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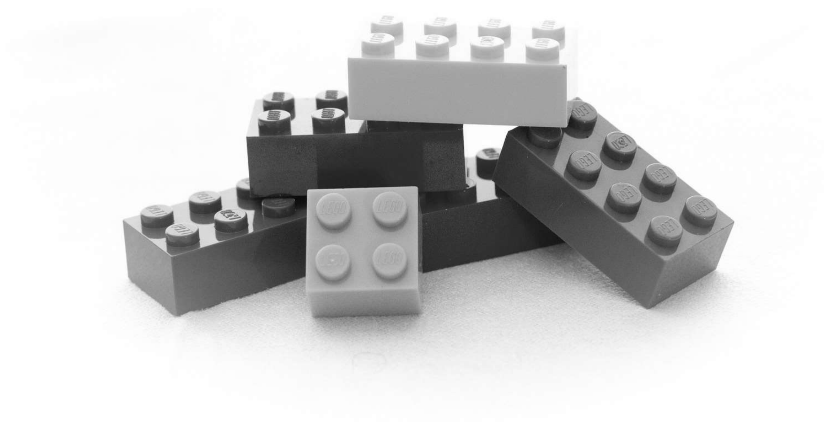

Principles for developing Time Blocks

Evaluating a tool for Time Data Management at Swegon

Master's thesis in Production Engineering

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Abstract

In contemporary industries, time data management relies heavily on traditional techniques. However, these methods are often time-consuming, expensive, and burdensome for the employees involved. This thesis addresses this challenge by exploring the concept of time blocks. The principles for developing time blocks was researched and evaluated through a mixed-method and design science approach. Time blocks offer a promising solution by aggregating predetermined time systems into customizable blocks that align with organizations' demands. Two approaches were employed to build time blocks, and the accuracy and deviation of the tool were validated against present-day data. This thesis contributes to understanding the application of time blocks in industry, presenting an innovative approach to time data management.

Keywords: time blocks, cycle time, principles, database, time-series-data-management, standard data, variable production, multi-model assembly line, time data management.

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List of Acronyms

Below is the list of acronyms that have been used throughout this thesis listed in alphabetical order:

BOM	Bill Of Materials
HVAC	Heating, Ventilation, and Air Conditioning
MTM	Methods-Time Measurement
ERP	Enterprise Resource Planning
MRP	Material Requirements Planning
SAM	Systems Analysis and Management

Nomenclature

Below is the nomenclatures that have been used throughout this thesis.

Definitions

Therbligs	The 18 different motions that can be used to analyze an industry operators job.
Element	A smallest step in the process, where one single therbligs motion is defined and executed. Of the 18 different therbligs motion that are defined, an element would consist of any one of them. E.g., pick 4 screws, use screwdriver, place a sheet on the work table
Activity	An activity is defined as a group of therbligs motions or elements, which would result in installing a part of the material or the material itself. E.g., preparing, installing, putting it away
Operation	A group of activities that constitute the elemental steps that would be used for installing one complete part that is specified in the Bill of Materials.
Assembly Process	The complete tasks that are executed at one station. This could be installing multiple materials on the product or one. All tasks that would be executed at a single station on the assembly line.
Production Process	This comprises of the actions in the entire assembly line. Where tasks from multiple stations are combined.

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1

Introduction

In this chapter the background and problem is described which can be seen today. The aim and delimitations is as well presented.

1.1 Background and Problem

There is a current trend with increased digitization, which has led to consumers expecting to get answers or products instantaneously (McKinsey & Company, 2022). Industry is therefore facing increased competition which sets pressure on manufacturing, to increase capacity and quality to meet higher demands (Manyika et al., 2017). In contrast to this, there is the pressure to reduce cost, where you are expected to do more work in less time. When this subject is brought up, automation is often pointed out as the solution according to McKinsey & Company (2022). When automation started to remove manual labor, the worry was that people would lose their jobs. Years later, it can be seen that employment did not decrease. The ones that lost their jobs got new ones that supported the new system (McKinsey & Company, 2017).

As the competition increases, demands from the products increases as well. To face this, the companies increase their product range or even integrate customizable items to offer the customer more (Kotler & Armstrong, 2012). The norm of today's society to have customizable products have resulted in manufacturing facilities adapting to the new trend of producing multiple products in the same production line (Mönch, Huchzermeier, & Bebersdorf, 2020). This increases the demand on the producers to be able to be more flexible. With the higher flexibility, the producers are turning to manufacturing strategies such as made-to-order, where you only produce what is needed as the production facilities cannot hold all the variations of the now-existing products in stock.

Companies must embrace new technologies and avoid falling behind their competitors to keep up with the demands of an evolving consumer landscape and competitive manufacturing industry. This is particularly important as data utilisation, especially output data, continues to rise, leading to higher demands for input data. Effective time data management is necessary to meet these demands, enabling companies to analyze data more efficiently and make informed strategic and operational decisions that are necessary to keep up with market requirements. The recurring theme of forecasting production and lead times is frequently discussed when addressing production issues, highlighting the need to balance the desire for greater control over the supply and demand chain with the goal of minimizing time spent while improving accuracy in predicting future values (Manyika et al., 2017).

As a solution for planning and optimizing production lines, companies are using expensive softwares with advanced and complex algorithms. The algorithms are designed to use time data with the intent to create a single solution that solves all their issues and plans production perfectly. These systems are therefore highly dependent on input data, on which the algorithms are basing their solutions. So without having data that is accurate and well-established, the point of using advanced algorithms for example planning, balancing or sequencing disappears (Almström & Winroth, 2010).

A challenging solution in relation to this is to use the correct time data. Today, there is a gap between planned and actual times, where faulty time data is used. A higher focus in the manufacturing industry is pointed towards lean production, where the only way to determine time that is mentioned is clock studies, something which is not very precise. The gap consists of a mismatch with several explanations, one of which is the lack of updated times. According to Almström and Winroth (2010) the problem is even more apparent when the assembly processes are manual, complex and produced in small quantities with large variations. Since time data is often based on predetermined times and not actual times, the algoritms will generate times based on predetermined times and not actual time.

Predetermined time systems were created to make time measurement more accurate (Taylor, 1911). This process involves breaking down an operation into smaller activities in order to determine an efficient approach to complete the operation. From this, standard data can be derived, which is then used in conjunction with predetermined time system data to establish standard data (Maynard & Zandin, 2001). This data will be the reference time and the point from which one's work would be evaluated. Nowadays, predetermined time systems are used at many Swedish factories, and variations of these systems, such as MTM-SAM, are used in a few of them. However, an issue with MTM-SAM is the time it takes to analyze an assembly process, it takes 50 minutes to analyze a minute of assembly process (Andersson, 2001).

Over time, predetermined time systems have gained a lot of recognition due to their potential in applying it in different areas. As complex assembly lines are the essence of manufacturing facilities today, the complexity of calculating predetermined times has increased. Since the time has to be established for all the elements and changes performed in a manual assembly, the process would be repeated for every variant of the final product, thereby ending up with a huge database of times for activities from the shop floor (Niebel & Freivalds, 2003). Recently, organizations' dependency on predetermined times has increased, but the time and resources the organization invests for this purpose is a hurdle. To tackle this challenge of minimizing the amount and effort in time studies, there is a need to create a tool that could help engineers better manage and use predetermined times.

Swegon is a company that specializes in Heating, Ventilation, and Air Conditioning systems (HVAC). The primary focus of the HVAC units is catering to large buildings, Swegon aims to accommodate specific conditions and preferences using a modular design that enables effortless adjustments to configurations. Their biggest production site, in the Nordic region, is in Kvänum, Sweden, outside Vara. At the production facility in Kvänum, Swegon has six lines set to produce various HVAC units specified with a configuration that suits the customer's needs. With many variants, Swegon cannot use one production line for all. Several lines with sub-stations that pre-assemble parts are necessary to assemble their products. Differences in units can be due to size, placement, and functionality. Swegon has a need to determine times for different sorts of modules which is very time-consuming. There is therefore a necessity to find more time-effective ways to do this. To find different ways to determine times more effectively, Swegon is part of a project called TIMEBLY where they want to investigate how they could better manage their time data. Evaluating different tools for time-series data management; led them to time blocks.

TIMEBLY is a project that evaluates Time data management by testing new methods to handle time data (*TIMEBLY*, n.d.). One aspect of the project is evaluating time blocks. Time blocks could offer a new approach to bridge the gap between different perspectives and potentially provide a viable solution to the problem described in the previous section. The ability to group similar and distinct activities could be beneficial for Swegon, especially since variants often have functional similarities. Time blocks would allow users to group and repeat different activities to generate variant times. By eliminating the need for method time measurement, engineers in the organization could experience a reduced workload.

The organization and its engineers strive to maintain a database of various activity times in the manufacturing process. Engineers at Swegon spend significant time maintaining this database and obtaining information from them. To reduce the stress and workload on engineers, Swegon would benefit from having a tool that helps calculate and edit information quicker. To have a better database to calculate cycle times for any module or to make changes and maintain the data, there is a need to evaluate different data management methods.

1.2 Aim

The thesis aims to develop principles for establishing time blocks in manual assembly operations and to determine how time block can be used as a tool, at Swegon. Furthermore how they should implement it at the rest of their production. In this case, the sub-assembly stations will be studied, and the panels which they assemble in it. The project is to develop a methodology to classify activities and assign them to variants. Thereby evaluating the use of time blocks in certain stations initially and eventually assessing the use of time blocks for the complete facility. The specific objectives under investigation are:

- Evaluate time blocks as a standard data management system
- Investigate if time blocks as a tool can manage time-series data in a case study
- Develop principles for building time blocks in a multi-model manual assembly line

1.3 Delimitation

The basic definition of time blocks is the same for all areas, including manufacturing. Since the project is based on a manual assembly line, its application in other fields must be evaluated. The principles around which time blocks are developed and assessed are only based on Swegons' manufacturing plant in Kvänum; the accuracy it could have in different manufacturing facilities might vary.

The project is firsthand limited to investigating the relations of operations, activities and setting the division of time blocks on sub-stations of one production line, named B-line. The project will furthermore be limited to analyze a limited number of variants in Swegons' portfolio since the method can be extrapolated or interpolated to other projects and variants too.

2

Theory

In the following sections, theories related to and relevant to the topics in this thesis will be presented. It includes subjects that stretch from Basic production engineering concepts to group technology.

2.1 Basic Production Engineering Concepts

Large amounts of data are measured and documented as tools for improving and increasing production efficiency in Industry 4.0. According to Grey (2012), the factories in the 20th century had low control and knowledge about how long the processes should take. Fredrick Winslow Taylor wanted to change this, he had studied organizations for a long time, and with Scientific Management, he presented his ideas to change how organizations handled their production and personnel resources (Taylor, 1911). To measure an assembly operation's time, Taylor proposed timing a worker for one complete cycle. This would establish the time a worker would take to complete it. This data was not used just to calculate the output a worker should put out in a day's work but, also to measure how much a worker should be paid, based on the output they put out. There were many drawbacks to this kind of work measurement, but the uses such data had were promising. The method of measuring such shop-floor activities evolved over time. According to Niebel and Freivalds (2003), the rapid developments and focus on lean methods complemented such data collection, as there was scientific reasoning for new methods of calculations.

2.1.1 Cycle time

Cycle time is a commonly used measurement in shop floor organizations. It measures the duration of a process, from when it technically starts to its completion. (Holweg, Davies, de Meyer, Lawson, & Schmenner, 2018). Cycle time dictates the shop floor's manufacturing capacity: the number of parts or products the manufacturing facility can make in a fixed amount of time.

For machined operations, the cycle time is consistent with predictable disturbances, however, this is quite different from manual operations. Having well-defined work instructions that are proven to take the same time in different circumstances helps maintain the cycle time to a consistent amount most of the time. This gave rise to the development of methods, which helped reach consistent and minimum cycle times could be maintained by the operators that execute these operations (Holweg et al., 2018). An organization can spend a significant amount of time measuring, analyzing, and further; reducing the cycle time for the production process (Niebel & Freivalds, 2003).

2.1.2 Takt time

Takt time is the tempo required for production to keep to meet the customers' production demand. The goal with the takt time is not to over or under-produce, but balance the output with the demand (Holweg et al., 2018).

$$\text{Takt time} = \frac{\text{Available production time per time unit}}{\text{Customer demand per time unit}} \tag{2.1}$$

Takt time is calculated with the equation 2.1, where the available production time per time unit is the planned production share of total calendar time. If you have a yearly available production time per time unit, of 1880h (8 hours a day for 235 days a year), and a customer demand of 470 units per year. The takt time will be 4h (1880 divided by 470) per unit, which means a product needs to leave the line every fourth hour for the demand to be met.

