TECHNISCHE UNIVERSITÄT MÜNCHEN

MASTER’S PROGRAM IN TRANSPORTATION SYSTEMS

Master’s Thesis

Logistical process optimization for the handling of historical vehicles in relation to automated Track and Trace

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December 31, 2020

Declaration

I hereby declare that this master thesis is my own work and it has not been submitted anywhere else for assessment. All sources and materials used in the thesis are referenced and acknowledged.

Munich, 31st December, 2020 Kateryna Shavrova

Acknowledgments

This thesis and the corresponding research were completed with the Technical University of Munich in cooperation with the BMW Group Classic in Munich, Germany.

Firstly, I would like to thank Prof. Dr. Constantinos Antoniou for supervising this thesis and guiding me through the process of undergoing the research and writing the thesis. I am grateful for his many insights, advice, and suggestions while completing the thesis.

Secondly, my sincere thanks go to Claudia Adelberger, who served as my technical adviser at BMW and gave me the chance to write my thesis in cooperation with the BMW Group Classic. Without her guidance, insights, experience, and encouragement during the scores of meetings and discussions, this thesis would not have been possible.

Additionally, I would like to thank my colleagues at BMW, who supported me with their feedback and their time to participate in the surveys and evaluate the results of this thesis.

I am very grateful and forever indebted to my parents, Larysa Shavrova and Tymofij Shavrov, for their love, continued support throughout my life and always believing in me during my endeavors.

Abstract

The navigation and localization systems are commonly used in different fields of industry and help to access unfamiliar environments. Various technologies enable object identification and tracking. In particular, parking area and warehouses require intelligent systems which can assist in proper management, guidance towards the parking facility, searching the unoccupied parking space, or tracking the vehicle. However, not every approach fits all the needs and requirements. In response to such problems, the focus is to review and analyze different reliable, intelligent and efficient vehicle identification technologies applicable for tracking and tracing of historical vehicles indoors and outdoors. This study introduces different indoor navigation and outdoor positioning technologies: Radio Frequency Identification (RFID), Bluetooth Low Energy (BLE), Automatic License Plate Recognition (ALPR), ultra-wideband (UWB), and GPS. Each location-sensing system differentiates by coverage area, level of accuracy, the purpose of the application, frequency of location updates, maintenance, and installation costs. The paper represents a general explanation, description and evaluation of each vehicle detection and surveillance technology and shines some light on the respective advantages and disadvantages as well as possible exemplary use cases for each approach. Moreover, the proposed technologies are investigated and contrasted by various evaluation criteria. The implementation of one of the discussed technologies helps to reduce problems that arise from the lack of reliable and modern systems and decrease human errors that influence the efficiency of the logistical processes.

The research offers an accurate vehicle identification technology for a variety of challenging environments. The proposal can improve the precise location of the vehicle and gain information about the current location of the resource using wireless data transmission technology.

Finally, this study is an attempt to implement the BLE technology in one of the leading vehicle manufacturing companies, give an insight into the economic analysis of such project and analyze its contribution, benefits, effects, and improvements in logistical processes.

Keywords: parking lot, radio frequency identification (RFID), vehicle tracking system, BLE technology, GPS, vehicle identification technology, tracking, warehouse.

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List of Abbreviations

ANPR	Automatic Number Plate Recognition
BLE	Bluetooth Low Energy
CPU	Central processing unit
EPC	Electronic Product Code
GPS	Global Positioning System
IPS	Indoor positioning system
IR	Infrared
ALPR	Automatic License Plate Recognition
RFID	Radio Frequency Identification
OCR	Optical Character Recognition
PBP	Payback Period
PGIS	Parking Guidance and Information System
UHF	Ultra-high Frequency
UWB	Ultra-wideband
VMS	Variable Message Signs
WLAN	Wireless Local Area Network

Chapter 1

1. Introduction

The first chapter starts with the description of the background, current situation and main objectives and questions addressed to the research topic. Then, the research framework is provided and, finally, the structure of the report is reviewed.

1.1. Background and motivation

Within the last years, technological achievements have soared around the world. During the last decade, new technologies hit the market and simplified life by atomization of logistical processes. ANPR and RFID technology was one of these groundbreaking innovations that completely changed the pace of development of many industries.

According to Apogee/Hagler Bailly (1998), vehicle detection and surveillance technologies are an integral part of Intelligent Transportation Systems and are being improved to provide advanced presence detection, distance measurement, vehicle classification, and speed monitoring.

Technology development added many advanced features to the vehicles. Different fresh technologies like the latest driver-assist systems, parking assistance, and satellite navigation systems simplify driver's life to calculate the shortest distance between point A and B, to avoid traffic congestion and assist the driver on the road. This study puts the main focus on historical vehicles from old times till nowadays, that is why it should be mentioned that some of them may not be equipped with innovative technologies.

Positioning systems have played an important role in everyday life since the Global Positioning System (GPS) became accessible in the late 1990s. GPS satellite technology revolutionized outdoor positioning. However, it has limited applicability in the indoor environment, in narrow streets and tunnels properly due to the tendency of attenuating and scattering by walls and roofs and inability of the satellite signals to penetrate buildings. Lately, indoor positioning has been considered a key technology for business intelligence applications, since location information becomes more and more important. Indoor identification technology becomes commercially accessible in different forms and quality. As navigation indoors is more challenging, there exists no one proven technique that could be sufficient for all purposes.

One of the biggest challenges in the logistics industry is the tracking of the objects. Current parking infrastructures do not have a central platform for real-time parking availability. Another issue appears at parking when drivers have to spend a significant amount of time searching for an available parking spot and locating the parked vehicles in huge parking lots, or searching for the specific vehicle at the multi-level building. Furthermore, employees face some challenges such as: maintaining the data of all vehicles by physically entering the information, which leads to the inability to accurately and intelligently identify and collect the vehicles entering and leaving the parking lot, and increases human errors (Ostojic et al., 2007).

Enterprises put more emphasis on warehouse management, which plays a key role in improving the productivity of the entire supply chain (Zhao et al., 2016).

Random placement and movement of the vehicles in the warehouse complicates warehouse management. Generally, most of the parking areas and warehouses are built indoors. Depending on the range of detection, various identification technologies are applied for indoor positioning. Integration of new technology into an existing system reduces the involvement of manpower by automating the processes and provides more efficient and fast parking management (Singh and Vaidya, 2019).

These technologies can automatically recognize and count the vehicles entering or leaving the parking area or warehouse for security reasons. Every technology uses its detection component. ALPR system captures the image with the help of a camera, while RFID, UWB and BLE send signals in a specific format (Stiawan et al., 2019).

Simultaneously, navigation vehicle systems still remain a part of daily life. They could be represented as an embedded system in the vehicle or an external system using a device with vehicle access.

Automated vehicle tracking is the basis of modern logistics management systems. Description of each technology in the next chapters provides general characteristics, functions and applications, installation and maintenance costs (Peerbits, 2020).

1.2. Research objectives and questions

The main contribution of this paper is to define and analyze technology appropriate for both vehicle identification in the warehouse or parking area and real-time tracking outdoors without any circumstances. The goal is to propose advanced technology to improve the speed of location and efficiency of vehicles’ detection in the parking area. A smart parking system has to provide current information about parking availability and automatically update all the movements of vehicles coming in or leaving the garage.

