Professional MBA
Automotive Industry

Implementation guideline of online inventory tool in context of RTLS inventory management

A Master's Thesis submitted for the degree of
"Master of Business Administration"

supervised by
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Vienna, 09.11.2022

Affidavit

I, **ING. PETER HRIC**, hereby declare

1. that I am the sole author of the present Master's Thesis, "IMPLEMENTATION GUIDELINE OF ONLINE INVENTORY TOOL IN CONTEXT OF RTLS INVENTORY MANAGEMENT", 85 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted the topic of this Master's Thesis or parts of it in any form for assessment as an examination paper, either in Austria or abroad.

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Signature

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Table of contents

ABSTRACT

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The automotive industry has a strong tradition in Slovakia, it has become the most important industry and the driving force of the Slovak economy. Currently, it is the strongest sector in terms of share in the total GDP of Slovakia, exports of Slovakia, but also job creation.

The current geopolitical situation has a significant impact on the functioning of this industry and, of course, on individual companies in the entire supply chain. One of the possibilities to eliminate adverse effects is the use of the most modern technologies. One of them is the Auto-ID technology, which can have a significant impact on the proper functioning of the company. The aim of this work was to obtain data that could be used in the creation of a guideline for the introduction of such a technology in the company.

The first part of the master thesis introduces the Auto-ID technologies, their applications and usage in theory. Main focus is related to inventory management and tracking of the work in process parts in real time and location. The second part explains the methodology of implementation of RTLS and furthermore Digital Twin in the given company. The goal of this chapter was to gain real experience in implementation from the timing, personnel and technology point of view.

In the last part, author analyzes the data from the questionnaire to explicit the experiences of directly involved participants.

Key words: Inventory management, Guideline, RTLS, Digital Twin

1. INTRODUCTION

The main aim of any Company on market is to maximize its own value. The research of elements, that are increasing company value has both theoretical and practical meaning. Scientific literature is full of information about those factors, which are influencing the company value. One of the most important factors is NWC and the elements that consist of, such as the level of cash tied in accounts receivable, inventories and operational cash balances.

The most important objective of the inventory management, as a tool to keep the inventory under control, is to hold the cost related to inventory on the low possible level in order to be still able to fulfil customer demands (Grzegorz, 2008).

1.1. MOTIVATION

My professional experience as a Production control & logistic manager at Tier 1 supplier show me, that the OEM´s are forwarding responsibility and putting more and more pressure on the suppliers in order to keep the market position. General terms and conditions clearly specify minimum stock levels at suppliers. The actual situation is characteristic with daily changes in call offs, significant drops or increases in deliveries and banking of productions. For all of these "effects" is inventory management the key to succeed.

There are several options how to track and monitor inventories. Barcode technology was introduced in a Cincinnati in the United States of America more than 50 years ago. Since then, several technology types were developed to meet user's needs – one-dimensional, two-dimensional and three-dimensional (Hiroko Kato, 2010).

New inventions and new technologies such as Barcodes, RFID´s, scanners and modern inventory systems helping the companies to reach their production and economical goals.

In order for new technologies to be fully utilized, it is first of all necessary for them to be successfully implemented. This work will deal with the issue of proper implementation of the inventory tracking system and subsequent development of implementation guideline. Inventory in this case will mean exclusively work in process parts (WIP), and by the term tracking, the task of this work will be to assess the available localization technologies of inventories.

Situation on the automotive market has significantly changed during the last years and even more last months. Strong support of EU government on EV strategy makes the automotive market very unstable. EU regulations doesn´t always match with the customers behavior, which has very negative influence on the Forecasting. If we combine the EU regulations with the Covid-19 factor, which is partially responsible also for the semiconductor shortage (Debby Wu, 2021), we end up with very unstable and unpredictable situation.

Due to the actual situation with the semi-conductor's shortage and Covid-19, many car producers decided to stop or moderate the production in their plants. Appropriate Inventory management became the crucial determinant to keep the companies competitive especially in the automotive supply chain.

1.2. RESEARCH FOCUS AND PROBLEM

Inventory levels of each company in automotive business are influencing the operation and economical results in many ways. Too high inventories have negative influence on the NWC but melting the money in inventories is not the only problem that company could face of. High inventories go hand in hand with incorrect and inaccurate data from counting errors, increased requirements for storage space and increased requirements on personal resources, which at the end are indirectly increasing the cost of inventories.

This master thesis is processed at Tier 1 suppliers in automotive industry, who installing their capacities based on the yearly contracts and expected weekly demands. Contracted weekly capacity is calculated at 15 shifts and usually the weekly demands (call offs), are following the contracted customer requirements. Any long-term capacity increase or decrease has significant impact on the equipment and personal capacities at suppliers.

Short term increases and peaks, which are no higher than 15% comparing to contracted volumes, are covered with production over weekends. Most of the production processes and capacities are shared between many products and customers. To make it even more difficult, each production process has different capacities.

For such company is the effective and correct inventory management mandatory. First, to fulfill the customer requirements and second to run the production effectively with high equipment utilization and low possible cost.

Currently, the company does not have any tool for monitoring work in process parts. Therefore, this work will focus on the selection of suitable technology for monitoring the production in progress, the subsequent implementation in the environment of selected company, and at the end will evaluate the individual steps of the implementation in order to create a implementation guideline.

1.3. MAIN RESEARCH QUESTIONS AND AIM

The main research question can be formulated as follows:

"How can an implementation guideline for online inventory tool be specified based on the current state of the art in practice insights?"

The sub-research question can be formulated as follows:

"How can be such a guideline defined and evaluated?"

"What are the most important points from timing, personnel and functionality point of view that should be included in the guideline?"

The aim of this master's thesis is to describe inventory management and subsequently to find a suitable tool for monitoring the production in progress in the given company. The next step will be its implementation and at the same time the evaluation of the steps of successful implementation. All these activities will serve as a basis for answering research questions.

1.4. MASTER THESIS STRUCTURE

This work is structured in to the three main parts:

Part 1: Theoretical framework

The theoretical part focuses on the main definitions related to inventory management with respect to inventory evaluation and systems based on the related literature. Main target of this part is to find out the state of the art for the methods and tools that are available in research and on the market.

Part 2: Practical research

The second parts contain detailed description of the implementation of online inventory tool – at Tier 1 supplier in automotive industry and consist of following steps:

a) definition of the status before implementation of online inventory tool
b) implementation of online inventory tool
    - Project team
    - Planning phase
    - Implementation phase
c) Development of implementation guideline

Part 3: Empirical investigation

The empirical investigation is carried out thru the questionnaire with employees, who are directly or indirectly involved in the implementation process of online inventory tool (IT department, lean department, production department, quality department, planning department).

Focus in the questionnaire is pointed on the evaluation of developed guideline.

At the end the data from the theoretical framework, practical research and investigation can be used to answer the main research question, by considering inputs of all parts.

2. THEORETICAL FOUNDATIONS

The theoretical framework will confer about main definitions, important inventory management terms, methods, actual available processes of managing inventory and also challenges and best practices for inventory management. It will also deal about the latest state-of-the-art technologies and systems currently used to track inventories.

2.1. INVENTORY

There are many definitions of Inventory that can be cited. According to APICS Dictionary (Pittman, 2019) "Inventory is defined as those stocks used to support production, such as raw material and Work in Process, supporting activities, such as maintenance, repair, and operating supplies, and finally Customer Service in the form of finished goods and spare parts." Ballou (Ballou, 2004) says "Inventories are stockpiles of raw materials, suppliers, components, work in process, and finished goods that appear at numerous points throughout a firm's production and logistics channel."
Using other words, the main functions of inventory are contribution to meet expected demands, protection against stock-out and active support for effective production.

In general, companies usually dividing inventory in to the 3 main categories:

a) Raw material
b) Work in Process Goods
c) Finished goods

Quantity of raw material on the stock is closely linked to the production consumption. Quantity of Finished goods on stock, companies evaluate like a combination of customer demands and production capacities. Main trigger in the production and inventory planning are therefore work in process goods.

The reason for inventories can varied from company to company. Prachi Juneja (Juneja, 2021) have identified six reasons for holding stock, specifically:

a) Accommodate fluctuating Production Demand. The production schedule is modified based on sales, predictions, orders, and stocking patterns. Consequently, the demand for raw material supply for production is dependent on the product plan in terms of specified Stock holding unit and batch quantities. Holding inventories at a nearby warehouse facilitates the timely delivery of the required amount and item to production.

b) Take into account cyclical and seasonal demand. Market demand and supply are cyclical, based on factors such as seasons, holidays, etc., and historical sales information enables businesses to forecast a sharp increase in market demand well in advance.

c) Scale economies in purchasing. It is discovered that for the corporation, buying raw materials in larger lots and keeping inventory is more cost-effective than buying frequently in small lots. At such circumstances, one makes bulk purchases and keeps inventories in the plant stock.

d) Use Price Increase and Quantity Discounts to your advantage. If a price increase is anticipated in a few months due to changes in demand and supply on the national or worldwide market, the influence of taxes and budgets, etc., companies will typically purchase raw materials in advance and maintain a stockpile as a hedge against rising costs.

e) Cut back on the price and duration of transit. The supply chain may be hampered by a variety of issues, which may cause shipping and transit delays, causing businesses to keep backup supplies of raw materials.

f) Long Items with a long lead time and high demand must be kept in stock. Vendors frequently have lengthy lead times that can reach several months for raw material supplies. Additionally, if a certain item is in short supply and in great demand, supply disruptions may result. In these situations, keeping an inventory and exercising control is safer.

2.2. INVENTORY MANAGEMENT

According to Tony Wild "Inventory management is a well-developed science, not a simple common sense". Companies control the level of inventories, which are the base stone for production processes. Only appropriate usage of all resources and correct inventory management can help to achieve business targets.

Wild (Wild, 2002) defined inventory management as "The activity which organizes the availability of items to the customers. It coordinates the purchasing, manufacturing and distribution functions to meet marketing needs. This role includes the supply of current sales items, new products, consumables, spare parts, obsolescent items and all other supplies. Inventory enables a company to support its customer service, logistic or manufacturing activities in situations where purchase or manufacture of the items is not able to satisfy demand. Lack of satisfaction could arise either because the speed of purchasing or manufacturing is too protracted, or because the appropriate quantities cannot be provided without stocks."

Inventory management basic function is to track the inventory, while trying to minimize the financial impact and optimize the inventory. Benefits of good inventory management are immediately visible in planning and forecasting, delivery time, costs and productivity. According to Relph and Milner (Geoff Relp, 2015) one of the 3 main pillars of inventory management is inventory control.

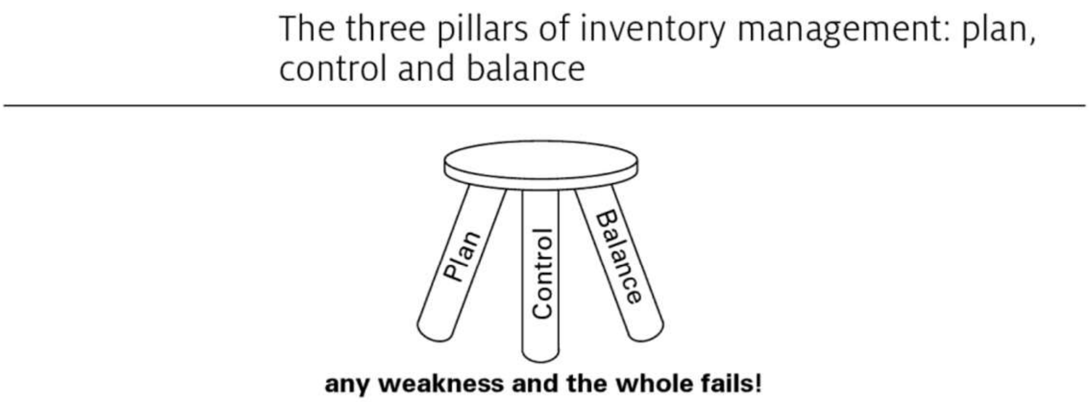

Figure 1 - (Geoff Relph, 2015) The three pillars of inventory management

“Inventory control is about managing the integrity of the stock. Data accuracy is essential:

a) Inventory moves through a physical process. The physical movements need to be tracked by system transactions to accurately reflect where inventory is in the process and in what quantities.
b) It is necessary to ensure that the system records of each product match the physical inventory held.”

(Axsäter, 2015) “Modern inventory control is based on quite advanced and complex decision models, which may require considerable computational efforts. There are important inventory control problems in all supply chains. For those who are working with logistics and supply chains, it is difficult to think of any qualification that is more essential than a thorough understanding of basic inventory models.”

2.2.1. ONLINE INVENTORY MANAGEMENT

Online inventory management as a cloud-based software system, provides organizations with a digitized, logical, and systematic procedure for controlling the incoming and outcoming flow of inventory material. (Chan, 2021)

Traditional inventory control techniques that require time-consuming and expensive manual labor are replaced by the automation built into online inventory management. It enables businesses to effectively manage and maintain inventory stock levels, ensuring that they have the appropriate quantity of merchandise accessible, in the proper location, at the appropriate time.

Every aspect of an organization is impacted by effective inventory management, from storage expenses to the timely and precise fulfillment of orders. Online inventory management is a useful tool for businesses since it automates inventory tracking, boosts revenue, enhances client happiness, and overall makes operations simpler.

2.3. INVENTORY MANAGEMENT METHODS & PROCESSES

Modern methodology offers several appropriate methods that helps you keep your inventory under control. Every business has different conditions, therefore there is no golden rule, which method is the best. Anyway, to use the most suitable method it is necessary to understand them in detail. To the most frequently used techniques belongs ABC analysis, Just in Time Inventory (JIT), First-In-First-Out & Last-In-First-Out (FIFO&LIFO), Vendor managed inventory, Economic order quantity (EOQ), Fast-moving/slow-moving inventory (FSN) and many others.

For the purpose of this master thesis, I have decided to focus on the Perpetual Inventory method as it is the most relevant for the processes, which are described in the work. The reason is that all businesses no matter if stores, warehouses or in this case production facility should be able to identify in detail their inventory. Focus in this master thesis is put on the inventory management and methods of WIP.

Especially in manufacturing companies, it is very important to have immediate information about the WIP parts. Otherwise, proper management, production and human resources planning won't be possible. On the one hand, it is crucial to know the number of parts before and after individual processes, and on the other hand, it is equally important to know where these parts are located. Therefore, we can speak about orientation in quantity and space. Both values are equally important, since for the machine to produce efficiently, it is useless for the company to know only how many pieces there are if there is no information about their physical location. The same is true the other way around.

2.3.1 PERPETUAL & PERIODICAL INVENTORY METHODS

(Perpetual Inventory System, 2017) “Perpetual inventory systems, also known as continuous inventory systems, are systems where the information about the inventory in a facility is updated in near-real time. As an item is used, it will be removed from the inventory system. As new items are brought in, the system will be updated to reflect this as well.”

Using a perpetual system to track inventory, gives the user immediate information about any changes in the amount of inventory and the cost of that inventory through an automated system.

In reality there are many options how perpetual systems for inventory can be used. Technically and this type of inventory of WIP can be handled using just simple excel sheet. Nevertheless, recent technology allowed companies to use much more sophisticated and efficient systems. Main Pros&Cons according to Kellet (Kellet, 2018) are:

Perpetual Inventory System Pros:

a) Knowing your stock levels in real-time allows for more accurate and efficient decisions
b) Real-time transaction data gives you insight into which of your products are selling well and which are not
c) A centralized system makes it much easier to track stock across multiple locations
d) Allows for management to have more direct inventory control

Perpetual Inventory System Cons:

a) Human error – if information is entered incorrectly or not at all, your records will be incorrect
b) Large up-front investment to purchase the software and train employees to use it
c) It takes time to enter every transaction, every time

(Sani B., 1997) Periodic review inventory control system has been claimed theoretically to be the best for the management of items of low and intermittent demand. Various heuristic procedures have been put forward, usually justified on the basis of generated data with known properties.