When the takt time is established and well integrated into the production flow, it is easy to use it as a tool. Setting up measurements allows you to compare your actual production to the required production level. This helps determine how efficient your production is. By identifying areas, one can improve production output when resources are used efficiently. The ultimate goal is to ensure that your takt time, which is the maximum time allowed to produce a unit to meet customer demand, remains stable and on track (Escatec, 2021).

Takt time is independent of process capabilities, unlike cycle time (Liker, 2004). Cycle time is dependent on process or resource capabilities. Takt time is a measurement that depends on the product's demand in the market. Therefore, cycle time is a measurement of an organization's capabilities while takt time is a measurement of the market's demand. The takt time decides the speed of the production it also predicts the production volumes. Mönch et al. (2020) mentions for a production with mixed models, with random customization, this gets challenging, since it is hard to decide which takt time you need to follow due to different cycle times for different models.

2.1.3 Throughput time

The throughput time is the time which a product takes to finish a production process. The time it takes starts when the work starts with a part and finishes when it is completed. It is therefore the time to produce a single unit in the production flow. The throughput time in a production flow is defined by the slowest time in the process, which is called the bottleneck. To increase the manufacturing capacity, the cycle time of the bottleneck station needs to be minimized. If an operation in the middle of the manufacturing chain takes significantly more time than the operations after it, there would be irregularities in the stations after it, as they would be waiting for previous operations. (Holweg et al., 2018).

2.2 Time Data Management

Time Data Management (TDM) involves the processes of "determination," "pre-processing," "application," and "administration" of time data (Kuhlang, Erohin, Krebs, Deuse, & Sihn, 2014). TDM includes how the operation time reflects the actual work conducted, and the interpretation of it. TDM is important because it allows gathering of data from manual assembly where process times can vary. By analyzing this data, we can reduce variations and make the process more efficient. TDM, therefore, plays a large role in today's manufacturing industry where time, in the context of strategic and operative planning and decision-making, is vital.

One issue with TDM is that little time is spent to determine the time data which creates a gap, or mismatch in time (Hedman & Almström, 2017). TDM generally includes the aspects of reflecting times in manual assembly where their variation needs to be considered. The different processes have various attributes and can typically describe the TDM process as well as its characteristics.

Attributes of general aspects are described as type of production, which can indicate what type of method would be suitable for time determination. Another important attribute of the process is the competence within TDM at the company that is applying it, the employees need to have some form of competence when working with it. Attributes such as the correctness of time data and review of the correctness of time data are as well described in this process. Where this reflects upon the gap in time that is created between the planned and actual times. Followed up with a review of the data and how the review is conducted (Hedman & Almström, 2017).

2.2.1 Time Data Determination

Attributes that are used to determine the data are based on which areas need to be to determined, for example, production, assembly, and maintenance. A method also needs to be established whereas the method should include time standards. The reason to use standard times is for predicting time in a consistent way (Kuhlang et al., 2014).

Methods to determine time can be done by two approaches, either by determination of actual times or by target times. Determination of actual times can according to Kuhlang et al. (2014) be done in five ways. By asking the worker (inquiry), self-recording from the worker himself, time study where an observer is measuring the task at the station, work sampling or registration by devices, automatic data collection with machines. Determining target times can on the other side be established by using methods such as comparing and estimating, PMTS, and calculations. The times which are set are based upon the actual times, but with factors broken out of them. The target times are what indicate the planned times. Niebel and Freivalds (2003) says time data that is collected in history does not imply how long it should take, only the actual times.

Kuhlang et al. (2014) claims different tools are suitable for different methods. Where more exact analyses require more exact and time-consuming tools, such as stop-watches, papers, time determination tools, TDM software, data collection, video analysis and motion capture, process planning, and simulation tools. The different tools require different amounts of time to process the data.

2.2.2 Pre-processing

The pre-processing process involves how the data is intended to be presented, this step involves using a morphology that describes attributes related to the type of actual or target time and factors influencing work duration. This includes the data presentation and how it should look (Hedman & Almström, 2017).

Attributes of time type can be categorized into blocks, based on the level of time available. As the blocks get more detailed, the reusability of them declines. The build blocks can be divided into product and process-based types, where product-based data defines operations and process-based data related to specific parts, components, and tools (Kuhlang et al., 2014).

2.2.3 Application

The application process within TDM describes how the time data can be used within the company. Strategic, tactical, and operational data applications are attributes which the time data can provide input for. The time data could then be used as a tool to evaluate an investment, design new work methods, and order and product-oriented data representation that could play a role in the decision-making (Hedman & Almström, 2017).

2.2.4 Administration

A big parallel process to the other three, as Kuhlang et al. (2014) describes it, is to administer the data. This involves designing a data storage system that suits the time data. A good data system according to him includes all the processes within TDM and is cross-integrated, which means that everything can be overlooked within the system. The purpose here is to describe the way it is integrated and the type of administration system.

Hedman and Almström (2017) stated that when arranging blocks as process-based you could combine and reuse 13 "variant strings" (A group of products that belong to the same variant) for a set of 48 different products. By using a TDM IT system you collect all time data in one place, when a time for an element or activity is changed due to a method or design development, all the related times would adjust, and by that create new time data for the other products.

2.3 Application of Time Data

2.3.1 Actual and Planned time

Direct measurement involves using a stop-watch, employing principles similar to those introduced by Taylor (1911), to measure tasks. This approach facilitates the calculation of cycle time for a single instance. These time calculations, referred to as actual times, rely on timing an activity directly. However, when utilizing a stopwatch, certain factors, such as workers performance, are not considered. Consequently, the time required for a worker to complete the same task multiple times can vary consistently. It would be impractical for a worker to achieve identical completion times for every job cycle.

In order to align the measured times with real-world scenarios, adjustments were made to account for various factors that could impact the worker's tasks (Niebel & Freivalds, 2003). These adjusted times, referred to as a targeted or planned time, provide an estimation of the duration within which a worker can complete a cycle of the job, even after working for extended periods, and is therefore useful for planning the production.

The speed at which the worker would conduct a task cannot be consistent but varies within acceptable variation limits. Each worker would have a unique speed at which they work at. To ensure there is a speed that everyone can maintain for a longer duration of time, considerations had to be made about the speed when measuring the time (Niebel & Freivalds, 2003). Although, Hedman and Almström (2017) claims that in a study of 60 companies, planned times were determined incorrect and only 25 % of the organizations updated the time data in their system.

2.3.2 Balancing

Line balancing is the process of optimizing the production line to ensure that supply meets demand efficiently. A key factor in achieving a well-balanced production line is having an equal takt time across all processes. Therefore, takt time is determined by the slowest cycle, which sets the pace for the entire line and represents the bottleneck in the production process. (Maynard & Zandin, 2001; Tulip.co, n.d.). In an assembly line, having a well-balanced production line can lead to lesser idle time for the line, according to Klein and Scholl (1996). Mastor (1970) furthermore says reducing labor and personnel in the flow since you have higher control of the cycle time.

There are many advantages to having a balanced production line according to Maynard and Zandin (2001), one of the pros is that the waste related to time is reduced by having a well-balanced line. Furthermore, by balancing the production line, organizations can reduce the impact of time-consuming activities on the output of the line, ultimately increasing utilization and productivity.

In a simple line-balancing model, the mathematical solution would be a simple arithmetic equation. But the complexity of the equation increases rapidly when constraints are added to the variable, which is usually the case in manual assembly. In a manual assembly line, each line would differ from the other, therefore the line balancing equation is usually solved with algorithms. These algorithms consider the case in hand and define the constraint or rules each station in the line must abide by, thereby having a specific solution for each assembly line (Qiao, Yuan, Zhang, & Liu, 2018).

As assembly line balancing relies more on computers, it is important to have accurate data for the balancing software. This software requires a database to work on, an information base that provides the capabilities, variations, and constraints of each station and these activities. The output the algorithm generates is only as good as the data's accuracy. If the data is incorrect, the operation times will be set incorrectly, leading to faulty balancing. This can cause disruptions, incorrect customer offers, and flawed investment decisions due to data errors. Therefore, ensuring the accuracy of the input data is crucial for reliable and effective assembly line balancing (Almström & Winroth, 2010).

2.3.3 Sequencing

Assembly lines are made up of multiple stations that conduct specific operations and activities on a product. After all of the activities are completed at one station, the product moves on to the next station within the line. The activities conducted have varying cycle times, which means that the product leaves some stations faster than others. This gives rise to random cycle times, that affect the manufacturing lines. While the balancing problem is solved by maintaining a constant cycle time across all tasks in a station, and sequencing problems are solved with fluctuating between high and low cycle times, which reduces and levels out the workload, to give the best volumetric output (Mönch et al., 2020).

When there are unequal cycle times, one challenge is to balance the workload between the stations. When a single station assembles a product with a high cycle time, the worker would be burdened and stressed. If another station at the same time assembles a less complex product that goes faster, an imbalance in workload is created between the stations. Maintaining and assigning a similar workload between the workers is necessary for the morale but also as the workload varies with the different variations, it is also easier to achieve a higher quality of the products, since a constant high workload will lead to quality issues in the production, due to tired workers (Alghazi, 2017).

Solving these problems gets complex when there is a huge variety of manufactured products, therefore heuristic rules are often used. Algorithms can also be used to solve such problems. These algorithms could be specific to one line or a single facility. For these tools to have an effect as desired, the data used in the algorithms must be accurate. To have an efficient line with tasks assigned according to Balancing and sequencing algorithms, there needs to be a preexisting data set with cycle times or other such data to enable these tools (Mönch et al., 2020).

2.4 Productivity

Productivity can be measured with Method Performance Utilization (MPU) for a aspecific process or operation (Almström, 2013). The different factors are also where you can improve productivity. The factors are M, P and U which stand for Method, Performance, and Utilization. The productivity is calculated with the formula 2.2.

$$Productivity = M \times P \times U \tag{2.2}$$

The Method factor is the ideal productivity rate and an inverse of the cycle time. The Performance factor represents the pace which the workers work at, where 100% is the normal speed for a full work day in MTM-SAM which also is the ideal cycle time, although without any training. The performance factor can therefore be both lower and higher than 100% since it is compared to the ideal time. The utilization factor represents the amount of time spent on performing the operations throughout the day, with the maximum level being 100%, where a higher utilization values indicate greater productivity. It is although important not to mix up productivity or utilization with efficiency, since efficiency is about doing things right and a higher utilization does not increase the efficiency.

2.5 Lean Production

Lean production is built on a foundation of removing waste, but there are many means to implement this. The Toyota Way, by Liker (2004), that respect for people and continuous improvements is what carries the ideology and keep it together. What you are doing with lean is creating a culture over time that will work towards creating organizations that strive to improve (Lean Enterprise Institute, 2018).

Removing waste is a term within lean that is used commonly. The meaning of this is to remove things that do not add value and minimize waste. Waste in a lean ideology is the same as a loss. Value-adding things are defined as moments that add value to the final product in production. This means that everything else is waste according to the philosophy. Due to the high focus on removing waste, much of the lean ideology is about making things simple. This includes the way to measure time. Time determination methods used in lean are only mentioned as, clock studies and observations. Papers, pens, and stop-watches are determination tools used for the methods to keep it simple (Liker, 2004).

2.6 Standardization

As production lines have evolved, manufacturing techniques have evolved too. Taylor (1911)'s principles of training a worker to follow a standard work method was an effective method to ensure quality could be maintained while working quickly, which bodes well with lean ideologies. The goal of standardizing is to get consistency within a process.

A standard work method would not just ensure the quality of the product manufactured. It would help meet the production demands. Liker (2004) describes how Toyota used standard work methods to measure work times to develop concepts such as Cycle time and Takt time required by the demand. A standardized working method and a standard work layout justify such measurement systems.

Standardizing is more than just establishing a standardized work method. The layout of a production line is as well an area that can be standardized between lines and how they are designed. Standardizing a layout can be as important as having a standard work method. Replicating the same operation at a different layout, than the one in which it was designed for, is not practical Niebel and Freivalds (2003). To ensure consistency and usability of measurements such as cycle times, it is essential for workers to adhere to an established method and work in a layout similar to the one in which it was originally planned.

