



## APPLICATION POSSIBILITIES OF RTLS SYSTEM IN PRODUCTION LOGISTICS

Received: 04 March 2021 / Accepted: 18 June 2021

**Abstract:** Determining the current position of objects in logistics processes (products, unit loads, forklifts, etc.) is the basis for new process development and optimization opportunities (e.g., development of storage strategy, forklift route planning, etc.) that significantly affect the competitiveness of companies. Background information systems that provide real-time data using localization, - or called RTLS (Real Time Location System),- are becoming more widespread. In the dissertation I summarize the operation, physical realization, conditions of use and advantages of a real-time technology that can be applied to a warehouse serving its production, as well as the steps of a possible implementation.

**Key words:** RTLS, real time location system, UWB technology, RTLS implementation, RTLS benefits.

**Mogućnosti primene sistema RTLS u proizvodnoj logistici.** Utvrđivanje trenutne pozicije objekata u logističkim procesima (proizvodi, jedinični tereti, viljuškari itd.) je osnova za razvoj novih procesa i mogućnost optimizacije (npr. Razvoj strategije skladištenja, planiranje rute viljuškara itd.) i oni značajno utiču na konkurentnost kompanija. Pozadinski informacioni sistemi koji pružaju podatke u realnom vremenu koristeći lokalizaciju - ili nazvani RTLS (Sistem lociranja u realnom vremenu) - postaju sve rašireniji. U disertaciji rezimiram rad, fizičku realizaciju, uslove upotrebe i prednosti tehnologije u realnom vremenu koja se može primeniti na skladište koje opslužuje njegovu proizvodnju, kao i korake moguće primene.

**Ključne reči:** RTLS, sistem lokacije u stvarnom vremenu, UWB tehnologija, implementacija RTLS-a, RTLS benefiti.

### 1. INTRODUCTION

Real-time logistics data and the well-defined functionality based on it can provide huge value to manufacturing or service companies [1]. More modern and efficient logistics processes can be created, which can result in lower unit costs and / or higher service standards. In everyday life, "GPS-based" applications using satellite technology are already in everyone's pockets, providing real-time data that allows users to enjoy simpler, more cost-effective, faster, more reliable, or even more enjoyable living conditions. The operation of these ordinary systems can be paralleled by the real-time positioning systems (RTLS, Real Time Location System) that have appeared in recent years, which enable to the company to do locationing "within four walls", for instance in case of path and trajectory planning of an AGV [6]. Using this new technology, new process development and optimization methods can be developed in the field of warehousing logistics, which are:

- optimization of picking processes,
- optimization of warehouse material handling activities,
- development of administrative processes,
- improving inventory accuracy,
- optimization of inventory mechanisms.

### 2. BASIC CONCEPTS OF POSITIONING

#### 2.1 Trilateration

The most commonly used method of positioning

uses geometric foundations to locate it. By measuring the distance of several known anchors, the position of a given point can be determined. If we can measure a certain distance, we know that we are in a circle of corresponding radius around the anchor (on a plane). If we measure the distance (on a plane) with three anchors, we can see that our position is uniquely determined by the intersection of the three circles. This method is called trilateration (or "multilateration" if more than 3 anchors are used).

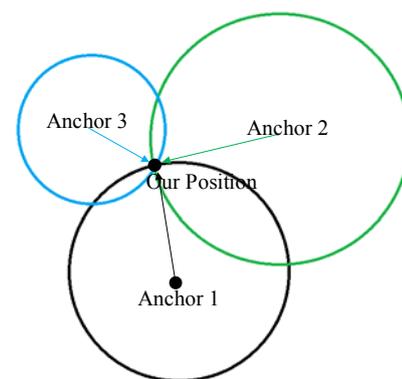


Fig. 1. Positioning in the plane - using 3 anchors

The difficulty with this approach lies in the fact that warehouse distance measurements are not perfect, only under "laboratory conditions". In a warehouse, there will always be some noise (disturbing signal) during "more realistic" distance measurements and because of this, the above hyperboluses will not intersect at exactly

one point. In determining the location of the intersection point, we try to use some algorithm to best characterize the point that is actually the possible position.