There is a necessity for research concerning tracking and monitoring of vehicle position identification in the warehouse. Thus, this paper aims to assess the feasibility of applying different tracking technologies for vehicle tracking and tracing purposes in the parking lot and when the vehicle is on the road.

This paper provides an analysis of indoor navigation and positioning technologies along with the recognition methods that can aid the indoor tracking. The difficulty is to offer the technology solution for the cases where GPS is not available (indoor multiple level parking garage or warehouse) and to combine possibility of indoor identification and outdoor tracking in one technology.

Human errors are the main source of wrong input data in the system, therefore identification and positioning technologies are turning out to be an integral research area for check-in/ check-out at the parking lot and guidance to and inside the parking facility.

This study shows the most suitable tracking systems based on the factors that can influence technologies. The accuracy of using a vehicle tracking system is investigated as well. These proposals are explored through a case study.

The proposed technologies will help to reduce the problems arising from the lack of a modern, reliable, efficient parking system, and the methodology of economic analysis will help in analyzing the feasibility of the projects.

Despite the general problems in warehouse management, the following challenges still exist:

- Which vehicle identification technologies exist?
- How are vehicles identified?
- How to apply each technology for vehicle identification?
- Why are BLE beacons replacing RFID tags nowadays?
- Which features do beacons have that RFID-based technology cannot accomplish?
- How to combine the indoor positioning system with the current working procedure of the company?
- Will the integration of the new technology bring positive outcomes compared to the current situation?
- Is it feasible to cover all the investments during the next five years?

All these questions will be answered in the next chapters during the research and analysis.

1.3. Research framework and report structure

This thesis is comprised of five chapters. The first chapter starts with the introduction, where the main problems and objectives are defined. The second chapter introduces the literature review, describes each proposed vehicle identification technology, and focuses on one of the objectives to define the most suitable technologies. In the third chapter, the methodology and analysis of proposed technologies are represented. The fourth chapter proposes an implementation of the technology in the warehouse of one of the companies as a case study and answers the rest of the research questions. The conclusion of the paper is described in Chapter 5.

The thesis framework is developed and presented in Figure 1.1.

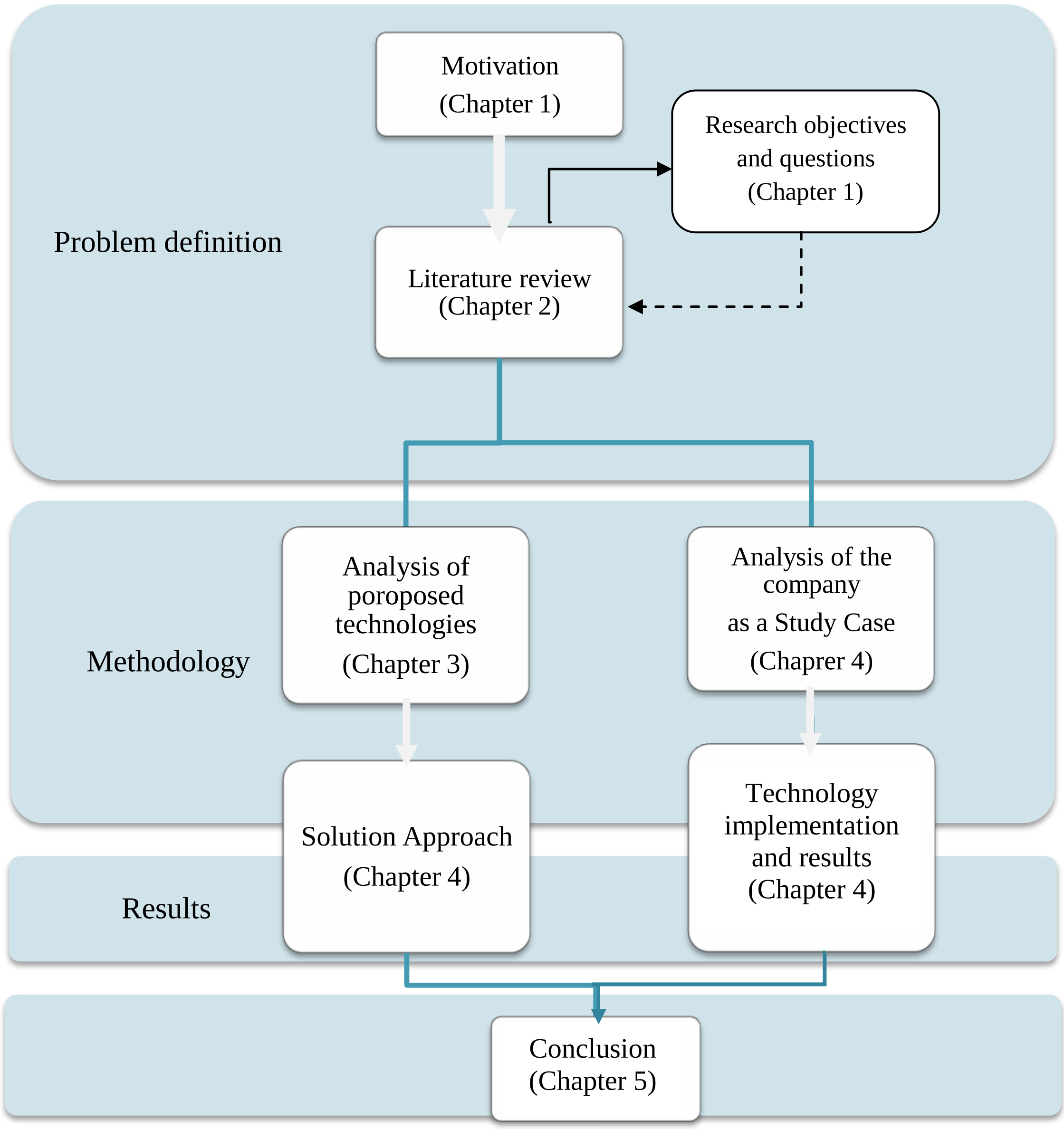


Figure 1.1: Research framework

Chapter 2

2. Literature Review

The first part of this chapter represents a literature review of identification systems that can be used for vehicle detection and tracking. The second part is focused on the general characteristic of exact vehicle identification technologies that can be applied indoors and outdoors.

2.1. Automatic Identification Systems

Automatic identification systems are used in different varieties of applications from authentication, tracking, security control, information management to process automation.

The systems are divided according to the type of technology used: magnetic stripes, smart cards, bar codes, RFID tags, Optical Character Recognition, Bluetooth, biometrics, or object recognition on video. The short introduction of each method is described below.

At the moment, barcoding is the most commonly used and widespread identification technology. It provides automatic entry of data with relatively low costs, speeds up processes, and reduces error rates. The barcodes are machine-readable and are printed onto or attached to the items. In most scenarios, the scanning is done manually as this technology requires line of sight (reader to the barcode). Additionally, only one barcode can be read at the same time. Barcodes are applied for the identification of packages, goods, documents, and cards.