Periodic inventory system depends on a physical counting of inventories at the end of specific time. This time is usually related to the accounting period, but not necessary. Due to the fact, that it could be really time-consuming method of inventory, most of the companies determine physical inventory only once per year. The period of counting of WIP pieces in production companies, could be much shorter. In order to track the movements of WIP between production processes, periodic counting could be done every day or even every working shift.

Periodical Inventory System Pros (Regoli, 2017)*:*

a) Simple and suitable for small businesses
b) Easy to use, no special training needed
c) Usually, the cheapest solution

Periodical Inventory System Cons (Periodic Inventory System definition, 2022)*:*

a) Minimal information
b) Not and adequate system for big companies, with large inventory
c) Large adjustments
d) Estimation errors.

2.4. INVENTORY MANAGEMENT TECHNOLOGIES AND LATEST TRENDS

Automotive in Slovakia is one of the most important industries in the country. (TASR, 2020) The share of automotive on the total industry reached in 2020 49,5% and export share reached 46,6%. The automotive industry in Slovakia directly employs more than 177,000 people and directly and indirectly generates up to 275,000 jobs.

According to (Mičietová Mária, 2010) companies are gradually changing from manufacturing to assembly types of productions. Necessary precondition for such a change must be strong logistic structure, supported with modern technologies in the whole production process.

Mičietová also indicated, that latest changes in automotive industry were connected mainly with the development of information technologies. The trends in the development of customer and manufacturer requirements for suppliers in the automotive industry can be presented as:

a) Globalization,
b) Pressure to reduce logistics costs to remain competitive in global markets,
c) Customer requirements on deliveries flexibility
d) The need of investment into the new information and communication technologies
e) Shortening of the product lifetime cycle

The main function of logistic information system is tracking the flow of material. To secure this function, clear and effective identification of material in production is needed. (Gleser, 2016) The best solution how to secure ideal overview about movements of the material in company, is to use one of the Auto-ID systems. The system can track passive components of logistic flow (material, product, raw parts), but also active elements, such as pallets or containers. Auto-ID refers to methods of automatically detecting objects, collecting data about them, and processing that data using computer systems.

Kolarovszki and Vaculík (Peter Kolarovszki, 2010) having the same opinion. Automatic identification and data collection (AIDC) is a compact unit dealing with methods of automatic identification of objects, subsequent data collection and their input into computer systems (without direct human intervention). The AIDC group of contactless identification technologies is often also titled as automatic/contactless identification, AutoID or automatic data collection. AIDC represents the process of acquiring external data, especially by analyzing images, audio or video. This data is collected by the sensor and converted into a digital file. Data collection can take place in many ways. Technologies typically considered part of AIDC include barcodes, radio frequency identification (RFID), biometrics, magnetic tags, optical character recognition (OCR), or voice recognition.

There is a wide range of Auto-ID Technologies like Barcodes, Biometrics, Card Technology, RFID, RTLS, Contact memory, Optical character recognition, Machine vision and many others. According to (AIDC Technologies - AIM North America, 2022) the most suitable Auto-ID localization methods for the tracking of movement of material, people or machinery include RFID and RTLS technology. Therefore, I deal with these two methods in more detail in the following chapters.

2.4.1 RFID TECHNOLOGY

Radio frequency identification (RFID) and electronic product code (EPC) are the next generation of automatic product identification. (What is RFID: Radio Frequency Identification, 2022) RFID technology is a simple method of exchanging data between two entities namely a reader/writer and a tag. This communication allows information about the tag or the element carrying the tag to be determined and, in this way, it enables processes to be managed more easily.

It is used to transmit and store information using electromagnetic waves with a frequency ranging from long waves to microwaves. The chip stored on a plastic pad and connected to a spiral antenna is used for a storing and transmitting of information. The EPC electronic product code is a number, encoded in electronic form and stored in a storage medium - chip, which consists of 4 parts. First part defines the type of encrypted number according to Global Standard 1 (GS1). Second part is the EPC Manager – product producer number. Third part is the type of product, and fourth part is serial number dedicated to the products. It allows the user to track all the information about the product (production date, date of use…). It also contains sensor with antenna – electronic device that mediates communication with tags via antenna and reads stored EPC code. At the end a software equipment is needed to filter and manage data in information system.

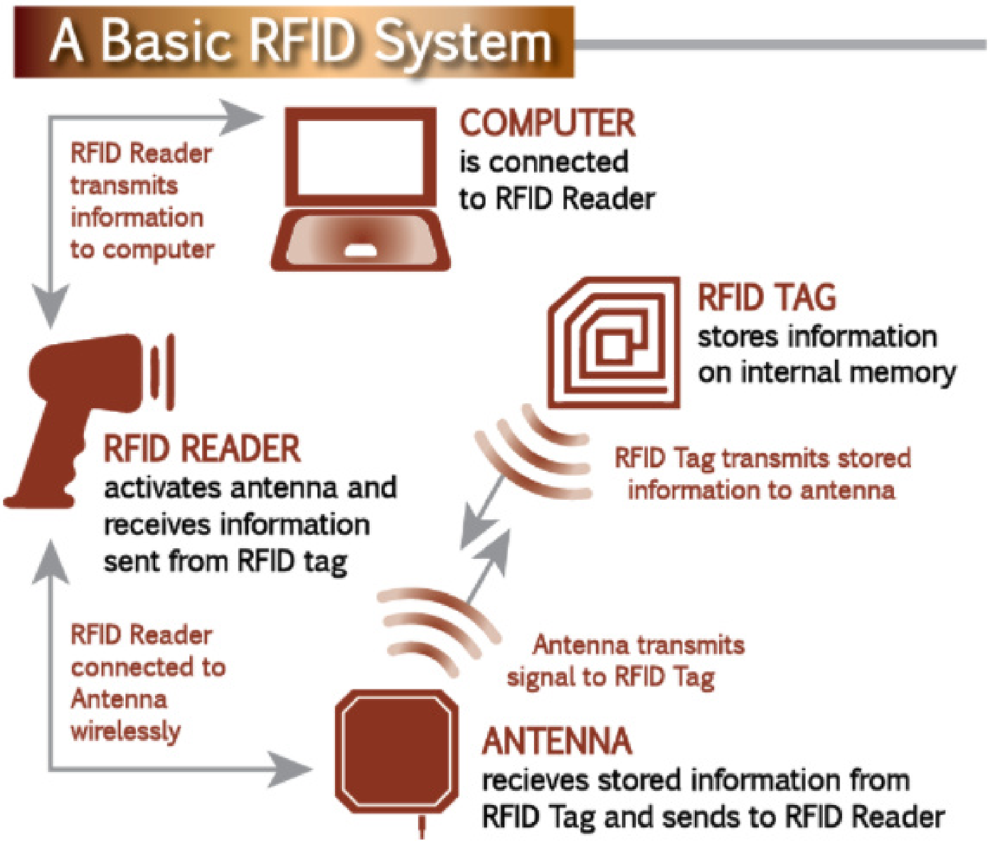

Figure 2 - RFID system (Smartt-tags, 2022)

The Auto-ID center has originally proposed EPCs of 64, 96 and 128 bits. The 96 bits is the most common and provides enough possibilities to cover each manufacturer worldwide.

Auto-ID has obtained a lot of use and attention in the last time. In common it can be stated that especially the RFID sector is supposed to grow in the following years and this technology will gain more and more in our everyday life but also in the industry. According to Raghu (Raghu Das, 2022) the global RFID market decline in 2020 compared to 2019, due to COVID-19's influence. The global RFID market is expected to grow 5% in 2022 comparing to 2021.

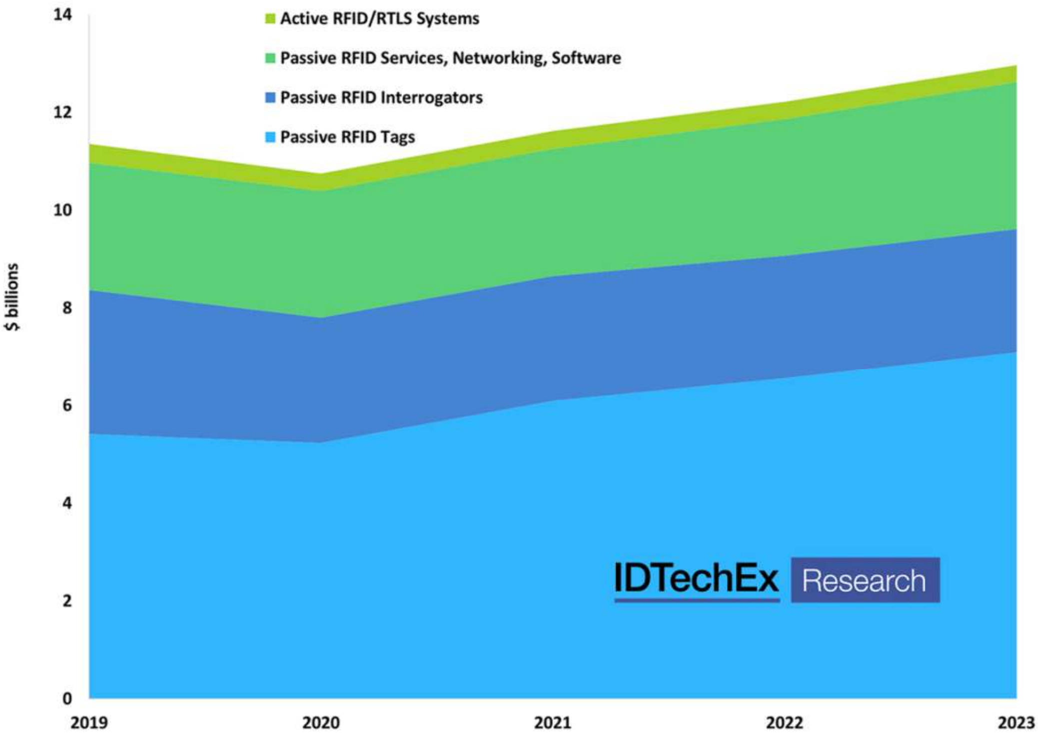

Figure 3 - The expected development trend of RFID technology (Raghu Das, 2022)

RFID technology is often implemented to reduce production cost and optimize operations. If we consider RFID technology to make the production more effective, to track and analyze data collection, there are pros and cons to be weighted.

Pros of RFID in Manufacturing:

a) Does not require line of sight to be scanned or identified
b) Readers can read hundreds of tags within second
c) Tags can be rewritten and reused
d) Tag data is encrypted and can also be locked for extra security
e) Tags are durable and can withstand impact
f) Tags can have additional information printed on them such as instructions, barcodes, or company names
g) System can be integrated with other internal systems or processes

Cons of RFID in Manufacturing:

a) RFID systems can be susceptible to certain materials and environmental factors
b) Initial system costs are higher than with conventional optical scanning
c) Partner companies may not use the same technology causing a disconnect
d) Vulnerability to software attacks (viruses and security breaches)
e) If a tag does become damaged, a redundant system is required
f) Privacy concerns

The most significant benefit of using RFID technology over other methods in manufacturing is that it does not need a line of sight to be scanned or identified. This gives more flexibility to the production and supply chain process. To locate things or persons, signals are transmitted between two or more communication devices. Active and passive RFID technology are the two categories to consider. More detailed description of RFID technology follows in chapter 3.2.3.. The superstructure for identifying objects in space is the RTLS technology, which makes it possible to precisely determine the position of a given object in real time.

2.4.2 RTLS SYSTEM

(Koenig Kyle, 2021) Real Time Location System (RTLS) is a technology that is setup to provide the instantaneous physical location of entities. Further, the accumulated transactional data can be used for reporting and analytics retrospectively.

RTLS is not a specific type of system or technology, but rather a goal that can be achieved through different asset localization and management systems. An important aspect of RTLS is the time at which assets are monitored, and this data can be used in different ways depending on the application. The ideal location system can accurately locate in real time, track and manage assets, inventory or people, and help companies make informed decisions based on the location data collected.

The RTLS system is used not only to identify the tag, but also to locate it and track movement in real time. The system determines the location using small devices located on the objects we monitor. RTLS technology is designed primarily for monitoring and locating objects indoors or outdoors and can be used in many industries.

According to Yujie (Yujie Zang, 2010) there are four classifications of RTLS in terms of locating distances:

a) Locating an asset via satellite - requires line-of-sight - accuracy to 10 meters
b) Locating an asset in a controlled area, e.g., warehouse, campus, airport - area of interest is instrumented - accuracy to 3 meters
c) Locating an asset in a more confined area - area of interest is instrumented – accuracy to tens of centimeters
d) Locating an asset over a terrestrial area using a terrestrial mounted receiver over a wide area, cell phone towers for example – accuracy 200 meters

For the purpose of this work, I will focus on the locating of an assets in a controlled production area, which most resembles the situation in the selected company

Philosophically RTLS resembles GPS but is designed for indoor use and monitoring and digitalization of objects movement in defined area can be both 2D or 3D.

RTLS solutions consist of various platforms like Wi-Fi, Infrared, Ultrasound, Radio Frequency, and others. Following picture is explaining comparison of chosen technologies usually used for RTLS solutions.

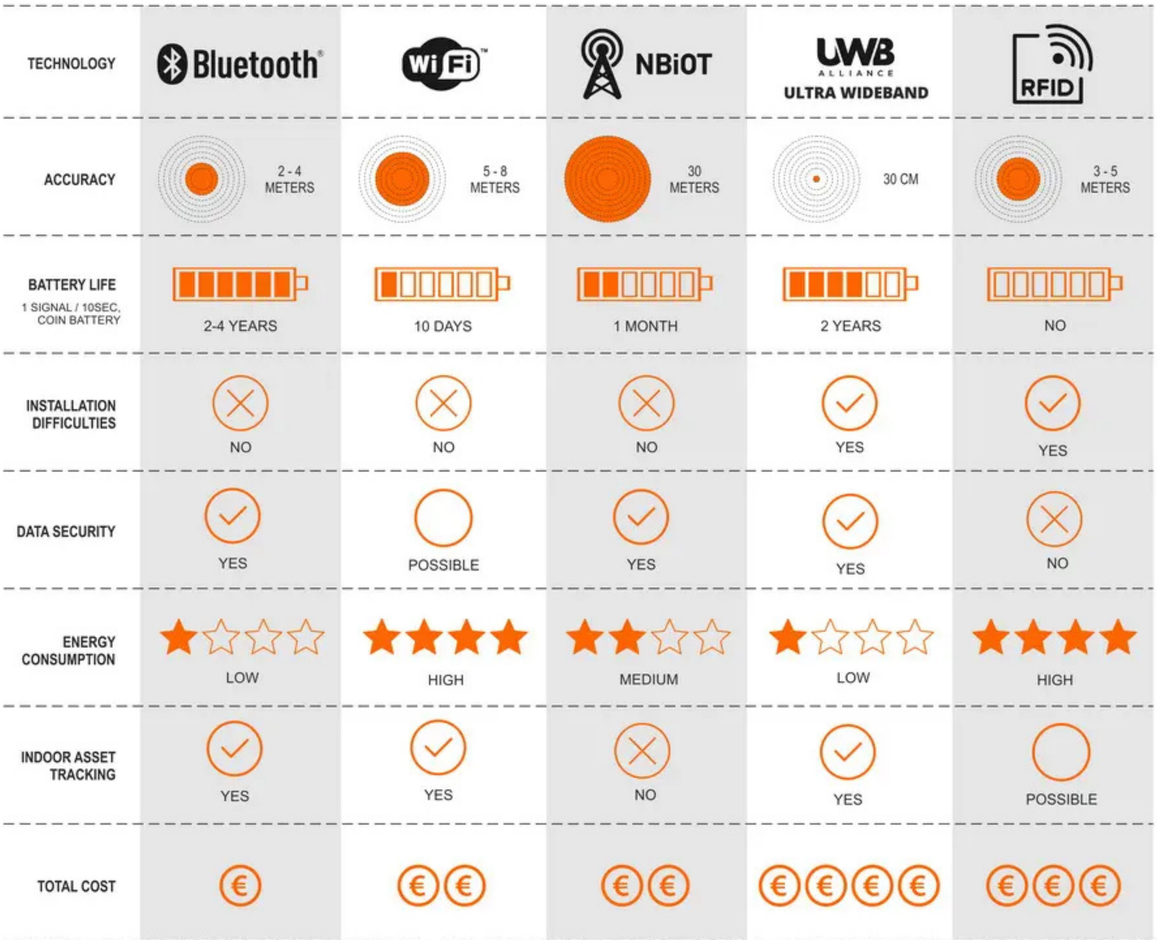

Figure 4 - RTLS technologies comparison (Greciot, 2022)

Different classification can be applied on different types of technologies that are used. RTLS technology can be different in price and functions. Each have advantages and disadvantages depending on the user's needs. Performing a site test is the best way to define the right technology for different types of productions.

