



AALBORG UNIVERSITY

STUDENT REPORT

P1 PROJECT
SOFTWARE

Prediction of Manufacturing Processes

A Program that Solves a Problem

Authors:

Andreas Løvig Borg
Benjamin Veje Smolt
Lasse Ryge Andersen
Lukas Juel Jacobsen
Marius Ihlen Gardshodn
Mikkel Hagerup Dolmer

Supervisor:

Mathias Ruggard Pedersen

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Dept. of Computer Science
Strandvejen 12-14
DK-9000 Aalborg
<https://www.cs.aau.dk>

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Participant(s):

Andreas Løvig Borg
Benjamin Veje Smolt
Lasse Ryge Andersen
Lukas Juel Jacobsen
Marius Ihlen Gardshodn
Mikkel Hagerup Dolmer

Supervisor(s):

Mathias Ruggard Pedersen

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Preface

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1 | Introduction

Today, basically every product used, touched, or seen is something that initially started out as one or sometimes thousands of raw materials. These products have all been manufactured. Manufactured meaning something made from raw materials by hand or machinery [1].

In Figure 1.1 the global manufacturing value added as percent of GDP (gross domestic product) is illustrated. Manufacturing value added of an economy is the estimate of net output of the manufacturing sector obtained by adding up outputs and subtracting intermediate inputs. Thus, manufacturing is an essential part of the world economy. In the last 18 years the global manufacturing value added as percent of GDP has been fairly steady between 15.2% and 17.4%.

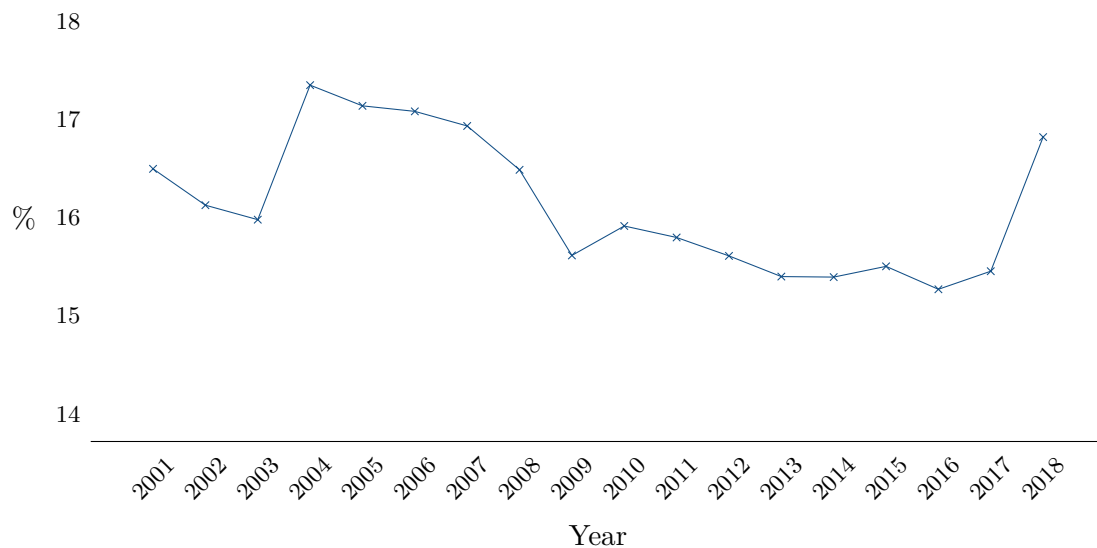


Figure 1.1: Global manufacturing value added as percent of GDP [2].

Manufacturing does not come without a cost. Specifically in manufacturing, it is obvious that amounts of physical waste is generated during the making of goods. This is shown in Figure 1.2.