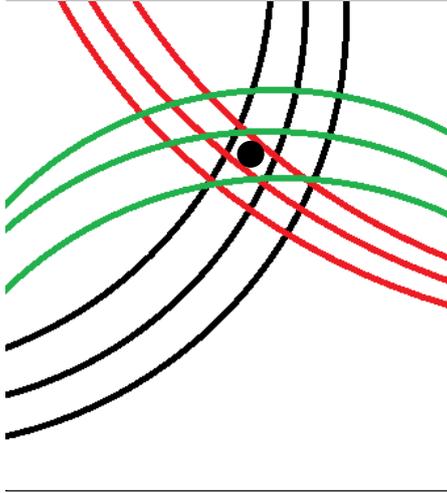


Fig. 2. In case of inaccurate distance measurement, an algorithm can be used to approximate the real position of the point

## 2.2 Distance measurement

How to quickly and efficiently measure distances in a warehouse environment? Stored various raw materials, packaging materials, warehouse material handling equipment, moving people, pallets, racking systems, etc. inhibit the measurement. Measuring instruments based on visual measurement are out of the question, as for most points the above warehouse instruments would “cover” the range used for the measurement. For the measurement, it is necessary to achieve an accuracy of approximately decimetres (10-50cm), since it is necessary to distinguish e.g. 80 cm wide pallets or 80 cm wide storage spaces apart. Usually, accuracy greater than 10-50 cm is not required. We can use radio waves to answer the question. The idea is to send radio waves from one point to another (from the current point to the anchor) and measure the “flight time” (ToF = Time of Fly) very accurately. So the question is, how long does it take us to get from our position to the starting point of the anchor? Since the radio waves travel at the speed of light ( $c = 299\,792\,458$  m / s, simply multiplying the flight time (ToF) by this speed, we obtain the distance to be measured:

$$s[m] = c \cdot ToF = 299'792'458 \left[ \frac{m}{s} \right] \cdot ToF[s] = \dots [m] \quad (1)$$

Radio waves travel fast, in a single nanosecond - which is a thousandth of a millionth of a second - a wave makes almost 30 cm. So if we want to perform a decimeter-accurate distance measurement in the warehouse radio wave may be suitable for this, but we need to be able to measure the flight time very accurately! So now the question is how to measure the flight time of a “piece” of radio wave from our point in question to the starting point of the anchor, i.e. the reference point.

## 2.3 Distance measurement with radio waves

The concept known from physics is Heisenberg's uncertainty theorem [10]. Among other things, the theorem states that it is impossible to know (measure) the frequency and timing of a signal at the same time. Take, for example, a sinus wave (a sinusoidal radio wave):

- a signal with a well-known frequency but a poorly definable timing,
- the signal has no beginning or end.

However, if we combine several sinusoidal signals with a slightly different frequency, we can create a “pulse” with a more definite timing, i.e. we can examine the pulse peak more easily. This is shown in Figure 3, which sequentially adds sinusoids to a signal to obtain a sharper, more contoured pulse [11]:

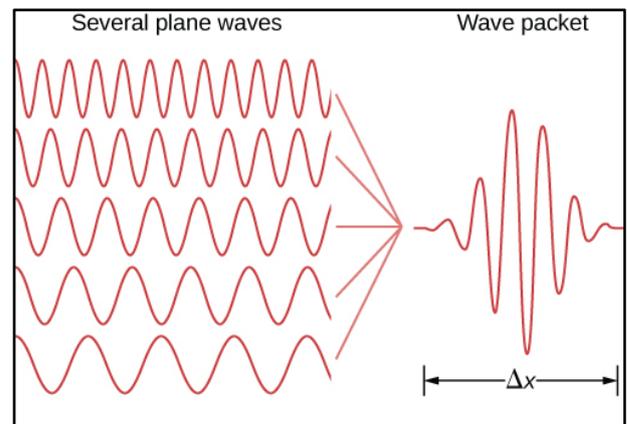


Fig. 3. The result of sinusoids sequentially added to a radio signal

In relation with the operation, the frequency range used for the signal to be produced, “ $\Delta f$ ” - is called bandwidth. Using the Heisenberg uncertainty principle, we can roughly limit the pulse width “ $\Delta x$ ” using the bandwidth  $\Delta f$ :

$$\Delta f \cdot \Delta x \geq \frac{1}{4\pi} \quad (2)$$

It can be seen from the simple formula that if we want to use a narrow pulse for distance measurement - which is necessary to measure the exact timing - then it is necessary to use high bandwidth in the measurement system.

