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# The impact of wireless pressure transmitters in test drive process

## – Sandvik Mining and Construction Oy

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Bachelor’s Thesis | Abstract

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# The impact of wireless pressure transmitters in test drive process

- Sandvik Mining and Construction Oy

The aim of this thesis is to investigate the impact of wireless pressure transmitters used in the test drive process. The objective is to examine how this method affects the process lead time, costs, and occupational safety. Wireless pressure transmitters are expected to improve the efficiency of the process, but this has not yet been studied. The research aims to present concrete observations of these effects.

The research utilizes a mixed-methods approach. The theoretical framework covers concepts related to processes, various process development methods, and process metrics. The empirical part of the study examined the current state of the process through observation, thematic interviews, internal company documents, a time study, and analysis of the time study results.

The results of the study indicate that wireless pressure transmitters have a positive effect on the test drive process. The research shows that the process lead time is shortened, and reduction can be quantified. The process becomes more cost-efficient, and work-related safety risks can be reduced or even eliminated.

Keywords:

lead time, process, process improvement, pressure measurement, occupational safety, cost-efficiency

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Ville Nisula

# Langattomien painelähettimien vaikutus koeajoprosessissa

- Sandvik Mining and Construction Oy

Tämän opinnäytetyön tavoite on selvittää koeajoprosessissa käytettävien langattomien painelähettimien vaikutusta. Tavoitteena on tutkia miten menetelmä vaikuttaa prosessin läpimenoaikaan, kustannuksiin sekä työturvallisuuteen. Langattomien painelähettimien on arvioitu tuovan tehokkuutta prosessiin, mutta sitä ei ole tutkittu. Tutkimuksella pyritään esittämään konkreettisia havaintoja vaikutuksista.

Tutkimus toteutettiin yhdistelemällä laadullisia ja määrällisiä menetelmiä. Teoreettinen viitekehys käsittelee teoriaa prosesseista, prosessikehittämisen eri menetelmistä sekä prosessimittareista. Työn empiirisessä osuudessa selvitettiin prosessin nykytilaa havainnoimalla, teemahaastatteluilla, yrityksen sisäisillä dokumenteilla, teettämällä työnmittaus sekä analysoimalla työnmittauksen tuloksia.

Työn tuloksena havaittiin langattomilla painelähettimillä olevan parantava vaikutus koeajoprosessiin. Tutkimus osoittaa toimeksiantajalle prosessin läpimenoajan lyhentyvän ja aika pystytään osoittamaan numeroin. Prosessista saadaan kustannustehokkaampi ja suoritettavaan työhön kohdistuvia työturvallisuusriskejä saadaan vähennettyä tai jopa poistettua.

Asiasanat:

läpimenoaika, prosessi, prosessikehittäminen, paineenmittaus, työturvallisuus, kustannustehokkuus

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# 1 Introduction

This thesis was commissioned by Sandvik Mining and Construction Oy. The aim of the thesis was to examine the impact of wireless pressure transmitters on the test drive process.

The objective of this study was to examine the effects of the method on lead time, costs, and occupational safety within the process. The research investigates whether the method has the intended impact on process lead time, how lead time influences cost formation, and whether the method can improve operational safety. All machines completed in production go through the test drive department, making this phase critical for ensuring proper machine functionality. The test drive is perceived as a production bottleneck, which highlights the importance of implementing development measures in the process to keep pace with overall production.

The choice of topic was timely due to the increasing number of machines coming out of production. The idea of using wireless pressure transmitters has been around for some time, but no one has explored its impact in depth. So far, only rough estimates have been presented. The topic was proposed by the commissioning company, and its nature was personally interesting, which helped deepen my understanding of the process and its development. Occupational safety is one of the core values of the commissioning company, and maintaining and promoting a strong safety culture is a top priority within the organization. (Personal statement 30.5.2025.)

The key sources for this thesis include literature related to the concepts of the research topic, which serve as the theoretical foundation for the study. The theoretical part of the thesis covers the definition of a process, the methods used to develop processes, and how job design and development influence both the process and occupational safety. The empirical part, or research section of the thesis, was carried out through interviews, observation, current state analysis, internal documents, and time studies.

The objectives of the study are presented through research questions. The study aims to investigate the effects of the method on the process and to answer the research questions. The research questions are listed below:

- How do wireless pressure transmitters affect the test drive lead time?
- Do wireless pressure transmitters improve the safety of pressure measurement?
- How do wireless pressure transmitters impact costs?
- What further development opportunities do wireless pressure transmitters offer?

The thesis begins with an introduction to the commissioning company, followed by the theoretical section, which aims to provide the reader with an understanding of the definitions of key concepts related to the research topic. After the theoretical part, the research methods used in the study and the implementation of the research are presented. Before presenting the research results, the reader is given a description of how the test drive process proceeds and the different stages it consists of. The results section outlines the study's findings and what was achieved, followed by conclusions and potential opportunities for further development of the method.

# 2 Sandvik AB

Sandvik AB is a swedish industry corporation operating globally in the metal and mining sector. The Sandvik AB is known for providing wide range of high-tech solutions for the industries operating in manufacturing, mining and infrastructure. Solutions aim to enhance profitability, sustainability and productivity. (Sandvik n.d.)

Sandvik AB operates in more than 150 countries and has approximately 41,000 employees worldwide. In the latest annual reporting, Sandvik recorded a revenue approximately SEK 123 billion. (Sandvik 2024, 51-52.) The company's core business areas consists of 3 areas, Sandvik Mining and Rock Solutions, Sandvik Rock Processing Solutions and Sandvik Manufacturing and Machining Solutions (Sandvik n.d.).

## 2.1 History

The company was founded in 1862 in Sweden. The founder of the company was Göran Fredrik Göransson. At that time, the company focused on steel production using the Bessemer method. The core values in its strategy were value creation, high quality, investment in product development, and close cooperation with customers. These values are still applied in the company's operations today. (Sandvik n.d.)

The company continued its operations by processing its own steel into various tools and machine parts, including mining tools used in quarries. In the early and mid-1900s, Sandvik began manufacturing stainless steel, cemented carbide, and cemented-carbide tools (Sandvik n.d.)

Today, Sandvik offers rock excavation and processing solutions for the needs of the mining and infrastructure industries. The product range includes, among other things, underground mining equipment for loading, hauling, and rock drilling, as well as machines for rock crushing. (Sandvik n.d.)

## 2.2 Sandvik Mining and Construction Oy Turku

In Finland, the company is called Sandvik Mining and Construction Oy and it is subsidiary of the Sandvik AB. Sandvik Mining and Construction Oy is part of Sandvik Mining and Rock solutions business area. (Personal statement 5.4.2025.)

The business area is divided into divisions and Sandvik Mining and Construction Oy Turku is part of Load and Haul division (Sandvik 2024, 6).

At the Turku’s facility, the company manufactures loaders and trucks for underground hard rock mining (Personal statement 5.4.2025).