2.6.1 Standard Data

According to Maynard and Zandin (2001), standard data is a system that makes it easy to set and maintain precise standards for work tasks. It does this by breaking down work tasks into smaller building blocks that are easy to understand. The size and number of these blocks depend on how precise you need to be, what kind of work it aims to be used for, and the flexibility desired. Once the building blocks are defined, you can use them to analyze and calculate how long it should take to do similar (or a group of these) activities. In essence, standard data makes it simpler and faster to set standards for work tasks similar to those you have done before.

Multiple advantages of implementing standard data are recognized. One major, which could be highly motivated by companies from implementation could be the reduction of costs related to the need to spend resources to the same extent. The monetary aspects involve a higher up-front investment and a time-consuming start-up period, resulting in less time needed to develop a more complete system (Barari, Vazquez, & Sabou, 2018). The following maintenance to the system and model will, in addition to this, require less time due to the need to maintain the building blocks to the same extent as without standard data. The consistency and accuracy can be increased since you do not measure individual processes to the same extent when implementing it, nor do you need to measure data in special circumstances, which can affect the data (Barari et al., 2018).

Maintaining engineering standards is easier when organizations pay importance to standard data, but the limitations of this approach has affected its acceptance (Maynard & Zandin, 2001). The excess need for standards in layout and processes is challenging to be maintained in some scenarios. Therefore, along with scientific work methods the organization should follow design for assembly, these requirements are quite challenging and therefore standard data needs to be adapted specifically for the case in hand (Maynard & Zandin, 2001).

2.7 Predetermined Time System

Predetermined time systems are used to calculate time data for activities, to establish planned times. It is built by breaking down operations into smaller activities, such as elements. Predetermined time systems can be used to evaluate complex scenarios where a time has to be established for an operation that does not exist yet, which makes it a useful tool. The time a specific activity takes is noted and can then be used for production improvements of various operations at facilities as an analysis tool (Maynard & Zandin, 2001).

When setting the time, it is important to decide what you want to measure, then divide it into different activities, e.g. reaching for a cup, picking the cup up, and moving it. This would be three activities where you measure the time for the three different steps to complete the operation. This gives you a very precise way to evaluate time in a system (Maynard & Zandin, 2001).

Using predetermined times for assembly processes led to the development of standard methods, as standard times can only be replicated if the activities conducted under them remain the same for every instance. The diverse approaches to measuring predetermined times meant there would be different measurement techniques. According to Niebel and Freivalds (2003) they can broadly be classified into three different categories: acceleration-deceleration systems, average motion systems, and additive systems. Standardizing methods and measuring the motion times of these methods gave rise to method time measurement (MTM). This technique falls into the average motion systems branch of classification. The average times of the motions are calculated, and predetermined times are assigned for these motions. This depends on the type of motions and the conditions under which they are executed.

A problem with predetermined time systems, according to Maynard and Zandin (2001), is that it is very time-consuming. The amount of time it takes to calculate the predetermined time does not seem profitable for some organizations. The simpler ways to establish times are often less accurate and are, therefore, a cheaper way to set times. Furthermore, the more accurate you want a system, the more time-consuming it will be. Therefore, it is a balance on how much time shall be spent on evaluating the activities (Niebel & Freivalds, 2003).

2.7.1 MTM-SAM

MTM-SAM is a variation of MTM–1 that was developed by the Swedish Efficiency Organization's Technical Committee in 1982, collaborating with major trade union organizations (Grupo Itemsa, n.d.). MTM-1 is an efficient method to optimize work methods evaluation, it is accurate but time-consuming. MTM-SAM employs the same techniques with better grouping, thereby it reduces the analysis time and provides the users with a quick and easy way to interpret the analysis. Analyzing one minute of video requires about 50 minutes (Andersson, 2001). A panel that takes five minutes to assemble would thereby take about 3 hours to analyze. Which makes MTM-SAM analysis very time-consuming.

MTM-SAM is better suited for manual assembly as it groups movements and other elements that are repetitive in manual assembly work. Another effective use in sequence-based analysis is, it helps analyze steps according to the order in which it is executed. This would help the reader to better understand the steps employed while conducting work in a scientifically established method (Niebel & Freivalds, 2003).

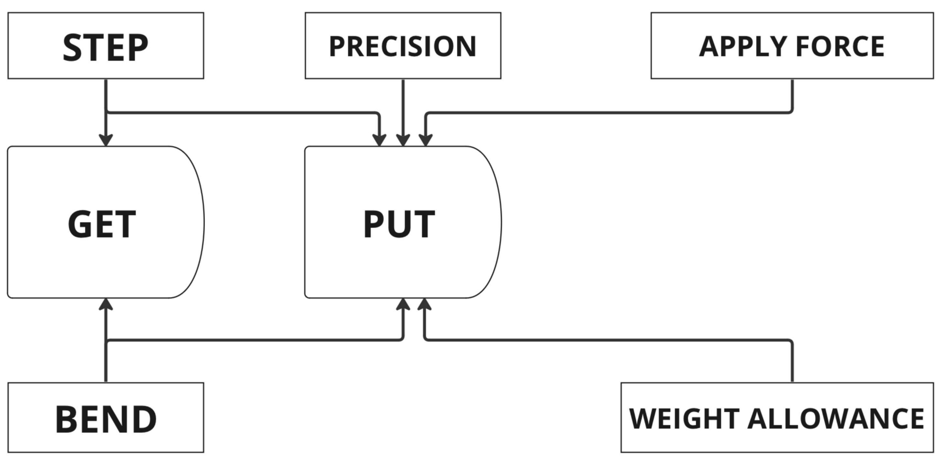

Figure 2.1: Functions in MTM-SAM calculation

The categorization of motions in MTM-SAM is shown in figure 2.1. When categorizing the motions into the depicted functions, classification becomes an easier task. The basic functions, i.e. "get", and "put", are supported well with peripheral functions. The functions and sub-functions are case-dependent and can be tweaked to accommodate any specific scenarios of manual work. It also helps obtain the absolute level of measure on the pre-established method (MTM-föreningen i Norden, n.d.).

2.7.2 Time Blocks

Recognizing the advantages associated with time studies led to Method Time Measurement (MTM) gaining preference, particularly among unions that embraced the idea of establishing standardized time measurements for manual activities.

Accroding to Niebel and Freivalds (2003) MTM analyses elements of an assembly process with a scientific approach, this analysis can then be replicated as building blocks and reused for similar instances. As they become more and more specific and the analyses more exact, they lose the reusability parallel to the exactness according to Kuhlang et al. (2014).

The data derived from the building blocks can aid management and financial decisions. Since these data sets determine the output of an organization's resources, it is of high importance that they are accurate. The accuracy of the time data determines the efficiency and utilization of resources, thereby, the organization as a whole (Almström & Winroth, 2010).

"Blocks" is a term used by Maynard and Zandin (2001) when the concept of standard data is discussed. Looking at possible scenarios where time blocks can be built, it can be derived from standard data (Kuhlang et al., 2014). The chapter on developing standard data needs to be revisited to understand and follow the principles behind which standard data is built. As Maynard and Zandin (2001) stresses the top-down approach for developing standard data, initially, it is necessary to design blocks for the purpose they will be adopted for. Each production floor could be unique regarding products and processes. Where the time blocks should be designed after the application and its purpose, but where attributes of the data set limitations as well (Kuhlang et al., 2014).

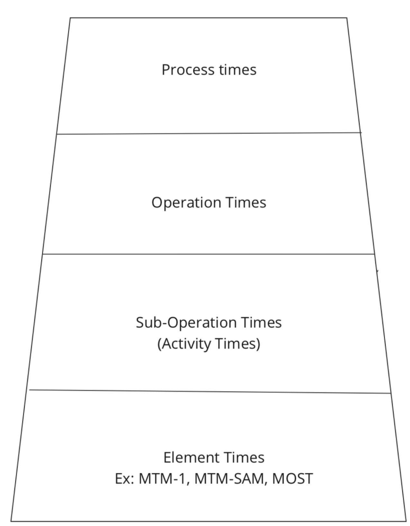

Figure 2.2: Building Blocks inspired by Maynard and Zandin (2001)

The concept of building blocks, visualized in figure 2.2, is used in Maynard and Zandin (2001) as a fundamental concept for gathering standard data. The levels in the blocks, is a categorization of the level of data that is captured. The lowest level would consist of lines of "element" data, data on the levels of MTM-1, MOST, or other similar measurement techniques. The highest level would group "operations" into a "process" to generate a specific process plan. The mention of "group technology" in this section by Maynard and Zandin (2001) specifies the possibility to group processes and operations, i.e, higher levels.

Any manufacturing facility can use three levels of standard data (Maynard & Zandin, 2001). By evaluating group technology concept, there was scope to build a tool to group different "activity" and "operation" blocks to generate a unique process plan. The effort to calculate time data for manufacturing times when a new product is introduced would be reduced if existing activities or operations could be grouped to generate the process plan for a new assembly (Hyer & Wemmerlöv, 1984).

In Sweden, time blocks can be found at Scania. Their Time block system is called STB (Scania time blocks). This is one of their ways to set time. At Scania, it consists of codes that are used to set the time for a process. They use MTM-SAM times in the development of these time blocks. That project is used as a pre-study in applying time blocks to manual assembly lines with such large variation (Svensson, 2021).

2.8 Data

Data is created to represent information and visualize the unknown and uncertain, something Shannon (1948) discussed long before computers became common. He also stated that data is communicated within channels to provide information. Data, particularly big data, will increase over time (Villars, Olofson, & Eastwood, 2011). We measure more and more things at an increasing speed, where you integrate data into everything we have, from phones to refrigerators. Enhanced data collection enables more informed business decisions by providing a more accurate representation of reality compared to previous methods. This improvement is expected to continue as the amount of measured and collected data within society increases. The society built around big data, complements its presence, thereby helping you capture and analyze the current state to a higher degree. Auschitzky, Hammer, and Rajagopaul (2014) says this can help improve productions, and this is where you could take advantage and use the information you gather. Money can be saved by efficiently using technology, but also time, since the time we spend on measuring things today is vital.

2.8.1 Manufacturing Execution System

A Manufacturing Execution System, MES, is a system that allows organizations to manage their production operations. Aspects such as dispatch production, detailed production, and scheduling are examples of areas that can be controlled via this system. A MES is described as what connects the ERP system to the actual processes. The MES system collects data from the processes within the facility and converts this into usable data which can be used for the ERP system, where the MES system can be used as a way to capture real data and be the link. By capturing real-time data, MES enables the analysis and optimization of production lines, offering valuable operational insights. This makes it an effective management tool that can be utilized to enhance productivity and drive improvements in various aspects of operations (Kletti, 2007).

2.8.2 Databases

Databases are places where you can collect and store data, which is easily accessible, and, very importantly, easy to navigate within (Codd, 1970). The database should, per see, not be limited to a small group of users who can understand the content, which can lead to the issue where people building the platform are the only ones understanding it. According to Codd, the database should be easy to understand and have relationships within columns and rows to make it possible to look for specific data. You should be able to store the information electronically and organize it. The database is a large amount of data shared in, e.g., a network. Furthemore Codd (1970) says that you can design a database in many different ways; there are small and large databases. The large ones require a higher level of organization or hierarchical level. Edmondson (2022) further claims that a database can improve an organization's consistency and reduce time spent on time management.

2.8.3 Input Data

Input data is of high importance in many instances, since this is what you base your models on when simulating or analyzing cases. The data is, therefore, essential since it can affect a project to a large effect. Therefore, the data used in a model is necessary to represent the actual scenario, accurately reflect what is important, and indicate the plan (Codd, 1970).

There are many problems with data input, where the representation of the actual occurrence can be hard to capture with numbers. There is a gap between the real data and the data used as an input. The deviation can lead to different problems. (Almstöm, 2022). Therefore it is important to ensure that the collected data represents the reality.

Mistakes in collecting data can cause problems with it, parameters missed in the data that affect them to a large extent, and false data where measurement has been set wrongly, to mention some. Setting data can also be biased since people have opinions regarding which data should be used and where it is collected from. To get around this and get good data, you should start by creating a model which can describe the system to easier understand the problem (Almström & Winroth, 2010).

Input data can be selected in various forms for probability sampling; simple, stratified, systematic, and cluster (Maynard & Zandin, 2001). The most common one is the simple way where you take a selection out of the entire population to choose a suitable size (Lantz, 2012). Data collection can be conducted in two ways, either experimental or observational.

2.8.4 Mismatch in Data

When the input data is wrong, faulty, or not appropriate for its use of it, it can be called bad data (Maynard & Zandin, 2001). It can lead to outputs that are wrong and misleading (Almström & Winroth, 2010). A significant problem with this, is that it is not something you easily can overcome in analysis and fix. When the input data deviates from the actual data, a gap is created. This gap in the data can be called mismatch and can cause long-term problems. A solution to this can be to analyze the input data and identify the gap, then replace it with data that is collected with a method that suits the purpose better.

