CHALMERS
UNIVERSITY OF TECHNOLOGY

Increasing Operator Availability and Reducing Downtime

A Case Study at an Automotive Company

Master's thesis in Production Engineering

AHMED MOHAMED ABOKOR
YALDA ATAIE

DEPARTMENT OF TECHNOLOGY MANAGEMENT AND ECONOMICS
Division of Supply and Operations Management

CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2026
www.chalmers.se

Increasing Operator Availability and Reducing Downtime

A Case Study at an Automotive Company

AHMED MOHAMED ABOKOR
YALDA ATAIE

Department of Technology Management and Economics
Division of Supply and Operations Management
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2026

Increasing Operator Availability and Reducing Downtime

A Case Study at an Automotive Company

AHMED MOHAMED ABOKOR
YALDA ATAIE

Department of Technology Management and Economics

Chalmers University of Technology

SE-412 96 Gothenburg

Sweden

Telephone + 46 (0)31-772 1000

Cover:

The Image on the front page is taken from (ATS-Tanner, n.d.)
Gothenburg, Sweden 2026

Increasing Operator Availability and Reducing Downtime

A Case Study at an Automotive Company

AHMED MOHAMED ABOKOR
YALDA ATAIE

Department of Technology Management and Economics

Chalmers University of Technology

SUMMARY

The purpose of this thesis is to examine operator-related downtime in an automotive manufacturing company and to explore how workstation design can improve operator availability. Using a literature study, work sampling, production data, and interviews, the authors identified the main causes of downtime - material handling, loading delays, late arrival, rotation, and staff missing. The proposals pertain to improving competence, relatedness, and autonomy along with increasing accountability to enhance operator performance and overall productivity.

Keywords: Operator availability, Work sampling, Productivity, Motivation.

List of Acronyms

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

CI	Continuous Improvement
KPI	Key Performance Indicator
OEE	Overall Equipment Effectiveness
SAM	Sequential Activity and Methods analysis
TMU	Time Measurement Units

Table of Contents

1.Introduction

This chapter introduces the thesis topic. It provides the main objective and presents two research questions. At the very end, the chapter clarifies the scope and limitations of the project.

1.1 Background

The automotive industry is noted for having sophisticated production systems where modern automation systems are employed alongside manual assembly. In body shops, the primary function of an operator is to feed robots with metal components. This is often done alongside automated operations like spot welding. Despite increasing automation, manual work is still central given economic constraints, flexibility requirements, and quality considerations. This phenomenon places high responsibility on production engineers with regards to the design and management of assembly stations. When an operator is assigned a task, workstation design is essential for ensuring availability, productivity, and performance. A workstation that is poorly arranged can give rise to ergonomic risks, reduced motivation, and increased downtime. In contrast, a well-designed workstation has the possibility to boost productivity, reduce ergonomic risks, and improve both physical and cognitive factors.

Operator unavailability is a common issue in manufacturing companies, and it could be linked to unergonomic procedures, insufficient cognitive support or organizational and motivational elements. Understanding how these factors influence the assembly process is vital for enhancing both operator availability and performance. Operator availability is the percentage of time an operator can work, and performance is the ratio with which they follow standards. Accordingly, this master's thesis examines automated workstations with coupled operators to pinpoint the root causes of operator unavailability and suggest improvements to reduce downtime. An operator is considered coupled when continuous interaction with a workstation is required to sustain production. On the other hand, decoupled operators fill buffers with material and after a buffer is filled, material gets processed. Coupled operators work in tandem with robots or machines while decoupled operators do not. For this reason, decoupled operators can be disconnected from workstations, whereas coupled operators can not. This thesis is conducted in an automotive manufacturing company. More specifically, it is done in a factory designed for producing car bodies. The main function of its operators is to continuously feed workstations with metal components that are processed by robots. In some of its stations, operators are required to manually weld components and tighten bolts. The company produces 24 cars per hour but has the capacity to increase its output by 40%. The workstations in this factory are disconnected, meaning it does not employ a continuous production line. Its workstations are noted for having low workload per cycle time and many of its personnel are senior operators or workers who have been moved there after rehabilitation.

1.2 Aim

The main objective of this master's thesis is to improve the productivity of this company to increase its profitability. This will be done by identifying how coupled operators cause stoppages in manual workstations. Based on these insights, the thesis aims to suggest practical improvements in the design and management of workstations to enhance operator availability. The thesis seeks to contribute to a more holistic understanding of manual work within highly automated manufacturing environments by combining established production engineering methods with motivational theories and ergonomic considerations.

1.3 Research Questions

Q1: What factors related to coupled operators contribute to downtime in loading workstations?

Q2: How can operator availability be improved?

1.4 Scope and Delimitations

The scope of this master's thesis is restricted to the evaluation of automated workstations that belong to one production line of this company. The study pertains to operator behavior, workstation design and management factors that impact availability and performance. The thesis will not address material flow, line-balancing nor product design. Operator availability will likewise not be calculated.

1.5 Outlines of Report

The report is organized into 8 chapters. It begins with an introduction presenting the background, aim, research questions, scope, and limitations of the study. The report presents relevant theories and previous research related to productivity, Overall Equipment Effektiveness, availability, Maslow's Hierarchy of Needs, self-determination theory, continuous improvement, and ergonomics. The methods chapter explains the research approach and the data collection methods. The results chapter presents findings from work sampling, disturbance data, and interviews. In the analysis chapter presents the must commen root causes. Improvement suggestions are then proposed to reduce operator-related downtime and improve operator availability. The discussion analyzes the findings related to theory, previous research, the study's limitations, and the results. Finally, the conclusion summarizes the most important findings, and future research opportunities.

2.Theoretical Framework

This chapter presents the theoretical foundations of this research topic. The purpose of the theoretical framework is to provide an understanding of key concepts, models, and analytical tools for analyzing operator-related losses in manufacturing systems. It sheds light on notions such as productivity, availability, work sampling, and self-determination theory. In addition, the 5-Whys method and continuous improvement are introduced to support the analysis of operator-related downtime and improvement opportunities.

2.1 Productivity

Almström (2024), explains time data management. He introduces two terms that are related to productivity: efficiency and effectiveness. The author defines effectiveness as satisfying customer needs whilst reducing resource consumption and costs. Efficiency, however, is utilizing available resources and producing products in the right way. According to Almström (2024), productivity is defined as the ratio of output to input.
This key performance indicator (KPI) can be measured at multiple levels: activity, company, and national. Almström (2024) writes that individual productivity can be determined by calculating the inverse of an activity's cycle time. When clarifying how these metrics interact, Almström (2024) says that high productivity causes a great level of internal efficiency. Similarly, he writes that high productivity together with the required quality cause high effectiveness. Three productivity factors decide the duration of tasks: method, performance and utilization. The first factor represents how an operation is planned, the movements a worker does to execute it and what tools they should use. The second factor symbolizes the speed with which one operates in relation to a performance standard. The last factor refers to the percentage of time spent on value-adding or supporting operations. In addition to this, it includes time when one deals with losses. Zandin (2001) agrees with the aforementioned definitions of efficiency, effectiveness and productivity. Zandin (2001) asserts that a company is not necessarily productive if it is only effective. Apart from producing goods and services quickly, companies must produce things that are demanded, when they are demanded and at a competitive price.

2.2 Overall Equipment Effectiveness

According to Muchiri & Pintelon (2008), the performance measurement metric Overall Equipment Effectiveness (OEE), is used to understand how effectively manufacturing equipment is used. According to (Hedman et al., 2016), this KPI was first used together with the introduction of Total Productive Maintenance. Hedman et al. (2016) further note that, within academia, this KPI is widely used within research related to performance measurement and productivity improvement. OEE helps organizations identify productivity losses and improvement opportunities by including availability, performance, and quality. Through availability, companies can measure the losses caused by downtime, breakdowns, and other stops. By including performance, they can measure losses that result from reduced operating speed and minor inefficiency. Finally, incorporating quality helps them measure losses caused by rework, defective products, and scrap. The OEE metric is calculated according to the following:

$$OEE = Availability \times Performance \times Quality$$

One of the greatest advantages of OEE is the ability to reveal hidden production capacity. Factories can use OEE to increase output by reducing existing inefficiencies instead of immediately investing in new equipment.

2.3 Operator Availability

In a report titled Standardizing Availability Definition, Katukoori (n.d.) defines availability, presents different versions of it and writes formulas via which they can be calculated. Katukoori describes availability as a percentage of the extent to which an asset is operable when needed. The researchers interviewed an engineer at the company about how it defines and calculates operator availability (N.M, Malmberg, personal communication, Feb 19, 2026). The interviewee shared that it employs a production system that consists of separate workstations with elevated buffers. Given this fact, when an operator fails to load material on time, the material flow is generally not impacted. The interviewee articulated that availability is understood as the percentage of time an operator can work as needed while excluding losses due to matters that are included in the process. Set-up time, changeover time, delivery delays along with corrective maintenance are examples of such factors. It is mathematically expressed as this:

$$Ao = 1 - \frac{\Sigma Operator\ related\ downtime}{Operating\ time - \Sigma Downtime\ due\ to\ process\ related\ factors}$$

2.4 Maslow’s Hierarchy of Needs

Trivedi & Mahta (2019), describe Maslow's Hierarchy of Needs as a theory suggesting that human behavior is driven by needs. This concept hierarchizes human needs into five and prioritizes them in the following order: physiological, safety, love/belonging, self-esteem and self-actualization. These needs are often illustrated in a triangle to show that they are not equally important. This theory states that when one’s needs are met, humans do not view it as a motivating factor.

Physiological needs are necessities that humans must have for their lives to be sustained. Clothing, shelter, water and food are matters that are included in this category. Until this type of need is satisfied, other needs do not propel human behavior. The second classification of needs relates to threats that are physical or economical. It covers job security along with fear of turmoil and natural disasters. The following class of needs concerns cordial relations. Humans are social creatures and desire to belong to groups. In addition to this, they also expect to be appreciated or loved by people they interact with. The third category of needs therefore includes the desire for social relationships together with being cherished. The subsequent classification of needs links self-esteem to either internal or external recognition.

Competence, self-respect and self-confidence are regarded internal recognition whereas respect by others due to one's reputation and status are deemed as external recognition. The last class of needs only includes the want to realize one's full potential. By gathering data from questionnaires and using regression analysis, Taormina & Gao (2013) confirms that satisfaction of lower-level needs leads to a desire to fulfill higher-level needs. While Taormina & Gao (2013) does not state that higher-level needs increase motivation, it supports that human needs can be viewed hierarchically and that people concentrate on higher needs after lower ones are met. Maslow's hierarchy of needs is presented in Figure 2.1.