# 3 Process, process improvement, documentation and measurement

All operations within an organization aim to achieve a desired goal, namely a product or a service. The transformation process model forms the foundation for all operations and illustrates how inputs are converted into outputs. Figure 1 presents the transformation process model. (Slack et al. 2022, 11.)

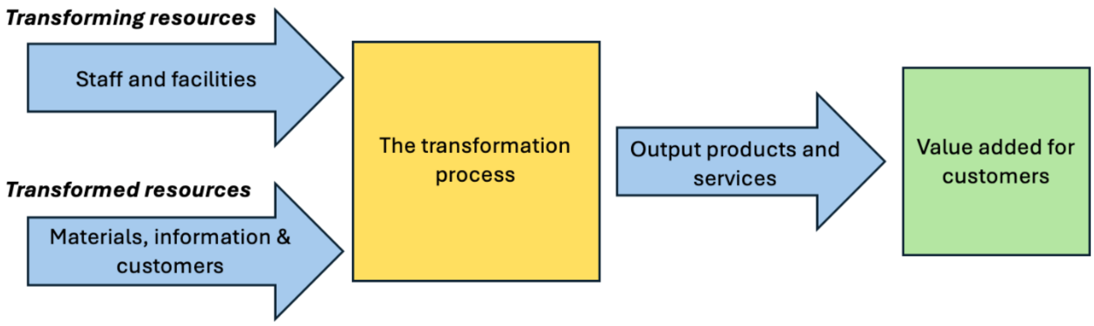


Figure 1. The transformation process model (Slack et al. 2022, 12).

Inputs are resources, and these resources are divided into those that perform the transformation and those that are being transformed. The output is the product or service resulting from the resources and the process. This sequence of events is referred to as a process. (Slack et al. 2022, 11-12.)

When considering a process, one must begin with something that exists in a stable and repeatable form, something that can be modeled and developed. Identifying and improving processes is a trend that applies to all organizations. The definition of a process includes a series of actions and the resources used to achieve a desired output. As previously mentioned, resources are divided into two categories, those that perform the transformation and those that are being transformed. The transforming resources include equipment, facilities, and personnel, while the transformed resources consist of materials and information. Outputs are achieved by refining the resources through the process. Simply put, the concept of a process consists of activities such as inputs resources, and outputs, and it is the process that generates performance as shown in figure 2. (Laamanen 2012, 19-20.)

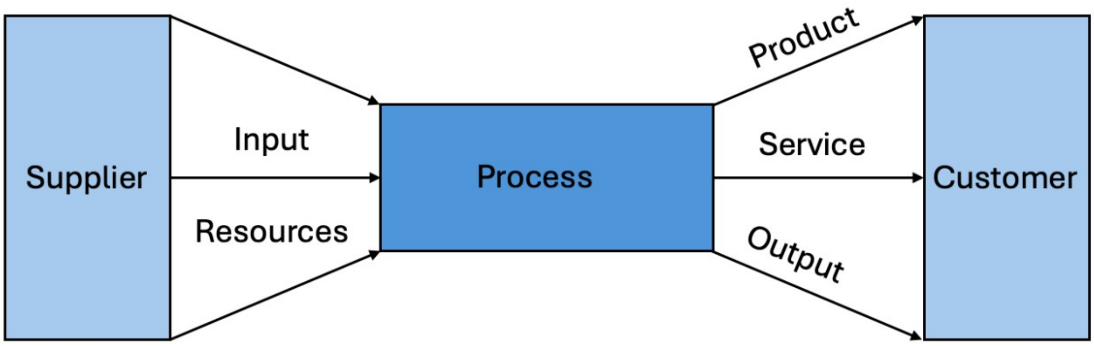


Figure 2. Process is a set of activities and resources (Laamanen 2012, 20).

Laamanen (2012, 19) states and recommends the following definition for a process in his book: “An operational process is a set of logically interconnected, recurring activities and the resources required to carry them out, through which the outcomes of the operation are achieved” (Laamanen 2012, 19).

Processes are classified into four categories by its character:

1. Primary processes
2. Support processes
3. Management processes
4. Key processes

Primary process deliver value directly to the customer. Common examples include marketing, sales, production and customer service. Support processes ensure smooth operation of primary processes and typically involve human resource management, accounting and workplace safety. Management processes include strategic and operative planning as well as change and improvement management. Key processes are critical activities for organization success and may belong to primary, support or management processes. (Tuominen 2010, 9-10.) In this thesis the focus is on key process.

## 3.1 Process improvement

Fulfilling a customer satisfaction and to be successful in a competition, organizations must develop more efficient ways to operate and improve processes due to dynamic, constantly changing, competitive environment. (Martinsuo et al. 2016, 358.) The starting point for process improvement can also be a recognized and known problem that the development aims to address, or the objective may be to enhance the organization’s operations, improve quality, or achieve cost savings (Digi- ja väestötietovirasto 2002).

There are various ways of improving processes to keep up with the competition. Improvement’s objective is for example reducing lead time, reducing costs, eliminate bottle necks of production or enhancing productivity of production. (Kvist et al. 1995, 100.) However, the things mentioned before are not suitable as improvement objectives, but rather sets the direction of improvement. The great objective must be expressed in figures, the objective have unit of measure and it is tied-up to time. Those three criteria indicate if the outcome of improvement is positive or negative. (Laamanen 2012, 203.)

Improvements can be either a small change including a single phase of the process or a large change covering the entire process. (Kvist et al. 1995, 100-101.) When considering which process to select for improvement, the following criteria must be taken into account:

- External or internal customer’s occured problems or complaints
- The size of process measured in costs
- The duration of lead time
- The process is knowingly worse than the best known example
- Possibility to utilize a new technology
- The staff has motivation to improve process (Kvist et al. 1995, 74.)

Improving processes can have positive impact on operations:

- Improved productivity: Process output achieved by reduced use of resources

- Improved speed: Process output produced quicker than before
- Higher capacity: Process is able to produce more outputs in the same period
- Better reliability: Process achieves objectives imposed by law and rules as well as health, safety and environment

(Tuominen 2010, 13.)

Standardization, continuous improvement and radical improvement are three different levels to improve processes. The objective of standardization is to standardize workflow, methods and work procedures. The continuous improvement is to improve workflow, methods and work procedures by small steps. The radical improvement is to take radical actions to achieve major improvements in performance. (Tuominen 2010, 13.)

### 3.1.1 Continuous improvement (Kaizen) and PDCA-cycle (Plan-Do-Check-Act)-cycle

Even though radical changes and large-scale developments aimed at major transformations are methods for improving processes, they are not part of the philosophy of continuous improvement. Continuous improvement is a state of ongoing development, where operations are enhanced gradually through small steps. This approach takes into account the involvement of the entire organization’s personnel. The idea behind continuous improvement is to engage employees in development activities, using their actions and tasks as the primary source of improvement ideas. (Haverila et al. 2005, 380-381.) Machines, materials, work tasks and procedures involved in production are part of continuous improvement (Kvist et al. 1995, 101). In the long run, the accumulation of small development steps leads to significant results, which is why continuous improvement as an operating model is an effective way to enhance operations. Continuous improvement also engages personnel more closely in development activities, which has been found to have positive effects on motivation and attitudes toward change. (Haverila et al. 2005, 381.)