Almström and Winroth (2010) claims the underlying root of the mismatch or gap can be considered to be unawareness of the mismatch, which is caused by faulty operation times and times that is not updated to the current situations. This also makes the gap bigger since allowance time has to be added in some cases. The solution to decrease or minimize the mismatch can be to understand the complexity of the problems and source to a higher level, to begin with, where better descriptions of the object which data shall be collected from would be present. The mismatch or gap can lead to problems related to a higher level of optimization and improvements for a system, faulty investments, and lower levers of throughput rate in a factory.

2.9 Group Technology

Group technology is an approach to maximize the efficiency in production by grouping manufacturing of components by various characteristics (Hyer & Wemmerlöv, 1984). The grouping is done by dividing the similarities for different parts and assemblies. The common denominator is something that can decide how the grouping shall look like. With this approach, you group components into different categories. The grouping can be by size, a certain option, or other similar characteristics such as a common problem which occurs.

Group technology can be used to sort common problems, which would help in better analysis in production according to Hyer and Wemmerlöv (1984). With the help of group technology, you can presumably save time. The time saved during analysis is mostly added up by avoiding duplicates, being able to repeat data, and at the same time accessing it in an easier and more understandable way. However, another part of saving time is the search for similar properties, considerable time is saved by looking up other related or similar items. Hyer and Wemmerlöv (1984) means that it is essential to have a library to keep track of everything, referable to a database. This database should contain all information about products and configurations. The database should have the capability to enable configuration searches, allowing users to find similar work and foster synergy among projects.

Group technology has been used since the 1940s and has shown to be a powerful concept to implement in a production (Hyer & Wemmerlöv, 1984). The tool mainly aims at production development; however, due to the way that it is used, companies get advantages from using it in other aspects as well, such as creating a new production process. According to Hyer and Wemmerlöv (1984), the savings could be substantial and increase parallel with the introduction of new components. According to them, what decides how much you can save depends on where you can draw benefits, how much use you can reuse from earlier projects, and how much you can integrate into the new process. Although, sorting and grouping components can help reduce repeatedly timing similar activities and enable setting cycle times for groups of components with similar characteristics.

3
Methods

This chapter outlines the methodology employed in the research project, providing a comprehensive description of the study's design. It also presents the approach used to develop principles for time blocks, offering insights into the creation process.

3.1 Research Design

This section outlines the research design used for the project, two approaches were used. A mixed-method approach combining qualitative and quantitative methods to develop a tool (Yin, 2018). The other approach, design science research, was used to develop and evaluate the principles of time blocks.

The data from qualitative and quantitative studies were combined to evaluate time blocks comprehensively. The findings from qualitative studies were used to analyze quantitative results, helping us understand the research areas better. The qualitative and quantitative studies will provide complementary insights into the research area, resulting in a more robust and reliable conclusion.

Design science is used while developing a solution to a practical problem (Johannesson & Perjons, 2014). The socio-technical approach of design science research is useful in evaluating the principles of time blocks. According to Johannesson and Perjons (2014), developing a solution for a practical problem requires evaluating a hypothesis that verifies the solution with scientific reasoning.

3.2 Literature

A comprehensive review of the relevant literature was undertaken to explore the current state of knowledge in the field. Searching for literature related to the subject was not only restricted to English but was conducted in Swedish as well since it was believed that there was literature in both languages highly related to the study.

With the help of literature study, other similar theoretical frameworks were collected and reviewed to understand how a method could look, be structured, or generate time blocks. The theory was collected from articles, papers, books, and with help and inspiration from Peter Almström. The search was mainly conducted in search engines; Scopus and Google Scholar. Relevant fields in other areas related to the subject were found in the review. However, similar concepts related and applied in other fields of science were found where conclusions could be made regarding this topic.

3.3 Design Science Research

The thesis followed a method framework while conducting design science research as described by Johannesson and Perjons (2014). The five-step approach is used to develop, what the author calls, an artefact. The author defines artefact as *"an object made by humans to address a practical problem"*. Addressing the challenges, organizations face in maintaining time data, the method framework for conducting design science research could be used.

Design Science Research (DSR) methodology is commonly used in research papers to develop and evaluate artefacts, such as tools, models, or frameworks, to solve practical problems. In this case, it would be the *"Principles for developing time blocks"*. The five steps of design science are;

1. Problem Identification: In this case, the problem is the need to build time blocks for assembly stations within Swegon's assembly line.
2. Objectives: Identify the objectives of the research, which includes developing a tool for building time blocks, evaluating its effectiveness, and comparing different classification approaches.
3. Artifact Design and Development: Design and develop the artefact (in this case, the tool in Excel) based on the identified problem, objectives, and literature review. The tool was built following the methodology described in the research paper.
4. Demonstrating artefact: The practicality of the Excel tool is evaluated with TDM data. The end users of the tool are used in assessing the practicality of the tool.
5. Artifact Evaluation: Gather data and analyze the results to assess how well the tool performs in building time blocks for assembly stations. The results are compared with existing approaches or methodologies.

3.4 Qualitative Study Data

Semi-structured shorter interviews were conducted with the aim of creating broader knowledge about the acceptance and understanding of time blocks. This also increased the possibility of giving more personal and honest answers than sending a form. Something that also can create data that is unexpected (Denscombe, 2018).

Additionally, the interviews aimed to determine whether the interviewees viewed time blocks as a feasible solution in the near future and whether implementing them was beneficial. By gathering the interviewees' opinions on the possible integration of time blocks into their system, it was possible to determine the viability and feasibility of integrating it on a larger scale.

The people interviewed were limited to three-person, due to the finite group that was part of similar studies in the organization. Some interviewees have maintained the organization's time data and calculated method time using MTM-SAM. In addition, people with previous knowledge about time blocks, more directly those who had taken part in the TIMEBLY project to learn and understand the concept of time blocks, were selected. The challenges the interviewees had while working in the area also helped us better define the requirements of time blocks. These things, in combination, limited the group of people having knowledge about the concept.

3.5 Data Collection

Data collection was conducted in two ways for building time blocks. One collection was done through an existing Casat database, where Swegon stores and plans its production schedule. The software focuses mainly on Time Data management. The other data section was captured with simple stopwatch time studies to document a few operations' actual times.

3.5.1 Database

The data collection that was conducted in Casat was mainly done by downloading the product structure's assembly time data, a list of element times. Every product article had a structure that contained either an MTM-SAM analysis, an Avix study, or a clock study. However, only articles that contained MTM-SAM data were chosen for the project.

The list could be downloadable as an Excel file, and the sheet that was created for each product article included information such as operation, activity, and element times, the three levels of time data in Maynard and Zandin (2001)'s standard data block levels. The list and elements were then processed and merged into one large master sheet where all the data was compiled. This was to get a better overview and understanding of how the different articles correlated to each other. The different panels, e.g. "baksida", "framsida", etc. had further on different operation steps, which meant that data collection for the different steps had to be conducted for all of the different panels. The collected data was analyzed and revisited to check for its correctness. Correct and updated sheets were grouped to form libraries to analyze the data and categorize them into predefined nomenclature.

3.6 Software

Excel and Avix were softwares available for the project. The existing data was compatible with Excel software. Requirements that are fulfilled by Codd (1970) and the theories about easy accessibility within databases, favoured Excel. Excel is also the software where the library would be generated and maintained. But more importantly, Excel's simplicity in solving equations that are based on synergies between elements and the ability to build libraries around our requirements, was the motivation to use Excel in this project.

3.7 Quantitative Data Analysis

After the data was collected and cleaned, it was analyzed. Similarities between panels and different operations were identified to understand how they correlated. This was done by sorting the data of different panels into categories of options. Along with the different panel sizes, there were multiple parts that could be mounted on these panels. Once the different part options were established, new sheets in the Excel file were created to keep them apart, so it would be easier to differentiate the operation steps that originated from the set process.

With the help of predefined nomenclatures and using the Excel sheet of MTM-SAM times of the assembly steps, a library was built that structured the data well. Differentiating the activities into understandable blocks that defined the assembly line process. Further, a tool was built in Excel to develop time blocks for a process. The chapters later on in this report explains in detail how quantitative data was used in building a tool. The project also included evaluating the quantitative results of the tool, to validate the principles that were followed in quatitative studies.

3.7.1 Slotting for Inconsistent Operations

As Maynard and Zandin (2001) mentions, there are operations where measuring time data is ineffecient — the operations where cycle times are not consistent between operators or repetitions. The working times would not be consistent like other manual assembly tasks due to a high variation in working methods. Calculating operation times with arithmetic formulas was impossible, therefore slotting was used. Alternate methods to calculate operation times were evaluated when cycle times in reality were not consistent.

Slotting creates a time basis when you have different groups within a data set (IBM, 2023). In this case, panel sizes were identified as groups, as time differed with respect to size. A stop-watch time study was first conducted for all the identified groups, where the operation times were measured. When this was done, all the times for the specific group were compiled, and then the average time for each group was set (Maynard & Zandin, 2001). Smoothing was also used for this to exclude some of the extreme points due to random variations that affected the operation times. 10% of the lowest and highest times were excluded when slotting, to obtain only one value per panel. In conclusion, all recorded times were rounded up to the nearest whole number. This decision was influenced by the limited statistical confidence in the precise timing measurements and the understanding that the decimal values would have a negligible impact on the final outcome.

3.8 Verification

By verification, we ensure that the data generated by the database or software is the same as input information (Naylor, Finger, McKenney, Schrank, & Holt, 1967). Verifying the data was done by ensuring that the results from the sheets created by the time blocks gave the same output as the times in Casat. Comparing the times generated by MTM-SAM in Casat with the results of the Excel tool, would evaluate the quantitative accuracy of the tool and, thereby the principles behind it. Qualitative data was used to support or challenge the quantitative results, thereby suggesting the possible answers to our research area.

3.9 Validation

Validation ensures that the output from the simulation model is aligned with real data(Naylor et al., 1967). The real-world observations are what you want to replicate in the simulation model. In our case, the equations used in the tool is validated to check how it aligns with Time data of the organization. If the requirements are unmet, you need to go back to data collection and understand where the data is corrupt. Almström and Winroth (2010) mentions distinct differences in data can increase mismatch when data validation is not conducted.

4

Current State Analysis

In this chapter, analysis is made on how time blocks can be built in the current state. The chapter includes production design, data collection and equation building.

4.1 Production Design

In production, they have six lines set to produce various HVAC units specified with a configuration that suits the customer's needs. With many variants, Swegon cannot use one production line for all. Several lines with sub-stations that pre-assemble panels are necessary to assemble their products. Differences in units can be due to size, placement, and functionality. The thesis focused on building time blocks at four sub-stations of the main assembly line-B, as this layout is common in all lines. The shop floor layout is shown in figure 4.1. The main assembly line that manufactures the final product picks panels from all three buffers. Panels are made of sheet metal with insulation in between. There are numerous functional components assembled on these panels. Materials for panels are delivered in carts to these stations. Once the panels are assembled they are placed in the buffers for the main assembly flow to use. The panels consist of various parts since they are configured in ways set by the customer to meet its need. Figure 4.2 shows an example of a finished panel produced at line-B.

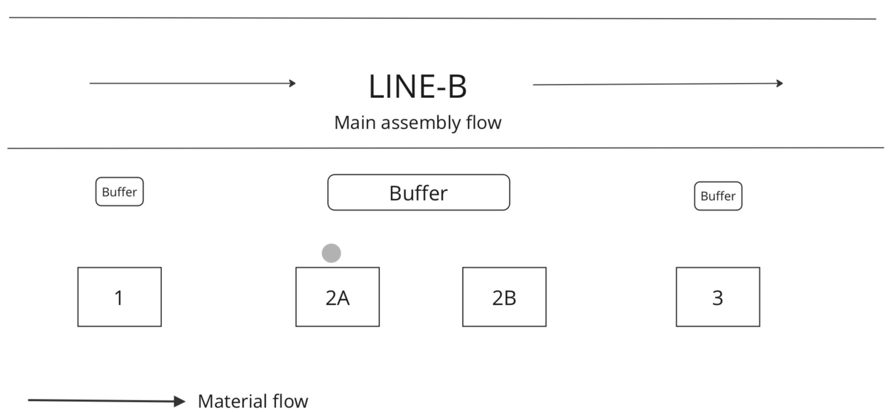

Figure 4.1: Layout-Line-B

For managing cycle time and other production-related data, Swegon uses an MES system called Casat for five production lines and a second system called Mbrain for line-B. Swegon is testing out the software practically in line-B before all plant lines adopt M-Brain. Swegon has stored all their production times for each module in the MES. These are calculated mainly by MTM-SAM but with some exceptions set by clock studies. These clock studies were excluded in this thesis

Figure 4.2: Exampel of panel produced at Swegon

4.2 Data Collection

When there is a certain degree of standardization in products and processes, time blocks can be effectively utilized. The level of data that is preferred for time blocks would be data on the lowest level, an element level. The element data at Swegon is generated with MTM-SAM, which is mainly used for line-balancing algorithms. The software Casat, uses this data for scheduling jobs at the assembly station. The data collection phase resulted in five files, one for each panel, with the elements from the MTM-SAM, needed to build a panel. Each file consisted of all the available features from Casat.