Figure 2.1: Maslow's hierarchy of needs
McLeod (2024)

2.5 Self-Determination Theory

In Deci et al. (2017), a team of researchers explain the self-determination theory as a macro theory concerning human motivation. This concept holds that environmental factors influence staff motivation through basic psychological needs. These needs are competence, relatedness and autonomy. Autonomy refers to having the ability to influence one's work while competence pertains to feeling capable of achieving desired outcomes. As for relatedness, it concerns inclusivity and being cared for by others. Van den Broeck et al. (2016) supports this notion after conducting a large-scale literary study concluding that competence, relatedness and autonomy impact motivation. The self-determination theory divides motivation into two: intrinsic and extrinsic. According to Deci et al. (2017), intrinsic motivation is a stimulus that propels an individual to perform an action for no other sake than the action itself. When one is motivated in this manner, their enjoyment acts as a reward mechanism. Children playing with each other without external influence or reward exemplify intrinsic motivation. The authors argue that when one is intrinsically motivated, they are inclined to perform and feel better. As for extrinsic motivation, it is explained as a force that drives one to do an action for a reward that is separable from the action itself. The reward can be tangible, such as one's salary, but it can also be nonphysical like acknowledgment or praise. Although external rewards have been observed to decrease motivation, they are not to be viewed as entirely "bad", as they have also shown to enhance it. (Mariza, 2016) agrees with the self-determination theory, linking motivation and employee engagement with performance. Adding to this, (Rodrigo, 2022) concludes that operators demonstrate high levels of productivity when motivated.

Using an autonomous spectrum, the researchers state that this theory distinguishes between different types of extrinsic motivation. External regulation is identified to be at the least-autonomous end of this scale and is actualized by conditional recompenses and threats. While it can have a strong impact, it reduces autonomous motivation and well-being. Introjected regulation is next in this continuum. It is self-controlled and realized by workers if they operate to receive approval and avoid disapproval. One that works in such a fashion has contingent self-esteem and clear personal interests. Identified regulation is subsequent on this scale and is realized when individuals recognize and accept the importance and value of their roles. This acceptance provides more autonomous self-regulation which allows the employee to act more freely. The authors place integrated regulation at the most-autonomous end of this spectrum. They underline that when regulating oneself in this manner, a worker integrates and assimilates their employer's values with their own.

2.6 Continuous Improvement

Bhuiyan & Baghel (2005) presents that continuous improvement (CI) is a way of working that focuses on continuously improving processes, products, and services through steady incremental changes. Cl emphasizes small, ongoing improvements that lead to significant performance instead of focusing on large, radical improvements. CI is closely linked to quality management and Lean production and aims to increase efficiency while reducing waste, errors and unnecessary variation in processes. An important part of CI is that the employees at all levels of the organization contribute to identify and suggest ways to improve daily operations. This creates a culture where people participate in improving the production process. CI is often implemented through methodologies such as Six Sigma, Lean Manufacturing, and Total Quality Management. These methods provide structured techniques and tools to analyze processes and reduce inefficiencies. These principles are important in manufacturing environments to improve performance, reduce downtime and support operators to work effectively. (Sahmi & El Abbadi, 2024) is a systematic literature review of how kaizen has been applied in various industries. Kaizen is synonymous with continuous improvement. Among its conclusions is that workers may sometimes resist change. To deal with this, (Sahmi & El Abbadi, 2024) suggests that each improvement project is adjusted to the company it is applied in and that organizations should train their staff to understand both the benefits of kaizen projects but also how to manage them.

2.7 Ergonomics

According to Berlin & Adams (2017), ergonomics or human factors are defined as the interaction between human capabilities and the design of the work. The purpose of ergonomics is to enhance human well-being and overall system performance. Ergonomics is not only about the prevention of injury or comfort, but also, it's about improving quality, safety, efficiency, and reliability in the work system. The authors also emphasize that ergonomics takes a systems perspective. That means instead of focusing only on the individual worker, consider the interaction between the human, the tools, the task, the physical environment, and the organizational structure. Problems in safety or performance are seen as design issues within the system, not the failure of the individual worker.

According to Berlin & Adams (2017), different errors have been understood from a human-systems perspective. The errors are distinguished based on their natures and origin. The common distinction slips and lapses versus mistakes. Slips and lapses occur when the intention is correct, but the action is executed incorrectly. These errors can occur due to distraction, fatigue, or automatic behavior. Mistakes happen when human decisions are wrong, and that is due to insufficient knowledge, lack of information, and unclear instructions. According to the book, ergonomic errors arise when the body is overloaded. Factors such as repetitive movements, fatigue, and high force requirements can lead to physical errors, which in turn lead to reduced precision and increase the likelihood of errors. It also highlights cognitive ergonomics, which are related to mental workload, decision-making, or unclear interfaces that are difficult to understand. Cognitive overload occurs when cognitive demands exceed a person's mental capacity, which can lead to slower responses and poor decision-making. As stated in (Read et al., 2021), methods for understanding human error can be categorized as either prospective or retrospective. Prospective approaches identify every possible human error that can happen so that workstation design can be improved in advance. Retrospective methods, however, focus on identifying behaviors that contribute to accidents.

3. Methodology

Moon (2019) sheds light on the concept of triangulation. To ensure that information from research data accurately corresponds to the object of study, Moon (2019) writes that a number of methods are used. One such procedure is triangulation method as shown in Figure 1. Moon (2019) explains it as a research strategy that includes several data sources, theories or researchers to ascertain that data, analysis and conclusions are exhaustive and accurate. Moon (2019) asserts that triangulation strengthens reliability, validity and legitimation which incorporate conformability, credibility and dependability.

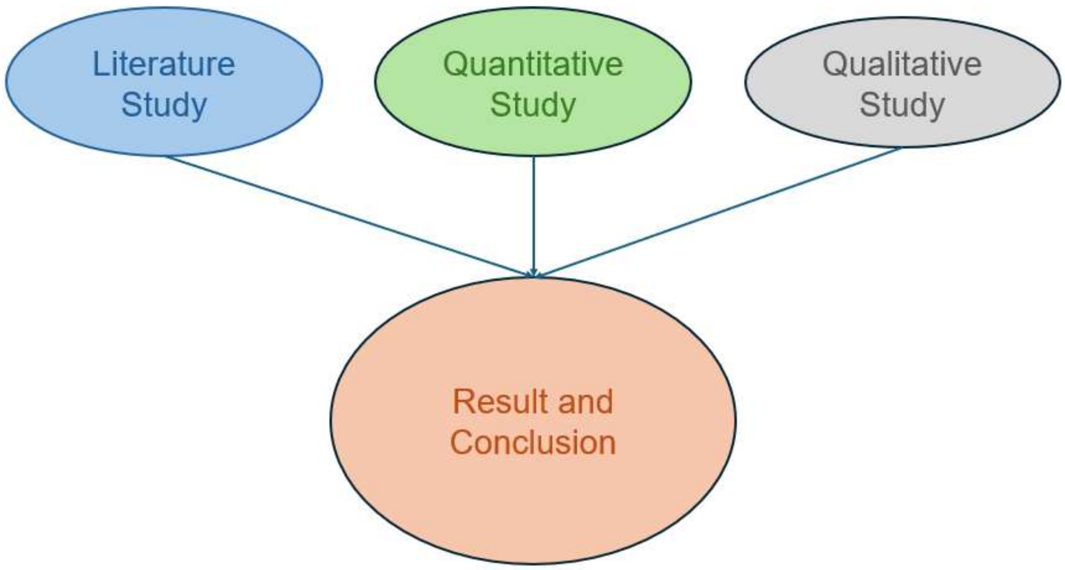

Figure 3.1: Triangulation Method

Triangulation has been applied in this project given that data was gathered through work sampling, disturbance registration, interviews and a literary review, combining quantitative, qualitative and literary studies to collect data. The overall methodology for the thesis was initiated by a literary study in which research articles and books were read to understand the theory and how similar problems have been solved. The following step consisted of work sampling and had the purpose of determining how operators spend their time. Subsequently, interviews with production workers were conducted to collect qualitative data. Following this, further quantitative data was gathered regarding disturbances through Power BI. The second last stage consisted of analyzing the results by comparing similarities and differences to draw conclusions. The last phase was about proposing solutions to the identified operator related factors that cause downtime, see Figure 2.

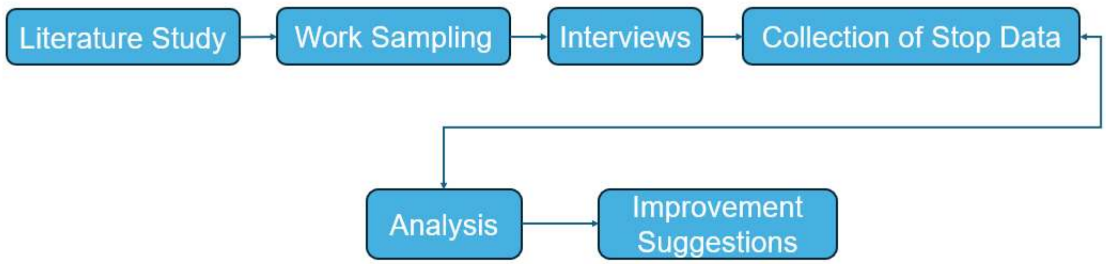

Figure 3.2: The steps in the methodology

3.1 Quantitative Research

This section describes the quantitative method used in the study, including work sampling and the collection of disturbance data. Work sampling was conducted to understand how operators spend their time at work, and disturbance data from Axxos Power BI, was analyzed to identify the most common operator-related causes of downtime. The company recorded and categorized production stoppages by using Axxos. This system enables also the distinction between operator-related and technical disturbances, that are recorded by team leaders. The stoppages that exceed one minute are systematically categorized.

3.1.1 Work Sampling

Based on the research objective of understanding how operators spend their time, work sampling was chosen as it provides a systematic method for estimating the distribution of activities during a work shift (Almström, 2024). This approach determines the fraction of time devoted to activities such as working, idle time or downtime. In order to have a set of activities to note, the researchers visited the shop floor and conversed with various personnel about working methods and frequent behaviours among operators. The researchers also drew inspiration from a database with information about downtime. When a set of assumed actions were written, a pre-study was performed. During the pre-study, observations were made every 20 seconds, and the observations amounted to 231. Observations were documented in a Google Spreadsheet, and the observation intervals were controlled using a timer. This pre-study was carried out to refine the assumed actions and identify the least relevant one, allowing the team to determine the total number of observations required for the time study. Observations can either be done at irregular intervals on chosen subjects or at continuous intervals on random subjects. The latter approach was selected because operators rotate between stations. The following two formulas were used to calculate the total required number of observations:

$$n = \frac{z^2 s(1-s)}{f^2}$$

$$f = f_{purpose} \times s$$

The value of $f_{purpose}$ was taken from a table in (Almström, 2024) and it was determined to be 10%. S is the smallest activity of interest from the pre-study. The action named "other" was recognized as least relevant with a fraction of 4.3%. The product of $f_{purpose}$ and s was computed to be 0,0043. Z is specified by a confidence interval that is chosen by the researchers. A 95% confidence interval would lead to a large number of observations. Due to time constraints of the study a 90% confidence interval was considered more practical, giving z a value of 1,65. The total required number of observations was calculated to be 6015. Similar to the pre-study, observations were made every 20 seconds. Google spreadsheet was likewise utilized to store and present data while smartphones were used to keep track of the time intervals. Observations were spread across 9 days.

