RTLS POTENTIAL FOR CHANGES IN THE TOOLING INDUSTRY BUSINESS MODEL TOWARDS SMART FACTORY

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Abstract

Digitization is a fundamental condition for the establishment of smart systems, including production and intralogistics. Today, several years after introducing the Industry 4.0 concept, we can observe that the penetration of enabling technologies depends on the type of industry. For example, we notice that the craft industries, for example, toolmaking, whose work is based on the engineer-to-order concept, are lagging. There is pressure to change the traditional business model.

In this paper, we develop the concept of capturing production data with minimal employee involvement. The production environment of toolmaking is usually still based on manual data entry and ongoing decision-making on the distribution of workpieces between machines according to the current situation. Laboratory testing justifies the introduction of Real-time Location System (RTLS) technology as a technology that captures real-time location data on the monitored items. The captured location data can trigger activities in other software solutions and free up employees of administrative work. In conjunction with the MES system, we can obtain sufficiently accurate data for more in-deep technological preparation of production as a prerequisite for more advanced planning and scheduling tasks among machines. Most importantly, this technology supports a change in the business model.

Keywords: RTLS, toolmaking, digitalization, business model, intralogistics

1. INTRODUCTION

In line with ever-new customer requirements, global competition, highly complex products and increasingly demanding legal and environmental requirements, there is a highlight on improved production efficiency, product quality, energy consumption and cost containment for manufacturing companies (Vrečko et al., 2019; Gajšek et al., 2019). Companies are intensively transitioning to an industry 4.0 based on digitalization. Technological development is taking place in parallel. As an example of technology, information systems are an enabler for increased sustainability along supply chains. Currently, companies are at different stages of technology development (Gajšek & Sternad, 2019). We notice that the craft industries, whose work is based on the engineer-to-order concept, are lagging behind. Each order is unique and treated as a project. Need to change the business model, there is high (Henriques & Peças, 2012). An example of such an industry is tooling (Radić et al., 2020), producing tools[1], dies[2] and jigs[3]. The recession in the automotive industry, as the largest customer, is further hampered by a technological breakthrough. Nevertheless, in the meantime, it is time to think about achieving a higher level of digital maturity in this segment of the industry and what effects can be expected from digitalization.

The technological equipment in the tooling industry is at a relatively high level. In practice, we find multi-axial CNC machines, industrial robots, machines for special machining, simulation tools, electronically supported development and modeling of tools, advanced programming of machining, and others. The opportunity for improvements lies in integrating all local information systems and using the obtained data in terms of network connectivity, such as reviewing the state of occupancy of production capacities, reviewing the implementation of individual projects, and planning and prioritizing individual positions in production. Most often, therefore, the capture of data on the real-time location and status of technical operations for mostly unique components with dimensions ranging from a few millimeters to a few meters is missing.

A prerequisite, a step 1 for advancing along the path to Industry 4.0 is "visibility," the establishment of a digital shadow (Pametne tovarne, 2017). The paper's contribution is to explore the potential of RTLS to provide data on the real-time location of parts of emerging tools with a vision of using the findings to support new business models in the tooling industry.

The paper aims to (1) explore the technical aspect of UWB's RTLS needed to build decision-makers confidence in such systems and (2) think about the potential usefulness of RTLS in a tool shop production hall when the tooling company is changing business model and (3) discuss the potential benefits of RTLS in the transformation towards a smart factory. To achieve these, the structure of the work is as follows: Section 2 presents the research background by exploring the basic concepts and state of research at the time of the creation of this research work. The Methodology is described in Section 3 and results in Section 4. The results mainly relate to the technical aspect of UWB's RTLS. The results and connection between RTLS UWB implementation and changes in the business model are discussed in Section 5. The paper ends with conclusions.

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[1] A tool is a precision device for cutting or shaping metals and other materials (Canis, 2012).
[2] A die is a form used to shape metal in forging and stamping operations. Dies also include metal molds used in making plastics, ceramics, and composite materials (Canis, 2012).
[3] A jig is used to hold metal while it is being drilled, bored, or stamped (Canis, 2012).

2. RESEARCH BACKGROUND

A closer look at the tooling industry shows that it is primarily organized as small and medium-sized companies and characterized by a high degree of heterogeneity and fragmentation. A study on tooling in Germany in 2020 (Boos et al. 2020) reports that in 2020, around 1% of German tool and die-making companies employed more than 100 employees, 65% less than 50 employees. With a production volume of € 5.6 billion in 2018, Germany is the largest and most important manufacturer of tools in Europe. At 48%, almost half of all German tool shops generate annual sales of less than € 5.0 million. In contrast, only 27% of the companies generate annual sales of more than € 10.0 million. Sales are mainly generated through the manufacture of sheet metal and solid metal forming tools or injection molding tools as well as services. In 2018, in Germany, there were around 3,800 tool shops with around 54,000 employees. Due to the increasing number of bankruptcies, however, a consolidation of the industry can currently be noted. This trend is similar across Europe because of growing competition from lower-cost foreign producers and China's sudden emergence with unbeatable pricing opponents.