The line balancing and scheduling software, Casat, plays a crucial role in assigning jobs to each station based on orders. Swegon's manufacture-to-order model results in job orders that lack consistency. This is due to the variation in customer-specific requirements, making it impractical to maintain these orders as inventory. The critical role of sequencing job orders within the line and balancing them to alleviate workload is efficiently managed by Casat. This function is significant in shop floor management as it directly influences the output generated by these stations. As the newly added M-brain lacks complete data, the product or variants assembly data were acquired from CASAT. This data was necessary to obtain accurate element times for activities within the assembly line.

4.2.1 Available Data

The assembly lines at Swegon have to manufacture unique and complex machines. The main assembly lines are supported with subassembly stations to complete the assembly in the least possible time. The available data starts at a process level in line-B, which the project is based on. The other assembly lines within the factory have a lower level of data maturity. The available data is insufficient at those lines, and the same structured approach might not be applicable at all the production lines due to their diverse operations.

	CO	Seq	Typ	What / How / Why	Key activity	Time
		1	**Instruction Group**	What: Lägg upp YP gavel och montera 2 st plasthörn How: Wingspeed		28.98
		2	SAM	Avsyna Casat		5.04
		3	SAM	Gå till luckpall, tag YP, gå till bord		6.84
		4	SAM	Kontrollera att YP inte har repor		5.4
		5	SAM	Lägg ner lucka på bordet		1.8
		6	SAM	Tag två plasthörn och montera första i närmsta gavelhörn		5.4
		7	SAM	Gå till nästa gavelhörn och montera det andra plasthörnet.		4.5
		8	**Instruction Group**	What: Skruva fast hörn How: Wingspeed		15.68
		9	SAM	Hämta dragare, skruva första hörn		7.3
		10	SAM	What: Gå och skruva nästa skruv How: Taga skruv ur ficka och mata skruv i dragare under steg		5.5
		11	SAM	Återlämna dragare		2.88
		12	**Instruction Group**	Isolera i YP gavel och skär ut för de runda hålet.		52.38
		13	SAM	What: Tag och placera isoskivor How: En skiva, placeras med kortsida mot långsida på YP		9.0
		14	SAM	Tag kniv, skär längs långsida på gavel, släng spillbitar		6.12
		15	SAM	Skär längs kortsida på YP, släng spillbit		6.48
		16	SAM	Justera isoleringsskiva mot kortsida på YP		1.44
		17	SAM	Skär längs kortsida på YP, släng spillbit		2.52
		18	SAM	Placera spillbit på långsida där det saknas isolering, skär till en bit som passar		6.12
		19	SAM	Skär runt i det runda hålet		7.74
		20	SAM	Gå runt, tag spillbit, placera och skär till, lägg ner kniv		8.28
		21	SAM	Tag spillbitar, släng		4.68
		22	**Instruction Group**	Lägg på IP		11.16
		23	SAM	Hämta IP		6.84
		24	SAM	What: Lägg ner IP , tryck till How: Passa in plåt		4.32
		25	**Instruction Group**	Skriva tur nr på post-it		5.94
		26	SAM	What: Gå och skriv en postit med tur nr och placera på lucka/baksida How: Tag block och penna Why: Återlämna		5.94
		27	**Instruction Group**	What: Ställ i luckställ How: Rak kant neråt		9.54
		28	SAM	Tag lucka,		2.52
		29	SAM	Placera i ställ		3.42
		30	SAM	Kvittera Casat		3.6

Figure 4.3: Data structure in Casat

All the collected data were presented in different sheets, divided after the type of panel it was collected from. Many of the products could be excluded due to being the same product variant as another article. One of the panel types is the Bottom panel. They had the least developed SAM data; seven different analyses were gathered and used as data. Including the activity related to clock studies in the data collection was necessary, even though it would not generate any usable data because it only covered some configurations. The times associated with this activity were included. Other panels would consist of a complete SAM analysis; however, the options were more complex. To create and understand the structure of the panels and cover all the options and possibilities, at least two different analyses of the same operation were preferable. The data was vastly different in some instances, and the available data was somewhat questionable. Much of the data missed well-described activities or had SAM data that could have been described in other ways to make it easier to understand.

4.3 Time Blocks in Current State

Time blocks use equations; solving these equations can obtain the time for operations and processes. An equation was therefore created for each operation of the product variant, and the times from all operations were grouped to generate process times. Further on, the chapter discusses how the current data is structured, categorized and analyzed to build time blocks.

4.3.1 Structure Data

The MTM-SAM data had essential times grouped in Casat as "Instructions Group". The Instruction groups comprised multiple lines of element data built by analyzing videos for making MTM-SAM calculations. The Instruction groups in the Excel data were operation descriptions. They were MTM-SAM data for operation times in different assembly processes. All operations that would be conducted while assembling a panel were listed in the Excel sheet that was accessible through Casat.

The collected operations were categorized based on panel type and product line being manufactured, and it was necessary to group elements within activities. The elements within the Instruction group could be grouped into four different activities. The four categories that the details in the operation sheet or Instruction groups could be grouped into were:

- Pick/Get Activities
- Preparing Activities
- Mounting Activities
- Returning Activities

All four activities would exist in each individual operation, as shown in figure 4.4, but the times for these activities while conducting the same operation vary. The variation was due to the number of repetitions within elements in the mounting activity and tools that would be used in the Pick, Get, and Returning activity. While creating a product-based library, the activities from one operation were not repeated in the other due to inconsistent data within the same.

GROUP	Hämta luckskoning från kitvagn och lägg på bordet	11.52
Picking (material)	Hämta luckskoning	7.02
Picking (material)	Lägg luckskoning nr 2, på andra sidan	1.62
Preparation	Ta isär kortsidorna	2.88
		11.52

GROUP	Tryck dit luckskoning	20.7
Mounting	Montera dit långsida 1	1.98
Mounting	Montera fast kortsida 1	1.98
Mounting	Banka dit kortsida	3.6
Mounting	Montera dit långsida 2	4.68
Mounting	Montera fast kortsida 2	4.86
Mounting	Banka dit kortsida	3.6
		20.7

GROUP	Skruva fast luckskoning	37.8
Picking (tools)	Hämta dragare, skruvar och sätt i en skruv i dragaren	5.76
Mounting	Skruva fast skruvar	30.06
Returning	Lämna tillbaka skruvdragare	1.98
		37.8

Figure 4.4: Product-based library

Type	*Activity*	*Time*
Picking (tools)	Hämta kittspruta	1.26
	Hämta papper	4.5
	Tag skruvdragare	0.72
	Tag hammare och placera den på IP	1.4
	Tag mejsel i ena handen	1.4
Picking (material)	Hämta luckskoning	7.02
	Lägg luckskoning nr 2, på andra sidan	1.62
	Hämta dockningsförstärkningar, gå till monteringsbordet och lägg dem i IP.	6.8
Preparation	Ta isär kortsidorna	2.88
Returning	Återlämna kittspruta	3.06
	Släng pappret	2.88
	Lämna tillbaka skruvdragare	1.98
	Lägg undan mejsel	0.7
Mounting	Sätt den första dockningsförstärkningen på plats och böj ner plåten mha mejsel	3.2
	Sätt dockningsförstärkningar ANTAL ex. första & sista på plats och böj ner plåt	3.8
	Sätt dockningsförstärkningar (sista) på plats och böj ner plåten mha mejsel	4.9
	Montera dit långsida 1	1.98
	Banka dit kortsida	3.6
	Montera fast kortsida 2	4.86
	Skruva fast skruvar	30.06
	Applicera kitt i skarv 1	4.56
	Smeta kitt på undersidan av skarven	3.6
	Dra längst med kitt-strängen och jämna ut	3.06
	Smeta kitt på ovansidan av gaveln	0.72
	Gå till hörn 2	1.44

Figure 4.5: Process-based library

The process-based library used the same type of categorization, see figure 4.5, but the activities were further reused with other operations' activities that consisted of the same data. For example, "get screwdriver machine" is an element in multiple operations, so the same line of elements was used in the process-based library. The equation is a process-based library was one single one with many more element repetitions. The number of variables reduced in process-based equations.

A library of operation times could be built by dividing operations into these two types. The data from these libraries can be used to build time block equations. From line-B, the different operations showed characteristics of different types: process, product, or layout based. The assembly line had most operations which were based on process-based operation. The result cannot be generalized overall lines but indicates how it might look at the rest of the lines.

Table 4.1: Estimation of activities in an operation

Type	Number	Proportion
Processbased	1	30%
Layoutbased	2	10%
Productbased	3	60%

4.3.2 Type of Blocks

Structuring time blocks depends on the process and products being manufactured. Number of variables in time block equations reduces with better standardization. The number of descriptive operations decreases if the products and processes have a high degree of standardization. When products are standardized, the tools used in assembly process will be common. So the times when tools are used, and other similar activities can be grouped together. No general solution exists to create a suitable block for all instances since therbligs motions are limited just to element similarities.

The grouping can be made according to the process or products to represent operation times as equations. Product-based blocks can be made based on product necessary functions, while generating the complete assembly time. Process-based block sizes are dependent on the repeatability of processes in product assembly. When more activities were repeated in process-based equations, the number of variables in the equation reduced compared to the product-based equation.

The constants in these equations could have more subdivisions, The most important one being layout-based operation steps. Layout-based operation steps would remain constant when a standard layout is used in all shop floor areas. But practically, there could be variations, which can be represented with layout-based operation steps. For this thesis, layout-based variations were considered constant. There were very few layout-based variations, but this was unprecedented, and with little attention, a standard layout could be maintained.

4.3.3 Building Equations

Using equations to derive time values makes it possible to scale elements according to their combination and repeatability. The equation could be divided into sections to differentiate between process and product-based operations. These sections and specific activities in operations can be assigned variables. Process-based variables would always be applicable; product based variables are subject to the manufactured product.

The final time value for assembly processes at a station was presented on the first page of the database. You also set up which options would be used for the time block value on this page. The time block equation on the "set-up" sheet adds up the time values of all individual operations. The presented time blocks consisted of the sum of the various operations and underlying activities to the operations. The equations always considered process-based operations, as these operations were always applicable to all products that were assembled in the station. The equation varied in length depending on how many different operations were used in each panel type.

The different equations which were used to sum up the total time were developed in various ways. The ability of time blocks to scale operations is achieved with equations. Therefore, understanding how the operations would vary, specifically the elements and activities within the operation that would need to be repeated to scale the operation, must be identified to build equations. In principle, an equation with variables would generate constant values when a user inputs constant functions as necessary.

An example of building an equation that is used in Excel tool for hexert's is described below; The operation starts with an operator picking hexert's from the cart and picking a hexert machine from the tool area. He then moves to the table loading the hexert on a hexert machine and affixing it on the panel. Process-based operations are picking and returning hexert machine and loading hexert on machine. With respect to the product being manufactured the number of hexerts would vary. Product-based activity which is mounting the hexert and picking it varies with number of hexert's used, therefore, this variable is scalable. A final equation for this operation is shown in figure 4.6;

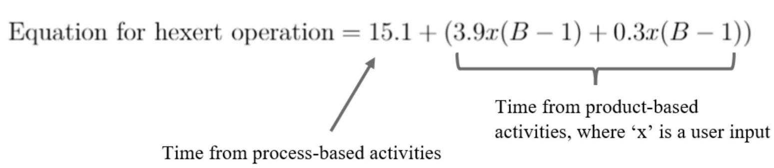

Figure 4.6: Hexert operation equation

Process-based activities varied because equipment for handling different sizes varied, generating other times. But the variables assigned to process-based equations always have a value from the equation. Whereas product-based actions might or might not exist but can be scaled by the user of time blocks.