3.1.2 Collection of Disturbance Data

To identify operator-related disturbances that lead to downtime, production data was collected and analyzed using the data tracking system Axxos. This system registers different types of disturbances that occur during production. Only disturbances categorized as operator-related were considered in this study. These disturbances represent situations where the operator, for various reasons, is unable to complete the assigned task within the defined cycle time, which leads to loading delays. The available data was extracted and analyzed to determine the frequency of the different operator-related disturbances.

3.2 Qualitative Research

This section explains the qualitative method employed, argues the choice of this approach, and delineates how it was planned and implemented.

3.2.1 Interviews

According to Berlin (2025), there are three types of interviews that can be held when conducting qualitative research-structured, semi-structured and unstructured (Berlin, 2025). When opting for the structured approach, Berlin (2025) explains that all questions are predetermined and that no other questions are allowed to be asked. Semi-structured interviews are also conducted with pre-planned questions but the order in which questions are asked is not rigid and interviewees are allowed to express themselves freely. Unlike the aforementioned interview types, in unstructured interviews, questions do not pertain to a specific topic nor are they prepared. The interviews for this project were semi-structured to allow flexibility but still maintain consistency. Due to rigidity, a structured approach might miss relevant data while the unstructured method might give inconsistent answers that are difficult to analyze. In Bearman (2019) posits a procedure that can be followed for semi-structured interviews. Bearman (2019) argues that effective questions provide rich information. The author holds that effective questions elicit multifaceted ideas and detailed explanations. Besides this, Bearman stresses that one must ask their respondents questions that are relevant and logical. He adds that asking open-ended questions is generally the most optimum way to receive rich answers. To exercise this, open-ended questions were structured according to the 5-Whys method and modified according to the role of each respondent. The procedure Bearman presents consists of three steps. The researcher should first formulate questions around events that pertain to the subject of interest. One could for instance ask their interviewee how a specific event took place, why it occurred and how they reacted. Applying this reasoning, the first question posed to operators in this project was whether they could describe situations where they were unable to load material within the cycle time. The second step is about forming a conversational structure that flows naturally. This was done by giving the questions to the respondent before interviewing them, allowing them to prepare beforehand. The final step is about revising the questions. Despite Bearman writes this stage as the last one, in this project, questions were amended prior to the second step. This is because the questions were given to the respondents prior to the interviews. The questions were discussed with a process technician for modifications. To draw conclusions from the answers, the researchers highlighted similarities and differences while linking them to literature.

3.3 Literature Study

The literature study was structured around the research questions, the purpose of the thesis and the overarching subjects it concerns. This thesis addressed two research questions. The first focused on identifying operator-related factors that cause downtime while the second examined how operator-related downtime can be reduced. The purpose of this thesis pertained to improving productivity. The subjects it relates to cover motivation, time data management, ergonomy and continuous improvement. Adding to this, the study was done at a factory that produces car bodies. In light of this, literature regarding the aforementioned subjects was gathered through previous course books and research articles. When searching for relevant articles, keyworlds such as “operator availability”, “work sampling”, “productivity” and “motivation” were used. The following table demonstrates the criteria that were followed when searching for articles in databases:

Table 3.1: Inclusion and Exclution criteria

Type of category	Inclusion criteria	Exclusion criteria
Time period	Between the years: 2006-2026	Before the year 2006
Language	English and Swedish	Every language apart from Swedish and English
Publication type	Academic publication	Non-academic publication
Type of source	Research articles, along with books and articles that explain theory	Articles from newspapers.
Accessibility	SpringerLink, Scopus, ScienceDirect and Chalmers library.	Databases other than SpringerLink, Scopus, ScienceDirect and Chalmers Library
Nature of studies	Quantitative and qualitative studies together with theoretical works.	There are no exclusion criteria for this category.

3.4 5-Whys Method

According to Al-Rafai (2025), the 5 Whys method is a problem-solving approach that is used to find the root cause of a problem by repeatedly asking the question “why”. The method extends beyond the initial obvious reason why something went wrong and attempts to discover the deeper cause-and-effect relationships. That is usually by asking “why” around 5 times, though the exact number depends on when a main cause is reached. This method was originally used and developed within the Toyota Production System and is widely used in Lean manufacturing and quality management. This method is strong in that it emphasizes understanding the process, not blaming people, and therefore supports CI efforts. Its effectiveness depends on the knowledge and critical thinking of the people doing the analysis. It is frequently suggested to be used with other tools such as fishbone diagrams to ensure that the identified root causes are feasible and correct. The 5 Whys method was used for the interviews and the analysis of the results.

4. Result

This chapter presents the results of the study based on quantitative and qualitative research methods. The quantitative method includes findings from work sampling and disturbance data analysis. Qualitative results are based on interviews conducted with staff. Finally, the chapter presents the root cause analysis used to identify the underlying causes of operator-related downtime.

4.1 Quantitative Study

This section presents the results of the work sampling and the disturbance data from Axxos Power BI.

4.1.1 Work sampling - Pre-study

The findings are presented in Figure 4.1 and Table 4.1. They demonstrate that operators handle material 54,11% of the time. “Assembly” makes up 17,75% whilst signaling that loading is finished amounts to 17.32%. In addition to this, 6,49% of the time is identified as “idle time” and 4,33% as “other disturbances”. A number of activities were not carried out by operators and were therefore not noted in pre-study. Performing maintenance, pressing emergency stops and changing electrodes were not recorded. Likewise, time losses such as “arriving late”, “leaving early”, "personal time", and "paid break" could not be observed. See Appendix A for more details.

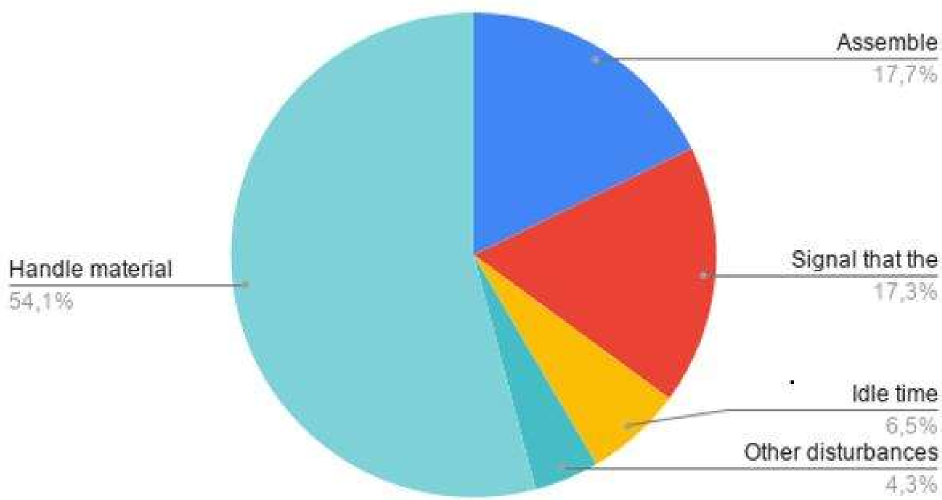

Figure 4.1: Result from pre-study

Table 4.1: Distribution of observed activities

Activities	Percentage
Handle material	54,11%
Assemble	17,75%
Signal finished material loading	17,32%

Idle time	6,49%
Other disturbances	4,33%
Urgent electrode change	0,00%
Press Emergency stop	0,00%
Corrective maintenance	0,00%
Preventive maintenance	0,00%
Personal time	0,00%
Arrive late	0,00%
Leave the station too early	0,00%
Paid break	0,00%

4.1.2 Final Work Sampling

The results from the final work sampling study are presented in Figure 4.2 and Table 4.2. Similar to the pre-study, the work sampling study showcases material handling as the most common activity, making up 38,96% of all observation. “Idle time” is the second most recorded activity with a fraction of 25,17%. It is followed by “other disturbances” at 12,91% and ” assemble” which represents 10,40% of the observed activities. Signaling finished material loading comprises 5,07% of the total time. The remaining activities all make up small fractions of the observations. Paid breaks constitute 4,49% and corrective maintenance forms 2,76%. “Personal time” adds up to 0,61%, while leaving a workstation early amount to 0.55%. See Appendix B for more detail.

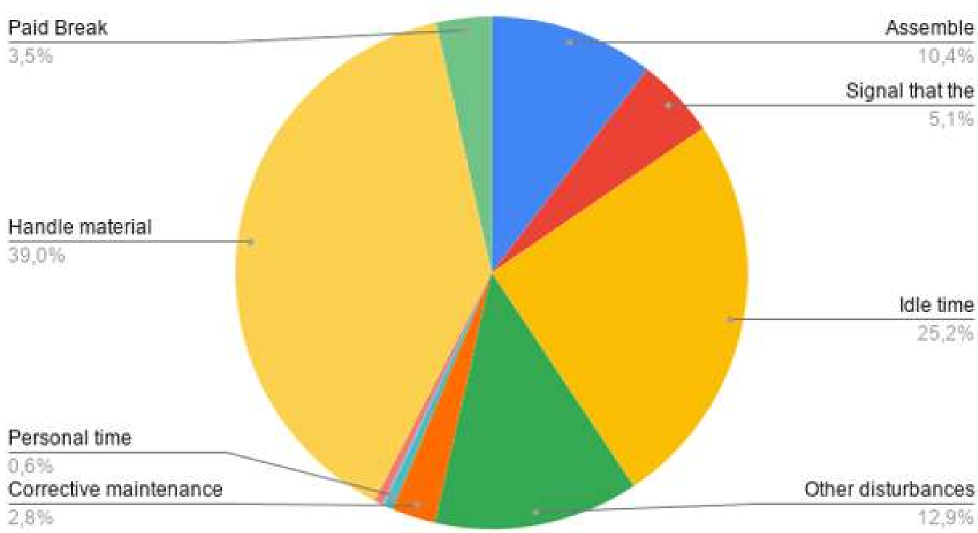

Figure 4.2: Result from work sampling

Table 4.2: Activity distribution

Activities	Percentage
Handle material	38,96%
Idle time	25,17%

Other disturbances	12,91%
Assemble	10,40%
Signal that the assembly is finished	5,07%
Paid break	3,49%
Corrective maintenance	2,76%
Personal time	0,61%
Leave the station early	0,55%
Arrive late	0,08%

Table 4.3: Operator activities and their definitions

Activity	Definition
Assemble	Join or fasten metal parts
Signal finished material loading	Press a button that signals that the assembly is finished
Idle time	Waiting due to production stops or preventative maintenance
Other disturbances	This activity includes the following: rework due to quality error, speaking with coworkers, rotations, team meetings, preparing work during stops, signing documents, walking, removing sheets and opening grids of metal boxes.
Do corrective maintenance	This activity includes repairing tools and changing electrodes of robots without prior plans.
Personal time	This activity includes drinking water and using one's personal device
Arrive late	This activity includes arriving late both when starting the day and after a break
Leave the station too early	Leaving the station before one is allowed to do so
Handle material	The activity includes loading workstations and moving material to workstations
Paid break	Having a break that is paid

4.1.3 Disturbance Registration

Table 4.4 shows the main causes of downtime based on data gathered from Power BI. It is important to mention that the results correspond to the same days when the work sampling observations were conducted. The researchers were given definitions of every disturbance category by a production technician and were thereby able to distinguish between stops that are related to the operator and those that are not

Material handling refers to delays that happen when material is replenished. When new material is brought to a station, workers rearrange material, move sheets and assist logistics personnel. Given that cycle times do not stop, these actions cause time losses that can lead to delays. This differs from the definition used in the Work Sampling study, where material handling refers to moving material to a station and loading it. Loading delay occurs when operators perform material feeding more slowly than expected, causing delays in the production flow. Late arrival refers to operators returning late to the production line after breaks. The definition of this disturbance category is different from the action "arriving late" for the work sample study. Rotation represents the time lost when operators rotate positions. Staff missing indicates situations where operators are not present at their assigned stations, either at the beginning of a shift or due to a toilet break while production is running. It also includes leaving a workstation too early.

