td>40,593</td>
<td>7,540</td>
<td>119,871</td>
</tr>
<tr>
<td>USSR</td>
<td>10,382</td>
<td>10,565</td>
<td>15,735</td>
<td>25,436</td>
<td>34,900</td>
<td>40,300</td>
<td>20,900</td>
<td>158,218</td>
</tr>
<tr>
<td>UK</td>
<td>7,940</td>
<td>15,049</td>
<td>20,094</td>
<td>23,672</td>
<td>26,263</td>
<td>26,461</td>
<td>12,070</td>
<td>131,549</td>
</tr>
<tr>
<td>Japan</td>
<td>4,467</td>
<td>4,768</td>
<td>5,088</td>
<td>8,861</td>
<td>16,693</td>
<td>28,180</td>
<td>8,263</td>
<td>76,320</td>
</tr>
<tr>
<td>Italy</td>
<td>~18,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canada</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16,431</td>
</tr>
<tr>
<td>Total</td>
<td>33,225</td>
<td>47,294</td>
<td>72,751</td>
<td>121,214</td>
<td>188,561</td>
<td>231,852</td>
<td>94,774</td>
<td>789,671</td>
</tr>
</tbody>
</table>


### Germans

As Uziel (2012) stated the Germans were trying to build a large airforce, but were much slower in applying new production methods. Arming the German war demanded strict and centralized management, which failed up to the end of 1941. The image of the Germans being super-efficient was not valid as they were extremely inefficient in many cases. One of their biggest problems was to move from the development phase to the production phase. Inefficiencies led to difficulties. The Messerschmitt case (Uziel 2012) demonstrates that power struggles, politics and administrative chaos were the main reasons for the Germans inefficiency.

Besides Volkswagen who produced wing sets for medium bombers, most of the German car industry stayed out of the more specialized aviation industry. Reports of high production rates of the US in 1942 aviation industry encouraged the Germans to modernize their production lines. As an answer to the ‘Willow Run’ the ‘thousand bomber plant’ was initiated, but the plant never was constructed. At this time he Germans had lost to the production war. In 1944 the modern production lines allowed the Germans to employ foreigners to boost the production in the aviation industry. This ‘production wonder’ came too late as the German airforce was already defeated plus there was a lack of pilots.

### Women in WWII

During the WWII the Americans faced a shortage of personnel in their production plants because a lot of men needed to fight in the army. Laurie Scriveener (1999) states that as the Germans forced foreigners to do production work, the Americans forced about 8 million women to take jobs during the WWII. 2 million woman worked as ‘Rosie the Riveters’: the symbol of feminism and the economic power of women. In the beginning of the war most women were clerical worker: typists, switchboard operators and stenographers. As the war proceeded women were used in more masculine jobs as truck drivers, airplane mechanics and gunner instructors.
3.2 Tank and ship industry

Tanks
In WWI the tanks that were used in combat had a far too immature technology to be used successful. Most tanks broke down before they even reached the combat zone, they were slow (4-5 mph), armor was too thin, they couldn’t cross trenches and had poor firepower. Only 7000 tanks were produced during WWI and in the interwar period there was much theoretical progress, but very little progress in tank production.

Particularly General Motors and Chrysler have been successful in adapting their mass production techniques in to the making of tanks during WWII. Their automotive engineers used the regular factory layouts, involving subassembly lines and final assembly lines, to create plants that produce tanks instead of cars. Raw materials were brought in on the railroad track and unloaded near the subassembly lines. From top right to bottom left the tank is build up. In the subassembly lines bodies, top decks, weapons, bogies, transmissions and tracks are assembled. These components arrive at the final assembly line and after the final assembly the tank is tested in the proving ground. If no problems are noticed the tanks are transported via train to be shipped to Europe.