The continuous improvement operating model is also known as “Kaizen”. The word kaizen is originally from Japanese and a creator of the word is Masaaki Imai. (Slack et al. 2022, 514.) The Japanese word kaizen stands for improvement and therefore it is used alongside the term continuous improvement (Haverila et al. 2005, 380).

Improvement ideas and initiatives raised by personnel can be implemented using supportive methods to promote continuous improvement. The PDCA cycle, also known as the Deming Circle (Figure 3), is one example of such a method. The abbreviation PDCA stands for Plan-Do-Check-Act. The purpose of the method is to control development activities and to analyze and verify the impact of changes within the process. (Haverila et al. 2005, 381; Slack et al. 2022, 517.) The PDCA cycle enables process improvement characteristics (documentation, measurement, analyzing and testing) demonstration in one place (Laamanen 2012, 209).

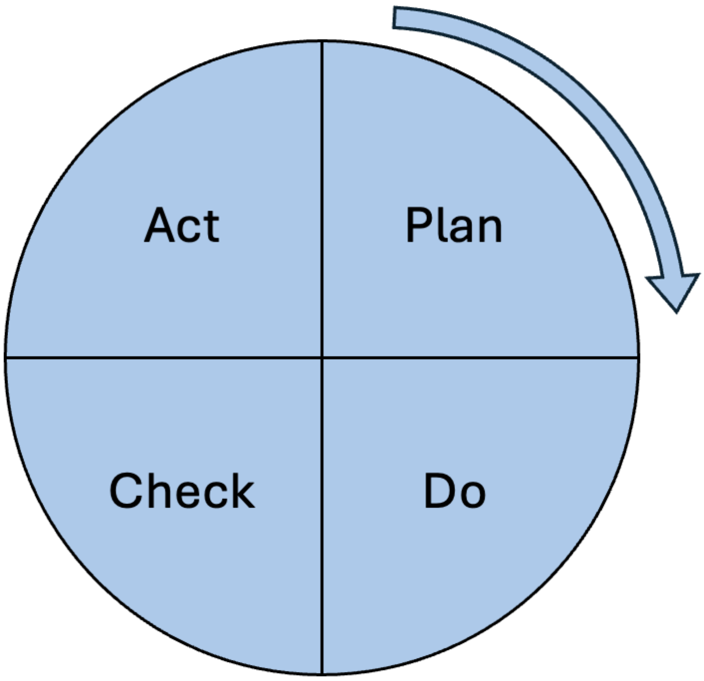


Figure 3. The PDCA cycle model (Haverila et al. 2005, 382).

The first step in the PDCA cycle is planning and setting objectives. Once the plan is completed, the next step is to implement and test the desired improvement action. It is recommended to carry out the test on a small scale. The following phase is to check and analyze the impact of the intended improvement action. The final step is to act according to the objectives. If the objectives were not met, the results are examined and improvements or corrections are developed, and the cycle is repeated. If the objectives were achieved, the change is stabilized and standardized as part of the process. (Haverila et al. 2005, 382; Laamanen 2012, 210.)

### 3.1.2 Improving work procedure

Process and operations improvement is strongly related to development of more efficient working methods, ergonomy, occupational safety, machines and work related equipments to enhance work phase performance of process (Tuominen 2021, 120). Job design is signifying newer, broader opinions of people's demands how to design and carry out work tasks. A term job enlargement is related to the job design. The job enlargement means one work stage is formed from consecutive work stages. The job enlargement can be utilized to enhance productivity. (Martinsuo et al. 2016, 296-297.)

According to Lean philosophy, in many processes, only a small portion of the time consists of value-adding activities, while the majority of the time is non-value-adding, also known as waste. Waste refers to those activities or parts of a process that do not create added value for the customer but instead increase costs. (Tuominen 2010, 7.) Examples of waste include process waste, task-related waste, and all unnecessary movement during work (Tuominen 2010, 15).

Process waste arises from unnecessary work stages or redundant features related to the product. It can also be caused by various factors such as continuing unnecessary processes or steps, lack of employee motivation toward improvement actions, or the attitude that “this is how it has always been done”. (Tuominen 2010, 24-25.)

Task-related waste, also known as work phase waste, arises from activities that are no longer necessary for achieving the final outcome. The way a task is performed also influences the level of waste and inefficient methods may be used. Movements involved in the work can be categorized into value-adding and non-value-adding. Reducing work phase waste aims to optimize the collaboration between the worker, machine, and materials. This optimization can be achieved by decoupling the worker from the machine and performing manual tasks simultaneously while the machine operates. All unnecessary motion during task execution is considered waste and should be minimized. Waste is present in all hand, body, and leg movements. Therefore, by minimizing unnecessary movements, waste can also be reduced. This type of motion waste can be reduced by optimizing human factors, the work environment, and the tools used in the task. (Tuominen 2010, 26-30.)

## 3.2 Process description

Processes must first be described in order to make their development possible. The purpose of documenting processes is to clarify and understand their flow, as well as to identify potential areas for improvement. Describing processes also offers benefits from various perspectives, such as making it easier to onboard new staff, eliminate unnecessary actions, identify relevant metrics, and detect and resolve issues more effectively. (Kvist et al. 1995, 77.)

Modeling processes through description also comes with challenges. A complex process can often be identified by the difficulty of describing it. The level of detail in the description must be carefully defined because too detailed description is time-consuming and may obscure the overall picture, while an overly superficial description fails to capture the process sufficiently, making it harder to identify areas for improvement. (Kvist et al. 1995, 77.)

When describing a process, it is important to highlight the following aspects:

- Resources that are central to the process, such as personnel, systems, and machines, should be included in the description
- All tasks related to the process should be visible in the description
- The products being produced should be shown in the description
- Goods, information, and services flowing between the resources involved in the process should be incorporated into the description.

(Kvist et al. 1995, 77-78.)

### 3.3 Measuring and analyzing processes

A characteristic of process development is that processes are described and measured (Laamanen 2012, 210). A metric developed for measuring processes must target the correct activity, provide the desired information comprehensively, and the resulting data must be easy to analyze and access. (Kvist et al. 1995, 84.) The purpose of measurement is to determine the state of something, with the objective of obtaining information about what is happening in, for example, a process (Laamanen 2012, 149). Putting pressure on personnel is not the objective of measurement rather notice potential deviation and problems immediately in the process (Kouri 2009, 28). In this way, attention is strongly focused on a specific issue and assuring problems and deviations occurred in the process are disclosed (Laamanen 2012, 149; Kouri 2009, 28). The overall efficiency of processes can be measured using various metrics, such as cost, lead time, quality, work-in-progress, and productivity. (Tuominen 2010, 11; Kouri 2009, 29).