Table 4.4: Downtime data from Power BI

Cause of downtime	Number of stops	Time (min)	Percentage of Time Lost Per Category (%)
Material handling	898	3048,7	27,79
Loading delay	1006	5000	45,37
Late arrival	442,5	40,8	0,37
Rotation	443	109	0,99
Staff missing	436	142,3	1,30

The results from table 4.4 shows that loading delay accounts for the highest downtime, with a total of 5000 minutes and 1006 recorded stops. Material handling is the second largest contributor, with 3048,7 minutes of downtime and 898 occurrences. Other causes, such as rotation, missing staff, and late arrival occur less frequently but still contribute to overall production interruptions. These results highlight those operational and organizational factors, particularly loading delays and material handling are the most significant causes of downtime. The percentage of total time lost due to operators is about 76,02% while the remaining 23,98% is caused by other types of disturbances as shown in Table 4.5.

Table 4.5: Time Loss Distribution

Percentage of Total Time Lost Due to Operators (%)	Percentage of Total Time Lost Due to Other Disturbances (%)
76,02	23,98

4.2 Qualitative Result

The qualitative data for this study was collected through semi-structured interviews with operators, team leaders, a production supervisor, a production technician and a production engineer. These interviews were recorded and later analyzed to capture different perspectives on operator-related disturbances. In addition to the interviews, the researchers conducted on-site observations at the company. This allowed the researchers to develop a deeper understanding of the current operational conditions as well as the organizational culture. The interview questions can be found in the appendix C.

4.2.1 Interview 1 - Operator A

Operator A has over 20 years of experience. They state that loading delays are caused by a number of reasons. Operator A mentioned material shortage as one such cause. They add that operators occasionally arrive late, speak with each other or use their personal devices. Operator A deems that most cycle times are realistic. They expressed that it is difficult to load material in stations that include mechanical work. Operator A mentions a station where operators are instructed to pick material twice within one cycle time. Operator A said that some workers incorrectly pick two components at once to not exceed the cycle time. Operator A relayed that placement of material can cause an operator to pick the wrong material. Ordering material late is mentioned as a common cause of stoppages. Operator A underlines that it occurs due to stress, not incompetence. They state that an operator might be mentally strained and find themselves organizing material for forklift drivers, mistakenly thinking that they have ordered material. Operator A articulated that experiencing fatigue is normal given the nature of the work but emphasized that it is manageable. Operator A relates that many workstations have a low degree of complexity since they, generally, do not require operators to pick different materials or work on them differently. Operator A answers that while rotations, lunch breaks and short breaks do not affect their performance, that extended production stops do. Operator A feels listened to for improvement proposals and is given support when errors occur.

4.2.2 Interview 2 - Operator B

Operator B has 11 years of experience. Operators are obliged to order new material when the remaining reaches a limit. This level differs from station to station. Operator B shares that there is a workstation where material often gets stuck together. When this happens, operators might need extra time to count the remaining material which in turn causes delays. Shop floor personnel rotate between workstations during the day and these stations differ in terms of pace and ergonomics. Furthermore, operators are required to work a little bit faster than usual 6% more than normal. Operator B expresses that many workers have a hard time fulfilling this requirement when rotating between "unergonomic workstations with high pace". According to Operator B, many of the workers in this factory are older and have experience in a nearby facility. This neighboring factory has higher workload per cycle time, a continuous production line and quickly delivered support. In the factory Operator B works in, workstations are generally not connected, the workload per cycle time is lower, and buffers are utilized. Due to this, a stoppage of one station normally does not affect other operations. Operator B reveals that laborers have noticed this and deliberately work slowly. However, Operator B does not view this behavior as a widespread phenomenon.

Operator B stresses that the biggest cause of production stops stems from delayed responses from team leaders. Operator B notes that they have had to contact their team leader using their personal phone, which is not allowed. Operator B also states that part-time staff and hired staff display high motivation and work well when starting off as operators or if they want to be hired full-time. If not, operator B says that part-time staff and hired staff perform worse than regular personnel due to a lack of motivation. Operator B also points out that part-time staff have established a friendly relationship with team leaders. They eat lunch together and exclude regular workers from their circle. As a result, part-time operators receive less feedback, nearly feel absolved of mistakes, and purposefully work at a slow pace. According to Operator B, some workers knowingly neglect standards or work at an unreasonable pace to free up time to rest. They report that operators walk many steps a day and therefore want to recuperate. Rotations and breaks do not affect Operator B's performance. Operator B enjoys complex tasks and finds that most workstations are low in terms of their complexity. They reveal that some leaders genuinely listen to operators while others argue back when operators raise their opinions.

4.2.3 Interview 3 - Operator C

Operator C has 9 years of experience. Operator C mentions material handling as the primary reason for loading delays. They similarly state that picking material that is stuck together is another major cause. According to Operator C, most workstations are generally not physically strenuous and do not contribute to delays due to their ergonomy. Operator C says that delays occasionally take place after rotations, breaks and shift changes. They underscore that material placement has a great impact on their performance. Operator C states that material orders are generally placed on time.

They first put aside a number of components that correspond to the aforementioned replenishment level. When material racks are emptied, Operator C orders new material. Operator C admits going against standards when working. When loading small components, they pick several at a time to walk less. However, when loading heavy components, they follow standards and pick one at a time. Operator C states that delays are noticed and reveals that feedback is not given quickly. In fact, they call their team leader for support when errors arise using their own phone, which is not allowed. Operator C adds that some showcase a lack of interest by not informing their team leader of faults and choose to sit until support is provided.

Team leaders have phones wherein they are notified of disturbances. The interview reveals that team leaders often forget to look at notifications, become oblivious of errors and fail to provide support on time. Operator C holds that motivation differs greatly among operators, irrespective of their job contracts. They mention that new operators often pick material wrongly which forces them to turn it before loading, making them lose time. Experienced operators do not make this mistake. At times, Operator C experiences stress and becomes exhausted due to the pace. They suggest improvements, consider themselves listened to and have only met objections for security purposes. Operator C does not become lethargic after prolonged stops.

4.2.4 Interview 4 - Team leader A

Team leader A has 8 years of experience. They state that there are common trends around operator-related delays. Operators have been seen searching for gloves and tools after lunch breaks, rotations and at the start of their shifts. This, despite having instructions saying that one should be fully prepared before entering a station. Team leader B expresses that a large proportion of laborers have previously worked in a neighboring facility with a continuous production line and a high workload per cycle time where support is provided quickly. However, the factory Team leader A works in has a low workload per cycle time, no continuous production lines, and employs buffers. Additionally, feedback and support are not given quickly after production stops. Team leader A reveals that many workers have noticed this difference and intentionally work slowly because they get away with it. They also mention team leader restrictions as a cause for this behavior. Team leaders can remind operators to work according to standard but cannot make any commands. production supervisors, however, are allowed to do this.

Team leader A notes that they have done observations together with production supervisors to identify improvement potential. They report that some operators tend to work according to standards when observed but not otherwise. When asked why stoppages occur, operators are often reluctant to answer due to shame and a dislike of being scrutinized. Team leader A says that regulations are instated that protect operators from getting fired. Because of this safety net, workers can repeatedly make mistakes without facing serious consequences. Team leader A points out that hired staff are motivated and perform well if they want to be hired full-time. They mention that late material orders happen frequently and that it could be caused by not complying with work standards. Some operators work faster than required or choose not to use lifts to get time to rest but forget ordering material when resting. Others, however, go against standards unknowingly. When new material is brought to a station, operators are often seen helping forklift drivers, placing material in new containers and pushing old ones. Logistics personnel are responsible for this, but they are often assisted by operators. When unknowingly going against standards in this fashion, cycle times continue and downtime occurs.

4.2.5 Interview 5 - Team leader B

Team leader B describes that loading delays tend to occur around break times. According to them, these delays usually happen when an operator begins a task, just before a break or after lunch. When workers return, their task may not be completed, which can cause them to exceed the cycle time. According to team leader B, common causes of operator-related delays relate to material handling. Other disturbances that stem from the operator is temporarily leaving the station, communication between coworkers and natural variations in human work pace. They also mentioned that rules exist to address issues such as leaving stations early. However, team leaders have limited authority when it comes to directing operators. Responsibility for long-term solutions lies mainly with production engineers and technicians who design the processes. Team leaders mainly focus on monitoring operators and reporting issues when they occur. According to Team leader A, material is ordered late 30-50 percent of the time.

Team leader B also highlights that ergonomics can affect performance. They mean that if a workstation is not well adapted to the operator, tasks may take longer to perform. Operators also rotate between stations to reduce physical strain and prevent injuries. According to them, differences between individuals can affect work performance. For example, height and age can affect work pace and performance. Younger or physically stronger operators may complete tasks faster. They also mentioned that hired staff often have less experience and familiarity with the process, which can make them exceed cycle times more frequently.

4.2.6 Interview 6 - Production supervisor

According to the production supervisor, the main causes of operator-related losses are related to material handling and workstation design, where layouts and material supply are not optimized for operators. In addition, issues such as variations in operator’s work pace, delayed material ordering, or necessities such as handling tasks outside one’s station can lead to production delays. They mentioned that losses occur around breaks, shift changes, or longer production stops, when operators may leave their stations slightly early or return late. The cycle times are generally considered realistic even though operators may sometimes perceive them as short.