Radio frequency identification method performs well in security-critical applications because it is hard to copy RFID tags and advanced encryption method could be incorporated into the system. The system can be successfully applied in healthcare, security, vehicle identification, real-time location tracking, and other areas.

Automatic video identification has several directions: recognition and verification of objects (comparison with a standard), face recognition, license plate recognition of different types of vehicles.

Optical character recognition (OCR) is used to read the human-readable characters with the help of machines. The system can visually read data in case of emergency and has a high density of information. However, it is not universal due to the high price and compared to other identification procedures OCR requires complex reading devices.

A smart card is an electronic storage system that is built into the plastic card. It is applied to provide services related to the security of information or financial transactions.

Magnetic stripe card is a low-cost identification technology that is used in credit and bank cards. In comparison to other smart cards and RFID cards, magnetic stripe card has lower security characteristics.

Bluetooth is short-radio links between mobile phones, mobile PCs, and other portable devices. All the Bluetooth chips have a unique identification number and send information itself directly to other Bluetooth chips (Kärkkäinen and Ala-Risku, 2003).

Table 2.1 summarises the application areas of different identification technologies.

Table 2.1

Different identifiction technologies classified by application types

Technology \ Application	Tracking	Automation	Authentication	Information Management
Barcode	X	X		X
RFID	X	X	X	X
Optical Character Recognition		X		
Vision recognition		X		
Smart cards			X	X
Magnetic stripe			X	X
Bluetooth	X	X	X	X
Biometrics			X	
GPS	X			

2.2. Vehicle detection and tracking techniques

2.2.1. Automatic vehicle identification systems (indoors and outdoors)

Operational efficiency and availability of vehicles are crucial areas in the manufacturing and transportation business.

Nowadays, different issues exist such as high error possibilities, manual entry, or check-in/check-out that leads to a higher possibility of human error, and permit slip is not identified with the vehicle's identity. Manual check-in/check-out process can cause errors in the accounting of vehicles, especially during peak hours. Some of the vehicles can be logged in with mistake, or missed completely. To improve it, organisations and companies are ready to adopt technologies that take care of vehicle tracking.

Automatic Vehicle Identification is a good solution to solve these issues, automate vehicle movement, and control and monitor vehicle and driver-related activities.

Automatic Vehicle Identification (AVI) system is designed to identify various vehicles in different traffic situations. It brings scalability, flexibility and responsiveness that organizations need today and delivers benefits in a reliable, secure and cost-effective way. It can be applied in different areas like parking (access control), traffic (traffic priority systems, electronic toll collection, access control), transport (speed control, corridor monitoring), aviation (commercial traffic regulation), petrochemical (automatic loading and access control) and railway (rail yard management) industry. AVI system provides up-to-minute, accurate information and powerful analysis features needed for making better decisions faster (Infronics Systems Limited, 2011).

At the parking, the AVI system is applied for the automatic controlling of vehicle access to the parking facilities. In case, when the parking operations are not for free, the system charges the driver based on prevailing parking rates. To speed up the process of payment and reduce risks, cashless payment is introduced. As a result, the driver can simply drive through the gate without having to stop.

Another growing concern in parking operations is improving security. In areas such as a vehicle, depots drivers change frequently. However, there is a necessity to define simultaneously which driver and when was driving a specific vehicle. AVI system features the unique ability to identify both driver and vehicle simultaneously.

Airports are another sphere requiring a high level of security. Airport terminals are opened areas to the public, while behind there are a lot of highly secured areas with restricted access that has to be maintained and protected from unauthorized vehicles entering the area. The AVI system can work by accurately controlling and monitoring traffic flow and human access at several strategic points throughout the airport. The gate area between the land- and airside of the airport has to be under special attention and protect loading platforms from entering unauthorized vehicles. Mostly, the doors of airside gates open after the vehicle has been identified and authorized to service the terminal.

In the transport and petrochemical industry, there are registration requirements and increasing plant security. With the help of AVI control systems, all the requirements (refueling, loading/unloading, and weighing) can be met.

The AVI system operates reliably in the extremely challenging and harsh conditions of the railway industry. Identification of train cars and engines is carried out to track rolling stock in tunnels, automate the refueling process, manage trains at a yard, or provide updated departure and arrival information.

Advantages of Automatic Vehicle Identification System:

— *Fast identification:*

It provides fast and reliable identification of vehicles at speed up to 200 km/h from distances up to 30 meters even in the most difficult transport conditions.

— *True hands-free access:*

No need for the driver to open the window to swipe a card or present the badge or card. AVI does not require driver’s intervention, the vehicle is identified automatically.

— *Parking Lot Access Control:*

Access control systems ensure that only registered vehicles are allowed to get into and get out of the parking area. A parking barrier drop-arm control system is used to control access to the parking zone. Parking barrier arms automatically lifts to let the vehicle pass through on successful identification of the vehicle tag.

— *Tracking vehicles within the area:*

The use of tags in the vehicle ensures optimal performance, increased efficiency and eliminates the possibility of theft and fraud.

— *Decreased operating expenses:*

Drivers no longer need cash or coins to pay parking costs, reduction of the number of toll stations because drivers do not require cash to pay for parking. This reduces the direct capital, operating and maintenance costs associated with new parking equipment. Cashless payment also enables more efficient cash collection and automatically eliminates the risk of theft associated with keeping cash at payment points.

— *Reduced congestion:*

The manual control of traffic throughput causes congestions in the traffic flow around refueling areas, barriers, loading docks, especially during peak hours and could result in costly delays. AVI helps to reduce congestion at parking facilities and to speed up the traffic throughput.

— *Error-free real-time tracking:*

Efficient yard and fleet management due to the integration of important yard management information such as vehicle movement, availability, fuel consumption, and vehicle maintenance history.

The implementation of the system improves efficiency and provides highly secure vehicle access and convenience, automatic data collection and revenue enhancement (Meyer Industrie-Electronic GmbH., n.d.).

The system for vehicle identification is designed to automate and make safe vehicle access to restricted areas. In this way, companies receive detailed information about their fleet, which allows them to use vehicles most efficiently. Using this solution, companies of any profile, as well as public transport services, can function more efficiently, optimizing their work.

Automatic Vehicle identification can be performed by using different vehicle identification technologies or their combination. Each vehicle identification technology will be discussed in detail in the next paragraphs with its advantages and disadvantages.

2.3. Overview of vehicle detection and surveillance technologies

In recent years, the most accurate and simplest method of counting vehicles was done manually by labor. The person had to either use an electronic hand-held meter or to record the data using a counting sheet. Nowadays, traffic monitoring and data collection use vehicle sensing technologies which can be divided into intrusive or non-intrusive.