Main criteria for evaluating different technologies can be accuracy, battery life, installation complexity, data security, energy consumption and finally and in many cases the most important aspect, the cost of implementation.

The implementation of RTLS systems in industry combines a well-thought-out combination of software and hardware support. Companies dealing with this issue also solve problems in the industrial sphere. Monitoring focuses on monitoring the position of employees, which aims to protect employees by increasing their safety, reducing the time required for assembly and rescue operations, increasing safety and simplifying the reconciliation of working time with the placement of various materials and semi-finished products in these warehouses.

Another application is forklift tracking. This application helps logistics and production managers achieve greater efficiency, profitability and safety by making better use of the fleet, reducing hours lost and, more importantly, accident prevention.

According to Bostelman (Bostelman, 2009), OSHA estimates 110 00 forklifts accidents in USA per year. Approximately 70% of all reported accident could have been avoided with proper safety.

Real-time asset tracking is the process of tracking physical assets in a facility to define its location. Materials or products that are monitored to monitor their flow during the manufacturing process can also be beneficial. The goal of asset tracking is to maximize asset utilization, prevent misuse, and optimize its role in all processes.

Bátori (Batori Tamas, 2021) summarized the main benefits for manufacturers:

a) Real-time tracking of moving objects
b) Generating of reports from the operation of a live logistics system
c) Change logistics processes, re-parameterize in the live warehouse

d) Option to manipulate and configure data between the logistics system and the company's ERP (Enterprise Resource Planning)
e) Fine-tuning the RTLS server system

Superstructure to the RTLS system is Digital Twin. (Real Time Location System (RTLS), 2022) The digital twin combines historical and current data with information from RTLS about the location of personal, forklifts and assets to create a dynamic, real-time digital image of a physical object or process. This tool gives greater control over everything that is happening in production and leads to a significant increase in efficiency and productivity. Following chapter is dealing with this topic.

2.5. DIGITAL TWIN

The manufacturing companies in automotive industry are subject to constant modernization, which is essential for success. The digitization of production data using industrial location elements such as RTLS systems is increasingly recognized. This is due to the results of these systems in the field of worker health protection, but mainly for saving production times, protecting property and products and for saving corporate finances. Within these applications, it is necessary to point out the importance of digital twins, which means "mirroring" physical classifications and processes, on the basis of which it is possible to visualize, evaluate and subsequently optimize the use of assets but also improve production. As a result, industrial practice gains more control over everything that happens in production, thus increasing the efficiency and productivity of the business.

We can consider the following statement (Glaessgen Edward H., 2012) as the main definition of the concept of digital twins: A Digital Twin (DT) is an integrated multi-physical multi-dimensional probabilistic simulation of a complex phenomenon or product, which uses the best available physical models, sensory interfaces, mathematical apparatus, etc. to create a mirror of the existence of its corresponding twin. The existence of a digital twin is conditioned by three components, namely: the existence of a real physical element, a virtual element and a set of data forming a link between a material (real) element or product and a virtual element.

Every second is to the net of Internet of Things (IoT) connected 127 new devices. The quantity of newly connected devices should reach value of 50 billion already in year 2023. With the increase of new technologies such as 5G, this quantity could be even higher. The growth of new technologies is changing the usual methods and established processes in a significant way. All fields are gradually undergoing a digital transformation. Industry and logistics taking the lead in the adoption and implementation of new technologies mainly due to the positive impact on productivity, quality and variability of products and services, as well as the added value that companies can generate through these technologies.

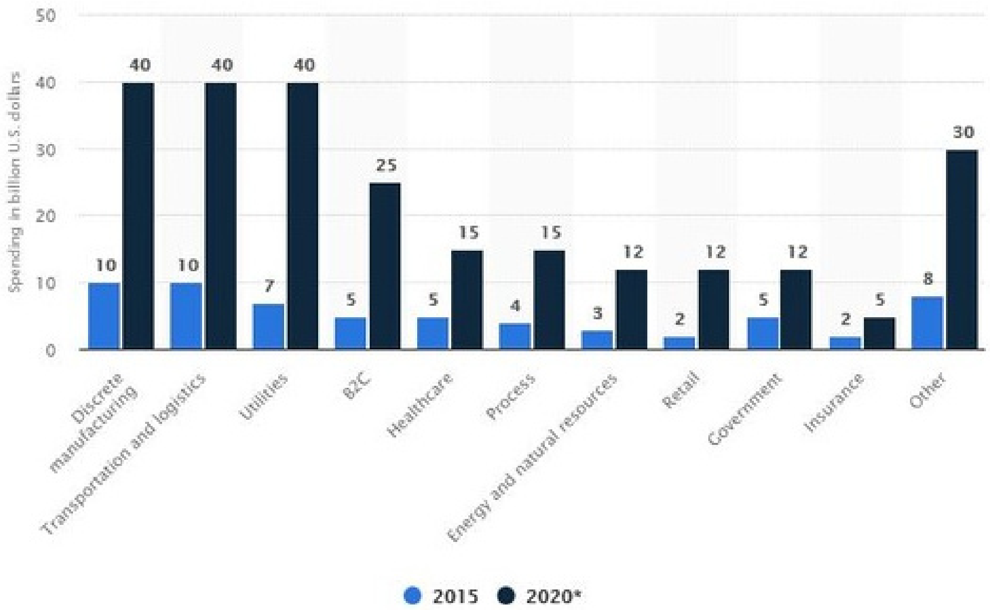

Figure 5 - Comparison of investment in to the IoT in 2015 and 2020 (Vailshery, 2022)

The digital twin is also one of the technologies of growing importance in the era of cyber industry and intelligent logistics. According to a study by the international analytical

company Gartner (Gartner, 2019), 75% of companies using Internet-based solutions (IoT) have already implemented digital twin technology or plan to do so within a year.
Due to the growing importance of the digital twin, Gartner has placed it at the top of the technology trends for 2019. The digital twin has thus entered the basic inventory of digital age industries and businesses, along with the Internet of Things (IoT), Big Data and Machine Intelligence.

Gartner also points out that the increased pace of digital twin deployment is also related to the ever-expanding opportunities that IoT solutions bring to businesses. It is the speed of adoption and implementation of this technology that also indicates the breadth of its use, also given the range of functionalities and added value that it brings to companies.

2.5.1 HISTORY OF DIGITAL TWIN

Concept of digital twin was established long before Industry 4.0. it beginning is dated in the 70-ties, when NASA worked on the project of Apollo. During the Apollo 13 mission, an oxygen tank exploded, seriously damaging the service module and endangering not only the mission itself, but especially the lives of the entire crew on board.
Fast and effective solution must be found to minimize the negative impact on astronauts. Because they had a faithful replica of the spacecraft on Earth with all the technical details, they could reliably simulate a dangerous situation and realistically test hypothetical solutions. It was the opportunity to physically test potential procedures that finally saved the crew. In addition, NASA still uses the twin concept - no longer analog, but digital.

The logic remains unchanged, as it is a virtual model of a physical object that allows you to remotely monitor the state of a real object in real time, as well as model various situations with accurate and real data. Glaessgen (Glaessgen Edward H., 2012) calls the use of the digital twin a paradigmatic move, as conventional methods no longer "meet the demands of next-generation projects."

The same principle applies to production and logistics processes, traditional technologies and methods have already become insufficient to ensure sustainable growth. This means that they can no longer meet the new requirements of the industry - from cost optimization to consumer customizations in mass production.

The term digital twin became more widely known in 2002, when Michael Grieves defined it in connection with product lifecycle management (PLM). He introduced the concept of the digital twin at the time as a virtual representation of the manufactured product and was to serve to compare the product with its engineering design. This definition later expanded and took beyond the original intention of the author. At present, the term Digital Twin means a virtual representation of physical and non-physical objects and entities such as production and transportation facilities, but also processes, systems, workers, data or the whole environment. Thus, the digital twin is no longer just a virtual model of the physical counterpart, but a dynamic carrier of data and status information obtained through a number of sensors and sensors connected by the IoT.

2.5.2 FUNCTIONS & IMPLICATIONS OF DIGITAL TWIN

According to (Paško, 2022), the are 6 most important data that can be gathered from DT:

a) Logistic data for optimization and automatic delivery management
b) Production data from every line and every system for quick decision making
c) HSE monitoring data for threat recognition and emergency response
d) Environmental data for facility management and employee's wellbeing
e) People, goods and forklifts positioning and navigation
f) 3rd Party integration e.g. MES / WMS / SAP / ERP / PLC / HSE.

Figure 6 - 3D live Digital Twin applications (own picture)

The added value for user grows exponentially with combination of different modules as described in table below:

	Description	Use case	Benefit
Location Based Services	Real time position	Track and optimize movement of material	Up to 20% decrease in fleet size
IoT sensors	Real time capture of sensoric and production data	Actual information for decision making	Fast response in case of line stoppage
Analytics & Reporting	Analytic and reporting from RTLS	Summary of events through time from RTLS	Increased efficiency
3rd party integration	Integrating data from other systems	Most important information from multiple systems	Transparent information available for everybody
PLC machines	Live machine data	Maintenance and engineering	Available data for maintenance in case of break down
Health & Safety	Application of HSE control	Control of PPE in dangerous areas	Fast response time in emergency situation
Automatic Ordering System	Uber for intralogistic	Delivery of goods managed automatically	Increasing of productivity
Computer vision	AI driven video recognition	Used cases where standard sensors are not applicable	Most versatile and easy solution for data gathering

Figure 7 - Implications of Digital Twin (Paško, 2022)

Based on the obtained data, the DT offers following features:

RTLS (Real-Time Location System) – The movement of machinery, people & material – who, what, where, when, how long, why?

Benefits: Perfect real-time overview whether logistics, material or people. Workload analysis drop for one device. Less time required for audits and potential fleet reduction.

Automated Ordering System – can be describe as UBER style management for internal logistic, which means calling system for material to production.

Benefits: Real-time control over the internal logistics. Elimination of the micro stoppages of production lines. Increased value added of logistic devices. Potential reduction of forklifts to lower speed.

e-Kanban – Real-time requisition monitoring using as a prevention of over or understocking. Benefits: automatic material supplies and significant reduction of inventory in the supply chain. Uninterrupted data flow and process transparency in real time. Reduced administration cost and considerably less room for human error.

Personal Protective Equipment Control – artificial intelligence scanning for helmets through cameras, recognition in real-time directly on a live feed.
Benefits: simple yet efficient was how to remind the personnel to look out for their own health and safety.

Buffer Analysis – artificial intelligence scanning for material in buffer warehouses, recognition in real-time directly on a live feed.
Benefits: like eKanban, but fully automated without the need of human interaction.

Live Inventory – work in progress goods management offering fast response in quality emergencies
Benefits: real time control of actual stock. Elimination of inventory counts and searching for goods. Optimization of WIP stock quantities.

3rd Party Systems (e.g., SAP Integration) - production data of all different kind under one roof, accessible from a mobile device.
Benefits: access to vital production data. Higher machine utilization thanks to an OEE detailed monitoring and preventive maintenance actions.

On the flight simulation – comparison of simulation with what really happened. Detection of bottle necks in real process against simulation.
Benefits: understanding of how production can run and what has to be done.

The digital twin is used to monitor physical objects and non-physical entities as well as processes in real space and time. This technology allows to create a very detailed digital image with real data. Their use in complex simulation models speeds up and simplifies decision-making processes, as it simplifies the direct identification of possible consequences of the considered changes as well as key patterns of behavior in individual processes.

2.6. GUIDELINES

The need for the existence and elaboration of internal guidelines in companies arises primarily from legal regulations and subsequently from the internal needs of work organization and management. From the point of view of the employer and its employees, it is necessary to identify certain activities and define the obligations of employees clearly and comprehensibly.

2.6.1. WHAT IS GUIDELINE

To better elaborate guidelines, we would need to look in couple of scientific publications. Schiffer (Schiffer, 2010), has defined the company guideline as the regulation with the highest importance and longer validity. He also pointed out, that internal guidelines should not only be created for the purpose to fulfil the obligations coming from the law, but mainly it should be the tool, to improve internal management. Landa (Landa, 2005) defines the guideline as a document in details describing specific activity in company, which determines the obligations of the relevant organizational units of the company and determines the procedures for fulfilling these obligations.

Guideline represents some process, norm or regulation, that has to be completed at specific situations and is crucial for correct assessment of reality. Correct evaluation of results is important for setting of additional tasks, that needs to be accomplished to achieve positive product. Therefore, it is very important, also for small companies, to have the system of guidelines and do not rely on memory of employees.

According to (Louša, 2002), guidelines can be issued as a manager's order, methodological guideline, instruction, circular, or in any other form. This is corresponding with the explanation of (Kovalíková, 2003), that guidelines can be issued as:

a) Methodical guidelines
b) Organizational guidelines
c) Internal guidelines
d) Instructions
e) Circulars
f) Letters
g) Decisions
h) Regulations
i) Commands
j) General director instructions

2.6.2. FORM AND ROLE OF GUIDELINE

According to (Kovalíková, 2003) the most important the content of the guideline and the practical usage of the rules and procedures, not just its formal side. It is also important, that the guidelines are not just on paper but are a living document that is followed and that workers are willing to work with when they need it for their work.

According to (Jakubka, 2008), the guidelines determine:

a) The ways of performing individual functions
b) The functional content of senior employees
c) Other relationships, e.g. method of selling information

They should ensure automatic operation and at the same time provide sufficient space for independent decision-making and activity of individual employees.

In general, we can say, that guideline help guiding employees through a process or task. A guideline gives specific instructions how to perform a task or how to proceed in a particular situation. It contains more details than a procedure and is only created if detailed step-by-step instructions are needed. A synonym is Working Instruction.

2.6.3. WRITING PRINCIPLES OF GUIDELINE

When writing internal regulations, the features they should contain should not be forgotten. This includes comprehensibility, materiality, brevity, unambiguity, complexity, inconsistency with the general binding regulations and follow-up to other internal regulations of the relevant entity. At the same time, internal guidelines should be reviewed and revised annually. At the same time, it should not be forgotten that changes to directives must respect legislative changes as well as practical experience during the application of directives (Schiffer, 2010).

According to (Kevin Wilson, 2010), by writing a guideline, following steps should be followed:

a) Create an outline of the topics that could be covered by the policy, rule, or guideline
b) State the purpose of the policy, rule, or guideline
c) State clearly what the policy, rule, or guideline allows and doesn't allow
d) Explain to whom the policy, rule, or guideline applies
e) Provide any background information that provides context on why the policy, rule, or guideline is needed
f) List any legislation that governs the policy, rule, or guideline
g) Describe any specific procedure that must be followed
    - Use short paragraphs or numbered steps
    - Group tasks together under subheadings
h) Explain what to do if violations occur
i) Explain any terminology that may be confusing to a general audience of employees
j) List any special circumstances when the policy, rule, or guideline does not apply
k) List any time restraints if applicable, including the effective date

Guidelines are general recommendations, or better to say, they are not mandatory. Their main role is to guide employees through a process or a task. Mostly they are offering only advice and if employees do not follow them, there should be no disciplinary punishment. Comparing to policies, guidelines are more informal, and they leave room for variability and space for employees to use their best judgment. Nevertheless, guidelines are through their best practices very important documents in companies.

Discussion

Effective inventory management in any manufacturing company is crucial for the healthy functioning of the company and the achievement of set economic goals. In general, we divide stocks in production companies into raw material, WIP parts and finished goods. The task of the previous chapters was to describe the importance of inventory management, the main methods of tracking WIP parts and outline new technologies that deal with this issue.