![Diagram of tank assembly](source: American WWII magazine: Life, August 10 1942)

Figure 7: Simplification of tank assembly

Ships
The ‘Liberty’ cargo Ship was designed by the British in 1940 and powered by a 2500 horsepower steam engine. The British placed an order of 60 Liberty ships and the US Maritime commission an order of 200 at the US shipyards. Components of the ship were produced all over the US and transported to the sixteen shipyards that would assemble the ship. The ships were produced according to the principle of the moving assembly line. At the start of the production the ships were assembled in 230 days, but Robert E. Peary had a publicity stunt where it was possible to assemble a ship in 4 days and 15.5 hours. The sixteen American shipyards managed to build 2.751 liberty ships from 1941 to 1945.
4. Impact of lean production on the other industries

In chapter 2 the lean way of thinking is described. When Womack and Jones introduced Lean to the western world and Lean is now used in public and private sectors around the world. Paragraph 4.1 describes the aviation industry adapting lean. The process industry, just a little different from the manufacturing industry, is a suitable industry for lean (paragraph 4.2). Paragraph 4.3 concentrates on lean applied in smaller versus bigger organizations.

4.1 Adapting Lean in the aviation industry

V. Crute et al. (2003) discussed the key drivers for Lean in aerospace and examined the assumption that cross-sector transfer might be difficult. They monitored the implementation of lean at multiple sites. An interesting conclusion was that lean capabilities are not firm-specific, but are plant specific. The results may also be achieved faster when improvement activities focus on a large part of an identified ‘product value stream’ rather than on a functional area which produces a range of products. Plant-specific strategies have to include internal targets as well as the development of supplier relationships with external partners. It is important that companies create a ‘Lean system’ rather than simply applying single Lean techniques and operations managers have to be willing to take on a more strategic role. Companies which have a culture of autonomous working and learning through experimentation will adapt lean more rapidly. If this is culture does not exist the senior managers will have to play a key role in showing that change is possible.

In table 4 multiple types of plants are shown which have different stages in the use of the lean way of thinking.

<table>
<thead>
<tr>
<th>Plant types</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stable and Lean</td>
<td>Japanese-owned plants, both in Japan and abroad that were early adopters of Lean production and continue to use this approach with great success.</td>
</tr>
<tr>
<td>Rapid move to Lean</td>
<td>Those plants in Europe and other regions that are relatively new to the industry and have been quick to adopt parts of Lean production systems, although not the entire system.</td>
</tr>
<tr>
<td>“Sticking-with-tradition”</td>
<td>The US-owned plants in North America that have been slow to adopt Lean production and, in many cases, have reverted to traditional mass production. Also, they have made only modest progress on quality and productivity.</td>
</tr>
<tr>
<td>Hybrid</td>
<td>Plants that have production systems that incorporate aspects of both Lean and mass production systems.</td>
</tr>
</tbody>
</table>

Source: Kochan et al. After Lean production: evolving employment practices in the World Auto industry
If a company is willing to adapt lean, it is suggested to create extra buffers of resources and space to not let the transformation affect the production demands. Transforming often requires the factory to change their layout and affects the space that is available.

### 4.2 Process industry:

What has lean manufacturing to offer the process industries? Melton (2005) has done a case study how Lean can be implemented in the process industry. He summarizes the process of how to start ‘lean thinking’:

- Document current process performance—how do we do it now.
- Define value and then eliminate waste.
- Identify undesirable effects and determine their root cause in order to find the real problem.
- Solve the problem and re-design the process.
- Test and demonstrate that value is now flowing to the customer of that process.

The process is mapped and 34 process steps were noticed with a cycle time of 10 weeks. Approximately 60% of these process steps were related to waiting or traveling: waste. Spaghetti mapping showed that the operators had to travel long distances during the production process. Figure 9 shows when in the 10 weeks cycle time there is value added to the product. Only 25% of the time is value adding.

![Figure 8: Value mapping, process industry example](image)

In the process plant there was a lack of flow and functional behavior. Each step was operated as a distinct entity; the functional teams were only praised for individual efficiency. Only the director was responsible for the delivery to the customer while he has no direct influence on this. With the current process, a lot of improvements are possible. Although a lot of these improvements seem quite obvious when a total process overview is made, lean is a handy tool to show inefficiencies. Melton (2005)
states that the process industry should welcome Lean with open arms to achieve financial, cultural and organizational benefits. Lean thinking is applicable to all business processes within the process industries. Melton (2005) does notice that the challenge is whether we know enough about our ways of working and what customers of the business processes truly value.

### 4.3 Adopting lean: small versus larger organizations

Because Lean is adopted in so many different industries it is interesting to compare the ability bigger and smaller organizations to adapt lean. Bhasin (2012) did a survey undertaken by 68 British companies that are divided in small, medium and large organizations according to turnover, Aggregate gross assets and number of employees (see table 5).