2.1. Trends

A decade after the beginning of the transition to Industry 4.0, there has been no noticeable increase in gross value added in Europe and globally because of this movement. In parallel, awareness that data business models offer great potential to address a lack of development is growing. With data-based services, the technical capabilities of Industry 4.0 can be translated into individual data business models and evaluated. Centralized data and data services based on them thus form the basis for new business models. This requires the use of intelligent tools for data collection and analysis during production. New possibilities for the tool shop are opened, as they can offer new services besides the tool as their core product. In Germany, as the leading toolmaking force in Europe, only 3% of tool and die-making companies offer data-based services in 2019, which no company converts into new business models (Boos et al., 2019).

2.2 New business models for the tooling industry

Regarding new business models for the tooling industry, we rely on the findings of Henriques and Peças (2012). The authors believe that product manufacturing excellence alone and improved internal efficiency are no longer enough for sustainable competitiveness. Companies should combine these efforts with innovation. Traditional innovation in production technologies should be joined by a strategic business approach, the latter as something new for the tooling industry. Henriques and Peças (2012) described three business models:

- operate as a low price producer, targeting customers that buy locally on price;
- expand the share of value-added activities in the supply chain of finished products, targeting customers who are open to outsourcing of services and engineering solutions providers;

- produce highly complex and innovative tools, targeting customers who are willing to be led by them in technological development.

Regardless of the type of business model chosen, its implementation is based on a digital model. Digital models can be seen as networked, up-to-date, trusted, electronically recorded data that electronically flow between different applications, databases, and users according to predefined rules. An example of an innovative tooling service for tool use at the customer is described by Schuh and coauthors (2015). An injection molding tool was equipped with a force sensor, position sensor, and solid-borne sound sensors for early online detection of tool wear. In addition, captured data, a diagnostic unit for data interpretation, and data storage improved maintenance and condition of the tool during its operational use.

2.3 Capture of production data

Tool production is carried out as a single piece or small batch production where each tool is a unique product that determines the shape and quality of a corresponding serial part. The components of each new tool travel through the tool shop through one of many possible sequences of technological operations. Furthermore, toolmakers are also faced with a high variance of order types. Besides producing new or modified tools, the tool shop is also responsible for providing serial production with ready-to-use tools. Tool production as such is unfavorable for achieving efficiency and low costs (Schuh et al., 2015).

The modern tool shop requires advanced manufacturing applications and equipment based on information technologies. There is almost no tool shop without computer-aided design (CAD), computer-aided engineering (CAE) and computer-aided manufacturing (CAM). Machines at the shoop-floor are mostly numerically controlled. The tool's design and planning of its technological procedure are supported by numerical simulation methods, such as Finite Element Analysis. Toolmakers differ in the deployment of product data management (PDM) systems, database management systems (DBMS), as well as production planning and scheduling (PPS) systems. According to Henriques and Peças (2012), who interviewed more than 100 individuals from Portugal, Finland, Germany, and Spain, these systems are in the initial deployment phase. In our experience, it often gets stuck in providing data for the operation of PDM, DBMS and PPS. Toolmakers also differ in the degree of digitalization of workplaces and the use of the Manufacturing Execution System (MES). MES is a computer system for real-time control and optimization of production process elements (McClellan, 1997), designed to connect the production and business environment. The MES database is, in a figurative sense, a production supervisor. It has almost real-time production data at its disposal and can offer a cross-section of the production status simultaneously with the help of implemented functions and procedures, giving a warning in case of errors. Advanced MES systems can use historical data and compare current data and roughly predict and alert upcoming events. Production data entry is performed by operators on machines using a user interface/scanners/RFID cards, or the data is automatically captured via OPC-UA from CNC machines. The data collected/displayed are: start/end of work on operations, start/end of congestion, start/end of the break, measurements, display documents for production, various data displays. According to an interview with a toolmaker, who does not have an MES system in place, employees, the reason for not using MES is the need to enter data by the machine operator and because workplaces with conventional machines would also need a terminal/computer. The data entry can be delayed, and the data entered can be incorrect. They are delaying the introduction of MES because they are looking for a faster and more credible system.

The least developed is the monitoring of the status and location of components at the time when they are not processed and the travel of components between workplaces. The tool industry does not have developed internal logistics like serial production since it consists mainly of micro and small enterprises and their specific characteristics. Instead of managing inventory at intermediate storage in production, visual management is more common, which, however, does not provide data in electronic form. Here arises the potential of using the Real-time localization system (RTLS), which captures the location data of the tagged thing in real-time, without human intervention. As reasons for its use are given: reduced search time for misplaced assets, reduced equipment movement, improved audits and recovered lost property, inventory and warehouse management, supported inbound logistics, a base for transportation management, captured disparate data, improved Cycle Time.