The production supervisor mentioned that the greatest challenge in reducing operator-related losses pertain to the factory layout and material supply systems. Another challenge is to ensure that operators consistently follow standard work procedures. Ergonomics itself is not considered a direct cause of exceeding cycle times. However, an operator’s physical condition or previous injuries can affect their ability to maintain the required pace. The production supervisor also stated that temporary staff is not considered a major problem, as they can perform according to standards. Axxos is used to record disturbances and distinguish between operator-related and technical stops. However, the accuracy of the data can be limited because team leaders sometimes need to estimate stop causes when categorizing disturbances, which reduces the reliability of the data used for analysis and improvement efforts.

4.2.7 Interview 7 - Production Technician

The production technician states that takt time is determined by customer demand. It is currently designed to deliver an average of 24 vehicles per hour. This requirement is based on sales forecasts and delivery expectations. To handle disturbances in the production process, the system has approximately 40% additional capacity in terms of output. Product variation can increase the risk of error depending on the workstation. When operators must choose between multiple components, the likelihood of selecting the wrong component increases compared to situations where only a single option is available. Such errors can lead to additional work. To prevent incorrect assembly, fixtures and sensors are used. The data tracking system Axxos distinguishes between different types of disturbances. Technical disturbances are related to equipment, automation systems or system performance.

Analysis of the production data indicates that delays sometimes occur more frequently around shift changes and breaks. Certain stations, particularly those located near common areas such as lunchrooms and toilets, show higher levels of delays during these times. Differences between shifts seem related to shift structure and working hours more than to the performance of the individual operators. One limitation of the production data is that only stops longer than one minute are systematically categorized in the system. Shorter stops are often not categorized, even though they may occur frequently and accumulate into significant production losses. Therefore, production data alone do not always explain the root cause of disturbances, demonstrating that shop floor observations are necessary to complement the quantitative data.

Some tasks are more critical than others. Manual welding operations were highlighted as critical tasks, as they rely heavily on the operator's actions and provide less automatic feedback compared to automated operations. If a weld is missed, the system may not immediately detect the issue, which increases the importance of operator's attention and experience. The production technician emphasized that the operator's work pace can influence overall production performance. The expected performance level in the system corresponds to approximately 106% of the defined base speed. However, maintaining this pace can be difficult depending on factors such as physical condition, experience, and health.

4.2.8 Interview 8 - Production Engineer

Cycle times are established through rough balancing by production engineers, where steps are analyzed and distributed across stations. An initial balancing is done by a planner based on assembly steps, which are later refined by production engineers. Time calculations often use the SAM method and are measured in time measurement units (TMU). The realism of cycle times can vary since they partly rely on judgment, and methods may differ between factories. Buffers are not normally included directly in the operator's work time but can be part of the overall target cycle time, which also accounts for machine time and process variations. Statistical analysis of operational disruptions can be used to see if extra time is needed.

In addition, the analysis revealed limitations in data quality and system consistency. Sequense-based Activity and Method (SAM) results and production data from Axxos sometimes provide conflicting information, making it difficult to perform reliable analyses. Axxos has general categories that are difficult to analyze in detail. One such downtime category is "Bolt error". For instance, a screwdriver not reaching the required torque, tightening bolts wrongly and using substandard bolts are classified as "Bolt error". It can therefore become challenging for production engineers to identify exact causes for downtime. Operator-related factors that contribute to loading delays, including insufficient training, unclear work instructions, and differences in work pace among operators. Workplace design and organizational factors, such as limited interaction or lack of social support, may also influence operator performance. In some cases, physical limitations or low motivation among operators were identified as potential contributing factors. Technical issues were identified as another cause of downtime. Examples include using screwdrivers that fail to reach the required torque and sensors that wrongly trigger alarms. The analysis also showed that large variations in cycle times between stations and product variants can create confusion and inconsistent work pace among operators. In some workstations, there are two product variants: metal components for hybrid cars and ordinary cars. Both variants are handled in the same way. Components for hybrid cars are heavier than those for ordinary cars.

Organizational factors influence operators' downtime. Limited follow-up from management and a workplace culture where downtimes are not always treated as critical issues may reduce awareness of their impact on the company. The production engineer expresses that factory workers are told to feed material within a specified cycle time. When this cycle time is exceeded, the light turns yellow. The interview reveals that many factory workers do not realize that delayed material loading results in economic losses. In cases where workers repeatedly work inefficiently, they are called to a meeting with their production supervisor wherein they are questioned regarding their performance. They can also be obliged to work on weekends. It was said during the interview that a significant percentage of the shop floor staff are senior operators or workers that have gone through rehab. Their bodies are simply not fit for this profession. However, they still work for financial reasons.

5. Analysis

This chapter analyses the five identified operator-related disturbances from Axxos based on the interview findings. It also connects common points across qualitative and quantitative studies and examines them with the theoretical framework. Above all, this section pinpoints the main root cause of operator-related downtime.

5.1 Material Handling Losses

The interviews reveal that the root causes of material handling losses are mainly caused by three activities, such as opening metal grids on material containers, removing sheets from boxes and assisting logistics personnel during replenishment. These tasks are largely driven by the packaging, storage and supply of materials, which means that operators have to spend time preparing and handling materials before production can continue. Another major reason is operators assisting logistics personnel, often because they don't know about the work standards, or they want to be helpful and maintain good relations. This is a good intention, but it interrupts production and causes more downtime. The root cause diagram for this distrubance category is presented in Figure 5.1.

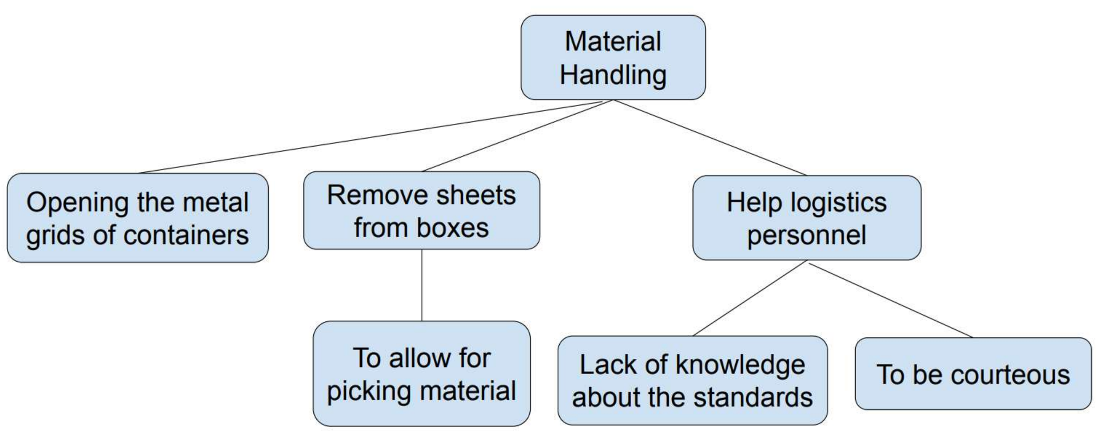

Figure 5.1: Root Causes of Material Handling Losses

5.2 Loading Delays

As explained previously, this category of downtime refers to loading that is performed too slow. The interviews reveal that this is caused by four matters: low motivation, poor physical condition, fatigue and human error. Operators are not reminded when cycle times are exceeded nor are they provided support quickly. Support is often delayed because team leaders are preoccupied with other errors, or they frequently forget to look at their disturbance notifications. This is a result of low motivation that is caused by supervisors do not hold team leaders accountable for not providing support promptly. In addition to this, given the fact that buffers are used and that workstations are disconnected, delayed loading goes unnoticed on the shop floor. This factory is furthermore characterized by having workstations with low workload per cycle time. Workers in general, but specifically those who have been moved from the neighboring factory have noticed this and intentionally work slowly.

Some shop floor personnel have ambitions other than working in a factory and some are financially motivated. They do not mind if material is not loaded on time. This is because they prioritize other matters above their work and do not face immediate consequences when downtime occurs. Adding to this, a large number of operators do not understand how downtime economically affects the company. They only know that they might be required to work on weekends if the company is behind schedule. An outcome of this incompetence is that many workers load material slowly and overall have an irresponsible mentality towards their work. Many workers struggle to meet cycle times due to poor physical condition. This is certainly the case for senior operators and those who have gone through rehab. In addition, it is natural for shop floor personnel to delay loading as a result of fatigue. The interview data reveal that downtime is also caused by human error. This kind of error can be traced back to a lack of knowledge regarding standards and cognitive overload. While feeding material, operators are required to keep track of remaining material, order material and maintain pace. This can cause cognitive overload and can, for instance, trigger one to forget ordering material. Workstation complexity can have a similar effect as operators sometimes pick wrong components, see Figure 5.2 for more details.

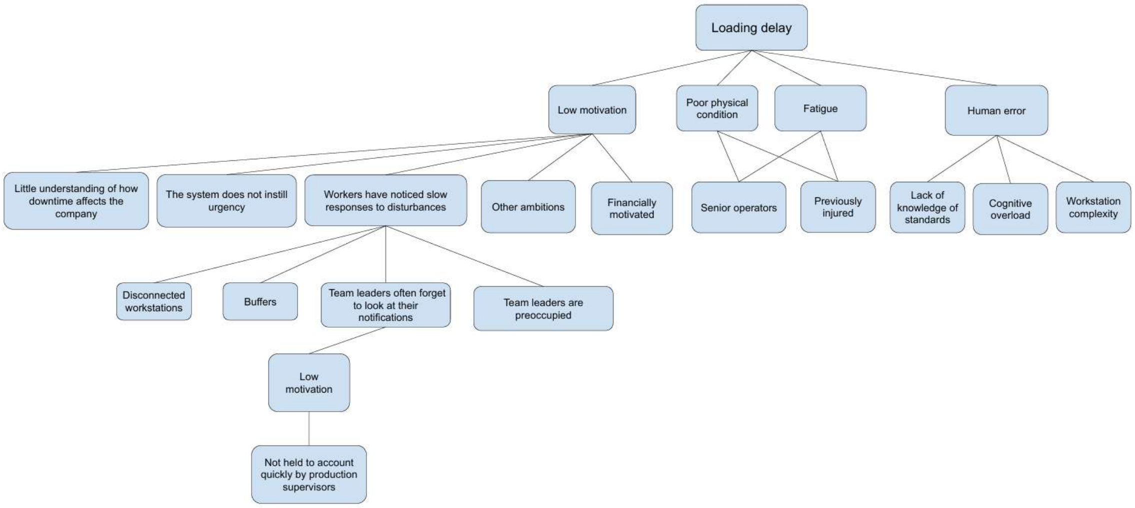

Figure 5.2: Root Causes of Loading Delays

5.3 Late Arrival

Figure 5.3 presents losses due to late arrival that occur after rests, especially after lunch breaks. This is mainly due to low motivation, many necessities to do in a short amount of time and interacting with colleagues. The factors leading to low motivation are discussed earlier. During breaks, Operators must warm their food, eat, walk, and use the restroom within a limited time, which can lead to dallying. In addition, a desire to socialize with colleagues can lead to further returning late.