Everything starts with analyzing the process and measuring the work, especially when examining the process lead time (Martinsuo et al. 2016, 362). Work measurement is defined as the measurement of the time required to produce a unit or complete a work phase, focusing on the personnel and the activities involved. Work measurement can be conducted through time studies and observational studies. (Martinsuo et al. 2016, 167.) Work measurement provides information about value-adding and non-value-adding time in the work, as well as the waiting and setup times included in the lead time (Martinsuo et al. 2016, 362).

### 3.3.1 Lead time and cost management

Lead time is a metric that illustrates how long it takes to complete a specific task from start to finish. In general, lead time can refer to the total process duration or it can be divided among different production processes, such as the lead time of the manufacturing process. Total lead time refers to the calendar time required for the order-to-delivery process, that is, the time from receiving the order to its delivery. The lead time of the manufacturing process reflects the time it takes to produce the product, from start to the finished product. However, lead time measurement does not account for what happens during the process, such as disruptions in production, set-up times or waiting times, instead, it reflects the total time required for manufacturing. (Haverila et al. 2005, 401.) Lead time is demonstrated in Figure 4, including setup times, waiting times and work cycle times (Martinsuo et al. 2016, 362).

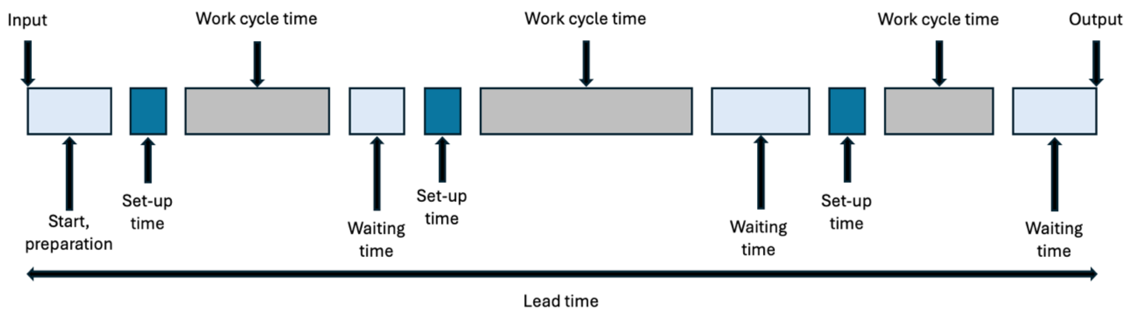


Figure 4. Demonstration of lead time (Martinsuo et al. 2016, 362).

Enhancing lead times do not base on pacing up the production rather eliminate various wait and idle times of machines in production. Research has shown majority proportion of total lead time in production consists of wait time. (Kouri 2009, 21.) Change of tools, materials, programs are set-up times of process.

Preparing to begin a work phase is set-up time as well and reducing set-up times is a way to have an impact on lead times. Size of production batch, use of unnecessary temporary buffer storages and unnecessary movement of products have a negative impact on lead time. Aiming to reduce the size of production batch and delete the unnecessary temporary buffer storages have an effect on reducing wait times and capital engaged in storages. (Martinsuo et al. 2016, 362.)

Companies' target is to reduce lead time in manufacturing process. Experience in the past has shown that reducing lead time enhance processes and performance of production, improve the quality of operation and reduce costs and amount of invested capital in operation. Controllability of operation, reliability of delivery and load factor of the production benefit from reduction of lead time. (Haverila et al. 2005, 357; Martinsuo et al. 2016, 362.)

Companies strive to maintain their competitiveness in current markets. To be competitive, they must define the key competitive factors through which they compete. These factors set the goals for the company's operations and management. Cost efficiency and time are key production objectives. Companies aim to reduce total operating costs by using resources efficiently. In most cases, material costs have a significant impact on cost efficiency, and it has been observed that labor and capital costs are lower than material costs. (Haverila et al. 2005, 357.)

Production time plays a significant role in manufacturing, especially in customer-driven production where products are made based on customer orders. It has been observed that shortening lead time has a positive effect on reducing costs. (Haverila et al. 2005, 357.) By shortening lead time, the capital tied up in work-in-progress and operations decreases. A company in Sweden has found that halving the lead time leads to a reduction in both production costs and tied-up capital. Improving lead time also reflects on enterprise resource planning and its manageability features. Manageability characteristics include the amount of work-in-progress, production lead time, and capacity flexibility. By developing these features, resources can be utilized more efficiently, and the amount of capital tied up in operations can be reduced. (Haverila et al. 2005, 402, 405-407.)

### 3.3.2 Capacity

As previously mentioned, companies use key figures and metrics that suit companies' needs to analyze the state of production and processes. These figures and metrics are used to monitor operations and to set goals for activities. One such metric that reflects operational goals is capacity. (Haverila et al. 2005, 399.)

Capacity, in its simplest form, reflects the amount that production is capable of producing in relation to time, that is, the performance of production. In this context, performance refers to the maximum output capability of a production unit over a given period. The way capacity is expressed may vary slightly depending on the industry and its capacity requirements. The choice of capacity unit depends on the requirements of the products being produced for example some products may require more work than others. There are also differences between industries, in which case capacity can be measured in tons per hour or tons per day. In assembly production, it is common practice to express capacity in hours per week. (Haverila et al. 2005, 399.)

Capacity is closely related to the concepts of load, load group, and utilization rate. A load group can refer to, for example, a single machine, a production line, a workstation, or a work team. Capacity and its load are observed as a whole that is, as a load group. (Martinsuo et al. 2016, 360.) Capacity load indicates how the planned production is allocated. The task of production control is to define the load groups whether broader load groups such as production lines are used, or more detailed load groups, such as machine-specific ones. (Haverila et al. 2005, 399-400.)

The performance of load groups can be expressed using the load ratio, and it can be calculated using a formula, as illustrated in Picture 1.

$$\frac{\text{Load} * 100\,\%}{\text{Capacity}} = \text{Load ratio} \qquad \frac{70\text{h} * 100\,\%}{80\text{h}} = 87{,}5\,\%$$

Picture 1. Load ratio (Haverila et al. 2005, 400).

The load ratio is obtained by calculating the planned load in relation to the available maximum capacity. However, the planned load does not always materialize as expected, which is why we refer to the utilization rate. The utilization rate describes the actual production and can be measured after production has taken place. The utilization ratio, in turn, reflects the utilization rate that is, the realized production’s relation to the capacity. (Haverila et al. 2005, 360; Martinsuo et al. 2016, 400.) The load ratio and utilization ratio are often used as synonyms, even though the input data for each differ slightly (Haverila et al. 2005, 400).

Theoretical maximum capacity is rarely fully utilized, which is why we refer to net capacity. The net capacity reflects the actual usable capacity. When calculating or estimating the net capacity, one must consider reducing production factors such as setup times, production disturbances, defective and incomplete products and materials, as well as staff absences. In most cases, theoretical maximum capacity is actualized at approximately net capacity of 50 – 90 %. (Haverila et al. 2005, 361; Martinsuo et al. 2016, 400-401.)