2.4 RTLS technology

RTLSs are simply a technology for real-time tracking and positioning different objects or people in indoor systems (Crespo et al., 2021; Budak & Ustundag, 2015). The advantages of using the RTLS system in a company are increased efficiency and quality of work, reduced processing time and costs, increased customer satisfaction, accelerated return on investment, and many others (Budak & Ustundag, 2015; Cho et al., 2012).

RTLSs can be divided according to the underlying technology through which the data is captured. The most common technologies are: Zigbee, Bluetooh, UWB, Wi-Fi and RFID (Sanpechuda & Kovavisaruch, 2008). UWB technology is proven to be more accurate than other solutions like Wi-Fi, Bluetooth and other active radio solutions (Xianjia, et al., 2021). For example, Bluetooth has the disadvantage of easily being disturbed by noise signals. WI-Fi has short-distance transmission, RFID has no communication ability, and the signal is prone to interface (Redpoint, n.d.). RTLS, which is based on UWB technology, does not have all these disadvantages. The disadvantage compared to other systems is only in the higher price. Capturing data in a metal-filled environment, which the tool shop is, is unhindered and reliable based on the correct system configuration. RTLS UWB is considered the most suitable for use in the tool shop according to the characteristics given in the literature.

RTLSs consist of several pieces of equipment. The main parts of RTLSs are anchors, tags and RTLS server. Anchors, a minimum of four per layout, are electronic devices that are static and with a known position in the space. They must be placed in such positions in space that a homogeneous network is established over the entire area within which users want to monitor locations of objects or people in real-time. One of the anchors is determined as a master to synchronize all others. Anchors gather ultra-wideband (UWB) radio impulses emitted by UWB tags and forward collected data to the RTLS server. All anchors must be seen by each other to communicate with each other efficiently. Therefore, it is ideal if they are placed into the vertices of a square to get the maximum efficiency from the system. The system operates at temperatures between - 20°C to 60°C, which covers most of the situations in the industry.

UWB tags are active locators which are used to track materials, people and vehicles. The tags can be placed on the objects or be carried around by the human that requires tracking. Their main task is to send the different data to the anchors. This data could be data about location (which is most commonly used), temperature, speed, height, rotation, movement, being in the particular area and many others (Budak & Ustundag, 2015), dependent on types of inbuilt sensors. The communication interval could be determined. The intervals differ from system to system. The tag's activity can be constant or triggered by the start of the movement.

2.5 Existing RTLS research in the context of the business model in toolmaking

Findings in the fields of scientific research was checked in the Web of Science. We were looking for research that would look for opportunities and added value of the introduction of RTLS on the business model of a tool company. From chapter 2.2 we already know that its implementation is based on a digital model regardless of the type of business model chosen. RTLS technology captures data on the location of an object or a person in real-time. It is a source of digitized data (needed for the operation of a digital model), the acquisition of which does not require human work or time. In this way, the introduction of RTLS certainly has a functional value in the business model "operate as a low price producer, targeting customers that buy locally on price." However, since data are collected on the locations of objects and people, the introduction of RTLS would have a useful value in the model "expand the share of value-added activities in the supply chain of finished products, targeting customers who are open to outsourcing of services and engineering solutions providers". Additionally to coordinates recordings, sensors built-in RTLS tags can also report a presence in the particular predefined field, ground clearance, rotation, acceleration, and others.

Linking RTLS technology to the business model is rare in the literature. However, if the mentioned link is the research subject, the business model refers to an industry that is not comparable to specific toolmaking. Several research works were found in connection with ports, but in these cases, RTLSs are based on RFID technology and not on UWB. For example, Park Doo-jin and coauthors (2006) propose a new business model for the ubiquitous U-Port, where the port quality of service is guaranteed utilizing the RFID-based RTLS. The added value of using the system and its integration into the port information system is recognized in lowering ship waiting time ratio and ship residing time. Unlike our efforts, their system is based on the use of RFID technology, and in addition it is a site under the open sky.

Much more often, the use of UWB RTLS is explored in the context of its operational value within the specific production hall. Regarding the type of production environment, papers on storage space and commissioning zones are very prominent. The amount of papers focused on the warehouse environment gives a positive impetus to the research of the practical value of RTLS UWB in a production environment. When we mention that it is not uncommon for papers to explore the purely operational value of RTLS use in a working environment, we have in mind papers such as the following from Zamora-Cadenas et al. (2016). This work presents a novel safety system for AGVs that is based on UWB RTLS technology. The authors proposed a safety system that does not require installing hardware on the plant's infrastructure. Instead, the AGV is equipped with sensors capable of locating the tag of a person or a mobile asset, which reduces installation costs, simplifies the deployment, and enables its use in dynamic environments.