4.4 Inconsistent Activities

For operations where the cycle time was not consistent when repeated multiple times, equations were not suitable to get operation times. For such operations alternate time-determination methods, that fall into the category of work sampling were used. The following sections describe how the operation times for these activities are calculated.

4.4.1 Insulation

At all the B-stations, one operation includes inserting insulation into the panels. The insulation shall be brought from a pick-up place and then pushed into the panel. This means the insulation must be the right size for the panel. This is done by cutting the sheets of insulation to the correct size. The cutting is done when the operator has pushed the sheet into the board on one side, and by that, easily can see where the cut shall be on the other side. The ideal method of this operation is that time should be prioritized and the insulation waste set aside. The time is, therefore, paid more attention to in the process; due to this, the workers shall always take new insulation sheets which fit the panels. Despite this, the workers collect and save the scrap parts from the insulation to puzzle them down in other panels where they might fit. Although this does seem reasonable to do, as these small pieces fit to sections on the panel that are not covered with complete insulation sheets. But, this is time-consuming as well as inconsistent in the process of assembling the panels. The operation, therefore, has a standardized process that, although is not be followed by the workers, and understandably so. The result is a high variation in finishing the insulation operation at the panels.

Slotting theory for the insulation process made it possible to see some correlation between the different panels. For all the smaller sizes of panels, the workers used one sheet and removed some of the insulation; this process took approximately the same time, no matter the size of the smaller panels; for the bigger panels where more sheets were needed, the time increased. For the panel sizes where one sheet was not enough to fit in the forum and additional insulation was required, the time increased exponentially along with the increasing size. The correlation that could be seen was that the more sheets needed to be fitted, the longer the time. The increase in time was not linear to panel size but highly related to how the sheets were used in the panels without any additional changes. When an option such as "panel window" was added, sheets were only cut first and then put in, so no full sheets were added to the panel when "panel window" was an option.

Table 4.2: Insulation operation times from Slotting

Size	Tak/ Botten	Framsida/ Baksida	Gavel
007-008	11	18	11
011-012	11	18	18
014-020	18	31	18
025-030	18	42	18

Using size as the only factor and creating a linear equation depends on panel size. This was not possible in our case due to a lack of data. A time setting that is dependent on the number of sheets and their sizes is a better alternative in this scenario. This combination of a step function and a linear correlation could be evaluated in the future.

The options related to the insulation could be analyzed in other operations, since the activities connected to these operations were done later. No significant changes could be differentiated between the sizes or panels, resulting in similar times over the process.

4.4.2 Sealing Strip

Operations like assembling sealing strips to the panels were done similarly but by setting a time for one standard length added on the panel; for every straight line of strip installed, a set minimum time was established, then a time for each added length of the strip. Another time constant was added for every corner that was taken when installing the strip. This method remained same for each panel which increased modularisation flexibility. This method to decide the time was used for all the models with a time factor; if there was a sealing strip of more rigid materials, this factor was multiplied by the average time. The equation below illustrates the time equation:

$$\text{Time block for sealing strip} = 11.9 + 0.6A + 3.1B \tag{4.1}$$

In the equation presented, A would be the distance added when exceeding 45cm, the standard length for which a sealing strip would be applied. B would be the number of turns that the sealing strip would take. An added factor of C would be added for the type of material, when the type of strip affects the operation times. This was done by giving options to the user to choose the strip that would be installed. In our case, there was one different material that increased the operation time and therefore, the factor C would correct this deviation. Although if there was uncertainty for the sealing strip operation, it was always possible to look back at the structure that MTM-SAM established. Having an option in this case which would replicate the MTM-SAM calculation if needed.

5

Evaluation of time blocks for Swegon

In this chapter, time blocks are evaluated for Swegons's case. The sections would gather the results from quantitative study and evaluate if the challenges found in qualitative studies on time data management are addressed

One approach to creating time blocks was to group the elements into blocks of operations. These blocks could be replicated in other scenarios where operations had similar activities. This meant that the time it took to analyze the operation only had to be conducted once instead of being done at multiple instances.

With the data available from Swegon, the accuracy of such grouping was less effective than the accuracy that was possible by grouping it with respect to products. The approach to group activities from different operations was not the first choice because of data inconsistency. When the data reaches a higher level of maturity and better structure, Swegon could use categorizing elements based on the process. But with the current data, such grouping would increase the data's challenge and possibly give inconsistent results.

5.1 Structuring Operations

Time blocks, as a time data management tool, are helpful for their ability to group elements that are similar. Lesser number of element rows would enable easy maintenance and accessibility. The number of elements that can be reused is case specific. Both kinds of grouping would use the same principle and would be based on grouping activities. The product-based approach would group activities specific to a product, while a process-based approach groups activities from different product operations to generate a block with only four segments of activity in the time equation. The section below will explain how elements can be structured with respect to products and processes differently.

5.1.1 Product-Based Blocks

An example of a product-based operation could be bringing the inner-panel and outer-panel. These are activities that generally would be the same for a majority of the panels; go to a cart, pick up the panel and place it on the table. Two variations would affect time, first, the distance to bring the panel, and second the weight of the panel. The distance would change the time which would be used for walking, something that can be depicted in the equation with a layout-based variable. The weight variation would decide if the operator would need a over head crane to lift the panels, move the panels, put them down, and return the over head crane instead of carrying it to the workplace. For a station that would assemble one of panels, e.g. backside, the time which it would take to bring the inner-panel would be the same as the outer-panel within the set block presented in table 5.1.

Table 5.1: MTM Structure for bringing a panel

Description of elements	Time (s)
Pick up Crane and walk to cart	1,7
Put hook on outer-panel	1,6
Lift outer-panel	3,2
Bring outer-panel to table	4,0
Lower outer-panel	2,1
Return Cranee	6,0
Pick up Crane and walk to cart	2,1
Put hook on inner-panel	1,5
Lift inner-panel	3,2
Bring inner-panel to table	5,5
Lower inner-panel while aligning it with outer-panel	3,9
Return Crane	5,8

The block would not be generalizable for all the outer-panel and inner-panel panels. Although creating two blocks, one based on the heavier panels, where the over head crane needed to be used, and one for the lighter panels, which could be lifted by hand, could be used. That meant that two blocks could cover all of the bringing of inner-panel and outer-panel sheets within two blocks. With the added equation of how many steps would be taken to bring the sheet, or an over head crane is used, this time block could cover many stations with similar operations in the assembly line.

5.1.2 Process-Based Blocks

When the same operation is categorized with respect to processes, the activities that are similar and have the same times can be repeated with a single value. Process-based categorization follows this principle. In Swegon's case, this principle is not directly applicable as two similar activities do not have the same time. Therefore, the activities in which the description was similar were grouped, although the times varied largely in some instances.

Table 5.2: Process-based structure for bringing a panel

Description of elements	Time (s)	Repetitions
Pick up Crane and walk to cart	1,8	2
Put hook on outer-panel	1,6	2
Lift outer-panel	3,2	2
Bring outer-panel to table	4,7	2
Lower outer-panel	2,1	1
Lower inner-panel while aligning it with outer-panel	3,9	1
Return Cranee	5,9	2

In table 5.1 an example of assembling outer-panel and inner-panel showed and could be grouped into a block with just five to six elements based on the variation shown in table 5.2. Doing this reduced the number of element rows considerably but removed the accuracy time blocks maintained in the previous categorization method.

5.2 Validation

Quantitative validation of time blocks is done against SAM data, this would help verify the quality of the equations used in blocks. This is due to the fact that time blocks were built with similar SAM data. It would only indicate the efficiency of such structuring. Since the cycle time of processes is not constant across stations due to a lack of standardization, having one time block sheet that can build cycle time values is impractical. Due to this hurdle, time blocks were validated more along the lines of different equations that were developed due to two different methods of categorization.

Table 5.3: Times for different methods in seconds for different panels

ID	CASAT (SAM)	Product	Process
20302	347,66	345,2	334,8
21000	345,8	352,2	311,8
12329	311,5	310,2	276,0
24695	347,7	345,2	334,8
21144	173,6	174,3	165,5

Table 5.3 shows the cycle times generated from processes and product equations and SAM times from TDM. The different IDs chosen had different options. The five product ID's will together cover all of the various options, so a holistic picture will be given. The panels' average deviation in assembly times is presented in table 5.4. The deviation is based on all the options for a weighted average. When looking at the data set, in table 5.3 for the product-based approach, the deviation did not

exceed 3% for a single panel. The accuracy of the planned times that were generated with time blocks could deviate as much as 15% in the same data set for the process-based approach. As Swegon would benefit largely from a much more trimmed and structured method of time blocks, the present data set did not allow for accuracy to be maintained for the process-based approach when looking at a single panel.

Table 5.4: Percentage of deviation from SAM in Casat

Category	Average	Deviation
CASAT (SAM)	100%	0%
Productbased	100,1%	0,1%
Processbased	93,3%	6,7%

This observation showed that the values generated from the operations' time equation were synchronous with CASAT times. This is also attributed to the present structure of CASAT that segregates operations into 'instruction groups'. The cycle times of process-based equations were close to actual values but were not as accurate as product-based equations. Although the average deviation in process-based cycle times was only 6.7%, it is important to highlight that this number does not cover all of the products, and some ID's can deviate more than this.

The next step was to analyze the reduction of SAM elements with the use of equations, this gave an estimation of the number of activities that could be repeated. The advantages of time blocks to group components for re-usability and easy maintenance is assessed in table 5.5.

Table 5.5: Amount of rows, *insulation rows excluded

Panel-ID	Casat	Product		Process	
20302	51	50	98.0%	39	76.5%
21000	69	52	75.4%	39	56.5%
12329	39	39	100.0%	31	79.5%
24695	53	49	92.5%	38	71.7%
21144	23	21	91.3%	17	73.9%
average	47	42.2	91.4%	32.8	71.6%

Table 5.6: Reduction of rows

	Product	Process
Total reduction of rows	4,8	14,2
Percent reduction of rows	10,2%	30,2%

The number of element rows in MTM-SAM data from CASAT is compared with both process and product-based equations. In this comparison, the insulation operation was excluded as the workers deviated from the instruction method, which would give an unfair comparison as both product and processes are based on standard working methods. The number of rows was considerably lesser when similar activities were repeated in multiple operations, enabling re-usability of data. The product-based equations, on average, reduced the number of element times by about 10 %, but process-based equations further reduced the number to about 30 %, on average. It is, therefore, evident that process-based equations are the ideal use of time blocks, but with the current dataset, just not practical.

5.3 Database

Requirements set by the company and the method resulted in a tool in Excel which in this case would be a future database for handling data and setting cycle and takt times. The tool's goal was to make it simple enough for any office worker to use it while calculating times. The idea was to set the panel sizes on the main page and check which options were used. Doing this makes it easy to use the tool without changing variables individually. The output which was given was the estimated cycle time for the given product with the set options.

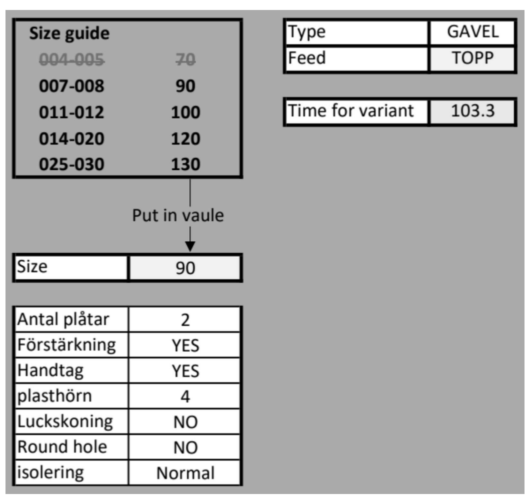

Figure 5.1: Start page in Excel as proposal

The Excel tool was built by using subcategories related to additional options and standard operations for every panel. By dividing them after the different operations and options, it is easier to get an overview which simplifies and helps change single things in the database. Creating an easy-to-follow structure made finding errors and faulty times in the model easier. If you notice that the cycle time for the panels is off, you can time the different operations related to the panel, when this is done, it should be easier to understand where the planned time differs from the actual time.

When the operation is identified, the activity or element which had the wrong time allocated to itself could easily be changed, and by that, you can change the output time or planned time.

For increased usage, sub-sheets with process-based and product-based libraries were created. With these, creating new time equations and comparing the structure between the different products was simpler. Introducing new components to the production could therefore simplify calculating new times even more due to the initial knowledge that lowers the time spent constructing it. Further on, it can be used as cross-integration between various production lines, with only minor tweaks in the distance to the actual item or workbench.