## 3. UWB (ULTRA WIDE BAND) TECHNOLOGY

UWB ultra-wideband signals have a bandwidth of at least 500 MHz, which can be used to generate 0.16 ns wide pulses. This timing resolution is so fine that at the receiver (reference point) we are able to distinguish the original (measured) signal (pulse) from its other reflections (reflections).

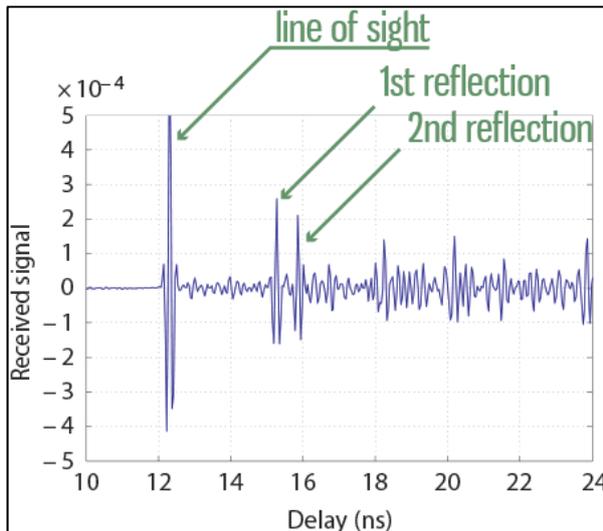


Fig. 4. UWB pulse signal reflection [10]

In a warehouse environment, we need the same thing for the optimal operation of all equipment using mobile technology (handheld mobile data loggers, forklift terminals, mobile printers, Pick by Voice devices, etc.): more bandwidth. In wireless communication systems, higher bandwidth means faster upload / download (i.e., information transfer). However, if all mobile devices transmitted signals on the same frequency, all signals would interfere with each other and no device could receive an interpretable one. As a result, the use of the frequency spectrum has been strictly regulated. How is it possible that a UWB gets 500 MHz of valuable bandwidth while other systems have to accommodate much less (e.g. wifi with 20 MHz)? Well, UWB systems can only transmit signals at low power (the energy spectrum density should be below  $-41.3$  dBm / MHz according to the standard). This very strict power limitation means that no pulse can go far: at the receiver, the pulse is likely to be below the typical noise level in the warehouse. To solve this problem, it sends a series of transmit pulses so that they contain only a single bit of information. At the receiver (reference point), the received pulses accumulate, and if there are enough pulses, the force of the “accumulated pulse” rises above the noise level, and a secure reception (i.e., measuring the propagation time of the signal) is created.

#### 4. POSITIONING IN UWB TECHNOLOGY BASED SYSTEMS

In UWB-based logistics systems, two types of location protocols are prevalent. Both protocols have advantages and disadvantages, but depending on the kind of the logistics process to be supported - you can choose from these for each application. The two types; TWR - two-way distance measurement and TDoA (Time Difference of Arrivals) - measurement based on time difference of arrival. To facilitate the interpretation of the protocols, it is necessary to define the concept of the RTLS tag; An RTLS tag is the usually small electronic unit whose position we want to determine in the logistics system. The RTLS tag is more than a geometric point that:

- has a battery / rechargeable battery or other resource suitable for independent power supply,
- is capable of emitting or emitting and receiving individual radio waves of a specified UWB standard,
- has some kind of mechanical enclosure and is suitable for attachment to materials, logistics equipment or people handled in the warehouse.



Fig. 5. RTLS tags [3],[12]

The time has also come to present the physical reality of the Anchors defined in 2. Well, anchors are also existing electronic devices that:

- can usually be operated with external power supply,
- are also capable of emitting or emitting and receiving individual radio waves of a specified UWB standard,
- have some kind of mechanical housing and are suitable for fastening as warehouse reference points,
- are connected to each other or to a common - but other network device - electronically or on a radio basis (synchronized).

The literature specifically calls these RTLS Anchors, as opposed to antennas used in Wi-Fi and other standard technologies, Access Points.