In conclusion, UWB RTLSs are very topical for research, as UWB technology has many advantages over RFID, which is an integral part of most older RTLS configurations. After more than a decade of development work, RTLS UWB commercial solutions are on the market, but they are sold along with development for a specific work environment. From the review of the scientific literature and the number of research papers, we estimate that UWB RTLSs are very relevant for their operational value research in various work environments. Research is intensive in warehouses, and very little is written about research in atypical work environments such as a tool shop. Almost nothing is written about the impact of RTLS UWB use on a company's ability to adopt a new business model or the correlation between them.

3. METHODOLOGY

The commercial solution of RTLS was tested if it could be the ground technology for a tool shop digital model. As mentioned in chapter 2.2, a digital model is needed to support a change in the tooling business model. Therefore, before developing the idea of using RTLS UWB in a tool shop production hall, we answered four research questions:

- RQ1: Does the system report location data for tags in an environment full of metal objects?

- RQ2: How large should be the radius within which the tag must be placed that we can say with certainty that the tag is located in the workplace/intermediate storage/...?
- RQ3: How can the use of RTLS in a tool shop production hall help change the tooling company's business model?
- RQ4: How can the use of RTLS in a tool shop production hall help the tooling company towards a smart factory?

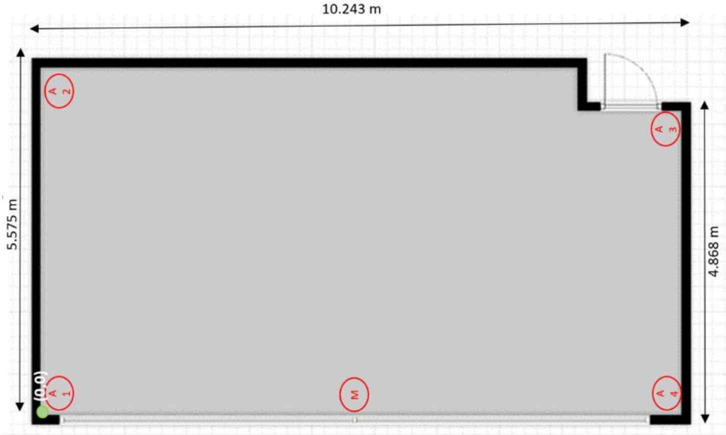
Locating the object inside the workplace through the use of RTLS tag can trigger a change of status in other applications and software packages like producing a notice, error, correction of a schedule, diversion, derecognition of material from a warehouse, or some other type of transaction carried out independently of employees. Most importantly, employees should spend their available time only on value-added activities and should not engage in data entry for traceability purposes.

We placed the commercial provider's RTLS in a real tool shop (RQ1) and in a laboratory environment (RQ2) to provide answers. RQ1 had to be answered before starting laboratory tests.

RTLS was first placed in a real tool shop. While moving the tag around the tool shop, we determined whether it remains visible to the anchors. We first moved the tag chaotically and then placed it in places where the presence of metal could make it impossible to exchange data between tags and anchors. Metal was not an obstacle. The system detected the tag on surface areas and under the thinner sheet metal, under the table with wooden surface, in the tool metal cylinder, etc. Given that in the current state, all the markings (written markings, signatures, labels) are placed in a visible place on the tool or its components, this practice will probably stay also with tags. RQ1 was answered with yes, and RTLS was moved to the laboratory environment.

To perform the experimental study, RTLS was set up in a 57m^2 room. The room was empty except for the desk and equipment needed for the measurements. Commercial RTLS consists of five anchors, UWB tag, and an RTLS server. The room's layout and locations of anchors are presented in Figure 1. Master anchor is marked with M. Installation was completed when anchors communicated with each other properly - that is, that there were no interfering factors in the space between the antennas.

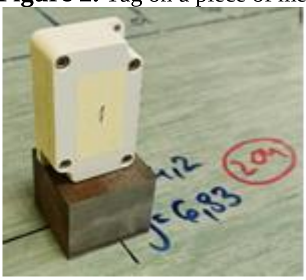
Figure 1. Laboratory's layout



Source: Own

Communication interval between tag and anchors could be set somewhere in the interval from every 10 ms to 60 s. We used a tag 45 mm width and 80 mm height (Figure 2).