#### Table 5: Classification of organizations

<table>
<thead>
<tr>
<th></th>
<th>Small</th>
<th>Medium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turnover (less than or</td>
<td>£3.1 millions (net)</td>
<td>£12.2 millions (net)</td>
</tr>
<tr>
<td>equal to</td>
<td>£3.76 millions (gross)</td>
<td>£14.5 millions (gross)</td>
</tr>
<tr>
<td>Aggregate gross assets</td>
<td>£1.9 millions (net)</td>
<td>£6.6 millions (net)</td>
</tr>
<tr>
<td>(less than or equal to)</td>
<td>£2.18 millions (gross)</td>
<td>£7.72 millions (gross)</td>
</tr>
<tr>
<td>Number of employees</td>
<td>50</td>
<td>250</td>
</tr>
<tr>
<td>(less than or equal to)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


Interesting is that the larger organizations have applied lean in the whole value chain two out of five, where the smaller and medium organizations only score one out of five. In small organizations the level of lean implemented in the internal organization is high, as it is easier to monitor and implement lean in smaller processes.

#### Table 6: level of lean applied in supply chain and internal organization

<table>
<thead>
<tr>
<th></th>
<th>Small organizations</th>
<th>Medium organizations</th>
<th>Large organizations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lean applied to the whole value chain including suppliers</td>
<td>20%</td>
<td>25%</td>
<td>40%</td>
</tr>
<tr>
<td>Lean is administered in the whole internal organization</td>
<td>80%</td>
<td>25%</td>
<td>43%</td>
</tr>
</tbody>
</table>


Larger organizations show to have used lean tools for a longer time than small organization:

- Average of 4.7 years for large organizations
- Average of 3.3 years for medium organizations
- Average of 3.1 years for small organizations

A tool that is used in smaller businesses for a longer time is process mapping. Where medium and larger organizations the tool ‘continuous improvement/kaizen’ is used for a longer time. Larger companies focus more on continuous improvement, 5 phases and attacking value with the 7 forms of
waste. They do focus less on single change, single minute exchange of dies and single piece flow operations but compared to the small organizations score more varied on the various applied lean tools. Bhasin (2012) concludes that it is not possible to simply copy the lean change process to other organizations, as there are too many differences in culture and supporting infrastructures are too different. The best way to start off is to launch Lean pilots until lean is implemented. Not only some lean-tools can help the organization; changes in formal policies, procedures, processes, work standards, job descriptions and skill classification are needed. In order to have the full effect of ‘lean thinking’ not only should lean be applied in the internal organization, but the entire supply chain. Large organizations have more success on this aspect, as they have more influence on the supply chain. Bhasin’s (2012) research shows that there is a wider application for lean tools in larger organizations and this wider application makes lean more successful.
5. Future of the auto industry: searching new energy sources

The environment continuously changes and so do the demands of the auto industry market. To survive the changes in the environment the car companies need to innovate and sometimes redefine their goals. Of course over time the cars have to look more dynamic, sexy and attractive, but they also need to become more economic and environmental friendly. In this chapter there will be focused on these last two items.

5.1 Environmental reconnaissance and definition of goals

People will need transport in the future and with the present infrastructure the car is and will be a popular way of transport. The environment demands high specifications of cars, which means that if a car company does not continuously improve their car’s looks and performances they will not survive. For decades there has been a trend to make the cars more environment friendly by reducing the emissions and produce more fuel-efficient cars. At European level there is made a system to classify cars by how economic the car is, named the Energy Label. More economic cars will benefit from government support via lower taxes: tax paid when the car is purchased and road taxes are reduced if the car is more economic. The conditions for classifying the cars have become stricter during the years and in 2015 only cars will benefit that have a CO2 emission lower than 83 gram per km. This stimulation of the government to make cars more economic results in setting goals of the car companies: making their cars more environment-friendly.

Source: Leduc G. et al (2010). How can cars become less polluting?

Figure 9: Process flow diagram of a car
What is noticed is that making cars more environment friendly has the most effect on the functions related to fuel consumption and on the usage of the car (Figure 11). Weiss M. A. et al (2000) shows that 75-90% of the energy consumed during the lifecycle is consumed during operation, which is important to realize. During operation includes the functions of acquiring fuel, repairing and maintenance. So we can conclude that one of the biggest challenges is to reduce the fuel usage or switching to another power source.