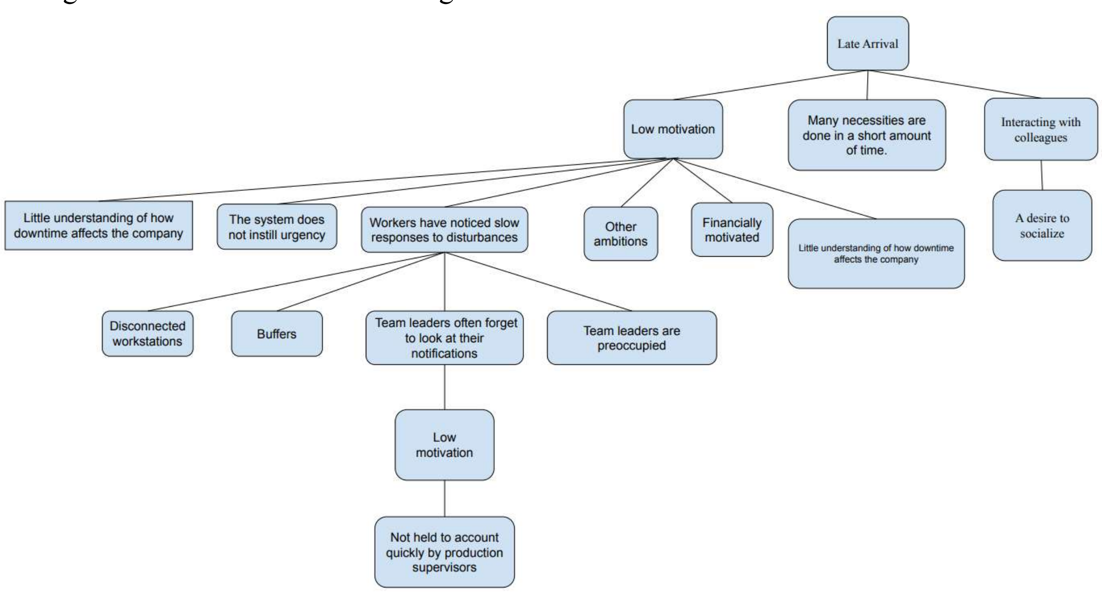

Figure 5.3: Root Causes of Late Arrival

5.4 Rotation Losses

The first two root causes are that factory workers walk slowly when rotating or speak with their colleagues as shown in Figure 5.4. Them walking slowly can be an outcome of low motivation. The things that cause low motivation have been previously elaborated on. Interacting with colleagues is normal and stems from a desire to socialize, as per Maslow's hierarchy of needs.

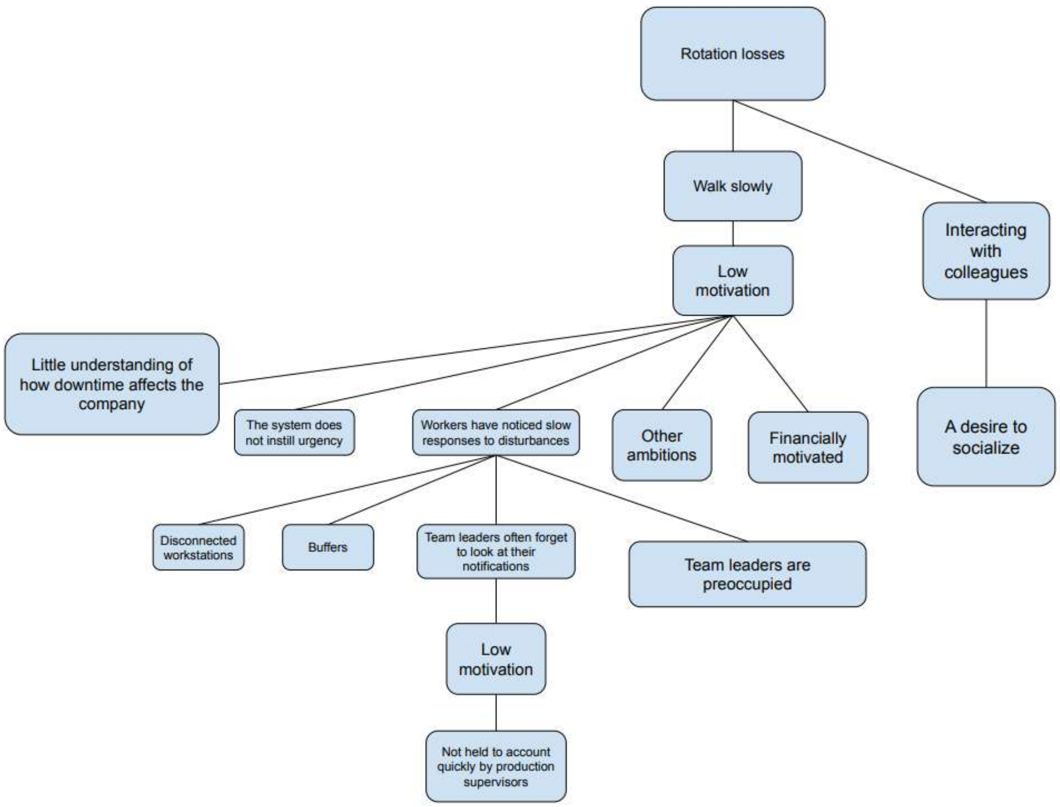

Figure 5.4: Root Causes of Rotation Losses

5.5 Staff Missing

Staff missing occurs when operators leave their station too early, take toilet breaks when the production is running, or when operators are not present at the beginning of their shift. The root cause of these behaviors is low motivation, which has been analyzed in the previous sections of this study, see Figure 5.5.

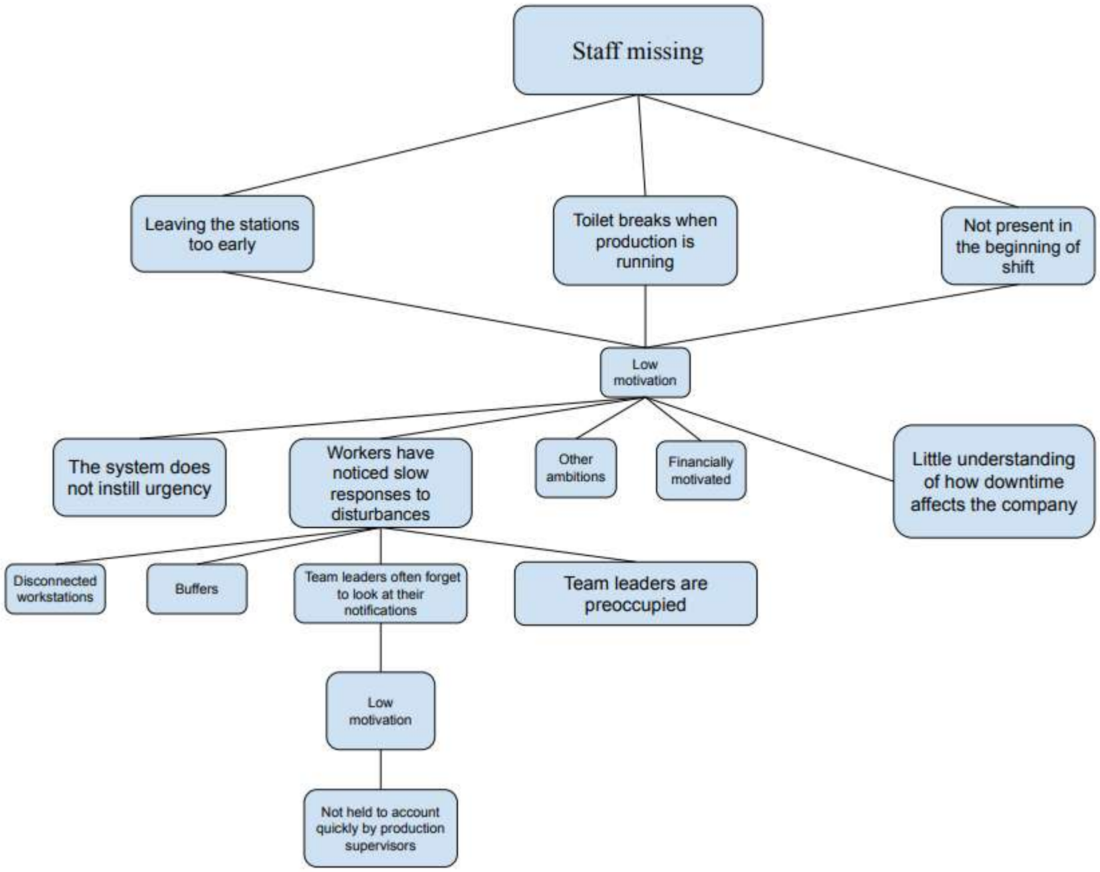

Figure 5.5: Root Causes of Staff Missing

5.6 Most Common Root Cause

The most frequent root cause across the tree diagrams is low motivation. It is identified as a root cause to four out of the five operator-related disturbances.

5.7 Main Observations Across the Results

Handling material is the most recurring action made by factory workers according to the work sampling results. 39% of operator's time is spent transporting or loading material. This agrees with material handling and loading delays being the main causes of delays, as per the downtime data. The work sampling study moreover shows that operators are idle 25,2% of the time. The stop time data show that time losses concerning late arrival, rotations, and missing staff have all been noted to take place 400 times across 9 days. The interview data shows that the production system consists primarily of disconnected stations with buffers. Therefore, disturbances will generally not have a direct impact on subsequent stations. The workstations of this factory are generally perceived to be less physically burdensome and team leaders are noted for responding late to errors. Many shop floor personnel are senior operators. Adding to this, a considerable number of its workers have been moved to it after going through rehab. In fact, many of its personnel have been moved from an adjacent factory with a continuous line and greater workload per cycle time. Furthermore, in this neighboring factory, support and feedback are provided promptly. Regarding shop floor personnel that have gone through this move, it was reported during the interviews that they feel very little accountability after noticing the disparity between these two factories. This behavior can be related to the time losses regarding late arrivals, rotations and not being at the station as required. This mentality can also be linked to the aforementioned idle time as workers have been seen sitting during machine failures and not contacting their team leader for support.

5.8 The Perspective of Motivation

Relating the interview data to the self-determination theory, it is evident that there exists an issue regarding operator competence. Shop floor personnel are instructed to handle material and feed machines within set cycle times. When delays occur, a light turns yellow. Workers mostly know that they should finish loading material before this light turns yellow. Many do not grasp that downtimes have an adverse economic effect on the company. After repeatedly working unproductively, workers are questioned by their production supervisor and sometimes obliged to work during the weekend. Adding to this, incorrect loading and re-handling of material are examples of common errors that can stem from incompetence. With respect relatedness, some appear to experience it at unreasonable levels while others seem to feel much less. One operator alluded to this when revealing that a number of team leaders have built close relationships with part-time staff, excluding full-time operators. It was for instance noted that team leaders usually eat lunch with part-time operators and leave out other employees. During this interview, it was reported that this has made part-time staff face less criticism and essentially consider themselves free of fault. Consequently, this has made them feel less accountable of how they work and have led them to perform poorly. As for autonomy, factory personnel are asked for improvement suggestions and are, at times, met with objections for security purposes. This proves that operators have the possibility to influence their work, showing a degree of autonomy. The qualitative study furthermore shows that many are financially driven, i.e. externally driven. According to self-determination theory, the combined effect of these motivational factors would translate into low motivational levels and unsatisfactory achievements. This inference agrees with the stop data, displaying 400-1,000 stops and time losses of 100-5,000 minutes over 9 days. Considering this data from the viewpoint of Maslow's motivational theory, it can be inferred that a large number of operators might not feel self-actualized by working on the shop floor.