Table 2.2

Sensing technologies

Category	Sensor Type	Application and Use
Intrusive	Pneumatic road tube.	Used for keeping track of the number of vehicles, vehicle classification and vehicle count.
	Inductive Loop Detector (ILD).	Used for detection vehicle’s movement, presence, count and occupancy. The signals generated are recorded in a device at the roadside.
	Magnetic sensors.	Used for detection of presence of vehicle, identifying stopped and moving vehicles.
	Piezoelectric.	Classification of vehicles, count vehicles and measuring vehicle’s weight and speed.
Non-intrusive	Video cameras.	Detection of vehicles across several lanes and can classify vehicles by their length and report vehicle presence, flow rate, occupancy, and speed for each class.
	Radar sensors.	Vehicular volume and speed measurement, detection of direction of motion of vehicle and used by applications for managing traffic lights.
	Infrared.	Application for speed measurement, vehicle length, volume, and lane occupancy.
	Ultrasonic.	Tracking the number of vehicles, vehicle’s presence, and occupancy.
	Acoustic array sensors	Used in the development of applications for measuring vehicle’s passage, presence, and speed.
	Road surface condition sensors	Used to collect information on weather conditions such as the surface temperature, dew point, water film height, the road conditions and grip.
	RFID (Radio-frequency identification)	Used to track vehicles mainly for toll management.

Intrusive sensors are embedded in holes or cuts of the road surface or on the pavement surface for data collection. They include magnetic sensors and magnetometers, inductive loops and pneumatic road tubes. In comparison, non-intrusive sensors are more reliable and easier to use as they do not require intervention. Non-intrusive detectors are those sensors that do not have to be installed on or in the pavement but are mounted above the surface ("overlane" sensor) or on the side of the roadway ("side fire" sensor).

Non-intrusive technologies comprise video image processing, ultrasonic and infrared detectors, radio-frequency identification, radar and laser detectors, light- and sound-sensitive sensors.

These technologies are currently being used to provide additional information for selected locations or specific applications (Yu and Prevedouros, 2013).

2.4. Existing Parking Systems

Smart parking systems consist of four main categories:

- Parking Guidance and Information System (PGIS);
- Automated parking;
- E-parking;
- Transit based information system.

Further characteristics and implementation of each category will be discussed below.

2.4.1. Parking Guidance and Information System

Parking Guidance and Information System (PGIS) is implemented in many cities in the United States, Europe, Japan, and the United Kingdom. Its implementation falls into two main categories: it can cover the entire city or function only in the parking lot. Both categories provide information to assist drivers in the decision to reach their destination to find a free parking spot within the car park facility.

PGIS composes 4 main components: information disseminating mechanism, information gathering mechanism, control center, and telecommunication networks.

The city-wide parking guidance and information system assist drivers to find vacant parking spaces around the city by showing occupancy status information at different parking spots. Furthermore, the same system guides in locating the vehicle within the parking spot.

Various dynamic or static Variable Message Signs (VMS) can be used for guidance in the parking area or on the road. Different implementation methods can be applied for coordination on the road. For example, one city in Japan is divided into four zones and the specificity of the information increases with each zone which the drivers cross to reach their destination. Meanwhile, the system in Pennsylvania separates the city into color-coded areas.

Another option for guidance is mobile phones that utilize Global Positioning System (GPS) for vehicle detection. Based on the current location of the patron, all the information together with three nearby car parking will be sent to the phone. Besides, the parking guidance system can work with the parking management system to guide drivers effectively. Each parking ticket is printed with a parking map and contains an RFID tag for guidance, so the drivers can easily find out the assigned parking slot.

The vehicle occupancy at parking is commonly detected by vehicle detection sensors that are installed at the entrance, exit and within parking space. Depending on the installation of sensors, the occupancy status can vary regarding vehicle counts from the level or block occupancy to accurate parking place information. Additionally, indicator lights integrated with sensors could be installed at each parking space within the garage.

2.4.2. Automated parking

Automated parking is designed to minimize the area or volume needed for car parking. The automated parking system is a multi-level parking garage that offers efficient in-car storage and maximum utilization of space as it is machine-controlled. The system works with the help of a computer-controlled mechanism, which allows the driver to drive up, bring the car to the APS entry area and leave it there, and then the mechanical system locks the vehicle, lifts it up and places it automatically in allocated space.

Implementation of this system is perfect for locations with limited room for expansion due to the structure. Among benefits are that this type of parking provides space-saving as there are no driving lanes and ramps, walkways, stairways, or elevators for pedestrians, and the distance between parking spaces are reduced to a minimum and extra safety, security measures that cover both drivers and vehicles.

Automated parking works well during balanced throughout (train stations or a shopping mall). However, there can appear some technical problems with the robotic parking system. Additionally, they are unsuited to huge volume during high rush hour.

2.4.3. E-parking

Electronic parking provides visitors with an alternative to inquire about availability and/or to reserve a parking space in the desired parking lot, so the driver has no issues in looking for vacant car park space.

The system is accessible through different methods like the internet or SMS. Reservations could be made with the help of mobile phones or other reservation centers.

One of the advantages is that the E-parking system can be extended and incorporated with the payment system to allow drivers to make payments without any problems using the same technology (phone App or reservation centers). Individual information could be provided to visitors before or during their trip to the car parking (Shaheen et al., 2005).

E-parking solution works easily with the app. After installation and registration, the user comes to the car park, scans the QR code to enter, and parks the car. The same action is done before leaving the car park. The driver scans the QR code to pay and exit (Figure 2.1).

Figure 2.1: Parking steps description by using the app (E parking Solution Sdn. Bhd., 2018)

Among the benefits of using the E-Parking app, all the information is saved on the phone with no risk to lose a parking ticket and parking fine, no cash is required and the user can save time from a long queue in front of a payment kiosk (E Parking Solution Sdn. Bhd., 2018).

E-parking system can be integrated with PGIS, where the users can book the parking lot after reviewing the parking status and proximity to the location of the driver (Idna and Tamil, 2007). Below (Fig. 2.2) is shown the example of a parking reservation system message that is sent to the user.

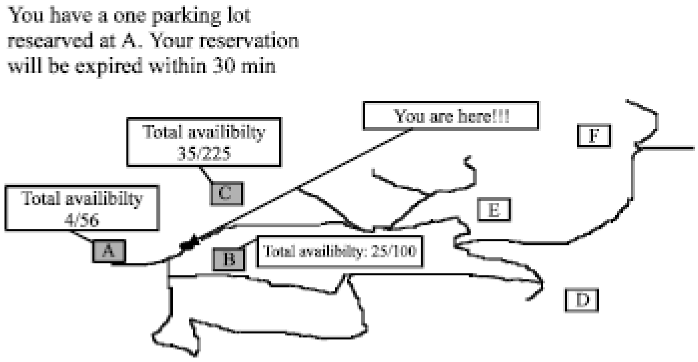


Figure 2.2: Example of a parking reservation message (E parking Solution Sdn. Bhd., 2018)

2.4.4. Transit based information system

Transit based information systems have similar functionality to PGIS. The main difference is that system is focused on guiding the driver to park-and-ride facilities. It shows the real-time information about status and availability of car park and provides information about public transportation including the schedule and traffic condition to the public. With the help of additional information drivers can plan easily their transit in advance (Chinrungrueng et al., 2007).

The park-and-ride facility allows commuters to leave their cars in the parking lot during the day and transfer to public transport to reach the final destination and retrieve their vehicles during the return trip. This type of parking system is usually in the suburbs of metropolitan areas or on the outer edges of large cities.