In 2007 the report of CNW Marketing Research shocked the Toyota Prius Hybrid drivers with a report ‘Dust to dust’ which claims a Hummer H3 SUV has lower life-cycle energy than a Toyota Prius. A quick re-analysis of Gleick P. H. (2007) shows selective and unsupported assumptions, data manipulation and errors in methods of analysis which lead to a false conclusion. Also an incorrect distribution of lifetime energy costs is applied.

5.2 Making policy

Improvements to reduce the fuel usage can be achieved by various ways:

- Improving conventional energies (new engines, weight reduction, making the car more aerodynamic)
- Using alternative fuels for example biofuels or adding other power sources as electric engines (hybrids)
- Change driver behavior to drive more environment friendly

The three improvements are within the power of car manufacturers to innovate and employ new technologies. To achieve new goals there has to be thought of which ways and means could be employed. Also it is wise to reduce risks by innovating in areas where the company (development function, production and marketing) has experience. With the current infrastructure and low sales of cars with alternative power sources the focus on improving diesel and petrol engines is still very important. Hybrid (electric and petrol powered) cars are promising to be the new trend as they can provide enormous fuel savings they can provide (Leduc G. 2010). The estimated operating cost of a plug-in hybrid vehicle would cost the equivalent of about 0.16 cents per liter of gasoline. With the current prices of 1.65 euro per liter this cost efficiency is highly attractive. This would also have an enormous impact on the oil consumption. The U.S. Department of Energy’s Pacific Northwest National Laboratory showed that if 75 percent of the passenger vehicles in the US would be replaced, that would save about 6.5 billion barrels of oil each day. That is about 52 percent of the total US import.

Influence of other industries

It is not clear which technology is going to function as alternative energy source for cars. The development of for example the electric motors has a long history and the auto industry can benefit from techniques outside the car industry. If in the future cars will run on an alternative energy source the size of the auto industry will contribute to intense developments of the ‘new engine’. This new or improved way of powering transport can be applied in other industries and once again other industries benefit from the developments in the auto industry
Conclusion

Henry Ford made cars available for the average citizen with his mass production. He developed mass production in three phases: introducing assembly stands, shortening the tasks of workers and introducing the moving assembly line. Ford tried to apply his new method to other industries like building tractors, airplane parts and vertical integration. He tried to control the whole supply chain from mining coal and iron to the final assembly of cars. When the stock market crashed in 1929 Ford became a popular employer as he paid his workers above average. Workers did not have to do heavy lifting, no stooping or bending over. Also no special training required; there were jobs that almost anyone could do. On the other hand the tasks of workers were very repetitive.

In WWII the mass production techniques of Ford were applied to produce vehicles that were used in combat. Ships, airplanes, tanks and other vehicles were mass produced. The aviation industry had difficulties applying mass production because the airplanes were too complex machines to be mass-produced. They would also require more high precision components which were hard to achieve with mass production. The Americans were successful in mass producing aircrafts during WWII by standardizing the aircrafts.

Womack (1990) introduced lean manufacturing to the world, a production practice developed by Toyota. The goal is to eliminate waste and in contradiction to Ford’s workers the needed more varied skills and were given responsibility of their own work. For lean manufacturing the whole supply chain has to cooperate so lean concepts as just-in-time, the pull-effect and multiple tier-supplier system can be introduced.

Lean manufacturing is adopted in a lot of industries and a lot of ‘guidebooks’ can be found on how to implement lean into a company. Lean capabilities are not firm-specific, but are plant specific. If a company is willing to adapt lean, it is suggested to create extra buffers of resources and space to not let the transformation affect the production demands. The best way to start off is to launch Lean pilots until lean is implemented. In the process industry there is a lack of flow and functional behavior and lean can provide financial, cultural and organizational benefits.

Larger organizations are implementing lean for a longer time than smaller organizations. Larger organizations focus more on continuity and less on process mapping.

It is shown that 75-90% of a car’s energy consumed during the lifecycle is consumed during operation. Car manufacturers are searching for new possibilities but a solution has not been found yet. Because of the size of the auto industry, changes of energy sources in the auto industry will have a big impact on other industries. Fast developments and benefits of economy of scale will let other industries benefit from the developments in the auto industry once again.

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5-27
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5-28