The best way to ensure the tracking of stock movement in the company is to use one of the Auto-ID systems. Among the most widespread technologies used in the industry to track inventory is RFID. Its use is also very popular in the automotive sector. RFID technology can provide accurate "point in time" information about the location of a given object. This means that additional location activity is required when the location is changed. If the company wants to have "in real time" information about the current location of the tracked object, it uses RTLS technology. This technology enables monitoring the movement of objects in a defined space and in real time. Usually, such monitoring takes place inside buildings, halls, or other objects. Basically, it can be said that it complements the Global Positioning System (GPS) with its philosophy. However, it is not excluded that RFID technology can be the basic building block of RTLS.

DT is a kind of superstructure of the RTLS system. DT is a solution built on the collection of data from processes, their evaluation and subsequent optimization of these monitored processes. A good RTLS integration into DT enables it to be used for numerous purposes across the entire facility, greatly improving operations and inventory management.

The mission of the digital twin from the point of view of Inventory management is to be able to quickly and accurately tell where the stocks are in real time and what their ideal level should be. It can also be said that DT optimizes the management of stocks and production processes, while primarily focusing on increasing productivity.

Implementation of any Auto-ID system in a manufacturing company is a complex process. Various factors enter it, whether from the point of view of technology, processes or personnel. Helping factor for the introduction of the Auto-ID system in the company could be a certain implementation guideline. In chapter 2.6. are described the main functions, tasks and forms of guidelines. This chapter is also dealing with their use and basic principles that should be adhere by writing them.

The following chapter describes the entire process of selection, implementation and testing of the selected Auto-ID system in Nemak Slovakia. The aim of this chapter is to gain practical experience in implementing such a system and use them to create the implementation guideline.

3. IMPLEMENTATION OF RTLS IN NEMAK SLOVAKIA – DEFINITION OF STATUS

The company, in which the practical research took place is a well-established Tier 1 supplier on the automotive market, focusing on production of aluminum components. Production process consist of several independent steps, each with a different capacity. Continuous production is running 24/7 with 4 shifts pattern. Because each process has a different capacity, planning department must calculate with buffers, which is significantly increasing level of work in process parts. Inventory of WIP parts is done with manual counting only with excel/paper evidence. Several workshops and projects were sponsored by the company in the past to improve accuracy of manual counting mostly only with small effect. Projects were targeted on to improve actual status by using existing systems and technologies. As main triggers to improve daily inventory counting were recognized following points:

- Same time principle: inventory is done always between 5am and 5:30am
- Same people principle: inventory is done always by the same workers
- Layout strategy: layout has been divided to 6 areas to avoid double counting and clearly specify responsibilities

As a result of a daily inventory counting of work in process parts an excel table is maintained every day until 8:30. Digits coming out of manual counting are than compared with the numbers coming out of the central company system, in this case SAP.

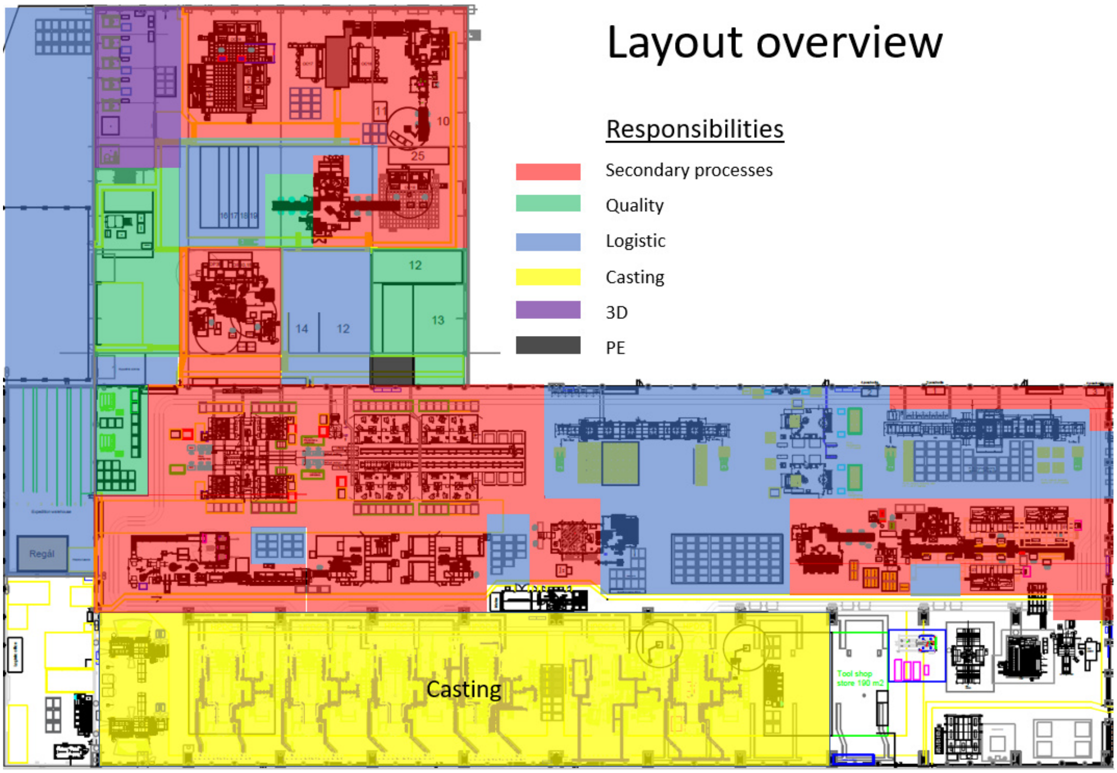

Figure 8 - Inventory layout (own picture)

As main disadvantages of manual counting were observed following points:

a) Counting is done by fully running production – movement of material
b) Counting errors – human factor
c) Very low declarative value and repeating counting
d) Negative impact on productivity and equipment utilization

As a result of above mentioned, company was struggling in proper utilization of personal and equipment. More than 60% of all downtimes in company were registered as a “lack of pieces”.

To improve the status, company has decided to implement online inventory tool.

3.1. IMPLEMENTATION OF RTLS

Before implementation of Digital Twin, company has decided to use the Canvas tool of The Value Proposition. Canvas main idea is, to ensure that a final product is positioned around the customer values and needs.

The Value Proposition Canvas can be used when there is need to refine an existing product or service offering, or where a new offering is being developed from scratch.

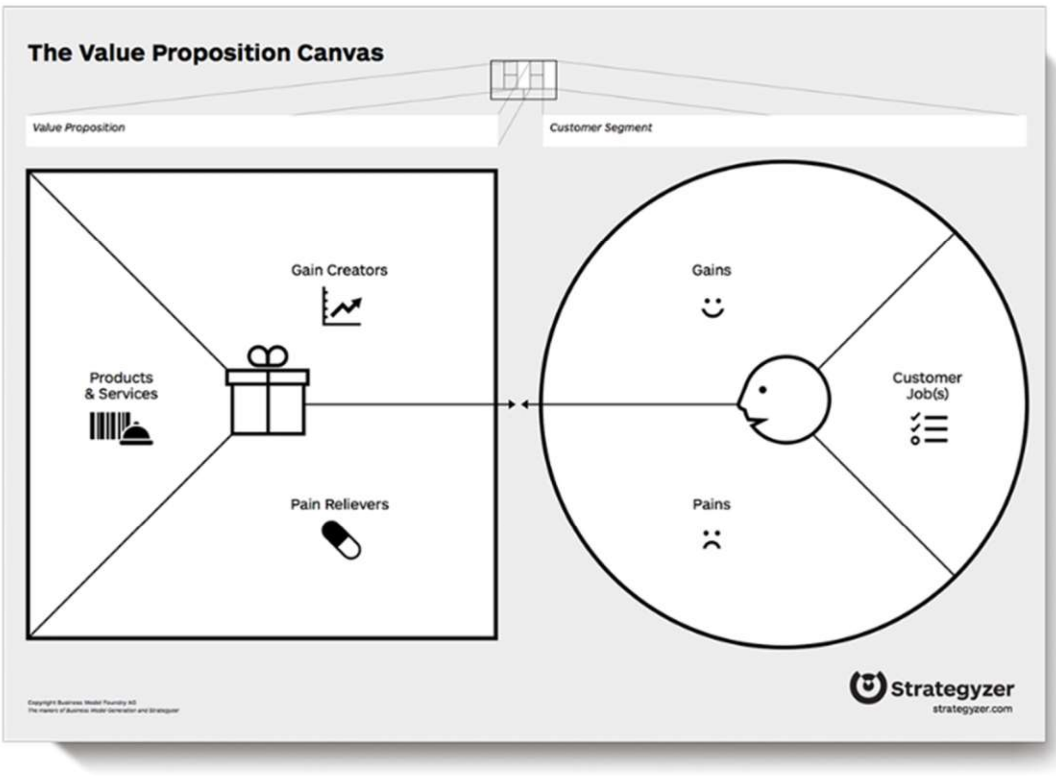

Figure 9 - The Value Proposition Canvas

The canvas consists of two parts – customer segments (circle on the right – Figure 8) and value map (square on the left – Figure 8).

a) Customer Segment

Gains – the benefits which the customer expects and needs.

Pains – the negative experiences, emotions and risks.

Customer jobs – the functional, social and emotional tasks.

A customer profile should be created for each customer segment, as each segment has distinct 'jobs to be done', pains and gains.

b) Value Map

Gain creators – how the product creates customer gains and how it offers added value to the customer.

Pain relievers – a description of exactly how the product alleviates customer pains.

Products and services – the products and services which create gain and relieve pain, and which underpin the creation of value for the customer.

Based on the Canvas tool, following points were identified in the company (Appendix 1)

a) Customer Segment:

Gains – electronic online WIP connected with internal production data capturing system

- Implementation of real time location of any part in production
- Better location of blocked parts
- Immediate quality feedback on suspicious parts

Pains – Paper evidence

- Blocked parts difficult to find
- Extra manipulation
- Manual inventory counting – extra personal needed
- No real time evidences

Job - Daily real time online inventory status

- Automatic OEE data capturing
- Casting and secondary operations

b) Value Map

Gain Creators –technology for location

- Mobile application with 3d layout
- Integration data from localization
- Unlimited versality

Pain relievers – localization <1m

- Real time electronic evidence
- Navigation according to paired DMC with box identifier
- Reduced manpower for manual counting

Product & Services – RTLS System

- 3D Layouts
- Logistic tracking and calling system
- Electronic data integration

With the help of the Canvas tool, the company was able to identify clear expectations, as well as the actual problems it faces by inventory management. The next step was to define a product that is precisely tailored to the needs of the company.

The result is that the product should meet the function of RTLS, 3D layout and should be compatible with the enterprise system. After the idea is clearly defined of what the product should look like and what functions it should fulfill, the implementation phase can start.

3.1.1. PROJECT TEAM

For the needs of this project, the stakeholder map tool was used to classify external stakeholders. The map is used to divide interested parties into 4 categories according to the impact on the result and the expressed interest in its fulfillment.

Power		Interest: Low	Interest: High
	High	**Keep satisfied** Management of company Bussiness unit management Quality department	**Manage closely** Lean department Logistic department IT department Production department Data capturing department
	Low	**Monitor** Project management	**Keep informed** Process engineers Customer service Planning department

Figure 10 - Stakeholder map

Based on the Stakeholder Map, the team was nominated from the following departments:

a) Lean Department – innovation department responsible for lean activities and implementation of industry 4.0.
b) Logistic Department
c) Data capturing Department
d) IT Department
e) Production

In order to track the project, team has evaluated simple A3 format based on the PDCA (plan-do-check-act) methodology to control all activities (Appendix 2).

PDCA cycle as well-known as Deming cycle is a method of continual process improvement. For example, the quality of products, services, processes, applications and data.

According to (Johnson, 2016) The concept of PDCA cycle was first discussed in 1939 in the book of Walter A. Shewhart, *Statistical Method from the Viewpoint of Quality Control*.

It takes place in the form of repeated implementation of four basic activities:

P - Plan - planning the intended improvement (intention)

D - Do - implementation of the plan

C - Check - verification of the result of the implementation against the original intention

A - Act - adjustments to both the intention and the actual implementation based on verification and the widespread implementation of improvements into practice

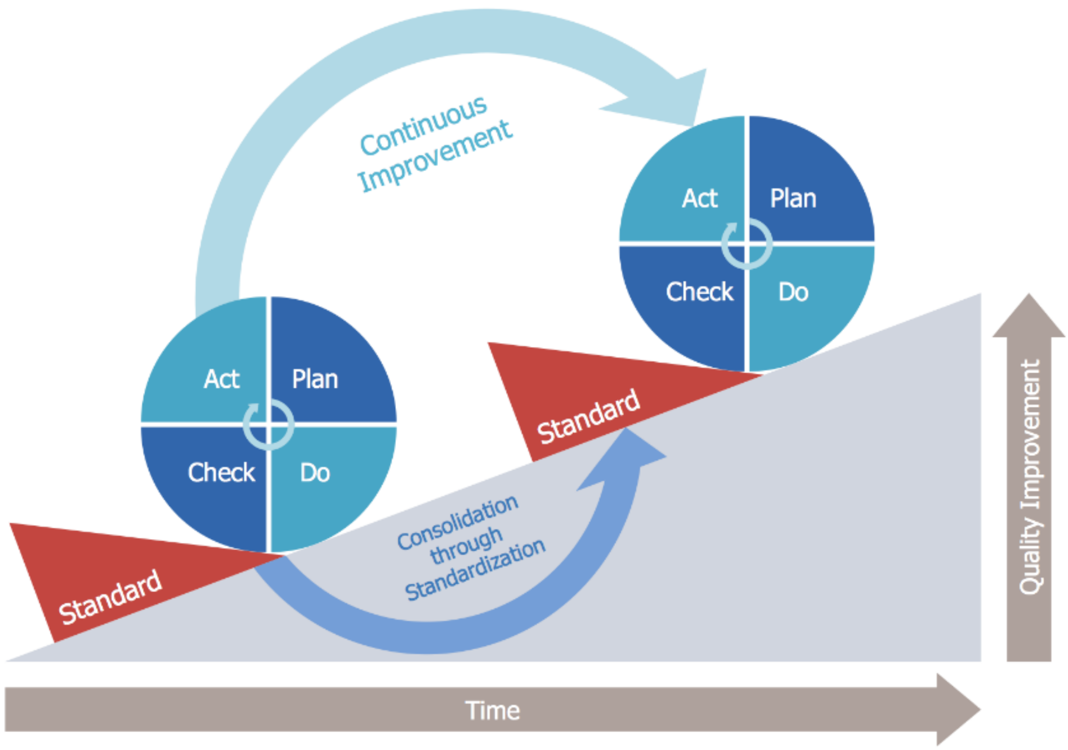

Figure 11 - The PDCA cycle of continuous improvement

The periodicity of the team meetings was once per week, where the A3 format was regularly updated. With the help of the Canvas tool the team was able to identify first activities on the beginning of the implementation phase. (Appendix 2)

1. Clear definition of expectations and needs
2. Market research – available suppliers on the market for RTLS
3. Choice of technology and supplier

3.1.2. PLANNING PHASE

1. Clear definition of expectations and needs

This job was already done and described in the chapter 3.1. Implementation of RTLS.

2. Market research

When researching the market, team focused mainly on solutions that offer the localization of goods in closed spaces. Thus, the main search condition was RTLS solutions. After a deeper analysis and several reference visits, the team came up with a proposal to implement Digital Twin as the most suitable solution for the online inventory management. The features of Digital Twin were already described in chapter 2.5.2.

3. Choice of technology and supplier

Following the results from market research, team was able to identify potential technical solutions. Each potential supplier has a chance to present their solution together with organization of reference visits. Based on the offers from potential suppliers, team created decision matrix to choose the most suitable solution.