6. Improvement Suggestions

The root cause of operator downtime is essentially low motivation. As explained by the self-determination theory, motivation influences performance and consists of three elements - autonomy, relatedness, and competence. This theory further categorizes motivation as intrinsic or extrinsic. It states that when one is intrinsically motivated, they are more likely to perform well and feel good. Operators should first be educated about what repercussions delayed material feeding has on the company. This would make it easier for workers to understand why cycle times are imposed and why operators must finish operations within them. More importantly, it would allow them to align their feelings and attitudes with the wider vision of their company, possibly enhancing their inherent motivation. This training would thereby increase operators' autonomy and competence. Further training should be given regarding how to pick and load material along with what pace to keep. This would reduce time losses related to re-handling and incorrect loading. It would also make operators understand that it is unfavorable for them to work overly fast to gain time to rest. It is unergonomic, makes one sluggish after resting and can make one forget tasks such as ordering material. Increased competence regarding appropriate work pace would thus assist operators in self-monitoring their pace according to set standards.

Shop floor personnel should be given a work phone with which they can call team leaders if support is not given quickly. With this phone, they should be able to highlight improvement potential. This can be done through an app that has a clear interface. It should show every workstation, have minimal text and allow one to express improvement potential by text and voice notes. Workers should be able to see feedback from engineers and technicians. This is so that engineers and technicians can be held accountable if they respond unprofessionally. With this app, operators should be able to evaluate how others perform, including team leaders, production supervisors, production engineers and technicians. The app should produce a weekly summary that shows one's performance. It should display words of encouragement for workers with satisfactory results and constructive criticism for those with non-satisfactory results. When this is sent, operators should be required to mark that they have read it, understood it and intend to work as they are meant to.

In terms of relatedness, the main issue is that team leaders socialize differently with operators. This can make some feel excluded, which consequently can make their motivation go down. Team leaders should be instructed to treat operators equally and eat with different workers every day. If possible, production engineers, technicians and operators should all eat lunch together. At times, shop floor workers begrudge engineers, envying their nonphysical work and thinking that their role is to make production work difficult. Efforts like this could bridge possible gaps between staff, make them understand each other's viewpoints and jointly steer them in the direction of their company's targets. In the beginning of each shift, team leaders should joyfully greet each of their subordinates, looking at them and saying their name. Additionally, they should praise and acknowledge at least two operators every day that perform well, not repeating with the same ones for two consecutive days. Due to shame and fear of scrutiny, shop floor personnel tend not to disclose why they do not meet cycle times when asked. Production leaders and team leaders should therefore decouple the workers from the process. When asking about common disturbances, they should for instance say, "What made this difficult" instead of "Why do you consistently perform at a substandard level".

Workers should be aware when the cycle time is about to end. To realize this, workstations can be equipped with speakers that give off a moderate pulsating sound, notifying the operator that they should finish loading material. If a cycle time is exceeded, this speaker should emit a similar sound with a greater decibel. The sound should then be turned off after the material has been fed. Besides this, factory workers are aware of regulations that protect them. For instance, they know that team leaders can not command them to follow standards. Giving team leaders this mandate could be another way to instill external motivation. The company should also assist its employees in achieving their full potential. It could do this by obliging their factory workers to fill out questionnaires asking them if their occupation makes them feel self-actualized. For those whose motivational needs are not fully met, the company could assess if opportunities that would make them satisfied exist.

Table 6.1: Proposed Improvements

Area of improvement	Improvement proposals
Competence	Educate operators on how downtimes affect both the company and the workers.
	Train operators further in how to pick and load material
	Train operators on the consequences of not following standards, including increased risk of injury, fatigue, and forgetfulness.
Autonomy	Provide each operator with a phone to contact their team leader for support.
	Develop an app allowing operators to suggest improvements.
	The app should enable operators to evaluate the performance of colleagues, technicians, engineers and leaders.

	The app should also provide weekly performance summaries with encouragement or constructive feedback.
	Ensure responses regarding improvements are not anonymous and encourage regular app usage.
Relatedness	Promote equal interaction between team leaders and operators. Team leaders should greet operators at the start of each shift.
	Encourage team leaders to separate individuals from the process when addressing poor performance.
	Engineers, technicians, team leaders, and operators should eat lunch together.
	Instruct team leaders to recognize and praise different high-performing workers each day.
Individual motivation	Identify unmet motivational needs via questionnaires and seek ways for workers to achieve their full potential.
Regulations	Enable team leaders to instruct operators to follow standards
Instill urgency	Employ speakers that warn when cycle time is nearing and when it has been exceeded.

7. Discussion

This master's thesis sought to study operator-related downtime in an automotive manufacturing company by answering two research questions: what factors related to coupled operators contribute to downtime and how operator availability can be improved.

7.1 Research Questions

The results point towards that operator-related downtime is caused by an amalgamation of operational, organizational and human factors, as opposed to isolated technical problems. Altogether, the operator-related causes for downtime were identified as five: material handling losses, loading delays, late arrivals, rotation losses and staff missing. The disturbance categories that induce the greatest amount of downtime were material handling and loading delays. Upon assessing all error classifications, it was revealed that most of them are primarily caused by low motivation among operators and leaders. This conclusion concurs with the self-determination theory and is strengthened by (Mariza, 2016), connecting motivation and employee engagement with performance. It is likewise supported by (Rodrigo, 2022), concluding that when highly motivated, operators display high levels of efficiency and effectiveness.

To address this lack of motivation, the study proposes enhancing operator competence, increasing autonomy and strengthening relatedness and leadership support. Additional suggestions include increasing operator awareness and accountability. Given that the major reason for downtime relates to motivation, the improvement suggestions were mostly formulated according to the self-determination theory. This was done by making recommendations that increase operator competence, relatedness and autonomy, helping factory workers align their mentalities and behaviors with greater organizational goals. In general, the proposals seek to enhance the intrinsic and extrinsic motivation of the operators. This approach is corroborated by (Ibrahim & Abiddin, 2024), asserting that influencing intrinsic and extrinsic motivation is essential for improving operator productivity.

7.2 Methodological Reflection

This study applied a triangulated approach, combining a literature review with quantitative and qualitative studies. The thesis includes work sampling, semi-structured interviews, analysis of disturbance data together with an overview of relevant theories. To calculate the required number of observations for the work sampling study, the researchers chose a confidence interval of 90 percent. Any higher confidence interval would generate numbers of observations that would be impractical, given time constraints. The work sampling provided data regarding the actions operators do and the percentage of time that was devoted to each activity. However, human error in the form of incorrect judgement of operator activity influenced the data quality. Moreover, the work sample study did not answer why the actions were performed. To answer this question, production staff were interviewed. These interviews enriched the study with multifaceted, in-depth information on operator behavior. Despite this, it undoubtedly included some biased responses. In addition to this, conflicting reports were gathered. For example, different answers were given on how the company reacts to the improvement proposals of factory workers.

One felt listened to, another reported to have faced objection, while a third stated that production engineers only argue against proposals if they add risks. Since the third answer incorporates the two previous ones, it was considered the most valid. Contradictory information was also received regarding how motivation and performance differ among hired staff, part-time workers and regular personnel. Nevertheless, some stated that hired staff that want full-time employment and newly employed operators demonstrate high motivation the most. This answer was regarded as the most reasonable one. This is because it is natural to exemplify enthusiasm when desiring a full-time contract or being new at work.

With respect to the supposed difference in performance, this matter could not be reconciled. As for impartiality, it was not deemed a significant drawback given the fact that a triangulated procedure was employed and that multiple perspectives were taken into account. The subsequent step included collecting data of operator-related downtime from Power BI. This data allowed the researchers to distinguish the disturbances in terms of their impact. It also enabled determining the fraction of downtime that is caused by the operator and the production system. Despite this, the data was not fully accurate, as team leaders occasionally have to estimate causes of disturbances when categorizing errors. The identified disturbance categories were then analyzed in root cause trees using the 5-whys method and interview responses. Further analysis was performed connecting shared points between both the quantitative and qualitative results.

8. Conclusion

To conclude, the assessment presents solid coherence throughout the quantitative and qualitative findings. Operator-related downtime is predominantly caused by a widespread lack of motivation among operators and leaders alike. This is manifest as recurring material loading delays and an environment that essentially accepts frequent disturbances. As opposed to solitary errors, operator-related downtime should be perceived as a systemic problem rooted in the design and management of the production system. To deal with this matter, the researchers proposed improving competence, relatedness, and autonomy along with increasing accountability to enhance operator performance and overall productivity.

8.1 Future Studies

This master's thesis had the objectives of identifying operator-related factors that cause downtime and suggesting ways in which it can be reduced. The purpose of this project was to increase the productivity of this company by enhancing their operator availability. The suggested improvements were not implemented, and a new operator availability number was not calculated. If this study was to continue, the proposed solutions should be put into effect. Following this, results should be analyzed and a new operator availability number ought to be calculated.

References

Almström, P. (2024). *Time data management*. Ale Tryckteam AB.

Al-Rifai, M. (2025). *Evaluating 5whys methodology for root cause analysis and problem-solving skills*. International Journal of Lean Six Sigma, 16 (5), 1276–1304. https://doi.org/10.1108/IJLSS-04-2024-0077

ATS-Tanner. (n.d.). *What is a production process and why is it so important for any industry?* [[Illustration]]. https://www.ats- tanner.com/en/news- and-applications/what-is-a-production-process-and-why-is-it-so-important-for- any-industry-134008

Bearman, M. (2019). *Eliciting rich data: A practical approach to writing semi- structured interview schedules*. Focus on Health Professional Education, 20 (3), 1–11.

Berlin, C., & Adams, C. (2017). *Production ergonomics: Designing work systems to support optimal human performance*. Ubiquity Press. https://doi.org/10. 5334/bbe

Berlin, C. (2025). *Data collection* [Provided in PPU215 course materials].