Figure 2. Tag on a piece of metal on the floor

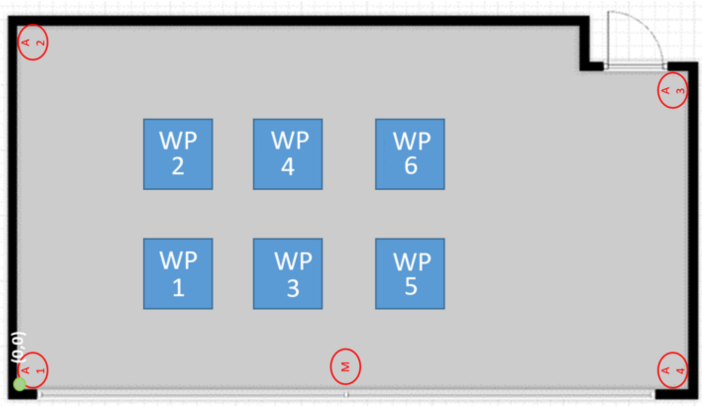


Source: Own

We determined and marked 243 points on the floor around a whole room. We wrote coordinates on the floor at each point, measured from the coordinate origin (x = 0, y = 0), marked with green in Figure 1. Later, we moved the tag from one point to another until we bypassed all 243 points. For each tag placement on a point, we read the coordinates x and y as (1) physically measured from the coordinate origin and written on the floor and (2) measured by RTLS. After the measurement procedure, we compared physical measurements with RTLS measurements.

The next step was to draw six squares presenting workplaces on the floor, each 1.2 m long and 1.2 m wide, to achieve the research objective. Their positions are presented in Figure 3. Positions of workplaces were not determined randomly but similar to the distribution of workplaces in production halls (W1 – W6).

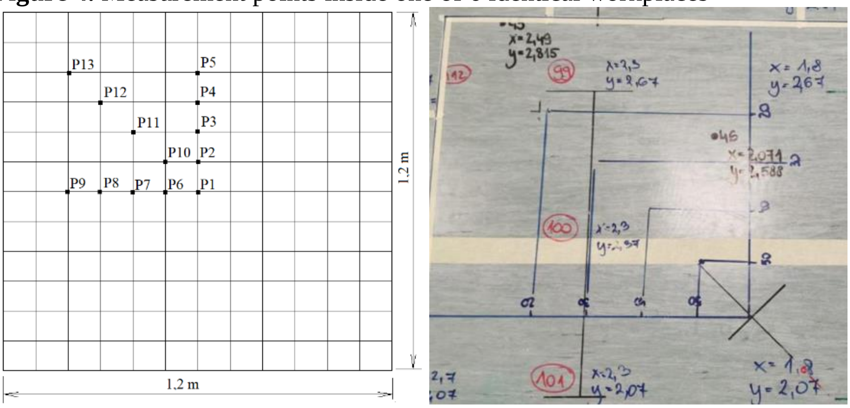
Figure 3. Room layout with marked workplaces



Source: Own

Inside each workplace from WP1 to WP6, we determined 13 measurement points from P1 to P13 (Figure 4). The tag was put on each of these points. For each placement of a tag on a point, it was determined whether RTLS detected a tag inside or outside the workplace. Physically, the tag was always placed inside the workplace.

Figure 4. Measurement points inside one of 6 identical workplaces



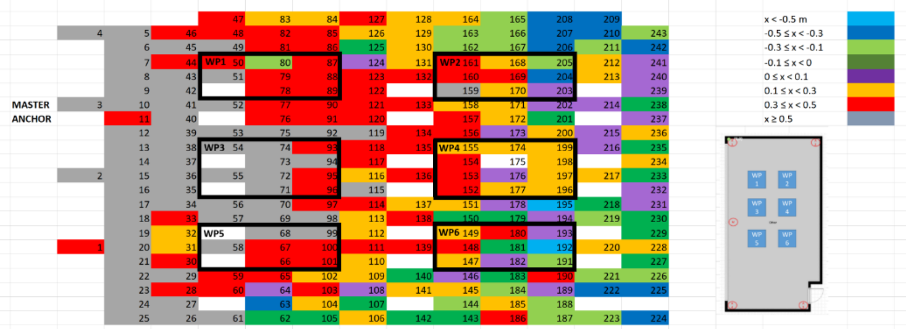
Source: Own

4. RESULTS

First, the results of the measurements in 243 points were analyzed and graphically presented (Figure 5). The accuracy of x coordinates for 243 observed points detected by RTLS is slightly smaller around the master anchor and increases with distance from it.

In Figure 5, we can also see the outlines of six workplaces (WP1-WP6) and the points within them. For example, WP1 contains points 50, 51, 80, 79, 78, 87, 88, 89. Points within workplaces WP1, WP3 in WP5 have bigger errors than 0.3 m. Only measuring point 80 has an error smaller than 0.3 m. On the right side of the room, away from the master anchor, where workplaces WP2, WP4 and WP6 were set, only a few points have a more considerable error in the measurement as 0.3 m.

Figure 5. The magnitude of the deviation from the actual value of the x coordinate

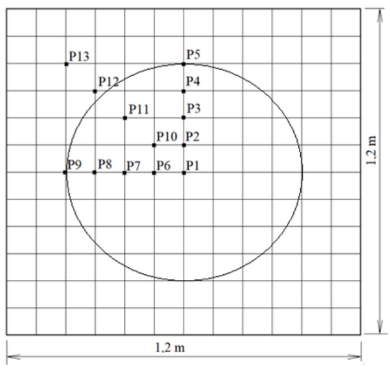


Source: Own

In the following step, we monitored whether the RTLS system detects the tag within the workplace or not when placing the tag at predetermined 13 points from P1 to P13 physically inside six workplaces from WP1 to WP6. Table 4 presents how often the tag appeared within the WPs at a specific point.