5.3.1 Library

The biggest advantage of time block is maintaining and reusing accurate times without repeating pre-determined time calculations multiple times. This results in libraries that individually store operation times while allowing users to scale operations. By analyzing the scope of each operation, the activities within these operations were given the option to be scaled according to the product being assembled. Maintaining time data has been given very low importance by many organizations, Swegon being one such. The Casat data is well structured in the time blocks Excel tool. Product-based operations were more scalable than process-based operations because they allowed the user to scale process-based activities individually. Process-based operations only varied based on size, therefore, the variation in process operations resulted from different sizes and numbers.

The "set-up" page asks the user to assign a constant to the varying elements. The equation can then be solved to obtain a constant value based on the input. For process-based operations, where size was the varying factor, the user could choose the size to be manufactured. This solved the process part of the equation, generating a value that is required for assembling the panel.

5.4 Production Engineering and their Thoughts

The interviews with the production engineering department brought up an issue regarding time blocks and equations, specifically the challenge of gaining acceptance from the Union. The Union insists on maintaining the work performance at the standard level or 100 MTM (Methods-Time Measurement), which is the average speed at which workers should perform. This means the Union-determined speed cannot be exceeded on the assembly line. However, deviations from the standardized work method can lead to time variations when workers work faster or slower than the MTM performance factor. Consequently, introducing a new method of setting times could face resistance from the Union during implementation.

According to the production division, there are advantages to using time blocks. It would reduce the effort required to keep the data up to date, allowing for updating specific parts without having to update all the time data in the system. The manager pointed out that updating all the time data becomes challenging when the differences between the times are small, as workers may not see the need to make changes for such minimal variations. Over time, these minor issues can accumulate, resulting in significant discrepancies. Currently, the production engineers occasionally use MTM-SAM and have challenges with it. Additionally, clock studies are preferred over MTM-SAM for certain values to establish the correct time. They believe a solution lies in combining different methods to create a flexible time system that integrates modularity.

According to the production engineering team, time blocks would be beneficial to increase efficiency in setting and updating times. This is particularly relevant since, as stated by a production engineer, analyzing one minute of MTM-SAM takes approximately 30-35 minutes. Thus, adopting time blocks would increase the value generated by each worker. During the interviews, estimates were made regarding the amount of time spent by full-time employees on setting and maintaining time. It was found that approximately 25% of a full-time employee's work hours are allocated to time studies, a significant reduction compared to previous years when changes were made to the measurement process in the production line.

5.5 Application

With standardized work methods, Swegon has established activity times at the stations that were chosen for this project. Time blocks must be based on planned times, and Swegon has used MTM-SAM methods to capture predetermined times. Stations in all assembly lines use standard work methods for assembling all variants in the product line. With limited time for the thesis, applying time blocks to all stations is impossible. The principles are applied to substations at Line-B to provide a way to use time blocks on the complete shop floor. The results would be evaluated, and the codes could be used for all other stations if an acceptable accuracy is reached.

5.5.1 System Integration

Mbrain is Swegons' new TDM system, which is Casat's successor. Mbrains functionality is less limited than Casats, which enables a higher level of customization to the software. This enables Swegon to integrate a possible solution such as time blocks. A potential integration into Mbrain would also allow a higher degree of application into the production system, where errors could be found with the help of a cross-integrated system that controls the time data. If an error is encountered, the software can identify and understand the error.

By integrating well-structured time blocks into an TDM system, the systems could work together and decide new cycle times for newly introduced products without an engineer setting the cycle time. When the system recognizes the parts' similarities, it can select the correct blocks to generate a time representing the panel.

6
Results of Design Science Research

Based on the literature understanding and Interviews with Swegon, a time blocks tool was built to address problems in managing time data. The principles for this tool were developed using a design science research method, as described in the methods chapter. The results of this study are presented in this chapter.

6.1 Design Science

The design science approach in the thesis was used for the benefit it has in evaluating a hypothesis, in this case, principles that were used in building the tool. A time blocks tool was built based on the literature understanding and interviews with Swegon. The interviews helped understand the need for time blocks in a live manual assembly line. The principles that were followed for categorizing were formulated with the help of literature, interviews and domian knowledge. The categorization is critical to the structure of time blocks.

The ability to categorize operations into pre-defined nomenclature is necessary when time blocks are used in a case. The categorization of time blocks was approached in two different manners, while maintaining the same underlying principle. The categorization was based on products, processes and layouts. This was to ensure that activities can be differentiated based on their relation to specific products and processes by this classification. This dual-format classification allows for a better understanding of the assembly line, considering the distinct characteristics and requirements of both products and processes.

6.1.1 Principles Evaluated through Design Science

Activities within operations were broken down to be categorized into one of the three categories: repeatable, combinable and inconsistent activities. By categorizing activities, it is possible to understand the logic for developing a time equation. Time blocks can be used to depict this equation in terms of variables. A group of variables were comprised to create a summation of the times for a block of operation steps. Each operation step was assigned a variable when there was a large variety of activities.

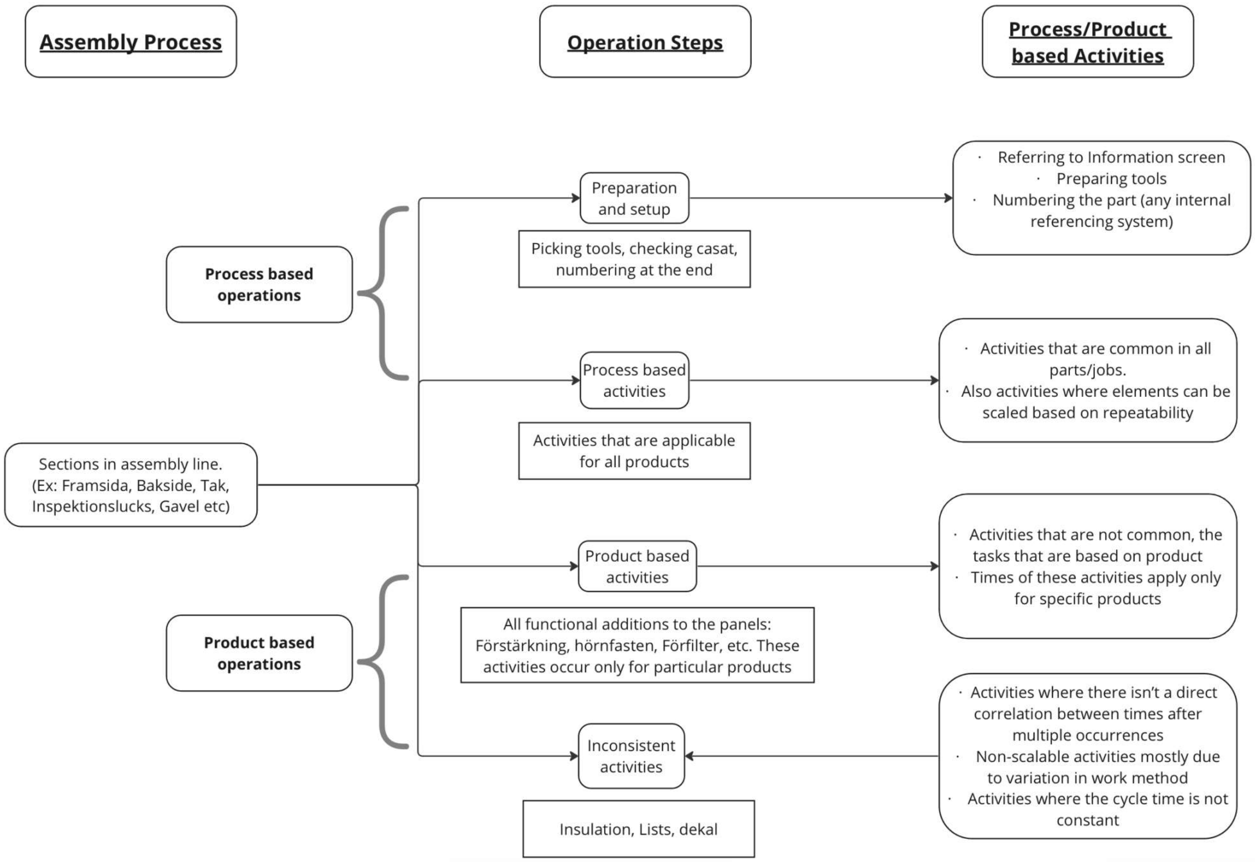

Figure 6.1: Illustration of how variables are classified

Two rules must be followed when categorizing time block variables; first, while assigning variables, it is necessary to check when a specific variable changes to a combination of variables. Secondly, variables and constant operations need to be distinguished (Niebel & Freivalds, 2003).

Following the design science methodology while building the tool, the principles followed were documented. When the output was validated alongside data from Casat, the tool was validated for a real-world case. By understanding how the tool performed, the principles for time blocks could be evaluated. To follow the principles, an organization needs certain prerequisites before considering time blocks. Without any existing use or calculation of time data, it would be impossible to use time blocks. The development of time blocks becomes easier and better structured when employees in the organization understand the principles of grouping time data into specific assembly lines. But before an organization invests in building data tools, it is necessary to evaluate if the tool suits the requirements. With investment in the wrong areas, the company's improvement projects would not have the same desired effect.

Before an organization evaluates if a time block as a tool for time data management can be used in their environment. Some of the points that would be a necessity for this tool are mentioned below. Only when the following requirements are fulfilled can the organization begin evaluating the feasibility of time blocks.

1. Work method: A clear and consistent work method should be established for each station/line where time blocks will be applied. This work method should take into account the sequence of operations, tools required, and standard operating procedures.
2. Standard work measurement system: A standardized work measurement system should be used to analyze the work methods in the stations. This system should be able to measure the time taken for each operation and provide accurate data for further analysis.
3. Documentation: All the time measurements for each operation should be documented. This will help in analyzing the data, identifying areas of improvement, and establishing benchmarks for future performance.
4. Nomenclature: A standard nomenclature should be established that defines the job levels on the shop floor. This will ensure that there is a common understanding of the roles and responsibilities of each employee, and it will facilitate effective communication among the workers and management.
5. Consistent layout design: The layout design of the stations should be considered to be the same across the shop floor. This will ensure that the work methods and time measurements are consistent throughout the assembly line, making it easier to analyze data and implement improvements.

When an organization checks off all the above mentioned prerequisites, it could focus on the principles for building time blocks.

6.2 Principles for Developing Time Blocks

A generic approach to building time blocks tool was documented while conducting the project. To specifically address the challenges and need for time blocks, the principles have to be refined to address case specific scenarios. But while considering time blocks initially, an organization can consider these principles, later they would build up from these basic principles as the project progresses.

The methodology that was followed to develop this tool, which would build time blocks for Swegon's assembly line, is described below:

1. Define nomenclature: Develop a standard nomenclature for the different types of activities and operations that take place on the assembly line. This should include clear and concise definitions that can be easily understood by all.
2. Collect and clean data: Collect standardized work measurement data on the assembly line process for building time blocks. Clean the data by removing any inaccurate or irrelevant data, and ensure right data format.
3. Identify repeatable and combinable activities: Analyze the data to identify activities that are repetitive, combination based, descriptive, and applicable across different product models. These activities should be descriptive and

easy to understand and should represent the fundamental work in the assembly process.
4. Assign variables: Assign variables based on the nomenclature developed in step 1. Further, variables should be assigned to elements whose times would vary. This step would help us formulate an equation to understand the relationship better.
5. Group variables: Group the variables into constants and variables based on each activity's variation in element times. Constant activities should have element times that do not deviate significantly, while variable activities should have element times that vary based on factors such as the number of repeatable actions.
6. Create a library of element times: Develop a scalable library that distinguishes between constants and variables well. This library should be based on the data collected in Step 2 and the variables assigned in Step 4.
7. Generate a formula: Generate a formula by identifying relationships between the variables using the library of element times developed in step 6. Assign codes to the elements in the library to make the formula more structured and scalable. This formula should take all connected activities into account.
8. Implement time blocks: Once the formula has been developed, implement time blocks by grouping activities that have similar element times and using the formula to calculate the time required to complete each time block.

By following this methodology, time blocks can be evaluated for different assembly areas within Swegon's assembly line.

6.3 Limitations of the Research Method

The design science research approach is focused solely on addressing the stakeholders needs, therefore these principles are directed at these needs. The only evaluation of principles was by validating the tool that was built for Swegon's requirements; applying the principles in a different scenario, would test its credibility.

The nuances of building time data management systems are considered in evaluating principles as mentioned by Kuhlang et al. (2014). The extent to which these principles might apply in different manufacturing areas has to be further assessed. Due to its generic approach, the method could be considered at the start of a similar project. The intricate details of any case must be incorporated into these principles so the results can be more precise to the case description.