# 4 Pressure and measuring devices

Pressure measurement is utilized in measuring various process variables through the use of pressure gauges and pressure transmitters. Pressure is the most commonly measured process quantity in industrial applications. (Saxholm & Rantanen 2011, 5.) In addition to pressure, temperature, flow, and level are among the most frequently measured quantities (Pihkala 2004, 9).

## 4.1 Concept of pressure

Pressure is understood as a quantity related to the liquid and gaseous states of matter. The magnitude of pressure is defined as the ratio of the force acting perpendicular to a surface to the area of that surface, as follows: (Saxholm & Rantanen 2011, 5-6.)

$$p = \frac{F}{A},$$

where

$p$ = pressure

$F$ = force

$A$ = area

The unit of pressure in the SI system is the pascal (Pa). One pascal corresponds to the pressure exerted when a force of one newton is evenly distributed over an area of one square meter (1 Pa = 1 N/m²). (Saxholm & Rantanen 2011, 6.)

Due to the small magnitude of one pascal, multiple units are often used alongside it. Common examples include the kilopascal (1 kPa = 1,000 Pa) and the bar, which is not part of the SI system (1 bar = 100,000 Pa). (Saxholm & Rantanen 2011, 6.)

## 4.2 Measuring devices of pressures

Various measuring devices and techniques are utilized for measuring pressures including pressure gauges, pressure sensors and pressure transmitters (Smart Measurement n.d). The use of electronic pressure sensors and transmitters in industrial environments has increased due to advancements in technology and electronics (Saxholm & Rantanen 2011, 5).

### 4.2.1 Pressure sensors

Conventional pressure gauges can be equipped with converter. The purpose of the converter is to convert a force, a motion or a pressure given by sensor to an electrical quantity. Electronic pressure sensors can be classified according to their measuring principles. Various pressure sensors are for example strain gauge, piezoresistive strain gauge and capacitive. (Pihkala 2004, 28.)

### 4.2.2 Pressure transmitters

The core elements of pressure transmitters are the same as those found in pressure sensors. The measuring principles are also similar, however, the key difference lies in the additional circuit. The transmitter has built-in additional circuit which linearizes, compensates, and amplifies the signal, enabling it to be transmitted over long distances between the pressure transmitter and a remote receiver. (Smart Measurement, n.d.)

# 5 Research methods and implementation

The aim of the study was to create a comprehensive overview of the current state of the test drive process, assess how well the process currently meets predefined lead time targets, and analyze how the use of wireless pressure transmitters affects the test drive process lead time, costs, and the pressure measurement phase.

Starting and conducting the research was facilitated by my employment at the commissioning company, which made it easier to familiarize myself with the company and the test drive process. Some of the issues encountered were already familiar to me. The thesis also draws on the researcher’s own expertise, gained through working at the commissioning company.

The thesis was conducted as a case study, serving as the research type for the work. During the study, the current state of the test drive process was examined to create a comprehensive overview of the process. The research methods combined both qualitative and quantitative approaches. Data collection methods included interviews, observations, internal company documents, and work measurement, all of which supported the chosen research methods and provided the necessary information for the study.

A typical case study can focus on a group, organization, or process as the subject of investigation. Regardless of whether a group, organization, or process is studied, they are connected by the scope of the research subject. In a case study, the research is built around a single phenomenon under investigation. The researcher personally analyzes the phenomenon and gathers relevant literature and data related to the case. There are various methods for data collection, with common ones including interviews, observations, statistics, and supporting documents related to the case. (Tietoarkisto, 2025.)

The choice of research methods guides which techniques are used for data collection in the study. Research methods can be divided into two main categories: qualitative and quantitative methods. Quantitative methods are characterized by statistical analysis, and common data collection techniques include experimental studies and systematic observation. This approach aims to represent the phenomenon under study using numbers and percentages. In contrast, qualitative methods seek to explain the research subject by exploring behavior patterns, reasons, attitudes, and values. Data collection methods for qualitative research include interviews, group and individual, participatory observation, and existing materials and documents. (Heikkilä 2014, 13,15.) Both qualitative and quantitative research methods were used in this thesis. Hirsjärvi et al. (2009, 136–137) present reasons why qualitative and quantitative methods can complement each other. For example, qualitative methods can serve as a preliminary study for quantitative methods. The intention is not to set the methods as opposites, rather, numbers support meanings, and meanings support numbers.

The purpose of interviews is to bring out the interviewees' ideas, thoughts, feelings, and beliefs. Interviews aim to study people, and there are various methods for conducting them. In this thesis, semi-structured thematic interviews were used as the interview method. A thematic interview combines elements of both structured questionnaires and open interviews. Typically, the topics of the interviews are known in advance, but the wording of questions varies between interviewees. Thematic interviews allow for a somewhat freer conversation between the interviewer and the interviewee and provide flexibility to guide the discussion. Therefore, a key advantage of this interview method is its flexibility. (Hirsjärvi et al. 2009, 205, 208, 212.)

Interviews reveal what is observed around, but they do not necessarily show what truly happens. Observation played a significant role in the implementation of the research and the results of this thesis. Through observation, it can be determined whether the thoughts, assumptions, and beliefs observed are actually realized. The advantage of observation is that it provides immediate information about what is happening in the environment, often referred to as studying the real world. However, when using observation, objectivity may suffer, or the subject being observed might alter their behavior during the observation. For these reasons, observation can sometimes hinder the collection of reliable data. (Hirsjärvi et al. 2009, 212-213.)

In this thesis, observation was conducted both systematically and participatively. I acted as an external observer and did not participate in the process. However, the observation was informal and did not involve a fully systematic observation approach.

Good research includes basic requirements such as validity and reliability. Validity in research refers to the accuracy or soundness of the study. Validity is achieved when the research methods measure what they were originally intended to measure. Achieving validity is guided by setting precise objectives. (Heikkilä 2014, 27-28.) Reliability reflects the precision of the obtained results. Repeatability and the trustworthiness of responses are key features of reliable research. By repeating the studied phenomenon, for example, through multiple individuals, and consistently obtaining similar results, the research can be considered reliable. (Heikkilä 2014, 28; Hirsjärvi et al. 2009, 231.)

When evaluating the validity and reliability of the thesis, it can be noted that the interviews used as a data collection method consisted of open-ended questions, which can be challenging to interpret. However, during the interviews, consistent responses were observed, and the interviewees were qualified to answer the questions. The research results also support validity, as the findings achieved the intended objectives. The time study conducted on the pressure measurement phase was weak in terms of reliability. The work measurement or the time study, was performed only once, with the pressure measurement phase monitored using a stopwatch. Ideally, I would have liked to measure the time multiple times to improve the reliability of the results, but due to scheduling challenges faced by both the commissioning company and the researcher, this was not possible. Nevertheless, the single time measurement is supported by interviews with the test drive personnel and the researcher’s own experience with the task.