Area	Evaluated indicator	Solution Nr.1		**Solution Nr.2**		Solution Nr.3		Solution Nr.4	
		Yes	No	**Yes**	**No**	Yes	No	Yes	No
Technical solution	Accuracy for localisation	X		**X**			X	X	
	Software interface	X		**X**		X		X	
	Technology roadblocks		X	**X**		X			X
	Required hardware (Printers, RFID scanner, RFID high distance scanner, Tags)	X		**X**		X		X	
	Software compatibility		X	**X**		X			X
	Maintenance	X		**X**		X		X	
	Logistic material - box suitability	X		**X**			X		X
	Preparation with IT infrastructure (wifi, connections)		X		**X**		X		X
Cost	Total cost including hardware and software		X		**X**		X	X	
Personal	Easy of use	X		**X**		X		X	
Timing	Implementation period	X			**X**		X	X	
Total Score		7	4	**8**	**3**	6	5	7	4

Figure 12 - Decision matrix

Together 4 areas were evaluated - technical solution, cost, personal and timing. In the area of technical solution team evaluated 8 most important indicators. Based on the decision matrix, team was able to choose the most suitable solution. In this case chosen supplier is meeting all technical requirements with the need of IT infrastructure preparation. Total cost and timing for implementation are exceeding budgeted values, but pros of technical solution were assessed as more important.

3.1.3. IMPLEMENTATION PHASE

Starting point of the implementation phase was clear identification of the process, that will be implemented as Digital Twin. Physical movement of the inventory in the plant is carried through out metal boxes. Each part in the process has its own unique DMC code and can be easily identified in any process step of the production. The main idea of the localization of parts in production is, to connect unique DMC code of each part with the RFID tag of the packaging. This would give to the users of the Digital Twin clear information of which part is placed in which packaging and where it is physically located. Following figure is explaining the process flow.

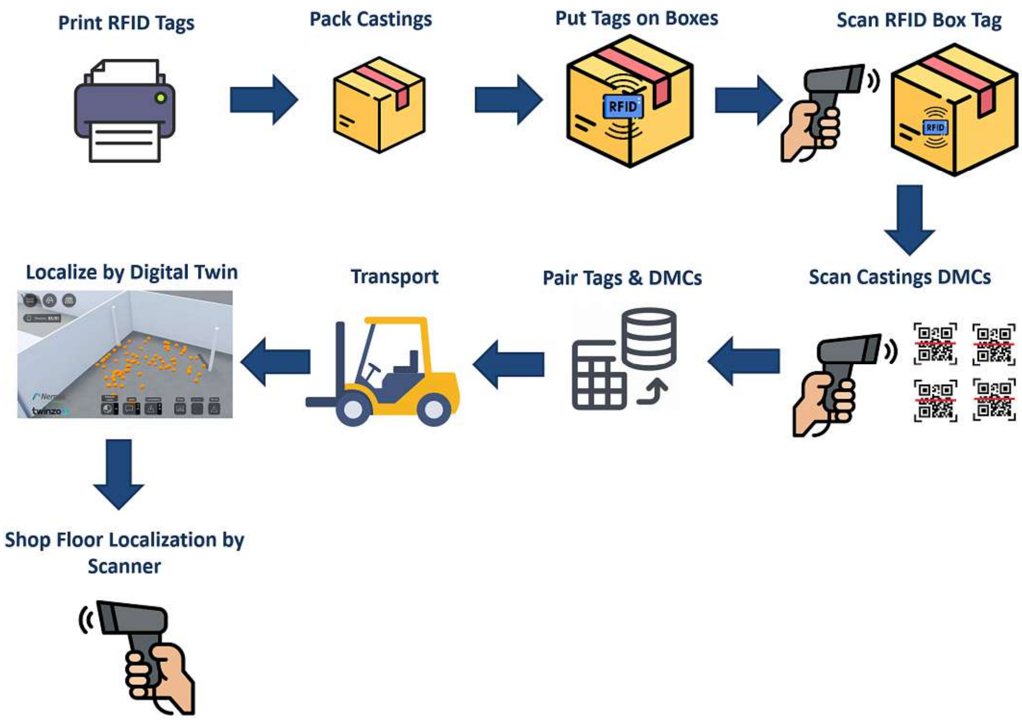

Figure 13 - Process flow of proposed solution (own picture)

From the technical point of view, implementation phase can be divided in to the two segments – hardware and software.

Based on the decision matrix mentioned in previous chapter, the team was able to identify the best solution for the company. The chosen technology for RTLS was based on the RFID technology. As described previously on chapter 2.4.2. it is a simple method of exchanging data between two entities – reader/writer and the tag. To be sure that the data are properly maintained and evaluated, appropriate software and interfaces are needed.

The DT has countless uses in manufacturing businesses. The main ones include the immediate detection of an undesirable event in the production or logistics process, optimization of the production process with regard to equipment performance and the production plan, and last but not least, the localization of products, people, machines and also forklifts. The introduction of Digital Twin in the environment of the given company is exclusively concerned with the topic of RTLS and therefore the localization of products in the production process and their subsequent visualization.

- **Setting up the area**

For this project, the team has determined the area within the production layout. In this case it was the area of secondary operations. For better understanding, secondary operations in the plant consist of following process steps: heat treatment, straightening, grinding, machining, washing, quality check, assembly and packaging.

- **3D modeling of the area**

Next step in the process was to mirror the chosen area into the 3D layout. This 3D layout is than used as a displaying background in the Digital Twin.

Figure 14 - 3D layout (own picture)

- **Installation of Antenna**

The performance of the antenna is very much affected with the environment in which the antenna and tags are placed. It makes a big difference if the tag is placed on the metal, paper, wood or living tissues. For this project the team together with the supplier choose the passive RTLS smart antenna CS-445B series with following specifications:

Tag read distance – 14m

Mounting height – 9m

Tag read period – 8ms

Location accuracy – 0,3m to 0,5m

Size – 60x60x10cm

Weight – 6,8kg

CS Smart Antenna Technology is the source of RTLS data, which is filtered and customized from the RFC Operating System. It is an essential component to delivering hands-free, continuous, 3D location of passive tags.

Figure 15 - coverage method & in reality (own picture)

Thanks to its size and weight, the antenna is suitable for installation under the roof.

- **RFID Tags**

Tags can be divided according to several aspects. They are divided according to the principle of work, according to the type of memory, according to the method of reading and according to the carrier.

According to the principle of work, tags can be identified as active and passive.

Active Tags - greater reading and writing distances can be achieved by supplementing the circuit with a miniature battery, which serves to power the RFID tag and enables a greater reading range. RFID tags equipped in this way are called active. The advantage of active RFID tags is not only greater range, but also the possibility of supplementing the functionality with an integrated shock, pressure, temperature sensor, etc. An example is a hybrid RFID tag with an integrated temperature sensor, which can record ambient temperature data at regular intervals, thereby ensuring loading control with meat products on their way from the producer to the refrigerated box in the supermarket. Active tags also have one indisputable disadvantage, namely a limited lifespan.

Passive tags - The actual communication between the RFID reader and the data medium takes place using radio waves, which are often also used for power supply data medium. In such cases we speak of systems with passive tags. Each RFID tag consists of a memory chip, a conductive connection, an antenna and a capacitor. A capacitor is an electrical component used in electrical circuits to temporarily store electrical charge. These tags do not need a power battery for their operation. They obtain the energy to power their circuits from the energy of the electromagnetic field emitted by the reading device. (Faranak Nekoogar, 2011)

According to the carrier there are several types of RFID tags currently used in the industry like self-adhesive labels, smart labels, plastic tags, ISO cards and many others. To the implementation of RTLS system in the company, the team has decided to test both active and passive type of tags. The goal of the test was to check following indicators:

a) Lifetime and cost
b) The accuracy of visualization in the 3D model of the plant
c) Method of attachment on the metal box

In total there were 3 types of tags tested:

a) Active plastic tag – including small battery
b) Passive self-adhesive label - without isolation
c) Passive smart label – with isolation

Figure 16 - Active plastic tag / Passive self-adhesive label / Passive smart label

A simple test showed the following results:

a) Lifetime and cost

The test was performed only in a short period of time, so it was not possible to prove the lifetime of the active tag. According to available information, the lifetime of an active tag is from 3 to 5 years, depending on the battery. The lifetime of a passive tag is unlimited and depends only on whether the given tag is damaged or not. The price of a passive tag is on average 30 to 50 times lower than the price of an active tag. (Proctor, 2021)

b) The accuracy of visualization

The conducted test had somewhat surprising results. Active tag and passive tag with isolation achieved the results declared by the manufacturer. Both were located with an accuracy of up to 1m. Conversely, a passive tag without isolation was not detected at all. The given result was probably influenced by the metal structure of the hall, as well as the packaging on which the tags were attached.

Figure 17 - 1 Active plastic tag / 2 Passive self-adhesive label / 3 Passive smart label

c) Method of attachment on the metal box

The way, that tags are attached generally depends on their design and the material they are attached to. In this case, the tags were sticked on the metal packaging. The active tag, wrapped in plastic, did not have a self-adhesive surface, therefore additional adhesive was used. Passive tags already contained self-adhesive material and therefore application was easier. However, both methods were sufficient from the point of view of the ability to stay on the given material.

When deciding which tags will be used in production, several aspects need to be considered. For some tags, it has been shown that the environment plays a decisive role in their localization. From the point of view of lifetime and costs, passive tags appear to be more suitable since their localization is important for the needs of Digital Twin and the tags do not have to fulfill other functions. When deciding what tags will be used, it is necessary calculate also with the way they are attached to the given product. Based on this simple test, passive smart labels with isolation appear to be the most suitable for the selected process. Printing technology for this kind of RFID tags is already well established and easily accessible. RFID tags can currently be printed in different ways and on different materials (Santanu Kumar Behera, 2021).

- **RFID Reader**

Readers are electronic devices that can capture the transmission of an active or passive tag. It does not only need to pick up the information but can also write it to the tag. The reader uses an antenna for transmitting and receiving signals.

According to (A. Schmidt, 2000) In the case of passive tags, the reader briefly supplies energy to the tag and then communicates with it. The readers can be distinguished according to several criteria:

a) Access mode – read only or read/write
b) Operating range – distance between the reader and the tag
c) Protocol- anti-collision to read tags simultaneously

The main aim of the RFID readers is the ability to maintain wide range of data. Readers must register already loaded tags and must also ignore signals reflected from stable obstacles like metal and water. It comes hand in hand with ability to read tags in relatively short time.

(Dokoupil, 2009) There are 2 main types of readers available on the market stationary and mobile.

Greater demands are placed on mobile readers, e.g. resistance to falls, extreme temperatures, dust or moisture. These readers mostly communicate wirelessly via WiFi or Bluetooth, using which the currently scanned values are transferred to a central database in real time. In addition to a wireless network, the reader can usually be connected to a computer via a USB interface. Stationary readers are used where it is not necessary to "walk behind the tags", but the tags (e.g. for goods equipped with tags on a pallet) pass around the reader, e.g. in the form of a reading gate.

In our case, the RFID reader plays an important role of pairing DMC codes and RFID tags. Considering the process that was set up and described in chapter 3.2.3. it is more appropriate to use mobile readers. The main and primary task of the reader is to read the RFID tag on the packaging and the DMC code on the casting. Using the software, this information is then paired and visualized in the Digital twin application.

If all the previous steps mentioned in chapter 3.2.3. were fulfilled it is only the matter of software to create a final product – Digital Twin.

Figure 18 - Digital Twin view

As already mentioned, the introduction of Digital Twin brings with it certain requirements. In order for the Digital Twin to work, it needs hardware devices that are interconnected by software. For a better understanding, the following figure of Digital Twin implementation phases will help.

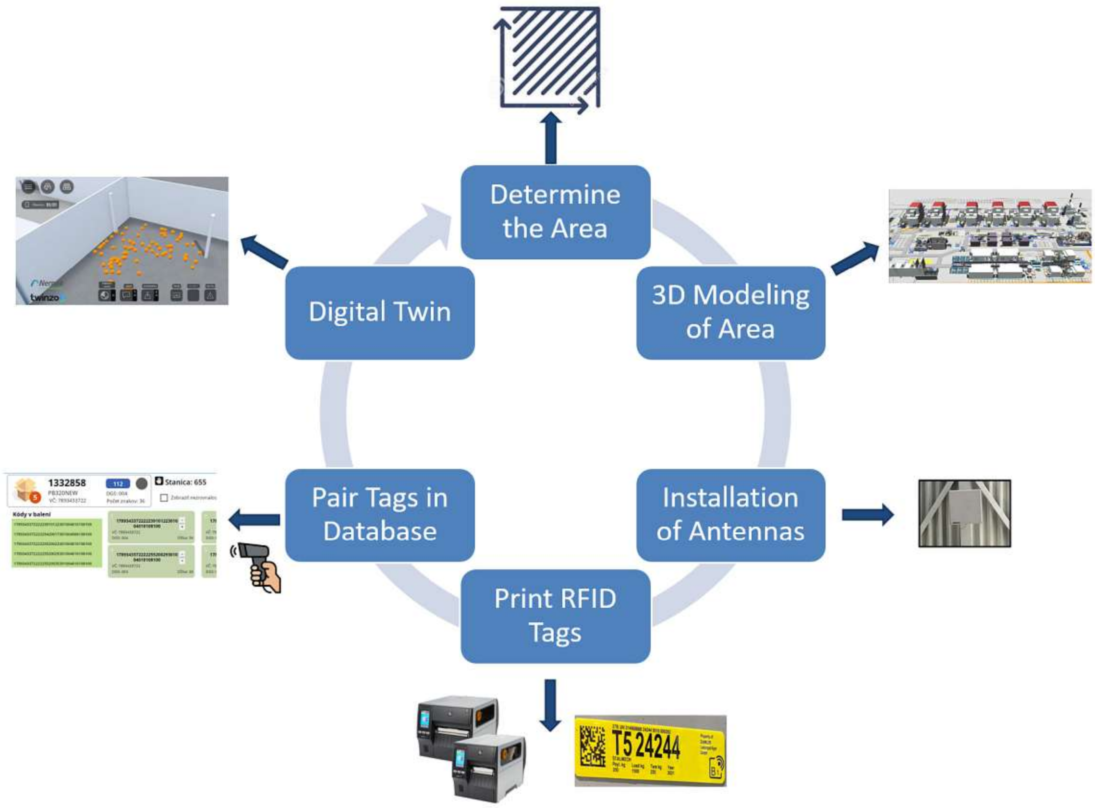

Figure 19 - Process of creating the Digital Twin (own picture)

Discussion

The main reason for the introduction of RTLS in the given company and its subsequent visualization in the Digital Twin were problems with the daily inventory of work in process parts. The number of castings in the process has so far been monitored in two levels:

a) First of all, it was tracking movements in SAP based on completed operations in individual production processes. When the given product went through some operation, it proceeds from one level to another. This way of tracking of castings does not inform about their physical location.

b) To determine the location of products, the morning inventory system described in chapter 3 has been used so far.

However, as it was proven, the given system had more disadvantages than advantages and therefore the company decided to implement an RTLS system.
The introduction of such a system could be divided into several important phases. Each production company has its own requirements and specifics. Therefore, to be able to choose a suitable online inventory tool, it is first necessary to understand these requirements and specifics. In this case, the Canvas tool was used, which clearly defined the current problems, the resulting expectations and the solutions in which these expectations can be fulfilled.

In the next phase of the project, an internal team of people responsible for implementing of solution was selected. The task of the team at the beginning was to choose a suitable solution and supplier. The usage of the PDCA cycle tool proved to be very effective, so it can be said that the use of management tools such a Canvas or PDCA could be an important part of the implementation guideline.

The third phase consisted in the implementation of the selected solutions. For successful implementation of this system is necessary, that both the hardware and software aspects had to be fulfilled. An important part of this phase was the testing of selected technologies in a real environment. For example, by testing of RFID tags it was proven, that the environment can really affect the parameters declared by the manufacturer.

The next chapter, based on the information obtained during the introduction of RTLS in the company, deals with the development of an implementation guideline.

4. IMPLEMENTATION GUIDELINE

Development of implementation guideline for online inventory tool is based on the knowledge obtained in the theoretical part as well as on the experience gained during the implementation of the RTLS solution in the given company.

IMPLEMENTATION OF RTLS SYSTEM

1.

Purpose & Scope

1.1 Purpose

Establish rules for managing the implementation of the online inventory tool and determine rights and obligations during implementation. Describe the implementation process.