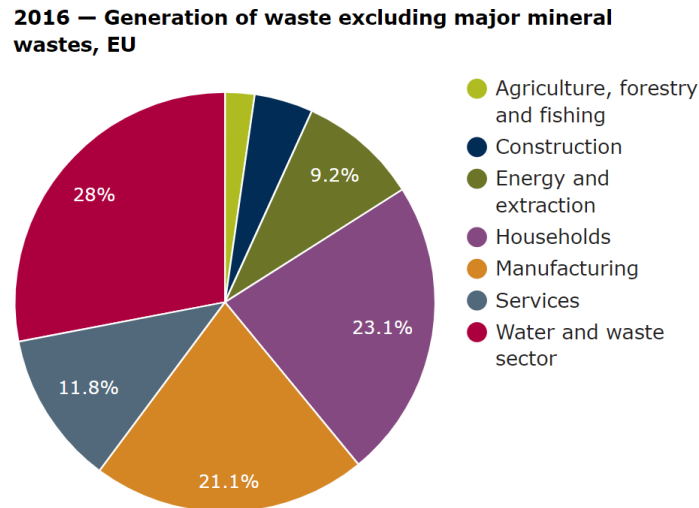


Figure 1.2: Waste generation from industries in EU [3].

Physical waste is not the only form of waste worth looking at in manufacturing systems. Whilst physical waste is easily measured, other forms of waste in manufacturing are equally important to consider when on the subject of manufacturing. These include the wear and tear of machine and human labour, as well as concepts such as time-efficiency and inventory management.

To understand how these different types of waste are expressed in manufacturing, as well as how to model manufacturing systems with intent of reducing different types of waste, it is important to understand the different types of manufacturing systems, as well as how the different types of waste are categorised.

1.1 Manufacturing

The following section is based on the source [4, Chapter 1].

Manufacturing is the action of producing a product from mostly raw materials, adding value in the process. This is done through use of human labour as well as machines and equipment, that carry out a broad range of actions in a predetermined order to produce the product. In today's world, this leads to the rather broad definition:

"[Manufacturing is] the making of products from raw materials using various processes, equipment, operations and manpower according to a detailed plan that is cost-effective and generates income through sales."

The manufacturing of a product is often described in a manufacturing system, which is just a series of processes, machines, etc. set together in such a way that they manufacture a product.

However, these broad definitions do not say a lot about how manufacturing is carried out in the real world. Since there is a variety of products being manufactured, many different manufacturing systems are used to describe different techniques and approaches to manufacturing. Firstly, this leads to two basic categories of manufacturing systems, namely:

1. Continuous process manufacturing.
2. Discrete parts manufacturing.

1.1.1 Continuous Process Manufacturing

Continuous process manufacturing deals with continuous processes such as those found in the making of petroleum, steel, or sugar, where the product physically flows. This is sometimes confused with flow production, another term for mass production, which just refers to the fact that the assembly line is always running, and not the state of the product. Production in continuous process manufacturing often involves the use of chemicals in various stages of the production, and might also involve mechanical means, all aiding in what is basically mixing the product following a recipe. However, it is important to note that no discrete product is made during processing as the product is ever changing until finally being complete, and instead the outcome of this type of manufacturing system is often measured in volume or weight. Continuous process manufacturing often results in specialized equipment operating 24 hours a day to make the exact same product, which makes this type of manufacturing system highly specialized, thus not very flexible.

1.1.2 Discrete Parts Manufacturing

Discrete parts manufacturing deals with countable objects such as cars, toys, furniture, and the likes. These products all have the property in common of being countable. The production of discrete parts, as opposed to continuous, also allows for customisation of specific products to a certain degree, as well as the ability to order anywhere from one to many millions of the product at a time, instead of always having continuous flow.

Discrete parts manufacturing is often further broken down into systems as shown in Figure 1.3. This figure also includes continuous manufacturing, which is not a type of discrete manufacturing. These different systems mainly describe the relationship between quantity and variety of the product, where larger quantities lead to less variety, and the other way around.

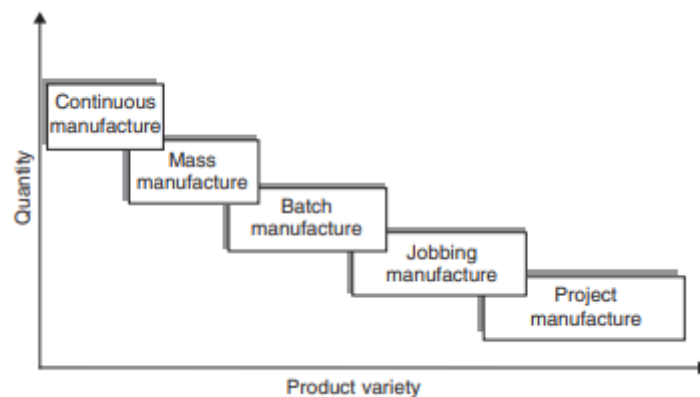


Figure 1.3: Quantity versus product variety in the different production systems [4, Figure 1.9].