When reflecting on the research, it is important to keep in mind that achieving completely accurate results regarding the studied topics is difficult. The research period was too short to obtain definitive outcomes. The test drive process should be observed and studied over a considerably longer time, especially since the cost impacts achieved through process improvements would be more reliable. There are multiple factors influencing the subject of the study, lead time, and as a result, the process lead time cannot be fully standardized. These influencing factors are recognized within the company. Nevertheless, the results are close to reality and provide the client with indications that the development idea is heading in the right direction and that process improvement using wireless pressure transmitters is feasible.

The research results were obtained using multiple data collection methods. A total of six individuals were interviewed. The interviewees consisted of test drive personnel, the test drive area supervisor, the commissioning company's production manager, and a production development engineer. The interviewees were selected based on their expertise, and the questions were tailored according to their areas of responsibility, while maintaining a generally consistent quality and focus on the research topic. The purpose of investigating the current state was to gain a more comprehensive understanding of the test drive process by breaking down the process into different phases and creating a process flowchart. The new working method, wireless pressure transmitters, was compared to the current test drive process, and this comparison was used to determine whether the wireless transmitters had the desired effect on the test drive process.

# 6 Present state and phases of test drive process

This section focuses on and explores the test drive process. By breaking the test drive process into different phases, it becomes easier to understand the overall picture of the process and the various phases it consists of.

The work phases of the test drive process do not always follow the same sequence, as they are influenced by prevailing conditions such as temperature, schedule, machine options, and any issues or challenges that arise during the test drive process.

## 6.1 Start of test drive process

Production consists of many different manufacturing departments and processes. Production includes frame manufacturing, sub-assemblies, cell assembly, assembly lines, machine testing, and finishing. The purpose of sub-assemblies and frame manufacturing is to produce parts for the main assemblies and thus support the manufacturing of the machine. The actual product, the machine, is assembled in the cell assembly or on the assembly line. After assembly, the finished product moves on to the test drive for testing. In the test drive, the main task of the department is to thoroughly test and inspect the machine, ensuring that the manufactured machine meets the customer's requirements, any installation errors do not reach the customer, and that the machine is capable of performing the tasks for which it was designed. (Personal statement 16.5.2025.)

After the assembly phase, the finished product is first sent for washing. The purpose of the wash is to ensure that the test drive phase begins with a clean machine. Cleanliness and dryness of the machine are important for detecting potential oil leaks and incorrect installations in the beginning of test drive process. During the washing phase, before the actual test drive phase begins, the machine specification sheets, bill of materials, and test documents are printed. (Personal statement 16.5.2025.)

After printing the needed documents and washing the machine, the test drive phase can begin with the inspection of the machine’s main components, such as the bucket, axles, engine, and transmission serial numbers. Before the first warm-up run on the test track, the machine is checked for any loose hydraulic connections and to ensure that all attached components are properly installed, which ensures safe operation of the machine. During the test drive process, the operator has the opportunity to digitally record observations made during testing and inspection, so that supervisors and production stakeholders are informed of any issues detected. (Personal statement 16.5.2025.)

### 6.2 First heating run

During the first warm-up run, the machine is driven on the test track to ensure that all functions such as boom suspension, engine brake, traction control, the machine’s transmission, and the torque converter operate as they should. While driving, the operator also listens and feels for any suspicious resonating noises from the components. The purpose of the first warm-up is to test the machine's functions, accumulate approximately 1.5 hours of transmission run time and about 15 kilometers of driving, and to raise the temperature of the machine’s hydraulic and brake oils. The oil heating is achieved by loading and driving the machine, while repeatedly lifting and lowering the boom. To speed up the oil temperature rise, a bucket weight is added to increase the lifting load and the overall weight of the machine. Brake temperature is increased by applying the brakes forcefully. After driving on the test track and reaching the target transmission hours, driving kilometers, and reaching optimal oil temperatures for the first warm-up run, the machine is driven back into the test drive hall where pressure measurement begins. (Personal statement 16.5.2025.)

### 6.3 Pressure measurement

After returning to the test drive hall, axle temperatures are measured, and pressure measurement of the machine begins. During the first warm-up run, the goal is to raise the oil temperatures to between 50–60 degrees Celsius, as this is the defined optimal temperature for pressure measurement and potential adjustments. Pressure measurement is performed using a separate device, of which two types are used in the test drive process. The pressure measurement devices are Hydrotechnik Multisystem 4010 and Multisystem 4070. Cables with pressure sensors are connected to the device. Sensors enable the detection of the measured pressure and transmit an output signal to the device, which then converts the signal into a readable pressure value, such as bar. Typically, three cables with sensors are connected to the device. The pressure values of the measured points vary depending on what is being measured, so pressure sensors with different measurement ranges are used. (Personal statement 16.5.2025.)

Measurement points in the machine include example flushing pressure, bucket pump pressure, steering pump pressure, and transmission clutch pressures. There are various measurement points available in the machine for pressure measurement, and usually, three pressures are measured at a time. During the measurement process, the cables must be switched between 4 to 5 times across different measurement points on the machine. Some of the pressures are checked directly from the machine's own display, the VCM, with the pressure data coming from the machine’s built-in pressure sensors. The measurement process requires the operator to work from inside the machine's cabin, but when changing cable positions, the operator must exit the cabin and climb onto the machine to disconnect and reconnect the cables to the new measurement points. The employee carries test documents that include acknowledgment fields for the measured pressures as well as optimal pressure values and tolerance ranges for each pressure. During the measurement, the recorded pressure values are written into the documents according to which pressure is being measured. (Personal statement 16.5.2025.)

Once all required pressures have been measured and documented, the employee disconnects the cables from the measurement points, collects the measuring device with its cables from the machine, and returns them to their designated storage location. Sometimes, the measured pressure does not fall within the specified tolerances and adjustments are required. Adjustment increases the time needed for pressure measurement and results in additional movement between the machine and the cabin, as the pressure must be re-measured after adjustments to verify whether the desired pressure value has been achieved. (Personal statement 16.5.2025.)

## 6.4 Inspection of machine and second heating run

After the pressure measurements and any necessary adjustments, the machine and its oils need to cool down. While waiting for the machine to cool, it is inspected for possible oil and fluid leaks. Sometimes the machine is still too warm, so the visual inspection and examination of the machine is continued before checking for oil leaks. Before the second warm-up drive, the machine's own lubrication system and the cabin air conditioning are also tested. (Personal statement 16.5.2025.)

The tasks to be performed during the second warm-up drive can be carried out in the way deemed most appropriate, depending on scheduling factors or the test driver's personal preferences. During the warm-up drive, additional transmission hours and driving kilometers are accumulated. The desired outcome after the first and second warm-up drives is that the machine has approximately 3 hours of transmission time and 30 kilometers of driving distance. During the warm-up drive, the machine is driven, stressed, and its functions are verified, and the machine's stall values are recorded. After the drive, the machine is taken for tractive effort tests, it is weighed, an oil sample is taken, and the alignment of the bucket is assured. The purpose of the tractive effort test is to verify the machine's pulling capacity and performance. All the aforementioned procedures have predefined tolerances, which can be found in the test documentation. (Personal statement 16.5.2025.)