1.2. Scope

This guideline applies to all production sites and areas.

2.

Definitions & Abbreviations

2.1 Definitions

Canvas – value proposition tool to ensure that a final product is positioned around the customer values and needs.

PDCA – plan-do-check-act method of continual process improvement.

RTLS – technology that is setup to provide the instantaneous physical location of entities.

Digital Twin - integrated multi-physical multi-dimensional probabilistic simulation of a complex phenomenon or product, which uses the best available physical models, sensory interfaces, mathematical apparatus, etc. to create a mirror of the existence of its corresponding twin.

RFID Tags - tracking system that uses smart barcodes to identify item.

RFID Reader - device that has one or more antennas that emit radio waves and receive signals back from the RFID tag.

GGU – General Guideline

2.2 Abbreviations

RTLS Real time location system

DT Digital twin

DMC Data matrix code

RFID Radio frequency Identification

3. Rights & Responsibilities

The head of the Lean department is responsible for developing and maintaining this guideline. All employees involved in the implementation are responsible for compliance with this guideline.

For the proper management of the online inventory implementation, it is necessary to assemble a project team. The periodicity of the meetings is once a week.

Project leader:

- manages the project throughout its duration
- comments on the goal and metrics of the project
- proposes a project plan
- records acquired knowledge and measured values in the prescribed form
- cooperates with management and presents results

Team member:

- actively participates in the project throughout its duration
- fulfills the tasks set by the project leader
- informs the team members about the acquired knowledge and measurement results

Team composition:

- Lean Department – project leader
- Logistic Department – team member
- Data capturing Department – team member
- IT Department – team member
- Production – team member

To monitor and evaluate the status of the project, the team leader will use the PDCA methodology, which will be monitored by using A3 format. (GGU xxx A3 format)

4.
Activities & Methodology

4.1 Vendor selection

Supplier selection is carried out by the purchasing department in cooperation with team members. The procurement process must be started well in advance, so that cooperation with the supplier can begin at the moment of process development. Due to the constant technological progress in this segment, it is necessary to do marketing research before choosing a supplier. By choosing a supplier, the following criteria will be evaluated (if necessary, they can be supplemented by the team):

- Accuracy for localization
- Software interfaces and compatibility
- Technology roadblocks
- Hardware requirements
- Preparation with IT infrastructure
- Maintenance

- Cost
- Timing
- User friendly interface
- Supplier reliability

If possible, team will participate on the referents visit.

4.2 Description of activities

3D Modelling - the project leader will provide all necessary documents to the supplier of solution for the creation of a 3D model of the existing hall/operation. The aim of this step is to create a faithful image of the existing premises.

Hardware installation - Installation of hardware components (antenna, RFID printer, and RFID reader) takes place in cooperation with the maintenance department and, if possible, at the same time. During the installation, it is necessary to test the functionality of the system to eliminate environmental influences. Testing should serve to confirm the parameters declared by the manufacturer.

Pairing tags and DMC´s – when creating software to pair RFID tags with DMC codes, the representative of the IT department considers all the requirements of the team.

Visualization in Digital Twin – based on the fulfillment of the previous steps, the supplier will create the final product - online tracking of castings.

For better understanding, the following scheme will help to explain main activities of installation.

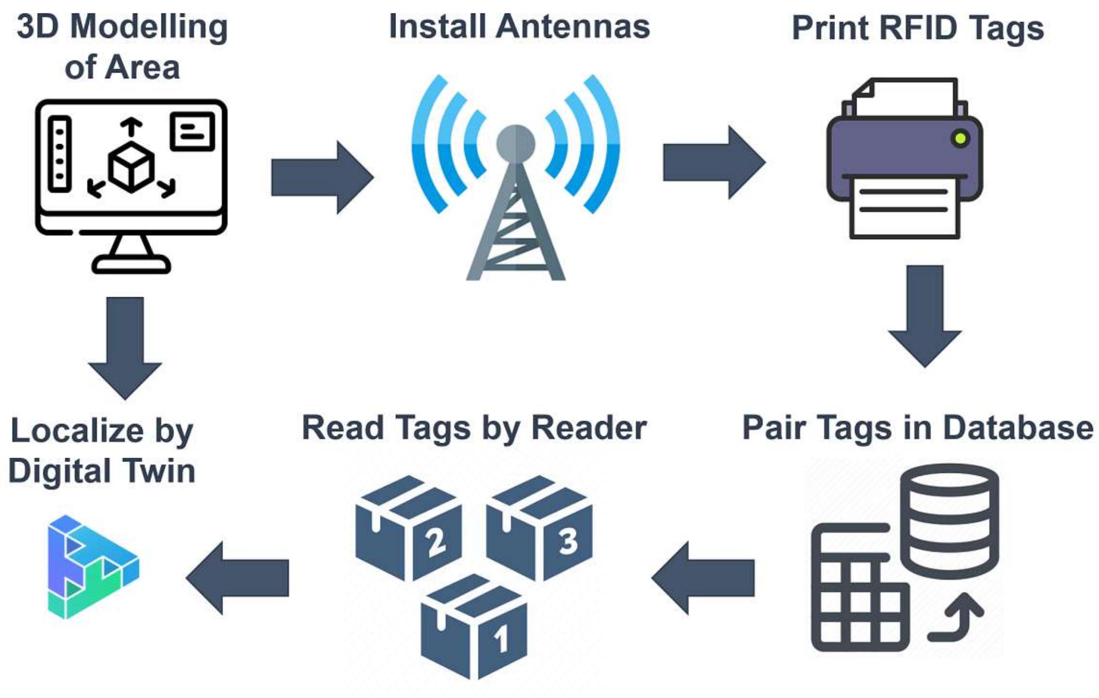

Figure 20 - Description of activities

4.3 Process description

After the installation and before active usage, the task of the team is to acquaint all stakeholders with the RTLS process. Project leader will organize a meeting to inform the stakeholders about the process.

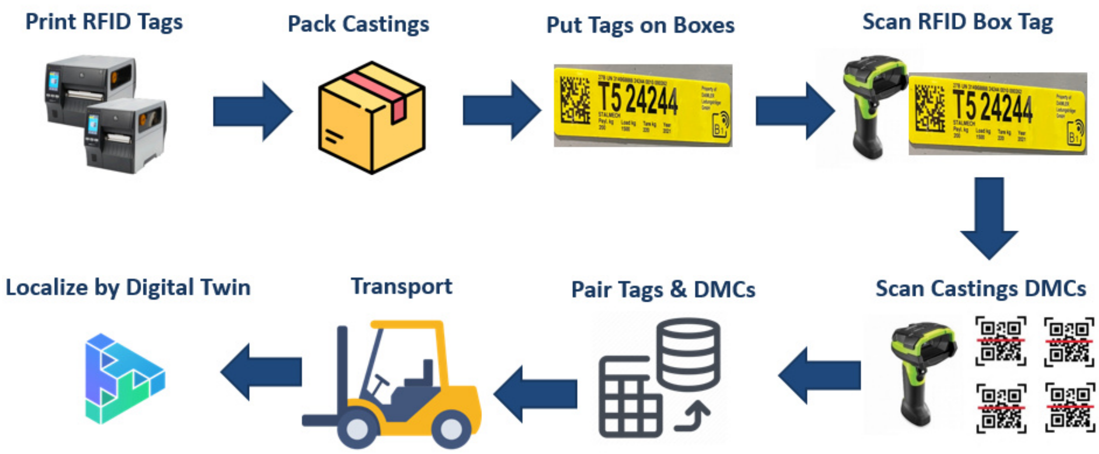

Figure 21 - Process description

4.4 Maintenance

Based on observations and testing during implementation, the purchasing department will negotiate a service contract.

5.
Documents & Contact information

5.1 Related Documents

GGU xxx A3 format

GGU xxx Continual improvement process

5.2 Contact Information

For questions or comments about this guideline, please contact the Nemak Lean area.

6.
Revisions & Approvals

6.1 Revision

Day – Month - Year

6.2 Created / Approved by

Approved: Position – Department – Month – Year

Created: Position – Department – Month – Year

Discussion

The creation of the implementation guideline is based on theoretical knowledge and practical experience gained during the implementation of RTLS in the selected company. The aim of the next chapter is to verify this guideline by using a questionnaire.

5. PRACTICAL RESEARCH - QUESTIONNAIRE

A questionnaire could be defined as a tool of the research method of inquiry, which takes the form of a form containing questions on a selected topic. Questions from the questionnaire are asked to the respondent either directly in written form and without the intervention of the interviewer, or orally through the interviewer.

In comparison to other forms of assessment, questionnaires have both positive and negative features as a means of gathering data and feedback from target audiences. Questionnaires are useful tools for gathering specific sorts of data quickly and easily. However, they should not be utilized in isolation from other methods of assessing and bettering classroom instruction because they are not designed to do so.

According to Nigel (Nigel, 2022) there are advantages and disadvantages of questionnaires.

Main Advantages:

a) Respondents may receive them in the mail, although this approach may lower the response rate
b) Large number of respondents can be questioned at the same time, which has positive impact on cost
c) The ability to remain concealed is one of their primary benefits. Anonymity might help improve response rates and the possibility that survey takers will be more honest in their responses
d) They give those who are being interviewed some space to think about their answers before giving them
e) Consistency. There is a same set of questions given to all respondents. When dealing with many respondents, it can be helpful to use closed-form questions because they allow for more uniform responses
f) capable of quickly and effectively addressing a wide range of pressing problems and questions

Main disadvantages:

a) They are not a good way of evaluation to use if you need to ask follow-up questions about the responses you received
b) Data quality is likely lower than with other methods, such as in-person interviews
c) To overinterpret the results of a survey is an example of how they might be misused
d) Getting a high percentage of responses could be challenging. Often, there isn't much in the way of incentive for respondents to fill out surveys
e) They are sophisticated tools with the potential to deceive in the wrong hands

1. Open vs closed questions

A lot of people say that closed questions are better than open ones. Anyway it is recommended that questionnaires include both open-ended and closed-ended questions. Both closed and open inquiries have their place and can yield different sorts of data depending on the circumstances.

In a closed question, the respondent is given a list of all potential options and must select one. In contrast, open questions are ones to which the respondent is not limited in their response.

2. Single vs. multiple response

Candidates have just one option for answering a single-choice question, while they have more than one from which to select the proper response for a multiple-choice question. By creating a questionnaire, it is always necessary to make clear what kind of answer is preferable.

3. Ranked and rated responses

It can be helpful to ask respondents to rate a list of choices from 1 to however many are relevant. A new variable will have to be created in the code for each choice. Data generation is a potential downside of this method, hence using too many variables is not recommended. Other than that, respondents have trouble making significant distinctions amongst many options.

5.1. EVALUATION OF QUESTIONNAIRE IN NEMAK SLOVAKIA

The goal of this chapter is to use a questionnaire to evaluate the implementation guideline developed in the chapter before by using experiences of the people who participated in the implementation.

The questions (Appendix 3) are divided into several areas to cover the personnel side, process, technologies and to give the respondents room for additional observations. Questions are formulated so that their answers can be used to evaluate the guideline and emphasize timing, personnel requirements and functionality of the system. The questionnaire was delivered to the respondents by e-mail with a link to the questionnaire page. In total, 16 questions were asked in the questionnaire, of which 3 were open and 13 were closed. People from the stakeholder map (Chapter 3.2.1.), whose interest and power are high, were involved in the questionnaire.

A total of 23 respondents from 8 different departments answered the questionnaire. 19 people from the total number of interviewees were directly or indirectly involved in the RTLS implementation project.

Question nr.3

As many as 61% of respondents identified the IT department as the most important department for implementation. 35%, on the other hand, identified the Lean Department as the most important department. It is therefore possible to consider changing the project leader to a representative of the IT department. Depending on the organizational structure and responsibilities in the given company, the project leader was chosen correctly.

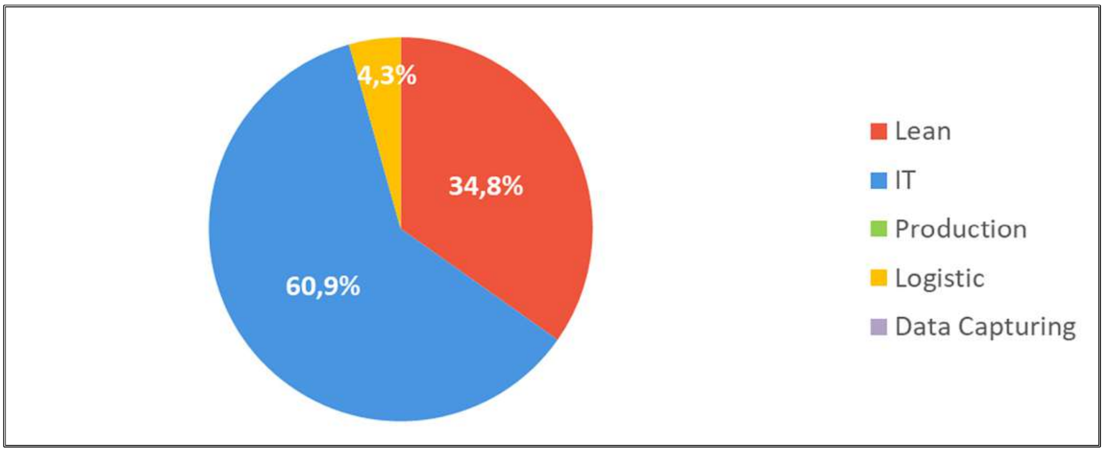

Figure 22 - Responds to question nr.3

Question nr.4

To the question "If you had the chance, which department representative would you add to the core team?" 39% of respondents answered in favor of the purchasing department, on the contrary, up to 35% claimed that the core team was sufficiently composed.

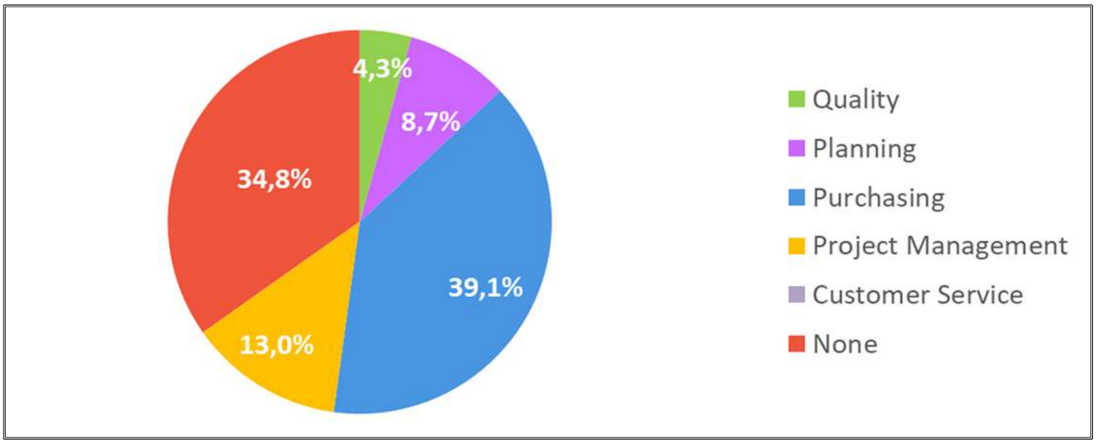

Figure 23 - Responds to question nr. 4

The purchasing department played an important role mainly in the supplier selection phase. The direct participation of a representative of this department would certainly be beneficial.

Question nr.5

The frequency of meetings once a week was evaluated as sufficient and the most effective, 70% of the respondents expressed their favor.