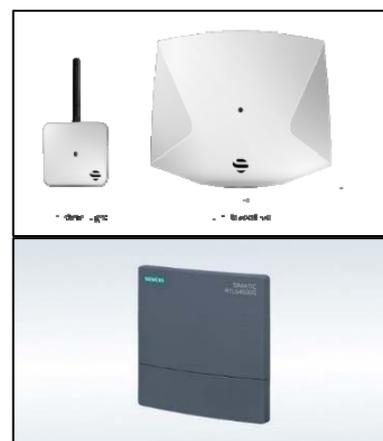


Fig. 6. RTLS Anchors [3],[12]

#### 4.1 The main UWB protocol - Time Difference of Arrival based Measurement (TDoA)

In TDoA mode, RTLS tags send an UWB flash (pulse) with or without a schedule, - taking into account other tags or anchors. Because the Tag only needs to send a single UWB signal, positioning can be done quickly and with low power consumption. Using the commonly used Aloha protocol, tags only send and never receive, resulting in incredibly low power consumption, and their battery life (500-1000 mAh) can last for several years. However, in order to limit interference with other tags used in the logistics system, the update rate may be somewhat limited. Alternatively, tag communication can be scheduled. When the RTLS tag sends information about itself in TDOA mode, e.g., "ID\_0011", any "visible" anchor installed in the warehouse receives this information. Anchors connected over ethernet lines / wireless send the time of receiving the Tag pulse to the location server accurately. Because the anchors are at different distances from the tag, although the difference is small, these anchors will receive the tag pulse signal (nano-seconds) at slightly different times. Based on these time differences, the serving RTLS server can calculate where the tag was compared to the anchors at the time the tag sent a pulse. Geometrically, the situation will be at the intersection of the hyperboluses determined by the measured time differences. The RTLS tag used in TDOA will therefore never know its own position in the warehouse unless it is sent back to it by some external system. For TDoA to work properly, Anchors installed in a warehouse must have the same time concept. To do this, their internal clocks must be precisely synchronized. Anchors communicate regularly with each other via UWB so they can synchronize their internal clocks. And in case you want to synchronize too many anchor clocks at once, we have the option to divide them into groups, and within a group, the so-called Create Master anchors. The master anchors then need to be time-synchronized in the first round. In all cases, it is advisable to choose a master that has an anchor "view" directly of the other, - intra-group anchors, so that intra-group time synchronization can be solved quickly via the UWB network.

Using Master Anchors, we can achieve RTLS in a larger logistics area. By connecting the anchors to a high-speed Ethernet network, a virtually unlimited scalable RTLS system can be created with up to many thousands of anchors and many thousands of tags. With the use of low-energy tags suitable for TDoA technology, a wide range of applications in the field of logistics are emerging.

#### 5. THE OPERATIONAL CONCEPT OF THE RTLS

Based on the operation described in the previous chapters, all goods / logistics equipment / human resources to be tracked can be tracked in real time in a properly designed RTLS infrastructure, warehouse environment, with an accuracy of around - decimeter. Once again, it is very important to emphasize that in Real Time, as RTLS differs from other point-to-point

discrete identification systems, such as RFID installed on doors / gates, or barcode identification attached to the start or end points of each logistics operation. The fundamental difference between the two systems lies in the continuous communication between the objects to be tracked and the background system. In other words, a non-RTLS system will know that a device is in a certain area, but it cannot determine exactly where that device is located. For example, a tracking system may tell you that an object has entered a warehouse if the label is read as it passes through the docking door; however, you cannot usually determine where the device is in the warehouse. This is not the case for RTLS systems. As a result of continuous and automatic communication between the tag and the system, RTLS solutions ensure the exact location of the device. Thus, tracking solutions can only be considered RTLS if they are configured for automatic and continuous reporting.

Each RTLS tag has a unique ID, which is accompanied by additional information from the Enterprise Business System that has an ultra-fast network connection to the RTLS server system. In the associated Business System, we store additional attached information (records) belonging to individual RTLS tags, such as the names of the persons connected to the Tag / the logistics ID, physical condition, maintenance log, etc. of the connected device, saving the UWB server network from this information traffic. It is characteristic of RTLS systems that their manufacturer provides the user with a real-time view of the warehouse via a graphical user interface. Typically, the Anchors in the warehouse / UWB covered area are "laid" on the floor plan of the warehouse, effectively producing a digital replica of the warehouse, i.e., a digital twin. In this digital twin, we can see objects moving in the RTLS covered area with their own unique identifier. The digital twin pair representing the real warehouse space can be used to follow the warehouse events in real time.