The source of grouping would be based on the kind of production that is being conducted, the above rules might act as a base to start. By defining variables, the extent to which movements can be grouped, is better understood (Maynard & Zandin, 2001).

7

Discussion

The term block has been used constantly mentioned when discussing time data. The thesis is an extension of time data management and previous such studies. This section discusses our findings while researching the concept - time blocks

7.1 Time Blocks

Time block is a potential time data management tool. It could also be used to calculate assembly time with the help of equations. By developing blocks based on products, processes and layouts, the time for manufacturing a complete unit can be calculated with an equation. The equations can be adjusted to incorporate changes when products have small variations.

Stopwatch studies have been preferred in lean over pre-determined time studies, because calculating it is very time-consuming (Liker, 2004). The reusability of data is practically the biggest advantage of using time blocks. Time blocks would still require each activity to be timed once, but then gives the option to repeat this in any shop floor area. The accuracy of this tool is based on preexisting data; errors in equations have to be evaluated during the development stage. The blocks' size depends on the organization's needs and differences in their product variation.

Variables within the equations are based on the combinability, repeatability, and scalability of elements within the operations. When equations are built product-wise, the variables are elements within that product's functions. Therefore, generating an equation for each operation in the product type. Equations based on processes assign variables similarly, but the variables are repeatable, scalable, and combinable across operations. This would generate one single equation for the complete process.

Time-data management systems are used today to gather, manage and store time data of shop floor activities. As data size increases, using TDM techniques to manage data gets time-consuming, costly and burdening on the employee. Time blocks could be a technique to handle such data, with the ability to group activities repeated in multiple products the organization manufactures. Time blocks would use an existing database of predetermined times; if this data is organized as a library such that any activity on the shop floor would have a one-time value, time blocks could calculate times much more simpler and more structured. This would allow us to minimize the time employees spend for time studies by repeating and grouping elements.

The development of group technology and its relevance to production has shown a lot of potential uses. The biggest one has been the ability to handle large data sets that are usually captured in production. Group technology is used to improve productivity within manufacturing by reducing duplicates and easy information retrieval. Time blocks could potentially help in these aspects. The engineers at Swegon believe the pilot tool in time blocks is promising, and a similar tool would help save time, reduce duplicates, and help them retrieve information faster. Another potential use of group technology is the ability to build new processes by grouping old ones, time blocks cater to this principle by repeating activities and giving the user options to group unique processes (Hyer & Wemmerlöv, 1984).

Time blocks classify operations and group similar activities together. When analyzing a large amount of data, group technology can be employed to examine operations that share similarities. This approach is particularly useful when differentiating descriptive operations that exhibit similar time characteristics. Additionally, time blocks can be utilized to estimate times for new processes by grouping existing operations together.

The rate at which individuals work cannot be consistent; this is where MTM-SAM's productivity factors have been preferred over others (Niebel & Freivalds, 2003). Time blocks retain the scientific measurements used in method calculations. The constant and variables in the equations are extracted in this thesis from existing MTM values. Method-based calculation of operation times was synchronous with operation equations that used MTM values.

Pre-determined times are challenging to be implemented in all shop floors because of its dependence on standardized working methods. As Maynard and Zandin (2001) mentions, there are often operations where methods and, therefore, time cannot always be consistent. In this thesis, insulation and sealing strips are some such operations. Setting times by using formulas and slotting was more effective for these operations. According to Kuhlang et al. (2014), there are different means to determine operation times, such as work sampling used in this case. The operation time from this calculation method was also closer to actual times than MTM-SAM times that are currently used.

Looking at the workstations at line-B as in this case, we can see that the workplace layouts are not fully standardized between each other, something that Niebel and Freivalds (2003) claims is important. The workstations at line-B have different layouts and walking distances between the operations that will be done. This gives a variation to the workstations and reduces the instances where a standardized time block can be used for multiple stations simultaneously. Time blocks incorporate a layout-based variable that can be utilized to address and rectify these deviations.

7.2 Manage Data

Swegon has collected and stored a data base to cover all the operations in production. As their products have a lot of variants, they have a challenge maintaining the database and the data within it now. According to Maynard and Zandin (2001), organizations use three or all four levels, but Swegon has a higher degree of complexity because of the large number of variants in its product line. The values must be generated by timing the same activity for different sizes when same components are used. Doing it for every product they manufacture is, therefore, impractical. If engineers could reduce the timing of activities/elements used in multiple variants, it would ensure accurate, consistent, and easily maintainable data. Edmondson (2022) claims that the organization could reduce time spent on time management by having a well-structured database since this could improve consistency. A database created with time blocks, structured after a product or process-based library, could be a beneficial solution for Swegon to handle their times easier.

The current structuring of MTM-SAM analysis in Casat lacks standardization for how the elements are decided. As presented in 5.1, we could see rows of the same activity differentiate from each other; this is due to the analysis not being done by the same person, which in Swegons case is a result of different ways of approaching the issue. This creates a deviation from the standard method of working. Since the SAM should be standardized, it should not be conducted differently between who is conducting the MTM-SAM analysis according to Niebel and Freivalds (2003). As both the interviews and the collected material point out, there is an apparent deviation in how the work has been done. An issue with this would be the increased level of knowledge that the person who would create and divide the time blocks would need higher level of knowledge for the work to be done, as earlier mentioned. Without a clear structure to the MTM-SAM analysis, grouping blocks will also be harder. The clear structure would be replicable in an easier way if you easier could identify where similarities within the production line.

Since the current structure in Casat requires high maintenance to be accurate, you could reduce the time spent on maintaining it by adapting to the approach of time blocks and process and product libraries. As data, according to Villars et al. (2011), inevitably will increase over time, in this case, along with Swegons new products, they must sustain data quality over time and create platforms that can analyze and handle it. Otherwise, the challenges with data maintenance will only increase over time, along with the more complex processes and products they introduce.

Something that Codd (1970) claims is if a project increases data understanding in the organization, it should be prioritized. At the current state for Swegon, only a few people understand the production line fully. Very few of these people have insights into all of the operations in the assembly lines, which was brought forward at the interviews. This further increases the issues of maintaining the data.

As Almström and Winroth (2010) discusses, it is essential to ensure there is no mismatch in data. In Swegon's case, it has shown that the mismatch is significant compared to what they base their cycle times upon now. One of the biggest causes is the lack of workers following the standardized working method in few operations and the lack of importance for updating times and structure. As discussed in the previous chapters, the MES function in the system schedules jobs considering times from the database. For smooth job scheduling and work balancing the software would need to have access to accurate data. When the time value deviates largely from actual values, the resources are inefficiently used. The gap can be minimized by using better input data, something Almström and Winroth (2010) proposes as a solution to this is better descriptions of objects and what they shall represent. MTM-SAM rows could, in this case, have better descriptions which, to a high likelihood, increases data understanding, which would help identify where the data mismatch is.

Since the planned time depends on the input data, the planned times will always deviate from the actual times as long as there is a mismatch between the real and input time. This gap which Maynard and Zandin (2001) is mentioning, can cause long-term issues. The issues that appear at the current production might be reduced with the help of implementing time blocks. With the help of time blocks, the input data could be updated more often and therefore generate more accurate planned times. As the times would be easier to maintain, the mismatch would also decrease due to being able to update the data more frequently.

7.3 Issues and Prerequisites

One issue with time blocks could be specific requirements when creating them and the initial investment cost related to this. The time which was spent on the project could mirror an early pilot phase for adopting the system and solution. The time required for creating a usable solution would therefore be allocated to an early phase in a potential project. According to Maynard and Zandin (2001), a top-down approach is required for standard data development. In line with this project's findings, the development time for time blocks is large.

7.3.1 Limitations

The project was limited by not having all the desired data. The tool is based on the current scenario; any past or future changes were not incorporated into the data used in the thesis. If other such data had been available different results might have been apparent. The angles from which the problem would have been approached were limited to the sort of data available. Another limitation could be the accuracy of the available data. Since the data was extracted from an TDM with MES functions, the data structure is limited to the system in place at Swegon.

7.4 Recommendations for Swegon

The challenge for Swegon is to maintain a good structure and, more importantly, a database that is easily understandable. The current data would need more accuracy and a better system so other members within the organisation could have the same understanding as the data developers. This could be the initial motivation to adapt time blocks - to better maintain time data. The developments the organization is making in establishing a better MES system makes it an optimal time to adopt such a tool.

The considerable variation in Swegon's product line and the frequent introduction of new variants is a reason to evaluate time blocks. As Villars et al. (2011) mentions, maintaining data becomes much more complicated when they are largely complicated. As Swegon adds more data to the existing one, its structure and maintenance get much more challenging. Therefore, investing in a tool that eases the maintenance of such data is something the organization would benefit from (Codd, 1970).

The ideal implementation of time blocks for Swegon is through a gradual process that could begin with having a robust data set. When the existing data is better structured and widely understood, building process-based equations reduces the data quantity. At the moment, classifying elements and having a single equation for process-based activities would be inaccurate; incorporating layout-based activities becomes challenging due to the lack of standard layouts. But these shortcomings are more apparent and well defined when the time block project is being evaluated. Other minuscule changes in the method and structure are better addressed with this tool. As Swegon's management's decisions and planning could be based on such data, having accurate data would ensure the management's projections are as close to reality as possible. The initial investment could be to reduce data mismatch and further move into a time data management system.

7.5 Sustainability aspects

In United Nations sustainability development goals, the thesis focussed on goals three and eight (United Nations, n.d.). Although Swegon's engineers take lesser time than the time MTM association claims for analyzing a 1-minute video, it is still considerably long. Maintaining such a complex data structure is understandably stressful and time-consuming. Accurate time data would provide significant benefits to assembly line operators as well. It would result in fair job assignments and ensure sustainable performance when the workload is appropriately distributed. UN's third sustainability development goal of good health and well-being is addressed with time blocks. United Nations', eighth sustainability development goal focuses on economic growth, which in this case would apply to the organization, Swegon, (United Nations, n.d.). We suspect the economic impact from time blocks could be due to two reasons, firstly the organizations would make decisions based on accurate and more recent data. Secondly, the number of man-hours spent for time studies is reduced.

8

Conclusion

In this section, the general conclusions and case specific conclusions, obtained while "Developing Principles of Time Blocks" is presented.

8.1 Academic Conclusions

Organizations spend considerable resources on time studies; and use time data to a large extent. Of the steps in time data managing, very little attention has been paid to administering time data in many industries resulting in a huge gap between actual and planned times. Therefore, the thesis evaluates time blocks as a potential time-series data management tool and a time data calculation system that is built on equations.

In theory, time blocks are an extension of predetermined time systems. It reduces repeatedly calculating time data by repeating time equations of activities from other operations. Transfer of information within departments of the organization is smooth when well-defined data and structures are used. Future developments and decisions can be based on a single information source; this would reduce basing decisions based on inaccurate data. Time blocks are based on equations that have variables and constants. The equations could be built with two different approaches. Both equations would arrive at the same result but with different grouping methods. Therefore, grouping activities in operations is a necessity for either of them. The type of grouping method chosen for time blocks depends on the similarity between processes and products manufactured. If the processes in manufacturing the product range are similar, grouping activities based on processes is effective. Time blocks could be used for time data management, where administering time data is equally important to capturing time data.

8.2 Conclusions for Swegon

The principles of building time blocks are evaluated for a company with a mixed-model-manual assembly line, manufacturing multiple variants. With many variants, the amount of time data is huge and with lack of maintenance, that data is not very accurate and has discrepancies. With these challenges, the approach to building time blocks based on products had higher accuracy than process-based equations. Product-based equations generated an accuracy of up to 98%, while process-based equations had up to 15% deviation in some instances. This deviation from one category of equations to another could be attributed to discrepancies in existing data. For the same data, process-based equations reduced the library by about 30%. For such a case, Time blocks are suggested to be incorporated into an MES system that would first help structure the data better, after which the discrepancies can be tweaked to have up-to-date, precise data sets. With better structure and more standardization on shop floor activities, process-based equations would have similar accuracy while reducing the library considerably.

8.3 Further Research

Since the interviews conducted were few and only at one company, this could be seen more as a pilot study towards acceptance and usage of time blocks. More interviews, to a more significant extent, at more companies and in the future would therefore be recommended as a continuation of the study. Additionally, outcomes and benefits in terms of time savings and long-term accuracy that were generated as a result of using time blocks have to be evaluated after Swegon employs it on a larger scale.

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