Table 1. The average performance of "inside WP" presence detection

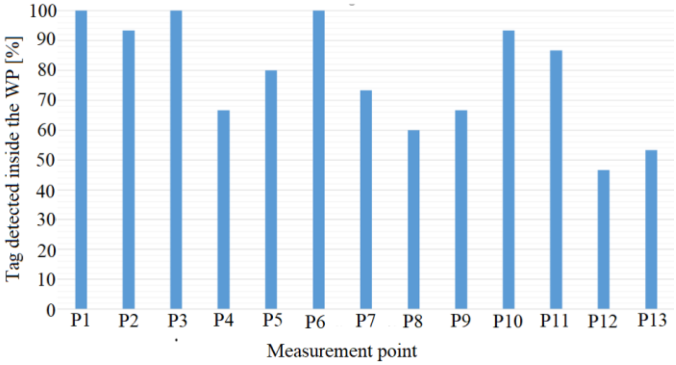
Point	Average performance "tag is inside" [%]
P1	97.7
P2	86.7
P3	80.0
P4	66.7
P5	76.7
P6	90.0
P7	76.7
P8	70
P9	56.7
P10	90
P11	76.7
P12	46.7
P13	33.5



Source: Own

As seen, tag placed on point P1 was almost on all WPs recognized as "inside the WP". The closer the point is physically located to the WP boundary, the less often the system has detected tag as present within the WP. The exception is point P5 (0.2 m from the border of WP), on which tag was more often recognized as "inside the WP" than on the point P4, which is more distant to the WP's border than P5. tag placed on P13, which is placed closest to the boundary on the x-axis and the y-axis, was most often recognized as "outside the WP".

Figure 6. Percentage of being "inside the WP" for points inside WP2, WP4 and WP6

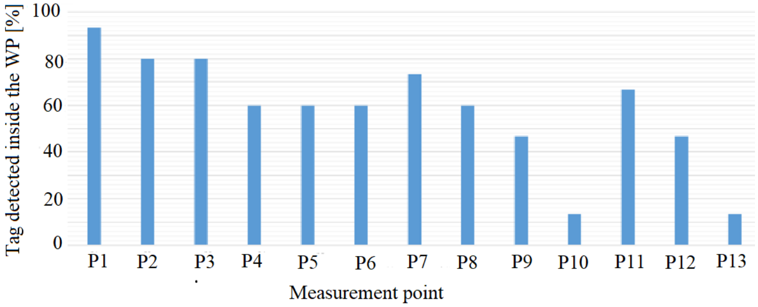


Source: Own

For further analysis, we divided WPs into two groups. The first group include WPs that have a greater expectation for location accuracy due to the results shown in Figure 5 and are more distant to the master anchor (WP2, WP4 and WP 6). The second group include WPs that have minor expectation for location accuracy (WP1, WP3 and WP 5) due to the vicinity of the master anchor. The percentages of situation when tag was recognized as "inside the WP" for different points from P1 to P13 are presented in Figure 6 for the first group (WP2, WP4 and WP6) and Figure 7 for the second group (WP1, WP3 and WP5).

As expected, RTLS was accurate enough to report for all tag placement on point P1 that the tag was recognized as "inside the WP" (the exact middle of the 1.2 m wide WP). The same was also noticed for P3 (0.4 m from the closest WP border) and P6 (0.5 m from the closest WP border). Good results were also achieved in P2 (0.5 m from the closest WP border) and P10 (0.5 m from the closest WP border). More than 50 % of measurements placed tag inside the WP also in points P4, P5, P7, P8, P9 and P11. Points P12 in P13, which are located outside the radius of 0.4 m, did not meet our expectations.

Figure 7. Percentage of being "inside the WP" for points inside WP1, WP3 and WP5



Source: Own

When experimenting with WP1, WP3 and WP 5 near master anchor, RTLS was not accurate enough to report that the tag was recognized as "inside the WP" for a specific point in all three WPs. WP1, WP3 and WP 5 were created at locations that had previously proven to be inferior in location accuracy.

5. DISCUSSION

Technologies capable of indoor positioning are not something new. Technologies like RFID have proven to be slightly problematic in an environment full of metal objects. However, it is still possible to capture location data with some forethought and design foreknowledge. Positioning accuracy at Wi-Fi, active RFID, or Bluetooth is up to several meters. That is not enough to provide a basis for a digital shadow based on automatic data capture in the tool shop and other production environments. We tested the commercial RTLS UWB to determine whether it can overcome three main barriers to use in a production environment, namely operation in a metal-full environment, location accuracy to a few 10 cm, and ease of installation.