Among its advantages is the increased use of public transport as the primary means of transportation, as the driver can easily leave the car in the parking lot and switch to public transport. This leads to a growth in transit revenue (Shaheen et al., 2005; Chinrungrueng et al., 2007).

The network flow-based technique, introduced above, improves the conventional spatial model that is used to determine park-and-ride facility location by considering the traffic flow. Besides that, it helps to reduce vehicle kilometers traveled due to the maximum interception of the vehicle at the initial stage of the journey.

The proper planning and selection of location for the implementation of a transit-based information system are needed to maximize transit whereby the concept of catchment area/commuter sheds is often used.

The system is implemented in Germany (Figure 2.3), Switzerland, France, United Kingdom, Ireland, and the United States.

Figure 2.3: Park-and-ride System in Munich (Own photograph)

2.5. Vehicle Detection

Different technologies can be applied to reliably detect vehicles. Many factors have to be taken into account to identify the right technology for vehicle detection application. These factors include sensing range, task, size of the target, and location of detection technology – indoor or outdoor.

Five main technologies are presented below. In some cases, many of these technologies can be used to solve the same application, and sometimes it is better to make a combination of two technologies to get the required precision level.

2.5.1. Radar Sensor

Frequency Modulated Continuous Wave (FMCW) radar is used by radar sensors to detect large moving and stationary objectives like cars, trains, trucks in extreme weather circumstances, while capacitive and inductive sensors detect only moving targets. Compared to ultrasonic and photoelectric sensors, radar sensors can easily work under such weather conditions as rain, fog, wind and humidity. As a result, indoor environment detection is accurate as well. They are perfect for long-range detection as the sensing range is up to 40 meters.

Moreover, installation and maintenance of senor radar are easier and safer compared to other technologies as it is mounted flexibly (not on the track), consequently has lower damage risk. Radar sensors are installed outdoor on a range minimum of 1.83 meters from the target.

The biggest challenge for radar sensors – is to detect small objects and vehicles that are closely driving or standing to each other. That is why they are commonly applied to detect train cars because of the big dimension.

Radar sensors can be used to determine the presence of a vehicle at the loading dock during harsh weather conditions. Train cars create obstacles that do not allow equipment to work properly. Passing train creates debris, dirt and wind. Despite this, radar sensors are perfectly adapted to different environmental conditions. Besides, the radar sensor can alert workers about the presence of a vehicle.

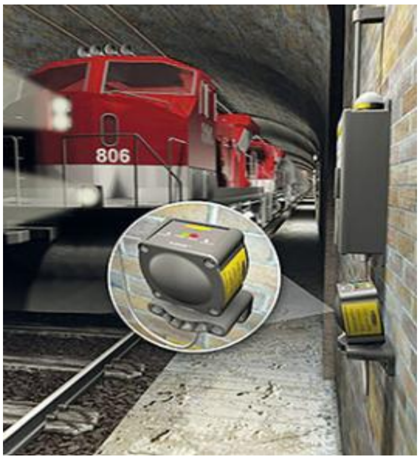


Figure 2.4: Train detection in tunnel with the help of radar sensor (Banner Engineering Corp., 2017)

2.5.2. Wireless Magnetometer

Figure 2.5: Wireless magnetometer for vehicle detection in automated car wash (Banner Engineering Corp., 2017)

Wireless magnetometers are used both inside and outside to detect different types and sizes of vehicles. With the help of passive sensing technology, wireless magnetometers detect various targets (rail car, truck and vehicle). When the vehicle changes the ambient magnetic field, a sensor detects these changes in a magnetic field. This technology is a perfect alternative. It is cost-effective, gives an accurate and repeatable answer and enables rapid, low-maintenance deployment compared to other technologies. Unlike wired magnetometers, wireless magnetometers do not require extra wiring and control boxes; they are small, autonomous and could be installed easily above grade or inserted into the grade (2-2.5 cm below). The below-grade installation consists of a wireless sensor encapsulated in rugged epoxy (to prevent moisture penetration and ensure long-term reliability during bad weather conditions) and built in a 7.6 cm hole drilled in the concrete. Wireless magnetometers include the battery itself which enables them to have a continuous lifetime.

Wireless Magnetometers can be applied in:

— Drive-through systems:

Magnetometer reliably detects cars at drive-through stations and informs personnel to initiate a timing system.

— Car wash:

Magnetometers detect vehicles at the entrance queue to provide avoidance of collision and an entry-door trigger.

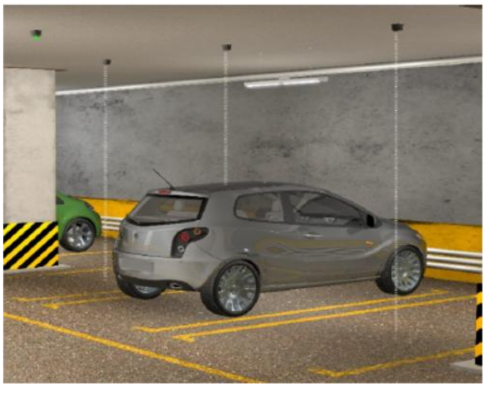
— Loading Dock:

The sensor can detect a vehicle that is moving backward to a dock, turn on the light in the building to notify the attendant that the vehicle is prepared for loading/unloading.

— Overhead Door:

Located below the grade, the magnetometer can detect forklifts or trucks coming to the door and, as result, trigger the opening of internal overhead doors.

2.5.3. Wireless Ultrasonic Sensor



Picture 2.6: Wireless ultrasonic sensor in parking for vehicle detection (Banner Engineering Corp., 2017)

A wireless ultrasonic sensor is a perfect solution for indoor vehicle detection. The sensing range of this type of sensor is up to 4 meters. It has to be mounted onto a ceiling of the indoor garage and with the help of sound waves; it detects the presence or absence of the vehicle below. Every sensor learns and acts in the area of its sensing range and distinct point. The presence of a vehicle will be determined when it will cross the area between distinct point and sensor face.

Wireless ultrasonic sensors with batteries decrease installation costs as there is no need for wires fastening. On another hand, overhead installation could be a challenge due to a lack of space. Another issue is the weather conditions. Strong wind can deflect a path of ultrasonic waves and temperature fluctuation can affect the speed of a sound wave. The result is – a sensor will work unreliably. The best solution for the closed area with changeable temperature conditions is to install wireless ultrasonic sensors with built-in temperature compensation capability.

2.5.4. Measuring Light Grid

Nowadays, toll stations have become more automatic to decrease human error. The main difficulty is that a different variety of vehicles (cars, trucks, motorbikes) is going through a toll booth and every type of vehicle has to be charged according to its category. Measuring light grids are ideal to get reliable data. They are used outdoors for vehicle detection to stop and start a transaction (toll payment at toll station). Light screens measure all sizes of targets at distance from 500 millimeters up to 2 meters. The sender and receiver are located on each side of the toll line and paired together with an array of light beams. The profiling of moving vehicles regardless of speed is quickly provided by measuring the light grid. When the vehicle enters, data from every light beam is used to define the number of axles, vehicle class and even smaller parts like tow bars.

Nevertheless, an array of light beams has to be protected from damage in case of collision. Talking about strange cold weather conditions, it is recommended to locate a light grid in a heated enclosure to help it operate reliably in any weather conditions.