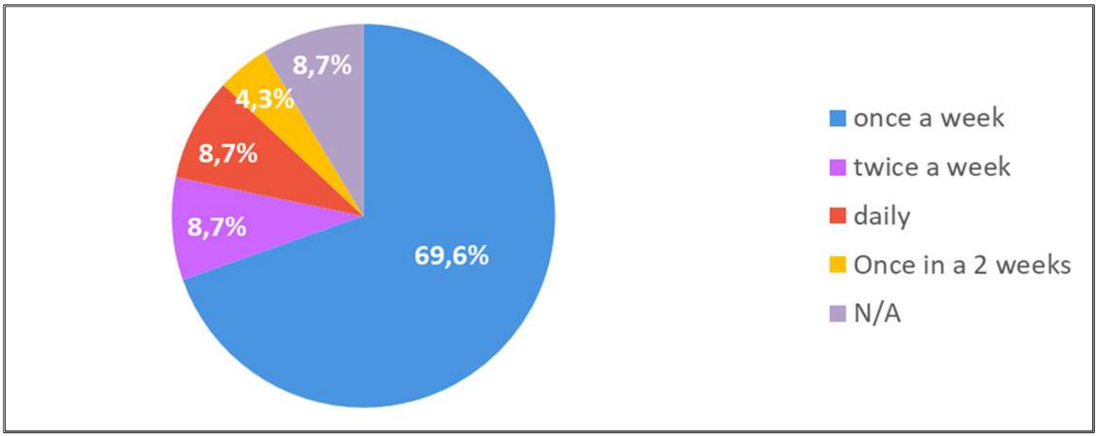

Figure 24 - Responds to question nr. 5

Question nr.6 & 7

The questionnaire further showed that up to 87% of the respondents were at least partially familiar with the proposed process flow solution in advance (Question nr.6), and at the same time, up to 90% of those who were familiar with the process flow evaluated it as an advantage in the further implementation process (Question nr.7).

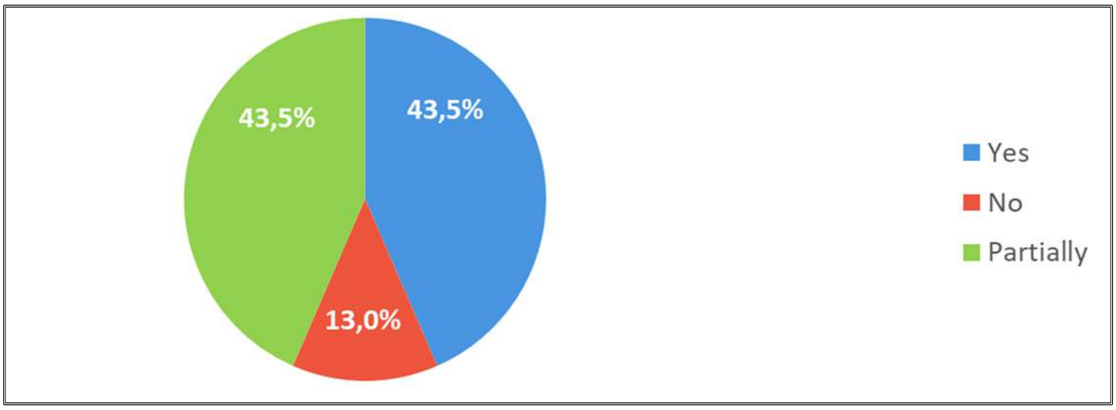

Figure 25 - Responds to question nr. 6

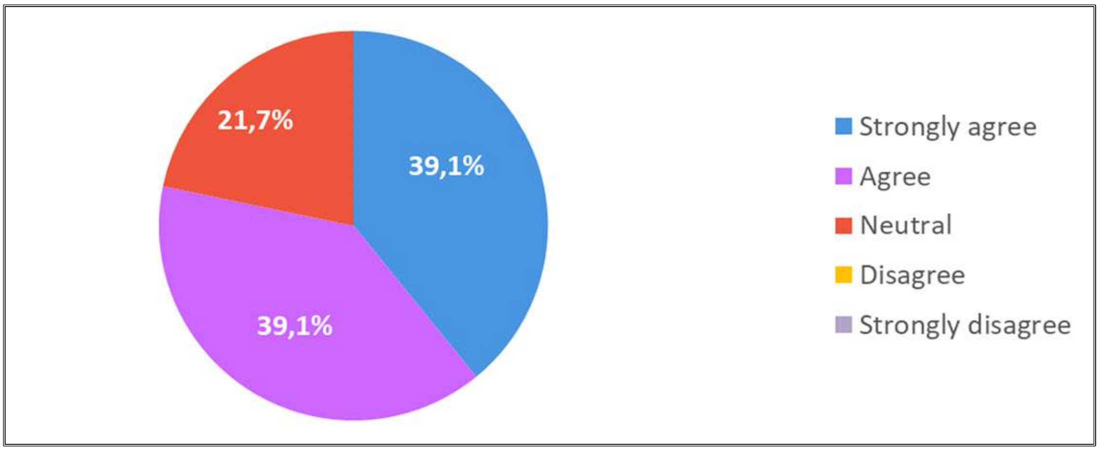

Figure 26 - Responds to question nr. 7

Based on the evaluation of questions no. 6 and no. 7 it is necessary to accept modifications in the created guideline. Specifically, it makes sense to reverse the order of points 4.2. and 4.3., that means familiarizing stakeholders with the solution before implementation.

Question nr.8 & 9

The chosen order of implementation steps in the implementation guideline of the localization system was evaluated as correct, which was confirmed by up to 65% of the answers and only 9% expressed the negative answer to this question. Recommendations out of these 9% were related to introduction of proposed solution to the team before implementation. These observations support the previous claims as well.

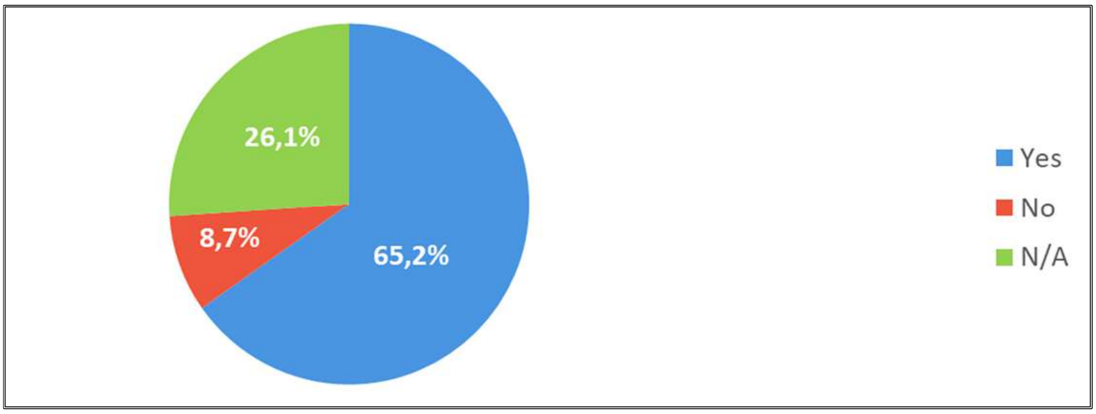

Figure 27 - Responds to question nr. 8

Question nr.10

Respondents identified the Planning phase, Definition of project team and Installation of antennas as the most important during implementation. The created guideline could therefore contain more details about the installation of individual hardware parts.

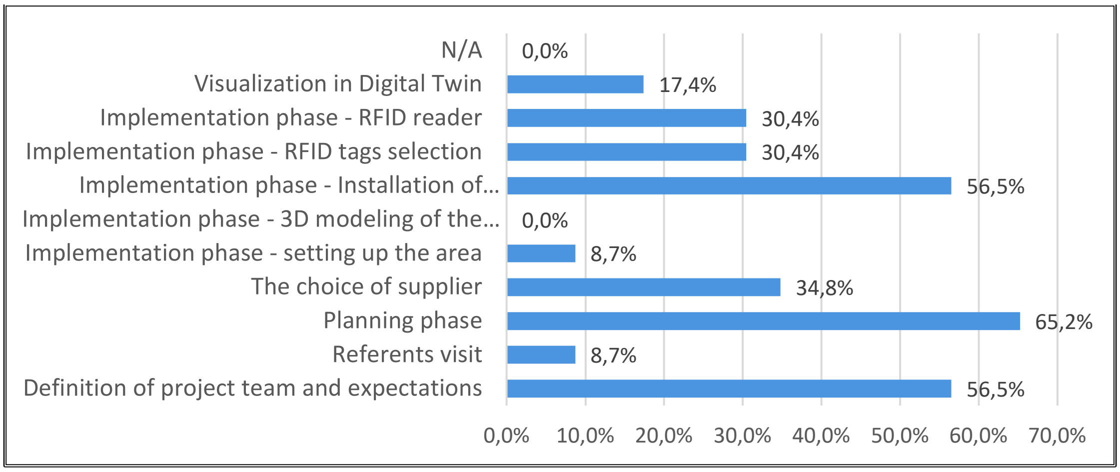

Figure 28 - Responds to question nr. 10

Question nr.11

To the question "which steps were the most time consuming?" almost 70% answered the choice of supplier. The installation of antennas was also evaluated as critical from the time point of view. On the other hand, Definition of Project team evaluated in previous figure as one of the most important, was not time consuming at all. It is up for consideration whether the guideline should contain even more points regarding the procurement process.

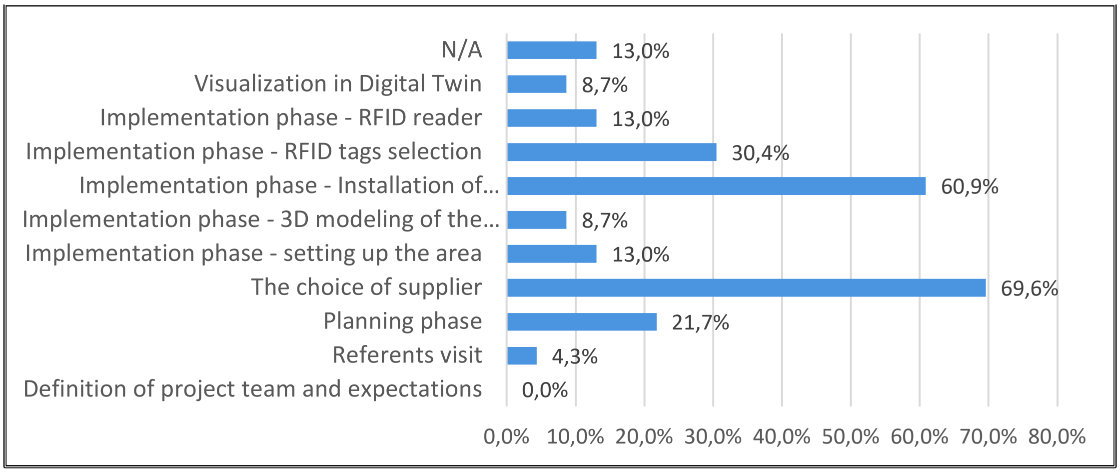

Figure 29 - Responds to question nr. 11

Question nr.12

In question number 12, up to 70% marked the content of the guideline as sufficient. 21% could not express themselves and only two respondents answered negatively. Their ideas were to involve more production representative and receive the commitment from the IT department before installation and testing.

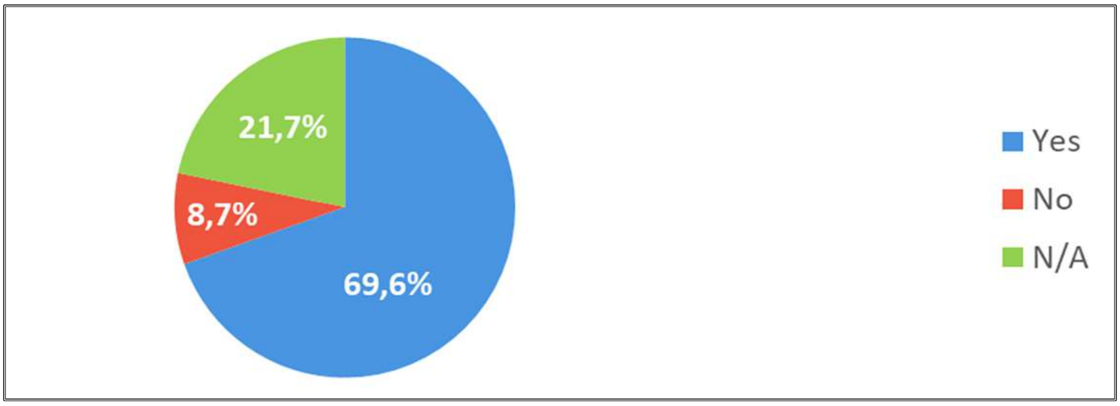

Figure 30 - Responds to question nr. 12

Question nr.13 &14

The questionnaire also tried to find and answer to questions "what were the biggest obstacles in the implementation of localization system?" and "what was most important for a successful implementation?". Internal support from the IT department and installation of hardware parts of the system were identified as the biggest obstacles. Implementation guideline could therefore be more specific in setting up the responsibilities and rights for the IT department.

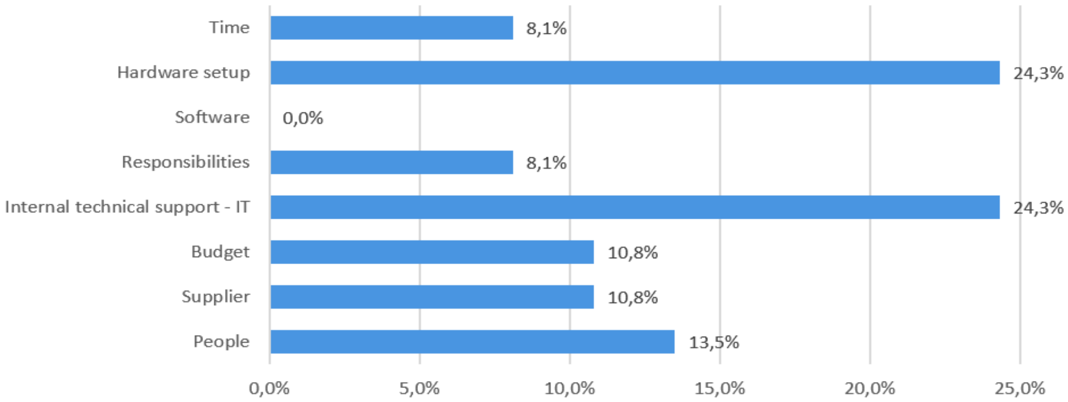

Figure 31 - Responds to question nr. 13

Interestingly, the support of the IT department was also selected as the most important for a successful implementation. More than 30% of the respondents also identified the planning phase as important for successful implementation.

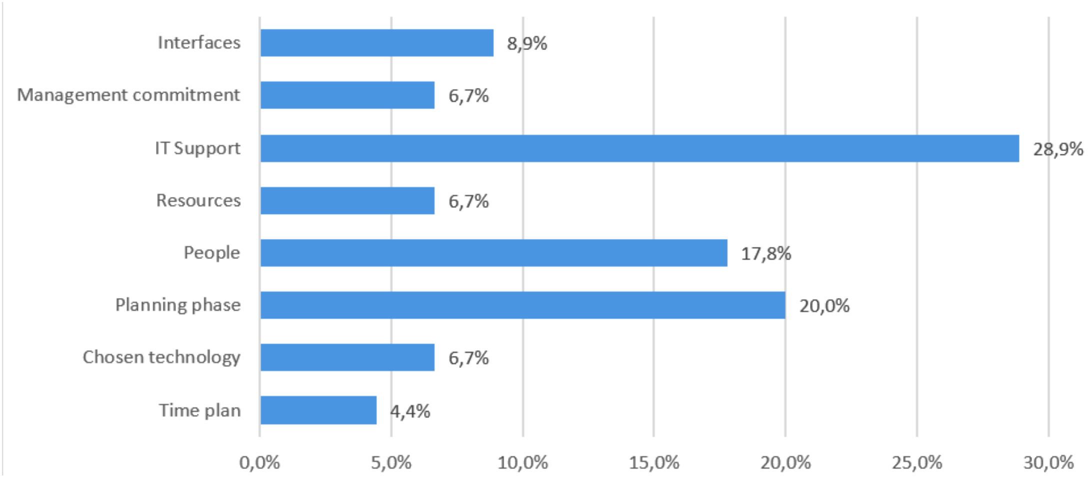

Figure 32 - Responds to question nr. 14

Question nr.15 & 16

The last two questions in the questionnaire were open and their main goal was to give space to the interviewers express their own view about the RTLS system and the implementation guideline.