5.1 Suitability of RTLS UWB for operation in a metallic environment

RTLS has been continuously sending tag location information in the real tool shop environment. There was no difference whether we placed it on the upper surfaces of the workbench, tools, machines or tried to hide it a bit under different surfaces. Employees of the company confirmed that they see no hesitation in thinking about using the system in their production environment.

A practical test in a real production environment full of the metal objects gave an affirmative answer to RQ1. An example of commercial RTLS UWB reports location data for tags in an environment full of metal objects.

5.2 Accuracy of reported coordinates of the tag

In the second step, we ensured the accuracy of the specific location by RTLS in the laboratory. The maximal error was 0.86 m and the average error was 0.26 m. We confirmed that the accuracy of the measured location depends on the anchors' placement. Commercial providers in their offers promise to configure such an anchors' layout that the maximum error on the desired layout will be less than 0.3 m. We, therefore, suggest that sufficient attention should be paid to setting up the system.

The result shows that even a slightly less professional RTLS UWB installation provides sufficiently reliable data to have sufficient usable value. The answer to RQ2 gives a radius of at least 0.86 m, which draws a circle inside which the tag lies reliably in a non-professional installation. Commercial providers provide a radius of 0.3 m.

5.3 Possible auxiliary impacts of RTLS implementation at changing the tooling company's business model

In the introductory part, we mentioned three directions of development for the transition to new business models. They are (1) operate as a low price producer, (2) expand the share of value-added activities in the supply chain of finished products, and (3) produce highly complex and innovative tools. The realization of all three is firmly based on digitization and the transition to Industry 4.0. Toolmakers are not at the forefront of digitalization, but as suppliers to the automotive industry and other emerging industries, they are indeed working hard to keep up with the digitalization of their customers. The visibility of what is happening in real-time in the tool shop is very much in customers' interest, who should change the way toolmakers are financed. The financing problem is described by Henriques and Peças (2012). At the same time, it is also in the interest of toolmakers seeking to reduce costs. Relieving the burden of administrative work for traceability will be reflected in the reduction of production time.

RTLS UWB introduction can help tooling company to reduce costs in production and along supply chain. If tooling company strategically focuses itself to be a low price producer this is necessarily linked to shortening the production cycle and better utilization of resources beside others. The paper shows that RTLS UWB is actually a suitable system for monitoring the locations of employees and things in the production hall, which by integrating this system into the production information system leads to parallel data capture and exclusion of these activities from the production process sequence. Data are captured without the need for physical entries. Visibility of events in production is achieved and consequently the possibility of automated planning of events or processing in production.

If tooling industry decides to expand the share of value-added activities in the supply chain of finished products, RTLS UWB can be an important information system’s component of enabling system. The detected presence of the workpiece at the key processing workplace can trigger the recording of a film that is accessible in real time to the customer requesting the reporting of the key processing. The departure of the workpiece from the machining center can trigger a call to confirm the milestone, send the measurement results, etc. It is a bit more difficult to clearly show the connection between RTLS UWB implementation and strategic decision to produce highly complex and innovative tools. We leave this open for further research.

5.4 The importance of RTLS introduction on the way towards smart factory

Based on the performed research, we confirm the potential of the RLTS UWB system for use in the tool shop. Capturing the location of tools, their components and employees can relieve toolmakers of manual data entry to monitor production and pave the way for the company to add new, more complex, smart services to customers.

Regarding the relief of toolmakers from manually entering data for monitoring production, we have shown that a place for depositing tags of components that are being machined can be determined within the workplace so that the RTLS system will report the presence of an item on WP correctly. Suppose the employees also carry tags, then in the back-office systems, the pairing of the employee, the workplace and the workpiece in work can be performed, which is now most often done by manually entering data via the MES user interface. Additionally, using the RTLS system also allows automated tracking of workpieces after they have already left the WP. This is now uncovered mainly by the information systems in the tool shop.

An important feature of smart 4.0 environments is that they are digitized and that the visibility of all key elements of the system is achieved. Pairing elements with UWB tags enables just that, digitization based on visibility, more precisely knowing their location and behavior. In connection with other elements of the information systemthis location data can be enriched with data on availability, status, master data and more.

6. CONCLUSION

In this paper, we summarize the developments in the tooling industry, emphasizing the need to change the business model and develop in the direction of a smart factory. Regardless of the type of business model chosen, its implementation is based on a digital model. New business models in the tooling industry have somehow been hinted at for years. With the evolving concept of the smart factory in mind, it is becoming increasingly clear that each new business model is based on an appropriate digital model. Regardless of the type of business model chosen, to reach its full potential, the visibility of events in the tool shop must be established. Ensuring the traceability of events is still ensured mainly by manually entering data by employees, wasting their time needed for value-adding activities. In the paper, we indicate the potential for change in automating data entry using UWB RTLS. The technology is suitable for use in a metal-filled environment, accurate to a few 10 cm, and relatively easy to set up. The price is also affordable according to the effects that can be achieved with its help.