Figure 2.7: Measuring light grid detection of vehicle and tow bar at a toll booth (Banner Engineering Corp., 2017)

2.5.5. Optical Sensor (Infrared)

Figure 2.8: Vehicle detection using infrared optical at exit from a car wash (Banner Engineering Corp., 2017)

Optical sensors are not commonly used for vehicle detection as other sensing technologies. Indoor vehicle detection of targets with the size of 5 millimeters and bigger, sensing range up to 200 meters is still a good option for some applications. An optical sensor consists of infrared light which can burn and detect vehicles on a long distance through high water pressure, steam, mist, temperature variations. The sensor defines the vehicle when it goes through between emitter and receiver and breaks the beam of light.

As opposed to other technologies, optical sensors are better working in an indoor environment because they are influenced by weather conditions (high temperature, water, high pressure, or sunlight).

Table 2.3

Types of vehicle detection

Type of detection	Maximum Sensing Range	Size of Target	Mounting
Radar Sensor	40 meters	Large predictable targets (f. ex. train)	Minimum of 1.83 meters from the target
Wireless Magnetometer	Depends on the size of target	All sizes	Can be installed above or below grade
Wireless Ultrasonic Sensor	4 meters	All sizes	Must be mounted overhead
Measuring Light Grid	2 meters	All sizes	Requires mounting for both emitter and receiver
Optical Sensor (Infrared)	200 meters	5 millimetres or grater	Requires mounting for both emitter and receiver

2.6. Exact Vehicle Identification

Different sorts of technologies exist for asset tracking data capture. However, each of them fits specific purposes. GPS is a great solution for the outdoors as it is suitable for any fleet management system, while BLE, LPR, UWB, and RFID are widespread in indoor areas.

Figure 2.9: Areas of application (Infsoft, 2020)

2.6.1. RFID

Although RFID seems to be new technology, however, it is older than barcodes. For the first time, it was used during World War II for identification of the airplanes. Later all American rail cars were equipped with RFID for identification. It took a long time for RFID technology to be widely utilized because of the high price and no standardization among the manufacturing companies (Jayalakshmi, Ambily, 2016).

Radio Frequency Identification (RFID) is one of the most fundamental technologies for wireless data transmission that made a revolution in automatic identification and data capture (Dowla, 2004). This technology is one of the main activators of the “Internet of Things”.

Radio-frequency identification (RFID) –is an automatic identification technology that can identify objects in a distance by using wireless radio waves. RFID permits a collection of real-time information from fast-moving streams at a distance of 5-8 meters in order to achieve a high degree of efficiency and quality (Ning et al., 2013).

This technology is commonly used in numerous fields like transportation, logistics, aviation, supply chain management, and healthcare (Tung and Jones, 2008). The companies have the possibility to look further into the supply chain than before because RFID provides accurate real-time information and improves process efficiency.

It is an important identification technology that is applied for different purposes such as personnel and vehicle identification, automation of factory, security access, automotive toll debiting, and inventory management (Ostojic et al., 2007).

Nevertheless, it is not a simple technology. A typical system (Figure 2.10) consists of RFID tags (transponders), antenna, RFID tag reader or transceiver, computer network, and other systems such as middleware and databases. The tags are usually located on the object that has to be tracked and identified. They are divided into 2 main categories: active and passive. The main difference between them is that active tags contain an internal battery, which gives the possibility to work on longer distances in large open structures and continuously or periodically transmits the own signal, while passive tags do not have an internal power source or battery. Passive tags transmit RFID signals only when they receive radio frequency energy from a reader that is within range. Compared to active tags, passive are smaller and cost less, however, they have a reduced reading range. This type of tag is perfect for tracing a big volume of low-value objects. In contrast, active RFID tags are ideal for monitoring high-value items with variable movement.

In this research, only passive tags will be considered (Pala and Inanc, 2009).

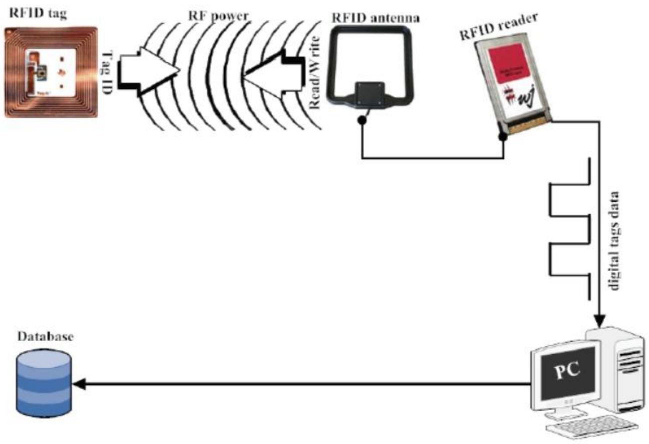


Figure 2.10: Basic components of an RFID system (Pala and Inanc, 2009)

An RFID tag is the main identification device attached to the vehicle that has to be tracked. It could be in a form of a) an ordinary plastic card, b) a sticker on the inner side of the windshield of a vehicle, c) a plastic nameplate, and d) a tag for replacement on car headlights.

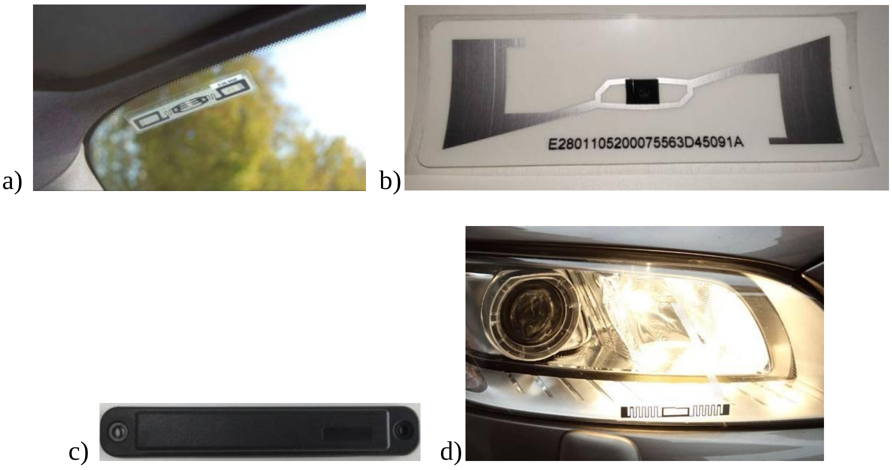


Figure 2.11: Types of RFID tag (ReUnit, 2020)

Another two components, a reader and antenna identify the emergence of tags and read all the information stored on tags.

The reader is the "heart" of the RFID vehicle identification system. This element, like a modern smartphone, has a processor part - where the software is installed, and a radio module - which is responsible for the radiation power transmitted to the antenna. These readers are usually designed for indoor use, which imposes many restrictions on their use.

An antenna provides the emission and reception of the reflected radio signal of ultra-high frequency from the tag located on the controlled vehicle. It transmits and receives a signal from a UHF transponder with a beam divergence angle of 55-75 degrees. There should be no metal barriers between the antenna and the tag to meet the traffic of marked vehicles.