The graphical interface helps the Logistics Manager in several ways:

- real-time tracking of moving objects (basic function),
- can generate reports that can be generated from the operation of a live logistics system,
- can order logistical restrictions / change logistics processes, re-parameterize in the live warehouse (eg geo-fencing, designation of security zones),
- can manipulate and configure data between the logistics system and the company's ERP (Enterprise Resource Planning),
- can fine-tune the RTLS server system (eg when relocating anchors)
- can be used to monitor the operation of the RTLS server system,

Of course, warehouse Logistics data can be integrated directly and automatically into the ERP (Enterprise Resource Planning) system to provide updates to key business processes such as warehouse management, production planning and scheduling, delivery planning, and other related processes. In this case, the digital twin of the RTLS system is not required, as all information

flows automatically between the two IT systems according to the pre-planned Logistics process. During the installations so far, our experience has been that it is always necessary to set up / create a digital twin during an installation - as this allows the system user to really see the mapping of the live system into the virtual world. Then, after understanding this, it is possible to build an automated connection system between RTLS and ERP based on a well-established and transparent schedule.

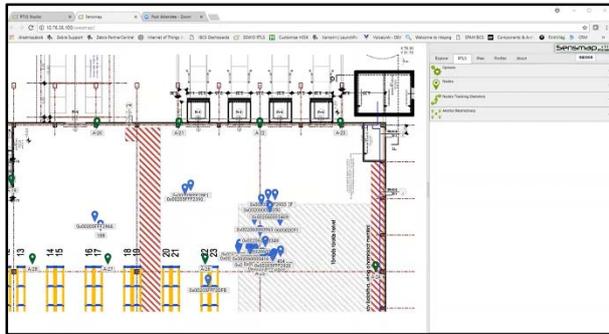


Fig. 7. RTLS Graphical Interface/RTLS Digital twin [3]

Of course, warehouse Logistics data can be integrated directly and automatically into the ERP (Enterprise Resource Planning) system to provide updates to key business processes such as warehouse management, production planning and scheduling, delivery planning, and other related processes. In this case, the digital twin of the RTLS system is not required, as all information flows automatically between the two IT systems according to the pre-planned Logistics process. During the installations so far, our experience has been that it is always necessary to set up / create a digital twin during an installation - as this allows the system user to really see the mapping of the live system into the virtual world. Then, after understanding this, it is possible to build an automated connection system between RTLS and ERP based on a well-established and transparent schedule.

## 6. WHAT FUNCTIONS CAN RTLS BE USED FOR IN PRODUCTION LOGISTICS?

RTLS is able to provide us with asset tracking capabilities, but this is only due to the basic operating principle that the solution supports within the company. Building on this, additional opportunities arise for a warehouse serving production; the features of the RTLS solution can be exploited for additional applications such as:

- **Increase efficiency** - Access to real-time driver motion information means you can work with your drivers to continually refine and improve performance, which benefits both the driver and the business. For example, a pallet is likely to be moved at least four times during its time at the distribution center: It arrives as a shipment and is unloaded on the floor. It is then picked up and moved to a storage location. Stored for a while and ready to be returned to the floor, it takes driving time (some shorter, others much longer). If a company delivers 10,000

pallets a week, taking an average of 3 minutes per pallet movement, the time spent moving 10,000 pallets is 30,000 minutes, or 500 hours. However, calculating efficiency is rarely simple, and most companies prefer the actual number of driving hours to more, and it is often very difficult to determine exactly where and why they spend the extra time. Using RTLS provides real-time, actual driver and pallet information that allows you to see exactly where and how time is being wasted. This will allow you to make efficiency changes that you know will work. It also helps drivers reduce time spent searching for pallets and locations, as real-time location information is immediately available to them. Within 6 months of the introduction of RTLS, your company can reduce the number of steps required by 20%.

- **Asset Management** - track, manage and utilize an asset. A warehouse property owned by a business that is held for business purposes to provide future benefits and is not expected to be convertible into cash in the current or next financial year. Assets are valuable to their owners - financially, operationally or emotionally. The required operation of the devices can be traced using the RTLS system. The accuracy of the kit is vital; the challenge is to achieve it. RTLS helps achieve and maintain inventory 99.9% accuracy without the tedious and often expensive inventory checks that can take hours or sometimes days. RTLS provides all real-time positioning information within seconds. Each barcode scan can take 10-15 seconds (screen analysis, device download and recording, screen verification), while in the case of the RTLS system, the operator can practically deal with material handling, the system does its job in the background. Thus, the RTLS system can save up to 4 hours of time when moving 1000 pallets.
- **Human Resource Management** - the workforce management of the company as it relates to operational and compliance activities. The RTLS system can be used to ensure that employees are able to achieve company goals and objectives. Common applications include time / presence, process compliance, time tracking between tasks, and associating employees or objects.
- **Supply Chain Management** - the management of affiliated businesses and business processes related to the production, distribution and sale of products and services. Supply chain management means the movement and storage of raw materials, inventories, processed and finished products from place of origin to consumption. Supply chain management covers both inbound and outbound logistics, as well as tracking the tools used by these processes (e.g., containers, vehicles) [13]. Newer RTLS systems also have site-to-site identification synchronization, which allows multiple site models to be mapped within an RTLS system.
- **Detection and monitoring** - integration of sensors into the RTLS system to monitor the physical environment of the object. Common sensors include temperature and humidity, as well as acceleration /