Most common answers for question nr.15 “Please write 5 things that improved after implementation of RTLS” can be expressed in the following structure:

- Online actual and reliable data
- Logistic
- Visualization and localization of parts
- Productivity and availability

Answers of the respondents to question nr. 16 “If you would create a guideline for the implementation of an RTLS tool, what shouldn´t be missing?” were focused on the following areas:

- Resources allocation
- Testing phase
- Maintenance of the system
- Interfaces with other existing systems

Discussion

The goal of this chapter was to bring to this work the real experiences of people who directly or indirectly participated in the implementation of RTLS in the company Nemak Slovakia. Based on the answers, it can be said that the most important role in the implementation was played by the IT department and its involvement plays a key role for a successful implementation. It is also valid, that the IT department can be understand as an obstacle in case of not clearly defined responsibilities and determination of resources. From the time-consuming point of view, it is important to pay sufficient attention to the selection of a suitable supplier and to the installation of hardware. Based on the results of the questionnaire, the following changes could be made in the guideline:

- Include team member from the purchasing department in the team
- reverse the order of points 4.2. and 4.3. to inform all stakeholders before implementation
- include more details about the installation of individual hardware parts
- involve more production representatives
- receive the commitment from the IT department before installation and testing
- be more specific in setting up the responsibilities and rights for the IT department
- include maintenance of the system

6. CONCLUSION

The framework of this master thesis is the implementation guideline for the online inventory tool. Inventory management in the automotive industry has never been an easy discipline, especially regarding performance, accuracy, punctuality and, of course, also regarding efficiency. In the last twelve months it is even more difficult because we are in a situation we have never been. Conditions in which the automotive is operate, changes from hour to hour. It is even more important to provide services and solutions that can cope with this situation, and moreover, it is necessary to approach this situation as a challenge and an opportunity to find new solutions and be even more efficient than ever before. One of the innovative options that offers a solution for increasing the efficiency and accuracy of inventory management are RTLS systems and their bigger brothers, Digital Twins. This work deals with the issue of introducing such a solution in a manufacturing company and tries to find answers to the research questions.

The main research question was addressing to specify the implementation guideline for online inventory based on the state of the art in practice insights. In searching for answers to this question, this work draws from several sources. The answer to this question can be understood on two levels, formal and content.

The literature mostly deals with the formal side of the guidelines, its roles, binding nature, and the principles that should be followed when creating it. Guidelines must be issued in writing and must not conflict with legal regulations or be issued retroactively. Usually, it becomes effective on the day specified in it, but the earliest is the day announced by the employer. When creating guideline, it is also necessary to consider the size of the company and its internal organization. Anyway, each manufacturing company probably has its own regulation for the creation of the guideline, which is regularly updated and revised.

From the content point of view, the guideline should consider the specifics of the company in which RTLS will be implemented. These specifics can be defined using various management tools. Among the most important aspects of a successful implementation is a well-chosen team of people, therefore it is important to have clearly defined responsible departments and responsibilities of individual team members. This could be different form company to company and is depending on organizational structure. Full awareness and support of management is crucial for successful implementation.

As the introduction of RTLS in given company showed, the environment in which it is installed has a great influence on the functionality of the technology. For the system to work properly, it is necessary to test the software and hardware during the entire implementation period.

The sub-research questions were addressing to the most important points from timing, personnel and functionality point of view, that should be included in implementation guideline and also definition and evaluation of such guideline. First, it is important to have a defined implementation schedule, agreed in advance with all interested parties. In this case, the choice of supplier proved to be the main time risk. In addition, companies must comply with established legal and corporate regulations, which may ultimately have an additional negative impact. On the contrary, with a good planning phase, these negative impacts can be minimized.

Both RTLS and Digital Twin represent top innovative technological solutions for the automotive industry. However, their effective introduction primarily depends on the available human resources. Just as it is necessary for human resources to be selected from the right departments, it is equally important that they have sufficient knowledge. However, it is not only about the implementation, but also about the maintenance of the implemented system and its continuous improvement.

Installation of equipment and software is an inseparable part of the whole process. For proper functioning, it is necessary to have sufficient resources. An important factor in choosing a suitable system is compatibility with existing company software. All the points mentioned above should be part of the implementation guideline of online inventory tool.

Digital Twin technology offers countless possibilities and solutions not only for the automotive industry. Its main goal is to reflect the existing process and propose an improved solution based on the obtained data. The market offers many companies and technologies dealing with this issue. For many companies, the question is not if they will choose this path, but when. The goal of this work was to find a way to travel this path as quickly and efficiently as possible.

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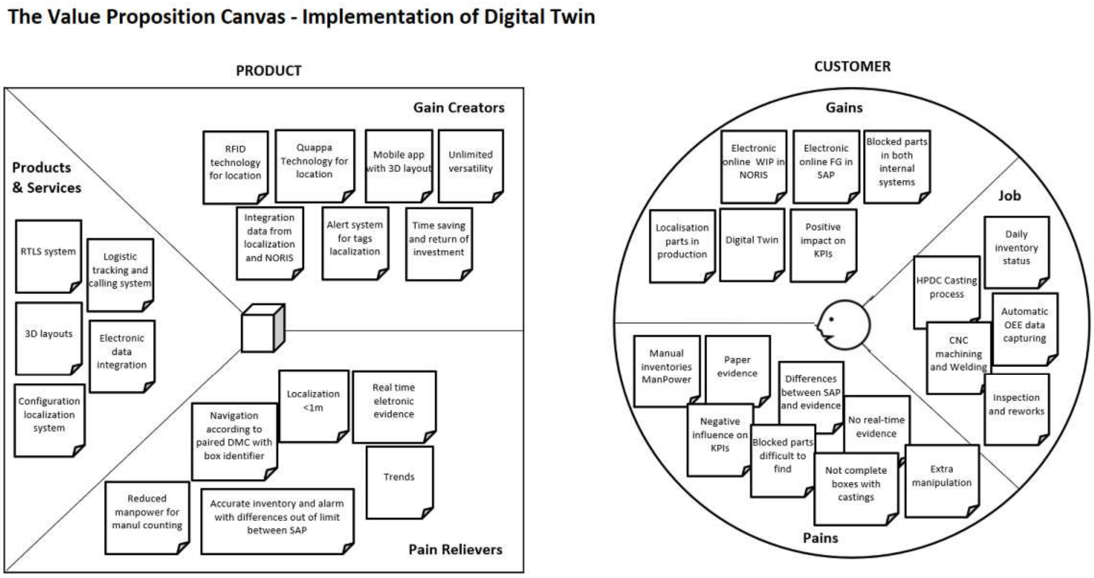
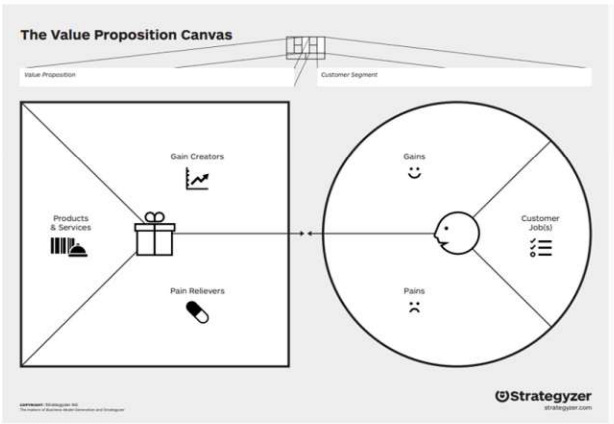
LIST OF ABBREVIATIONS

AIDC	Automatic identification and data collection
DMC	Data Matrix Code
DT	Digital Twin
EPC	Electronic Product Code
ERP	Enterprise Resource Planning
EV	Electric Vehicle
HSE	Health, Safety and Environment
IoT	Internet of Things
MES	Manufacturing Execution System
NWC	Net Working Capital
OCR	Optical character recognition
OEM	Original Equipment Manufacturer
OEE	Overall Equipment Efficiency
PLC	Programmable Logic Controller
PLM	Product Lifecycle Management
RFID	Radio Frequency Identification
RTLS	Real Time Location System
SAP	System Applications and Products in Data Processing
WIP	Work in Process
WMS	Warehouse Management System

LIST OF FIGURES

APPENDIX 1 – CANVAS TOOL





APPENDIX 2 – PDCA TOOL

Ciele (SMART Definícia) — Definuj

Výzva:	Meraný ukazovateľ		Kouč:	Marek Minda
Leanadsa	Počiatočný stav:	0	Zlepšovateľ:	Radoslav Palacka
	Cieľová hodnota:	300ks rozdiel medzi el. a fyz.	Tím:	M. Bindasová, L. Čierťaská, M. Mokrý, E. Vargová, J. Cabánek, Ľ. Hromota, P. Hric, I. Veselý, P. Valenta, P. Mácel
	Trvanie projektu			
	Začiatok projektu:	16.2.2021		
	Plán ukončenia projektu:	31.12.2022		

Súčasná situácia — Meraj

Parametre procesu

DMC generovanie, uzatváranie, zmätkovanie
NTS - live report k aktuálne otvoreným DMC
Koncoročná iventúra, SAP, Blokovacia aplikácia, Dohľadateľnosť po operáciách, Denná inventúra

Zrealizované aktivity za rok 2021

WAREHOUSE MANAGEMENT SAP
Účel: Zaskladnenie hotovej výroby vrátane DMC odliatkov do SAPu a výdaj k cez vyskladnenie zo SAPu
Zrealizované:
- Navrhnutie systému a konfigurácia v spolupráci s FRA
- Testovanie v kancelárii • Jan2022 test vo výrobe

BALIACA APLIKÁCIA
Účel: uzatvára odliatky v NORIS databáze WIP inventúry ako posledná operácia. Power Apps dopĺňa o funkcie globálnu app
Zrealizované:
- Zavedenie Power app na PB300/320 ako reakcia na pomiešané diely. Doplnenie zvyšných produktov. Zapracovanie Big DMC pre účely Warehouse manažmentu. Zakúpenie 10x Poľských nemrznúcich touch panelov
- Návrh a úprava Power App pre automatickú linku EA211 (signalý z linky, tlač manuál)

FYZICKÁ INVENTÚRA SO SKENOVANÍM DMC
Účel: NORIS inventúra len s nájdenými odliatkami, vyčistenie od starých neuzavretých DMC
Zrealizované:
- Organizácia I. a II. inventúry so skenovaním DMC. Čistenie databázy od starých DMC. Vytvorenie report el. inventúry k 5:45.
- Identifikácia 3 hlavných príčin vzniku rozdielov:
1. Po odliatí robotom vyhodený odliatok do koša bez vyzmätkovania (NOK po pavúkovi alebo plný dopravník) - Zrealizovanie zvukovej signalizácie na výstupnom plnom dopravníku na všetkých OB. Automatické skenovanie DMC na OB3 po uložení na výstupný dopravník.
2. Nájdene nevyzmätkované odliatky v sklade kovu – preškolenie ľudí na RTG a ZK
3. Zmenou KK1, KK2, 100% kontroly nie je jedna operácia uzatvárania WIP – pomôže len zavedenie Warehouse manažmentu

LOKALIZÁCIA
Účel: Potreba dohľadania blokovaných dielov v priestore
Zrealizované:
- Výber pilotnej plochy blokovacieho skladu a 2 technológií lokalizácie (RF Controls, Quuppa)
- Osadenie antén, dodanie vzorových tagov a privedenie sietí

Čo nám bráni dosiahnuť cieľ? — Ishikawa — 5 Why — Analyzuj

#	Prekážka	Popis prekážky
1	lokalizácia odliatkov v procese	Lokalizácia nám pomôže identifikovať odliatky v priestore
2	El. inventúra v NORISe	Reporty po operáciách so statusom 5:45 neobsahujú nadpráce
3		
4		
5		

Road Map (Stratégie - Aktivity - Návrhy) — Vykonaj

#	Dátum OD/DO	Stav PRED	# Pr.	Ďalší krok	Zodpovedný	Očak. PO	Stav PO	Čo sa stalo, čo sme sa naučili?
Lokalizácia			1,2	Zadefinovať očakávania a potreby	Team	--	--	Na trhu je množstvo firiem, ktoré ponúkajú riešenia digitálneho dvojčaťa
			1,2	Prieskum trhu	Team	--	--	Už aby sme to mali
			1,2	Referenčné návštevy	Team	--	--	Stať sa "trensetterom" v spoločnosti Nemak
			1,2	Výber technológie a dodávateľa	Team	--	--	
	1.1/31.1	0	4	Pripojenie technológií Quapaa a RF Controls do 2 rôznych sietí	R. Maruška	2	1	Technológia RF Controls fungoval krátkodobo, potom došlo k jej výpadku, Quapaa nefungovala vôbec
	7.3 / 30.5	0	4	Preveriť výpadok u dodávateľa RF Controls	Infotech	0 (známa príčina)	0 (príčina dodávateľom identifikovaná	Odporúčanie reštartovať a natiahnúť nový software
	7.6 / 21.6	0	4	Reštartovať fyzicky z pripojenia anténu RF controls pre natiahnutie nového softwaru	R. Maruška	1 (funkčná)	1 (funkčná)	Po natiahnutí nového softwaru sa naténa oživila
	21.6 / 28.6	0	4	Otestovať viditeľnosť 2 tagov, lepeného aj plastového	Palacka	2 tagy	2 tagy	Oba použité tagy sú viditeľné
	21.6 / 15.7	2	4	Rozlíšenie tagov medzi zákazníckymi. Vrátiť tagy do výroby a poslať emal s označením na Infotech.	Palacka, Infotech	Filter		

Kontrola dosiahnutia cieľa — Kontroluj

Aká je potrebná štandardizácia?

Je riešenie použiteľné aj inde?

Náklady (€)	Prínosy (€)

APPENDIX 3 – QUESTIONNAIRE

1. **Please select your department**
   - Lean
   - IT
   - Production
   - Logistic
   - Data Capturing
   - Quality
   - Planning
   - Other

2. **Were you involved in any way in the implementation of the localization system?**
   - Yes
   - No

3. **From your point of view, which department was the most important during the implementation?**
   - Lean
   - IT
   - Production
   - Logistic
   - Data Capturing

4. **If you would have a chance, which department representative would you add to the core team?**
   - Quality
   - Planning
   - Project Management
   - Purchasing
   - Customer service
   - None

5. **Based on experience, what periodicity of meetings would you determine if you were to implement RTLS from the beginning?**
   - Once a week
   - Twice a week
   - Daily
   - Once in 2 weeks
   - N/A

6. Were you familiar with the proposed process flow before implementing the localization system?

- Yes
- No
- Partially

7. Was it useful for you to be familiar with process flow before implementation?

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

8. In your opinion, are the implementation steps of guideline in correct order?

- Yes
- No
- N/A

9. If not, what would you change?

10. Which steps do you think were the most important for the successful implementation of the localization system?

- Definition of Project team and expectations
- Referents visit
- Planning phase
- The choice of supplier
- Implementation phase - setting up the area
- Implementation phase - 3D modeling of the area
- Implementation phase - Installation of antennas
- Implementation phase - RFID tags selection
- Implementation phase - RFID Reader
- Visualization in Digital Twin
- N/A

11. Which steps were the most time consuming?

- Definition of Project team
- Referents visit
- Planning phase
- The choice of supplier
- Implementation phase - setting up the area
- Implementation phase - 3D modeling of the area

- Implementation phase - Installation of antennas
- Implementation phase - RFID tags selection
- Implementation phase - RFID Reader
- Visualization in Digital Twin
- N/A

12. In your opinion, is the content of the guideline sufficient?

- Yes
- No
- N/A
- If no please describe

13. In your opinion, what were the biggest obstacles in the implementation of localization system?

- People
- Supplier
- Budget
- Internal technical support - IT
- Responsibilities
- Software
- Hardware setup
- Time

14. What do you think was most important for a successful implementation?

- Time plan
- Chosen technology
- Planning phase
- People
- Resources
- IT Support
- Management commitment
- Interfaces

15. Please write 5 things that improved after implementation of RTLS

16. If you would create a guideline for the implementation of an RTLS tool, what shouldn´t be missing?