The machine may have an optional integrated scale, which informs the operator of the weight of the material in the bucket. Usually, the scale can be calibrated during the second warm-up drive, either before or after the stall and traction tests. The oil temperature must be raised above 40 degrees Celsius for the scale calibration. After all these procedures, the machine is driven back to the test drive hall. (Personal statement 16.5.2025.)

### 6.5 Finishing off test drive process

Upon arrival at the test drive hall, the machine is inspected for possible fluid leaks, and the final components are checked along with testing any remaining options that have not yet been performed. The inspection targets include the interior of the cabin, boom assembly, lift cylinders and their hoses, safety rails, testing the machine's own fire suppression system, and visually checking the radiators for any defects. Possible options to be tested include the Proximity Detection System (PDS) and the machine’s remote control (RC). (Personal statement 16.5.2025.)

After all these phases of the process, the values recorded during the test drive process are entered digitally into the test documents, after which the test phase can be closed and the machine is ready for the next stage (Personal statement 16.5.2025).

# 7 Research results

This section examines the observations that emerged in the study and presents the research results. The results are compared to the previously defined research questions, focusing on how wireless pressure transmitters affect the test drive process.

The research results were obtained by comparing observations from the current state analysis, utilizing the company's internal documents, testing the wireless pressure transmitters, and conducting a time study. During the observations, employee movements, work methods, and the functionality of tools were also examined and monitored together. This monitoring allowed for close attention to be paid to work performance, working conditions, and safety-related aspects of the work environment.

During the interviews, the interviewees, especially the test drive personnel highlighted factors affecting lead time. Weather conditions have a significant impact on the pressure measurement phase and the time it requires. Outdoor temperature and the humidity caused by rain notably influence how quickly the machine's oil temperature can be raised and how fast the machine cools down before the actual pressure measurement. Due to these weather-related challenges, work tends to become more rushed as efforts are made to minimize the rapid cooling of the oils. From the perspectives of work quality and safety, this increased rush is a negative factor, as it can lead to accidents, disrupt the process, and increase the workload as the process progresses.

The purpose of the test drive is to ensure that customers receive consistently high-quality products and that the machines can perform the tasks for which they were designed. The most significant factors affecting the smoothness and lead time of the test drive process are the quality and success of the assembly lines. This means there are numerous factors influencing the process lead time, and it is nearly impossible to predict the lead time of each machine with minute-level accuracy. Regarding pressure measurement, the biggest influencing factor is the adjustment of pressures.

Product engineer defines tolerances for the machine's measurable pressures, and if the pressures fall outside these tolerances, adjustments are made. The adjustment work itself causes unnecessary movement between the cabin and the machine, extending the time required for the task and consequently increasing the lead time. The need for pressure adjustment depends on the success of the assembly line, where pressure adjustments should primarily be carried out.

## 7.1 Lead time

The study was conducted by selecting as the research subject Sandvik's largest and most common underground mining loader, the LH621. *This section has been carried out as a practical implementation for the commissioning company.* Data on actual load hours of previously completed machines was collected from the company's internal documents. This allowed for the examination of lead times achieved using wireless transmitters and comparison of the method's impact against previously recorded lead times to determine whether the desired outcome is a reduction or increase in lead time. *This section has been carried out as a practical implementation for the commissioning company.*

*This section has been carried out as a practical implementation for the commissioning company.* A key focus of the study was to investigate the impact of wireless transmitters on the lead time. Therefore, the use of wireless transmitters was examined to evaluate how it affects the process duration.

The study of the time required for pressure measurement was carried out in cooperation with the test drive personnel. The investigation was conducted by determining the time taken for pressure measurement using the current method by the test drive personnel. The timing was performed under normal conditions, and the test driver timed the duration of the procedure with a stopwatch.

*This section has been carried out as a practical implementation for the commissioning company.*

Observations of the method’s application revealed that the wireless pressure transmitters enable the combination of the first heating run and the pressure measurement phases. This allows combining of consecutive work stages into a single operation. The observed reduction in lead time within the test drive process is primarily due to the elimination of one separate work phase, achieved by overlapping it with another phase. Wireless pressure transmitters facilitate pressure measurement directly on the test track, allowing real-time monitoring during the heating run. Nonetheless, the test drive process still requires the heating run regardless of whether pressure measurements are conducted. During the initial implementation phase, the new method slightly affects the duration of the first heating run due to its novelty, however, once the method stabilizes, the time required is expected to align with previous benchmarks.

With the implementation of the new method, the pressure measurement procedure was modified, allowing one work phase to be combined with the preceding phase.

*This section has been carried out as a practical implementation for the commissioning company.*

The time required cannot be considered constant due to the number of influencing factors. However, the interviews and observations support the findings. *This section has been carried out as a practical implementation for the commissioning company.*

The time study conducted as a stopwatch measurement revealed that the duration of the initial heating run and pressure measurement decreased by 30,6%, resulting in a 2% reduction in the overall test drive lead time. Considering influencing factors, wireless pressure transmitters effectively accelerate the pressure measurement by 28–40%, which corresponds to a 1,9–2,7% reduction in the process lead time. The adoption of the new method enables a more efficient and productive process.

## 7.2 Productivity

During interviews with the company’s production manager and area supervisor, it emerged that the cost of direct labor constitutes a smaller portion of total costs compared to the materials procured for product assembly. In this thesis, the core task of the test drive phase is to test the finished product, meaning no further components are installed during this stage. Therefore, costs do not arise from materials added to the product but rather consist of personnel wages, capital tied up in the labor process, work-in-progress inventory, and the productivity of the testing phase. Previous studies have shown that reducing lead time can positively impact the amount of capital tied up in work-in-progress and improve productivity.

Interviews revealed that the costs of the test drive are monitored using productivity metrics, which serve as indicators of the process’s cost-efficiency. The study’s results indicate that the lead time of the test drive process can be reduced through the use of wireless pressure transmitters, meaning the process becomes capable of producing more output while maintaining the same capacity.

The study utilized internal company metrics to observe productivity growth. Among these metrics, the focus was placed on the number of machines completed through the process. To monitor productivity improvements, the analysis was first conducted on a single machine model and then expanded to include all machine models passing through the process. *This section has been carried out as a practical implementation for the commissioning company.*

Based on the results, it can be concluded that the productivity of the test drive process increases as the lead time decreases. Wireless pressure transmitters enable faster machine throughput, allowing the process to produce more machines without increasing capacity. With increased productivity and efficiency, the process becomes more cost-effective. Time savings accumulate as the number of machines , resulting in long-term cost savings for the company. Additionally, faster machine throughput reduces the amount of capital tied up in work-in-progress inventory.