deceleration or rotation angle [14].

- **Security** - managing, ensuring, and adequacy of the security and safety of the business, its employees, assets, products, and processes. An average of 20,000 people are seriously injured in forklift accidents each year in the United States, and the cost of forklift accidents is estimated to exceed \$ 100 million. RTLS provides all the information needed to find the root cause of problems; either the designation of accountability or the redirection of the stock exchange to eliminate accidental hot spots. A great example of this is the use of driver data to understand how and why an accident occurred. Analyzing route and speed data makes it easy to find out what went wrong and how to ensure it doesn't happen in the future. The RTLS system can be used to prevent accidents (eg crossing forklifts within a warehouse, or human entry into danger zones, or just keeping a social distance due to a pandemic).

## 7. POSSIBLE PROCESS OF AN RTLS SYSTEM IMPLEMENTATION

RTLS solutions are currently mostly used by Tier 1 and Tier 2 vendors, however, as the technology is relatively new, - it is expected to continue to grow in popularity. Currently, there are 10-12 important manufacturers on the market who have done larger RTLS implementations [2] [3] [4] [5] [6] [7] [8] [9]. Despite the benefits of the system, RTLS is not a useful solution for all companies. In the following cases, however, it is essential to examine its use in production logistics:

- The use of mobile warehouse devices plays a significant role in the operation of the store / warehouse / is critical.
- The supply or value chain is complex and consists of several product sets / types.
- The strong need to add more value to the company / warehouse to the customer and improve their satisfaction.
- There is a need to reduce the order and cash cycle, improve transfer speeds and simplify processes.
- There are significant MRO and / or compliance requirements. Current asset tracking solutions do not provide the necessary transparency.
- Employee management and security is critical to the success of the business / warehouse.

Successful implementation of an RTLS is not an easy task. The technology itself is mature, Anchors and Tags can be set up quickly, the server RTLS subsystem can be started in as little as a few hours - but this is not the success of the project. It is very important to understand and feel the business benefits provided by RTLS, which radically change the hitherto well-known chain-linked logistics processes using real-time data. In the case of RTLS, there are no checkpoints, no dedicated points, to the status of which the background IT system responds and even warns or alerts the operators. Workers in the RTLS system will not initially feel the feedback of their work, they will feel lacking,

they may become insecure in their work. Therefore, the most important rule for installing an RTLS system is to always : Start small! RTLS vendors usually have a demo system that can be set up quickly or even on site. These systems can be assembled within 1-2 hours and can be used immediately in the warehouse to serve a snatched space or logistics sub-function. Plan the operating processes of one such subfunction or delimited space in advance, compile the input and output information in this test cell. Let's start using the RTLS cell step by step, then check the operating states. Explain to logistics staff that their actual activity (e.g. material handling) induces a real-time information flow. Help us understand with screens fed back into processes that we no longer need to use later. We test these cells for several weeks, fine-tune the operation, teach the warehouse staff how it works, and once everything is working, just start expanding in both space and functionality. They will see that this means less risk and investment to prove the concept. The return will also be more measurable and the time to achieve the expected return will be faster. It will improve the level of knowledge of the business based on real experience. It simplifies the rationale for further investment in the solution (already proven to add value to your company). Provides the right choice for your RTLS solution provider (lower risk testing option with vendor). It facilitates the size, expansion and further integration of (established infrastructure).

## 8. SUMMARY

As a result of striving to satisfy individual customer needs, logistics processes are becoming more and more complex, the transparency and manageability of which can only be increased by digitizing the processes. The dissertation described the technological possibilities of real-time positioning, after the analysis of which the UWB (Ultra Wide Band) technology applicable to the tracking of storage processes was selected. The technology used is only the first step in developing a well-functioning and fast payback system. During design, it is very important to make a well-thought-out decision on the use of RTLS, and to select well-thought-out and well-thought-out implementation steps and their control during the project.