For each direction, there should be installed the own antenna. For example, entry and exit to the territory occur through the same barrier - two antennas are required, directed in opposite directions. One will look for the presence of transponders at the entrance, and the second at the exit from the controlled area.

The middleware aims to make easier communication between RFID devices and the system. After receiving the information this software processes transmission of information between a transceiver and other applications. Overall, all the components fit each other.

How does the RFID system work?

The communication is performed through the reader antenna that sends radio waves and receives tag response signals within its reading area. When a tag enters the area of the RFID reader, it finds out the reader's signal with the help of the coil it contains, and then the coil converts the received RF signal into an electrical signal. In the process of making the tag identification, the reader has to decode signals. It firstly sends a request signal to tags in its field, and then the tags, which received the request signal, respond by sending their ID to the reader immediately. It is sufficient to charge the microchip present in the tag with this converted signal. After the microchip is powered up, it sends data (unique identifier) that are stored in it. Finally, the reader passes the information to the middleware. The above working principle is for passive tags. Considering active tags, the signal detection is from the reader only to trigger the circuit and make the tag ready to send the data to the reader, as active tags include a built-in power source.

With the RFID system, it is possible to:

— Register events such as entry, exit time, stay period in the vehicle zone, for example, when loading and unloading operations or cargo-handling operations at a warehouse.

— Track the movement of vehicles on the territory of the facility, multi-level parking, or at specified points of the route.

— Recognize license plates of vehicles when entering/exiting the territory of the enterprise or parking, to provide additional control.

— Search for a car on the territory of the enterprise or a specified route.

— Control vehicle access to various zones on the territory of the parking or enterprise.

— Control external devices such as barriers, sensors, electronic boards, automatic gates, traffic lights.

— Control the route of movement of transport on the territory of the company or transport movement outside. The system records all the movements of the car, including the time spent at the stop point on the route, the correctness of movements of the vehicles between the points of the route.

— Control the route of transport movement on the territory of the enterprise or when moving transport between subsidiaries.

System application:

— in parking lots, in car parks (to control the entry/exit of vehicles, to enlarge the throughput by reducing the idle time of vehicles associated with the human factor);

— in warehouses /logistics centers (register entry and exit time, time of stay);

— on toll roads (for registration of vehicles that use the road);

— in transport companies (to control the entry/exit of vehicles and the time spent in various zones on the territory) (IT project, 2020).

Figure 2.12 represents one of the options for implementing an RFID system to control the movement of vehicles on the territory.

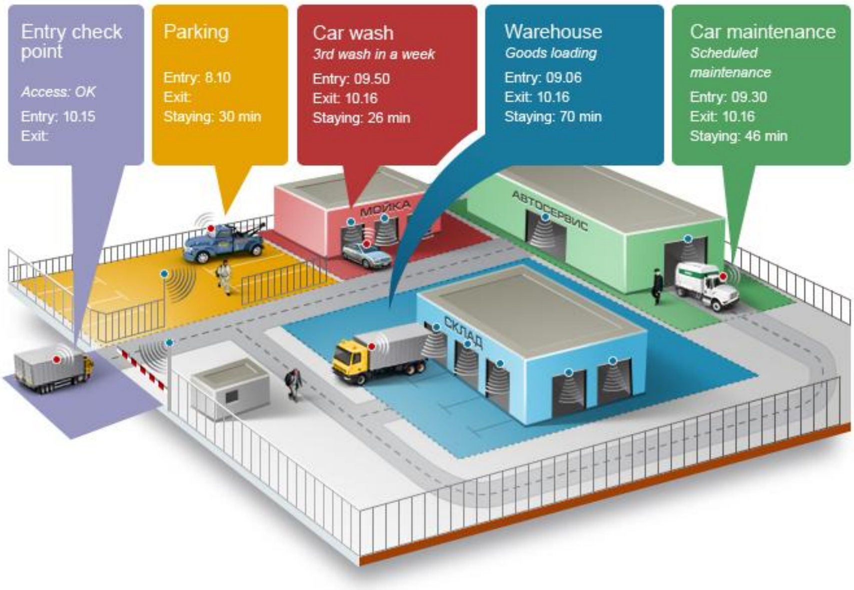


Figure 2.12: Example of RFID system implementation to control the movement of the vehicles on the territory (IT project, 2020)

Benefits of using an RFID system:

— Automatic tracking of vehicle movement.

— Parking capacity utilization improvement.

— Simplification of entering and exiting parking lots by the elimination of queue and time spent reaching to card readers.

— All information is automatically saved in the database and with the help of special software, it is easy to analyze work efficiency. As a result, there is no longer a need to maintain complex paper documents on counting the movement of vehicles.

— Reduction of the human factor and related errors.

— Diminishment of the risks associated with unauthorized access of vehicles into objects and human intervention.

2.6.2. UWB System

Ultra-wideband (UWB) technology is wireless radio high-bandwidth communication technology that offers short-range, precise localization, and high range accuracy of devices and items even in a multipath environment. It is mainly used for short-range communications and is applied in indoor positioning and tracking.

In recent years, the indoor positioning system based on UWB got much interest and became popular. UWB offers measurement accuracy at the decimeter level with coverage of several tens of meters. The use of UWB is especially evident in cases where extreme accuracy is required (D´ıez et al, 2018).

UWB has the ability of an anti-multipath effect and allows determining the location with precise accuracy at distances of up to 30 meters, making it easy to track goods and assets within centimeters or millimeters, depending on the application.

UWB technology has high indoor positioning accuracy values, which are unattainable with conventional wireless applications (RFID, WLAN), and therefore it is very beneficial for applications requiring a high level of real-time accuracy for 2D and 3D localization (Contigiani et al., 2016).

This type of method measures the running time of light between several receivers and an object. UWB based indoor positioning system can obtain more accurate position information than other systems thanks to the trilateral method (Figure 2.13). Direct line-of-sight has to be between transmitter and receiver. In addition, at least three receivers are necessary for the exact localization (Hu et al., 2017).

When the signals are sent very quickly across a wide range of radio high frequencies, the UWB receiver translates them into data, and after UWB transmitters can measure the distance between one another by measuring the time taken for a signal to travel between the devices.

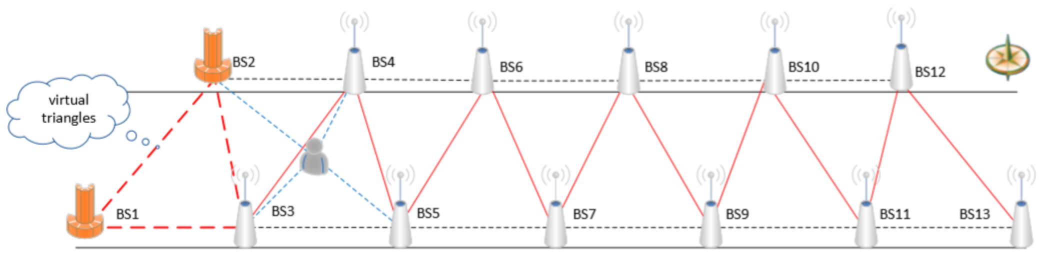


Figure 2.13: Diagram of building virtual triangles (Yang et al., 2019)

However, it has a drawback. A big amount of base stations has to be pre-installed to get the target location information. They will provide location information for calculating a target reference location (Yang et al., 2019).