As seen in Figure 1.3, some of these different varieties of discrete manufacturing are as follows:

- Job manufacture.
- Batch manufacture.
- Mass manufacture.

Further explanation of these specific discrete manufacturing systems will be provided, as well as insight in what this means for the workforce and tools needed to manufacture products using these systems.

1.1.3 Mass Manufacturing

Mass manufacturing is all about producing high rates of a specific product. To do this, specialised equipment and processes are used, which in turn means that the workforce has a lower skill level, due to this specialised nature of the machines used in mass manufacturing. Machines in mass manufacturing are often arranged in a specific sequence to carry out their exact function one after another. To accomplish this, conveyor belts are often used to carry individual devices through the different machines in a predetermined sequence. This results in a sharp contrast to job manufacture, where an individual person can craft the entire product himself.

Mass manufacturing instead focuses on specialising individual processes in the making of the product and distributing these processes to different machines. This is much alike batch manufacturing, only on a larger scale with larger quantities and less variety. Mass manufacture is used to produce products which normally require a more steady output flow than batch manufacture, which is why it is also referred to as flow manufacturing.

1.1.4 Batch Manufacturing

Job manufacturing and batch manufacturing have quite a few similarities and are therefore often confused with one another. Normally batch manufacture is a production of medium size lots. These lots are approximately 5-1000 units, and sometimes even more. The difference between job manufacturing and batch manufacturing is not the number of components nor the number of lots, however, it is how the manufacturing itself is conducted. With batch manufacturing similar items are produced together and each batch of components goes through one stage of the manufacturing process before going into the next stage. An example of batch manufacturing could be in a bakery where buns are prepared together, baked together, and they always stay together throughout the process.

1.1.5 Job Manufacturing

Job manufacturing is, as seen in Figure 1.3, a manufacturing system that focuses on variety and customisability as opposed to quantity. This means that lot-sizes are small, but the finished products are often unique. Manufacturing a lot of unique products requires machinery and tools which are non-specific, so they may be used for different purposes when producing different products. However, this requires the workforce to be highly skilled since they must fulfill different assignments depending on the specific variety of a product being manufactured. The same person might also be the one to make an entire individual product.

1.1.6 Project Manufacturing

The characteristics of project manufacturing is the layout of the work. The product remains in the same position through the whole process, whereas in other manufacturing processes it typically physically moves through the different phases of the production process. The reason for the product being in the same place, is usually because of its size and weight. These types of products usually have a low production rate. Workers, tools and equipment used to produce these products are gathered around the product. Sub parts of the product

might be manufactured outside of the manufacturing process, but are used as components in the process. The workers working on the product are usually highly able and material handling is high as well. Examples of this manufacturing process is ships, building, bridges etc. As seen in Figure 1.3, there is a lot of variety in the products rather than quantity.

1.2 Manufacturing Effectiveness

The downside of the manufacturing industry is all the physical waste that is generated when raw materials are transformed into consumer goods. Some types of physical waste include various metals, oils, and chemicals, which may be hazardous and consequently dangerous. However, waste within the manufacturing industry is not limited to only physical waste. Non-physical waste also exists, and normally occurs during the manufacturing process. These other types of waste are described in the methodology known as Lean manufacturing.

1.2.1 Lean Manufacturing

The term Lean manufacturing refers to the application of Lean practices, principles, and tools to the development and manufacture of physical products. For many people, the term Lean manufacturing is synonymous with waste removal. But the ultimate goal of practicing Lean manufacturing is not simply to eliminate waste, instead it is to sustainably deliver value to the customer. To achieve that goal, Lean manufacturing describes waste as anything that requires an investment of time, money, or talent that does not create value for the customer [5].