## 7.3 Occupational Safety

During the observation of the test drive process and interviews, it became evident that the use of wireless pressure transmitters brings significant improvements related to occupational safety. Performing pressure measurements within the test drive hall generates substantial noise due to operating the machine at maximum engine revolutions, and this noise disturbance would be unavoidable.

The noise poses a risk to hearing, despite warnings and the provision of hearing protection to employees. Additionally, noise exposure often negatively impacts mental well-being, as it is perceived as irritating. Psychologically, exposure to noise reduces work efficiency.

At the same time as the engine’s revolution speed must be increased, the machine’s own fans operate at a speed that circulates air within the test drive hall, causing contaminated air to spread throughout the space, even though regular cleaning is maintained. Another factor is the generation of exhaust gases in the hall. To mitigate this, the hall is equipped with exhaust extractors intended to prevent the spread of harmful fumes. While these extractors successfully reduce most of the exhaust emissions, they are not capable of completely eliminating all fumes.

Pressure measurement is often conducted in the test hall at a location where there is an oil pit. Personnel frequently communicate with each other to ensure that no one else needs to use the oil pit, allowing the work to be completed without interruptions. However, this ideal situation is not always possible, and another test driver may need access to the oil pit. This scenario introduces risk factors, as the urgency and pressure to complete the task quickly can increase the likelihood of workplace accidents and errors during the pressure measurement.

During the task, the employee must install pressure sensors with their gauges onto measurement points on top of the machine. There is a risk of tripping over the sensor cables while walking to the machine, during the connection of the sensors on the machine, or when returning from the top of the machine to the operator cabin. Another risk factor is a high-pressure oil spray caused by incorrectly installed hydraulic hoses or faulty components. In such an event, the surrounding facility and personnel may be unexpectedly exposed to the oil spray, which poses a critical health and safety risk.

While working on top of the machine, there is also a risk of slipping, especially during winter conditions or when the machine is wet and humid after rain. In summer, heat presents additional challenges that negatively affect workers' endurance and performance. For pressure measurement, the machine's oil temperature rises up to 60 degrees Celsius, and heat can be burden during warmer months. It was observed that during the pressure measurement of one machine, workers need to climb onto the machine 4–5 times, which increases physical strain as well as the risk of slipping and tripping. Connecting and repositioning the pressure sensors on the hot machine exposes workers to heat stress, which in the worst cases can cause dizziness while working on top of the machine.

The study revealed that significant occupational safety risks during pressure measurement arise when using traditional pressure gauges inside the testing hall. The implementation of wireless pressure transmitters demonstrated that, instead of the conventional method, pressure measurements can be conducted already during the first heating run on the test track. This eliminates the urgency and pressure to perform the task quickly, as there is no longer a need to reserve space in the test hall. Performing the task outdoors removes several hazards from the indoor environment, including excessive noise, potential high-pressure oil sprays, and harmful exhaust emissions. While the risk of an oil spray incident remains, if such an event were to occur on the test track, neither the test driver, the test hall, nor nearby personnel would be exposed to danger.

Moreover, clear procedures are in place for managing oil spills that may occur on the test track.

The risks of slipping and tripping on top of the machine are eliminated, as pressure monitoring is conducted on the test track during operation, removing the need to exit the cabin during measurement. Consequently, exposure to heat-related strain from repeatedly climbing onto the machine is minimized, allowing employees to maintain higher efficiency especially during the summer months. From an ergonomic perspective, the new method offers significant improvements such as pressure values can be monitored on a separate display while driving, eliminating unnecessary movement between the cabin and the machine.

**Other observations**

Wireless pressure transmitters enable real-time verification of pressure values, and the data can be stored on a device, allowing for the analysis of cause-and-effect relationships regarding the machine's behavior during operation. The method also simplifies the training of new personnel, as pressure measurement can initially be challenging, particularly remembering the exact locations of measurement points and which point corresponds to which pressure. With the new system, such memorization is no longer necessary.

# 8 Conclusions and further development opportunities

The purpose of this thesis was to investigate and examine how wireless pressure transmitters impact the test run process. At Sandvik Mining and Construction Oy, the use of wireless pressure transmitters for pressure measurement during test runs has been under consideration for quite some time. Until now, any assumptions regarding their potential effects on the process have been based solely on speculation among the originators of the idea. Therefore, conducting a study on the subject was both necessary and valuable. The research aimed to analyze lead time, costs, and occupational safety. The company has set future objectives to improve and shorten the lead time of its test run process, making the investigation of this development idea particularly timely.

The objective of the study was to examine the effects of implementing a new method on the target process and to analyze the outcomes of these effects. The main results of the work include a reduced lead time and a working method that promotes occupational safety. The findings suggest that shorter lead times positively influence productivity and, consequently, impact costs. The study confirms the theoretical assumption that wireless pressure transmitters can significantly minimize, if not eliminate, occupational safety risks. Therefore, it can be concluded that the results of the research successfully address the predefined research questions.

The results obtained from the thesis are indicative rather than definitive, as it is challenging to assess the impact of process-related factors on a machine-specific level. The timeframe allocated for the study was not sufficient to draw precise conclusions from the findings. Nevertheless, the results indicate that the chosen development direction is appropriate, and the outcomes may also be applicable to other sectors within the industry.

The study aimed to map the effects on the process and serves as a foundation for improving operations through the use of wireless pressure transmitters. The potential for further development is promising, and it is recommended that the company consider at which stage of production the devices should be installed, who is responsible for their installation, and how they will be returned to their original location after use.

To verify the pressures measured by the wireless pressure transmitters, it would be beneficial to have a device for viewing the pressure readings, along with a mounting bracket for the device inside the machine’s cabin. I would suggest that the pressure transmitters are installed during the final stages of the assembly lines. This would enable their utilization during assembly and not just during testing. The transmitters could then be removed during the tightening phase and returned to the assembly line. However, implementing this approach requires careful planning and further research.

Additionally, machine washing presents challenges in protecting the pressure transmitters, as it is carried out using high-pressure washers operating at elevated pressure levels.

The research was conducted using only one machine model, but it would be advisable to consider applying the method to multiple machine models. The test drive personnel also expressed a desire to direct a related inquiry to product design. The aim of this proposed inquiry would be to request more lenient pressure tolerances, which could reduce the need for pressure adjustments. Additionally, an improved version of the pressure transmitter is available, which would enable real-time transmission of pressure data to a separate network drive.

The test drive phase represents a production bottleneck, as all machines completed in production must pass through this process, and not just anyone is qualified to perform it. Delays in the assembly lines are reflected in the test drive phase as increased workload and pressure. The findings of this study help to alleviate this issue, as the test drive process can now handle machines more efficiently, thereby improving both its throughput and operational flexibility.

The final results enable the commissioning company to make informed decisions regarding the implementation of wireless pressure transmitters and to assess whether the method achieves the desired improvements in the process, from their perspective.

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