Bhuiyan, N., & Baghel, A. (2005). An overview of continuous improvement: From the past to the present. Management Decision, 43 (5), 761–771. https://doi. org/10.1108/00251740510597761

Deci, E. L., Olafsen, A. H., & Ryan, R. M. (2017). *Self-determination theory in work organizations: The state of a science*. Annual Review of Organizational

Hedman, R., Subramaniyan, M., & Almström, P. (2016). *Analysis of critical factors for automatic measurement of OEE*. Procedia CIRP, 57, 128–133. https://doi.org/10.1016/j.procir.2016.11.023

Psychology and Organizational Behavior, 4, 19–43. https://doi.org/10.1146/ annurev-orgpsych-032516-113108

Ibrahim, I., & Abiddin, N. Z. (2024). *The role of intrinsic and extrinsic motivation in enhancing employee performance at private manufacturing organisations in the klang valley*, malaysia: A preliminary study. Pakistan Journal of Life and Social Sciences, 22 (2), 6672–6680. https://doi.org/10.57239/PJLSS- 2024-22.2.00504

Katukoori, V. K. (n.d.). *Standardizing availability definition* [Accessed: 2026-03-13]. http://plant-maintenance.com/articles/Availability_Definition.pdf

Mariza, I. (2016). *The impact of employees' motivation and engagement on employees' performance of manufacturing companies in jakarta indonesia*. International Journal of Applied Business and Economic Research, 14 (15), 10611– 10628.

McLeod, S. (2024). *Maslow's hierarchy of needs* [Accessed: 2026-05-30]. https: / / www.simplypsychology.org/maslow.html

Moon, M. D. (2019). *Triangulation: A method to increase validity, reliability, and legitimation in clinical research*. Journal of Emergency Nursing, 45 (1), 103–105. https://doi.org/10.1016/j.jen.2018.11.004

Muchiri, P., & Pintelon, L. (2008). *Performance measurement using overall equipment effectiveness (oee): Literature review and practical application discussion*. International Journal of Production Research, 46 (13), 3517–3535. https: //doi.org/10.1080/00207540601142645

Read, G. J. M., Shorrock, S., Walker, G. H., & Salmon, P. M. (2021). *State of science: Evolving perspectives on "human error*". Ergonomics*, 64*(9), 1091–1114. https://doi.org/10.1080/00140139.2021.1953615

Rodrigo, K. (2022). *Impact of employee motivation to employee turnover: Machine operator category at abc* (pvt) ltd [Research Project Report]. Chartered In- stitute of Personnel Management, Sri Lanka.

Sahmi, Z., & El Abbadi, L. (2024). *The evolution of Kaizen in the industry: Systematic literature review*. International Journal of Production Management and Engineering*, 12*(2), 169–179. https://doi.org/10.4995/ijpme.2024.21143

Taormina, R. J., & Gao, J. H. (2013). *Maslow and the motivation hierarchy: Measuring satisfaction of the needs*. American Journal of Psychology, 126(2), 155–177.

Trivedi, A. J., & Mehta, A. (2019). *Maslow's hierarchy of needs - theory of human motivation*. International Journal of Research in All Subjects in Multi Languages, 7 (6), 3841.

Zandin, K. B. (2001). *Maynard's industrial engineering handbook* (5th ed.). McGraw- Hill.

Van den Broeck, A., Ferris, D. L., Chang, C.-H., & Rosen, C. C. (2016). *A review of self-determination theory's basic psychological needs at work*. Journal of Management, 42(5), 1195–1229. https://doi.org/10.1177/0149206316632058

Appendix

A. Pre-study

Assembly	Amount	Percentace	Disturbances	Amount	Percentage	Personal time	Amount	Percentage	Managing Stock/Material Handling	Amount	Percentage	Paid Break	Amount	Percentage	Total
Assemble	41	17,75%	Idle time	15	6,49%	Personal time	0	0,00%	Handle material	125	54,11%	Paid Break		0,00%	231,00
Signal that the assembly is finished	40	17,32%	Urgent electrode change	0	0,00%	Arrive late	0	0,00%							
			Press Emergency stop	0	0,00%	Leave the station too early	0	0,00%							
			Other disturbances	10	4,33%										
			Corrective maintenance		0,00%										
			Preventative maintenance		0,00%										
			Things incorporated within "Other disturbances": Assembly error, human error, rework due to quality error, speaking with coworker, MOP rotate												
			Things incorporated within "Personal time": Drink water, use personal devise												
			Things incorporated within "Handle material": Handle packages, order new material, move material												

Pre-study results

B. Final work sampling

Assembly	Amount	Percentage	Disturbances	Amount	Percentage	Personal time	Amount	Percentage	Managing Stock/Material Handling	Amount	Percentage	Paid Break	Amount	Percentage	Total
Assemble	626	10,40%	Idle time	1515	25,17%	Personal time	37	0,61%	Handle material	2345	38,96%	Paid Break	210,00	3,49%	6 019,00
Signal that the assembly is finished	305	5,07%	Other disturbances	777	12,91%	Arrive late	5	0,08%							
			Corrective maintenance	166	2,76%	Leave the station too early	33	0,55%							

Things incorporated within "Other disturbances": Rework due to quality error, speaking with coworker, MOP rotate, Team meating, preparing work during stops, signing a document, walking, moving sheets, opening grids to metal boxes
Things incorporated within "Personal time": Drink water, use personal devise
Things incorporated within "Handle material": Load workstations, move material to workstations
Observations are made every 20 seconds

Work sampling results

Recorded observation times during work sampling

Week and day for the observations	Time
2026-02-25	10:00 - 15:20
2026-02-26	09:31 – 10:45
2026-02-26	11:17 – 13:00
2026-02-26	13:33 – 14:00
2026-03-02	13:42 – 14:48
2026-03-02	14:52 – 15:25
2026-03-03	08:56 – 09:15
2026-03-03	10:43 – 10:45
2026-03-03	12:03 – 13:05
2026-03-04	08:38 – 10:45
2026-03-04	11:27 – 11:57
2026-03-04	12:08 – 13:05
2026-03-04	13:33 – 14:21
2026-03-04	14:30 – 14:50
2026-03-04	14:48 – 16:46
2026-03-05	12:26 – 13:30
2026-03-05	13:54 – 14:20
2026-03-05	14:31 – 15:50
2026-03-06	08:56 - 10:29
2026-03-06	11:40 - 12:28
2026-03-06	13:15 - 13:28
2026-03-06	13:35 - 14:40
2026-03-06	14:40 - 14:48
2026-03-09	9:05 - 10:45
2026-03-09	11:17 - 13:15
2026-03-09	13:30 – 15:25
2026-03-23	09:51 – 10:19
2026-03-23	10:32 – 10:45
2026-03-23	11:39 – 15:54

C. Interview questions

Interview Questions - Operator

1. Loading Delays
    a. Can you describe situations in which you are unable to complete the work within the cycle time?
    b. What do you perceive to be the main cause of overcycling?
    c. Why does this situation occur?
    d. Are there specific tasks at the station that more frequently lead to overcycling or production disturbances?
2. Workload and Cycle times
    a. Do you perceive cycle times to be realistic during normal production?
    b. Which tasks are the most difficult to complete within the allotted times?
    c. Do you experience that disturbances accumulate during the shift?
3. Material and Logistics
    a. How does material placement affect your performance?
    b. How often does it happen that materials are not ordered on time by the operator?
4. Ergonomics
    a. Are there tasks that are physically demanding?
    b. Do awkward working postures (or heavy lifting, etc.) affect your working speed?
    c. Does fatigue affect your ability to maintain the cycle time?
    d. Does rotation time affect your performance and motivation?
5. Cognitive Factors
    a. Are the work instructions always clear?
    b. Does increased task complexity raise the risk of delays?

c. Does this complexity affect your motivation?

d. Do you experience stress when working as an operator?

e. Does stress affect your performance? If so, how?

f. Does the workstation design affect your motivation in any way? How?

g. Is your performance affected by long stoppages?

h. Do you become less alert as a result of longer stoppages?

6. Autonomy and Support

a. Are you able to influence how the work is performed? If you propose improvement suggestions, are they implemented?

b. Can you provide an example of such a suggestion?

c. Do you have the opportunity to suggest improvements to reduce stoppages?

d. Do you feel confident in handling disturbances?

e. Do you receive sufficient support when problems arise?

Interview Questions - Team leader

1. Are there any observable trends regarding when operator overcycling occurs, for example after lunch?
2. What do you perceive to be the main causes of operator-related overcycling?
3. Why have these issues not been eliminated previously?
4. What prevents the implementation of long-term solutions?
5. How often does it happen that materials are not ordered on time by the operator? Do you see any possible solution to this problem?
6. Is ergonomics a contributing factor to overcycling? If so, in what way?
7. Is there any variation based on gender, height or age? If so, how does this variation manifest?
8. Do losses occur due to temporary or agency staff? Please explain

Interview Questions - Production Supervisor

a. What do you see as the main underlying causes of operator-related losses?

   - Why does this problem occur?

   - Have you observed losses related to job rotations, breaks, during shift changes, or after extended stoppages?

1. What is the greatest challenge in reducing operator-related losses?
2. Are cycle times realistic?
3. How often does it happen that materials are not ordered on time by the operator?
4. Is ergonomics a contributing factor to loading delays? If so, in what way?
5. Is there any variation based on gender, height, or age?
6. Do temporary staff and part-time staff perform worse than regular staff?
7. Do you differentiate between operator-related stoppages and technical stoppages? If so, how is this done?
8. To what extent do team leaders perform correct stoppage coding?

   - Is it sometimes necessary for team leaders to guess the cause of a stoppage

   - If so, what effect does this have on the improvement initiatives undertaken?

   - Are there defined categories or definitions for the causes of stoppages?

Production Technician – Interview Questions

- How was the cycle time for the stations determined?
- Is there variation between different product variants that affects the operator's work?
- Does this lead to more stops at stations where variations exist?
- Do you distinguish between operator-related stops and technical stops? If so, how do you do this?
- Do you see any patterns in the over-cycle data? If so, what patterns do you observe? (For example, do loading delays occur after lunch or breaks?)

- What problems or weaknesses exist in the data you use to measure stops and down times?
- Are there tasks within the station that you know are more critical than others?
- Can you give an example of a common cause that leads to operator-related stops? Why does this problem occur?
    - Why does it occur again?
    - Why has the problem not been eliminated earlier?
    - What prevents a permanent solution?
- What are the most common causes of operator-related down time?
- To what extent do team leaders make correct codings?
- Is it possible that team leaders sometimes have to guess the cause behind a stop?
    - If so, what effect does that have on the improvement measures you implement?
    - Are there defined categories for the causes of stops?

Interview Questions - Production engineer

1. How are cycle times determined? Are the cycle times considered realistic?
2. Is any buffer included in the time calculations?
3. Do you differentiate between operator-related stoppages and technical stoppages? If so, how is this done?
4. Do you observe any patterns in the overcycling data? If so, what patterns do you observe?
5. What problems or weaknesses exist in the data used to measure stoppages and overcycling?
6. What are the most common causes of operator-related loading delays?

DEPARTMENT OF TECHNOLOGY MANAGEMENT AND ECONOMICS
DIVISION OF SUPPLY AND OPERATIONS MANAGEMENT
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2026
www.chalmers.se

CHALMERS
UNIVERSITY OF TECHNOLOGY