## 9. REFERENCES

- [1] Tamás Péter, Illés Béla, Dobos Péter, Waste reduction possibilities for manufacturing systems in the industry 4.0, IOP Conference Series, Kozani, Greece, September 23-25, 2016.
- [2] Zebra Technologies Corporation, Know in Real-Time the Quantity, Location and Condition of All Your Assets, [Online]. Available: <https://www.zebra.com/gb/en/products/location-technologies/ultra-wideband.html>.
- [3] SEWIO Corporation, SEWIO UWB Real-Time Location System (RTLS), SEWIO Corporation, 2021. [Online]. Available: <https://www.sewio.net/real-time-location-system-rtls-on-uwb/>.

- [4] VERO Solutions., Track your stocks, pallets and inventory, VERO Solutions, 2021. [Online]. Available: <http://vero.solutions/solutions/stock-pallet-inventory-management/>.
- [5] SYOOK Corporation, Syook RTLS impacts for warehouse sector, Syook Corporation, 2020. [Online]. Available: [https://syook.com/wp-content/uploads/2019/08/Whitepaper\\_Warehousing-Operations.pdf](https://syook.com/wp-content/uploads/2019/08/Whitepaper_Warehousing-Operations.pdf).
- [6] WISER Systems, Work-in-Progress Tracking: Automotive Manufacturing, WISER Systems, 2020. [Online]. Available: <https://www.wisersystems.com/applications/automotive-manufacturing>.
- [7] CISCO Corporation, Location-Based Services and Enterprise Visibility Solutions, CISCO Corporation, 2019. [Online]. Available: [https://www.cisco.com/c/dam/en\\_us/solutions/industries/docs/manufacturing/cisco-aeroscout-pov.pdf](https://www.cisco.com/c/dam/en_us/solutions/industries/docs/manufacturing/cisco-aeroscout-pov.pdf).
- [8] POZYX Corporation, RTLS Solutions for manufacturing and warehousing, POZYX Corporation, 2019. [Online]. Available: <https://pozyx.io/industries/manufacturing-and-warehousing/>.
- [9] IBCS Hungary Kft., RTLS Helymeghatározás, IBCS Hungary Kft., 2021. [Online]. Available: <https://ibcs.hu/megoldasok/rtls-helymeghatarozas/>.
- [10] Wikipedia Org., Uncertainty principle, Wikipedia, [Online]. Available: [https://en.wikipedia.org/wiki/Uncertainty\\_principle#Heisenberg\\_limit](https://en.wikipedia.org/wiki/Uncertainty_principle#Heisenberg_limit).
- [11] OpenStax University Physics, The Heisenberg Uncertainty Principle, OpenStax University Physics, [Online]. Available: <https://cnx.org/contents/pZH6GMP0@1.364:cNerpl43@2/The-Heisenberg-Uncertainty-Principle>.
- [12] SIEMENS Corporation, SIMATIC RTLS – Real-time locating system, SIEMENS, 2020. [Online]. Available: <https://new.siemens.com/global/en/products/automation/industrial-identification/simatic-rtls.html>.
- [13] Bányai, Tamás; Illés, Béla; Bányai, Ágota: Smart Scheduling: An Integrated First Mile and Last Mile Supply Approach, COMPLEXITY 2018 Paper: 5180156 , 15 p. (2018)
- [14] Skapinyecz, Róbert, Illés, Béla, Bányai, Ágota: Logistic aspects of Industry 4.0, IOP CONFERENCE SERIES: MATERIALS SCIENCE AND ENGINEERING 448: 1 Paper: 012014(2018)

**Authors: Péter Tamás**, University of Miskolc, Faculty of Mechanical Engineering and Informatics, Institute of Logistics, Hungary, H-3515 Miskolc-Egyetemváros, Phone: (36) 46 565-111/17-39  
E-mail: [tamas.peter@uni-miskolc.hu](mailto:tamas.peter@uni-miskolc.hu)

**Tamás Bátori**, Branch Office Manager at IBCS Hungary Ltd., PhD student at University of Miskolc, Faculty of Mechanical Engineering and Informatics, Institute of Logistics, Hungary, H-3515 Miskolc-Egyetemváros, [Batori.Tamas@ibcs.hu](mailto:Batori.Tamas@ibcs.hu)