One of the first people credited with introducing Lean practices at the workplace is the founder of Ford Motor Company, Henry Ford. Ford streamlined the process of manufacturing the Model T car by arranging workers, machines, parts, and tools in a continuous system. However, it was not until the 1930's that Toyota came up with the modern concept of Lean Manufacturing, when they invented the Toyota Production System (TPS). Toyota initiated the idea of "manufacturing to order" instead of "manufacturing to fill warehouses", because they realised products piled in warehouses without buyers were no more than just wastage. It made financial sense to base production targets on actual sales. This style of manufacturing eventually became known as Just-in-time (JIT) manufacturing [6].

TPS explicitly defines seven types of waste, which continues to be relevant in Lean manufacturing today. They are often referred to as TIMWOOD [7]:

- **Transport**

Transportation of a product does not add any value to the product and is not a part of the manufacturing process, but it is a crucial part of the delivery of a product, hence, it can not be separated from the process.

- **Inventory**

Unnecessary stock can be a result of overproduction. The company has bought too many materials, finished goods lying around, etc. These items are piling up in the storage and taking up too much unnecessary space.

- **Motion**

Unnecessary movement is movement of humans and/or machines, that are inefficient, e.g. grabbing a heavy object of the floor, instead of doing it from an appropriate height. Lifting it from an appropriate height would put less strain on the person and

make the activity faster and more effective. Another waste of movement is travel time between work posts.

- **Waiting**

If everything in the manufacturing process is not working optimally at the same time, e.g. damaged machines, inefficient manufacturing methods, insufficient amount of materials, etc. This may result in the workers having to wait. Often workers are spending a lot of time waiting for experts to fix the machines, waiting on supplies and so forth, so that they are able to go back to work.

- **Overprocessing**

Overprocessing is the usage of unsuitable techniques, unfitting tools, doing processes that are not needed by the customer, etc. All of the above are very unnecessary and will cost time and money in the end.

- **Overproduction**

If a company is manufacturing too many products for the users, it will result in an overuse of materials, energy, and human work.

- **Defects**

When a defect occurs, actions must be taken in order to fix the problem. This may result in waste of material, energy, rescheduling, paperwork, losing a customer, etc.

Elimination or reduction of the seven types of waste mentioned above is crucial for any manufacturing company, and if successfully done, it would lead to a more time and cost efficient production.

1.2.2 Overall Equipment Effectiveness (OEE)

Overall Equipment Effectiveness, referred to as OEE, has been well known in the manufacturing industry since 1980's and the concept itself originated from Japan. In the end of the 1990's, OEE became more accessible and feasible for the companies in the Western part of the World as two books, about OEE, called "OEE Toolkit" and "OEE for Operators" where published [8].

OEE is a calculation method used by manufacturing companies to identify the effectiveness of their production line. This is often associated with companies that want to optimise their production. Companies make use of OEE to set a benchmark for themselves. With the OEE calculation they can figure out the percentage of waste within; planned production time, run time, net run time and fully productive time. As a baseline OEE can be used to measure a companies progress in eliminating waste from a given production asset [9].

OEE is based on calculations from availability, performance and quality and is a number from 0% to 100%, where an OEE of 100% would be described as a perfect production.

2 | Problem Statement

Throughout time, the concept of manufacturing has been under constant development, which has led to the creation of different manufacturing methods. Furthermore, different methodologies have been developed to reduce waste within manufacturing, one of these methods being Lean manufacturing. Lean builds on the principles of limiting any activity that requires time, money, or talent that does not add value to the customer. Combining a specific manufacturing method with the idea of reducing time waste leads to the problem statement:

"Is it possible to implement a software solution capable of aiding the planning of batch manufacturing, thus reducing time waste."

New: *"Is it possible to implement a software solution using OEE to aid companies to streamline their manufacturing lines, thus reducing waste."*

3 | System Description

Inputs: (Metrics)

Availability: Run Time, Planned Production Time and Stop Time

Performance: Ideal Cycle Time, Total Count and Run Time

Quality: Good Count and Total Count

Metrics in total: 6

Outputs:

- Overall Equipment Effectiveness (OEE)
 - Availability Loss
 - Performance Loss
 - Quality Loss
- Prediction of future OEE

$$\text{OEE} = (\text{Good Count} \times \text{Ideal Cycle Time}) / \text{Planned Production Time}$$

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