We see the planning of individual workplaces with the inclusion of RTLS and the verification and development of connections with other information systems and applications in the production company as an opportunity for further research.

7. REFERENCES

Boos, W., Kelzenberg, C., Prümmer, M., Goertz, D., Boshof, J., Horstkotte, R., Ochel, T., Lürken, C. (2020). Tooling in Germany 2020 [available at: https://www.ipt.fraunhofer.de/content/dam/ipt/de/documents/Studien/Studie_Tooling-in-Germany-2020.pdf, access June 17, 2021]

Boos, W., Kelzenberg, C., Wiese, J., Goertz, D., Boshof, J., Busch, M., Kessler, N. (2019). Digitale Transformation im Werkzeugbau, Aachen: RWTH Aachen Werkzeugmaschinenlabor.

Budak, A., Ustundag, A. (2015). Fuzzy decision making model for selection of real time location systems, *Applied Soft Computing*, 38, p. 177–184.

Canis, B. (2012). *The Tool and Die Industry: Contribution to U.S. Manufacturing and* Federal Policy Considerations, Congressional Research Service

Cho, H., Kim, T., Park, Y., Baek, Y. (2012). Enhanced trajectory estimation method for RTLS in port logistics environment, *IEEE 14th International Conference on High Performance Computing and Communication & IEEE 9th International Conference on Embedded Software and Systems*, Liverpool, UK, p. 1555–1562.

Crespo, G., Teniente, J., Ederra, I., Gonzalo, R. (2012). Experimental study of the antenna influence in RTLS based-on RFID, *2012 6th European Conference on Antennas and Propagation (EUCAP)*, Prague, Czech Republic, p. 2500–2504.

Gajšek, B. & Sternad, M. (2020). *Information Flow in the Context of the Green Concept, Industry 4.0, and Supply Chain Integration*. In: Kolinski A., Dujak D. and Golinska-Dawson P. (Ed.). *Integration of Information Flow for Greening Supply Chain Management*. EcoProduction (Environmental Issues in Logistics and Manufacturing). Cham: Springer, pp 297–323.

Gajšek, B., Marolt, J., Rupnik, B., Lerher, T. & Sternad, M. (2019). Using maturity model and discrete-event simulation for industry 4.0 implementation. International Journal of Simulation Modelling, 18(3), p. 488–499.

Henriques, E., Peças, P. (2012). New Business model for the tooling industry. In Nelson, W.D. (Ed.). Advances in business and management. New York: Nova Science Publisher.

McClellan, M. (1997). *Applying Manufacturing Execution Systems,* Boca Raton, Fl: St. Lucie/APICS.

Park Doo-jin, Park Jin-hee, Kim Hyun and Nam Chan (2006). Research of business models to ensure QoS in container terminals using RFID. *Journal of The Korean Port Port Bay*, 30(3), p. 211–217.

Radić, I., Rupnik, B., Šinko, S., Kramberger, T. & Gajšek, B. (2020). *Redesign of the Workplace for Toolmakers Towards Industry 4.0*. In Karabegović, I., Kovačević, A., Banjanović-Mehmedović, L. and Dašić, P. (Ed.). *Handbook of Research on Integrating Industry 4.0 in Business and Manufacturing*. IGI Global, pp. 492–511.

Redpoint (n.d.). Why is UWB better than other signals for indoor/industrial RTLS? [available at: https://www.redpointpositioning.com/why-uwb-better/, access June 18, 2021] .

Sanpechuda, T., Kovavisaruch, L. (2008). A review of RFID localization: Applications and techniques, *5th international conference on electrical engineering/electronics, computer, telecommunications and information technology*, Krabi, Thailand, p. 769–772.

Schuh, G., Rudolf, S., Pitsch, M., Sommer, M., Karmann, W. (2015). Modular Service-Oriented Cyber-Physical Systems for the European Tool Making Industry. Applied Mechanics and Materials, 752-753 (2015), p. 1349–1355.

Vrečko, I., Kovač, J., Rupnik, B. & Gajšek, B. (2019). Using Queuing Simulation Model in Production Process Innovations. *International Journal of Simulation Modelling*, 18(1), p. 47–58.

Xianjia, Y., Qingqing, L., Queralta, J.P., Heikkonen, J., Westerlund, T. (2021). Applications of UWB networks and positioning to autonomous robots and industrial systems, arXiv preprint arXiv:2103.13488.

Zamora-Cadenas, L., Velez, I., Sierra-Garcia, J.E. (2021). UWB-Based Safety System for Autonomous Guided Vehicles Without Hardware on the Infrastructure. *IEEEAccess*, 9, p. 96430–96443.