UWB can operate together with RFID in the same area without intervention due to differences in the radio spectrum and signal types. Comparing RFID and UWB technologies, RFID transmits single bands of the radio spectrum, while UWB simultaneously transfer signals on multiple bands of frequencies. UWB signals are transmitted with a shorter duration and as a result, consume less power and could operate in a wider area of the radio spectrum. Furthermore, UBW signals can get through devices and walls without interference (Contigiani et al., 2016).

UWB technology has some advantages over other technologies that make it being attractive in different applications such as radar and wireless body area network, communication and tracking. These advantages include:

- low power consumption;
- very high positioning accuracy;
- strong multipath resolution;
- low system complexity and cost;
- high data rate transmission;
- large instantaneous bandwidth;
- immunity to passive “interference” (fog, rain, metalized strips, aerosols);
- increased immunity to co-located radar transmissions due to decreased pulse-on-pulse probabilities (Fontana, 2004; Wang et al., 2020).

2.6.3. BLE System

BLE technology developed in the last years. The first prototypes only detected the beacons that were the closest to the user, nowadays distance data can be used from many beacons and the object can be positioned within the indoor area in 2D space.

It is common to use Bluetooth technology for different purposes in daily life. As the development of energy-efficient connected devices has become important, IoT manufacturers have developed a new technology, known as BLE, to meet such environmental concerns.

What is BLE? What does it stand for?

BLE stands for Bluetooth Low Energy (Bluetooth LE).

Bluetooth Low Energy technology is similar to the Bluetooth used in various wireless accessories. However, the main distinction is that BLE utilizes significantly less power while providing a similar range. Consequently, it is useful in areas where extremely long battery life is important (Kontakt, 2019).

BLE is low power and inexpensive wireless communication designed for short-range communication that uses radio technology. It was identified as a potential solution for localization. Bluetooth Low Energy (BLE) is an industry technology that allows to quickly transfer low-consuming data such as movement, temperature, humidity. The battery lifespan is serving twice longer than that of conventional Bluetooth technology.

The Bluetooth tracking system works by constantly searching for devices in the frequency range of the receiver. The main advantages of Bluetooth technology are low power and low cost, high throughput, standardized specification, and hardware availability (ELA innovation, 2020).

Beacon tracking systems encompasses just three primary components:

1. Compact Bluetooth beacons - BLE beacons or tags:

The beacons transmit a small amount of data in a short-range at regular intervals, consuming much less power.

2. BLE Readers;

Readers are Bluetooth-enabled receivers that receive the transferred data from tags or beacons in their range and transmit the current location of the objects to the tracking system. They monitor the exit/entry of the assets and provide real-time tracking information.

3. Tracking Platform.

A tracking platform is a software used for asset tracking. All the information obtained and displayed by BLE readers is reflected in the asset management software.

What is a Bluetooth Low Energy (BLE) beacon?

BLE beacon – is a small radio transmitter with very long battery life (years) that consumes very little energy by using the same battery power supply as Bluetooth and can be used for vehicle tracking. Beacons are strategically installed in different locations to transmit Bluetooth Low Energy signals within a given range. On average, the range of beacon devices is up to 80 m. The main goal of the beacons is to help to determine the location of the object. Due to their size and shape, they can be easily located inside or outside the building (inside/outside the vehicle, on walls or floors). The average price of the beacon device is around 20 euros/piece (Locatify, 2020).

Beacon technology is being rather used compared to other alternative technologies for three main reasons: beacons are cheap and small in size and can be placed easily anywhere inside/outside the car or inside the building. This means that beacons could be implemented easily in a smart city application such as smart parking as their characteristics make them being a budget-conscious (Plum, 2020).

By using beacon technology indoor navigation indicates the recommended route, marks important places and offers step-by-step instructions, which is helpful for shopping malls, multi-story stores and museums (Adarsh, 2020).

What form factors are available?

Bluetooth beacons and their smaller version, tags exist in different shapes and sizes depending on the requirements for a specific use case but are generally small and inexpensive. They vary from small, compact flat cards, palm-sized pebbles to big boxes.

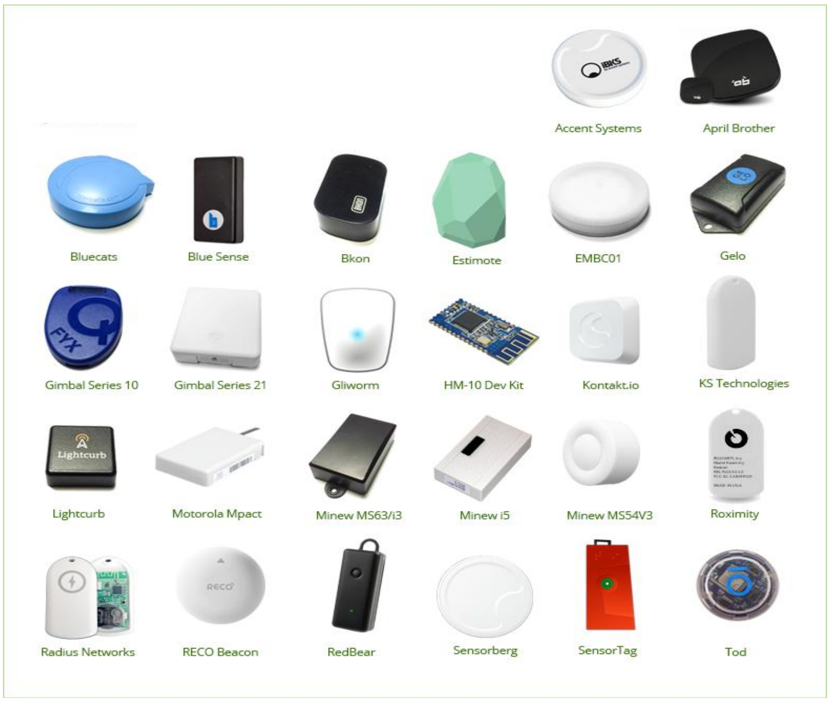


Figure 2.14: Types of BLE beacons (Aislelabs, 2015)

BLE is small enough and can be located in various areas by using a variety of options. The most common are wall and ceiling mounting. The main condition is that the signal could be lost if it is blocked by metal or water. For this reason, the best option is to locate beacons on the ceiling in case it is not higher than 3-4 meters or on the wall above 2.5 meters high. The beacon could be placed at or under the object as well if there occurs no blocking.

BLE beacons pay attention to their location by periodically transmitting data packets containing a unique identifier. By using Received Signal Strength Indicator (RSSI) techniques location or region can be identified. The data transfer of BLE is one-way communication (Plum, 2020).

Bluetooth Low Energy beacon device either broadcasts identifiers to mobile devices at regular time intervals or listens for the unique identifiers of BLE tags attached to objects. Preset services on smartphones nearby detect these data packets. This BLE communication launches BLE actions (Fig.2.15) such as sending a message or promotion applications (BLE mobile Apps, 2019).

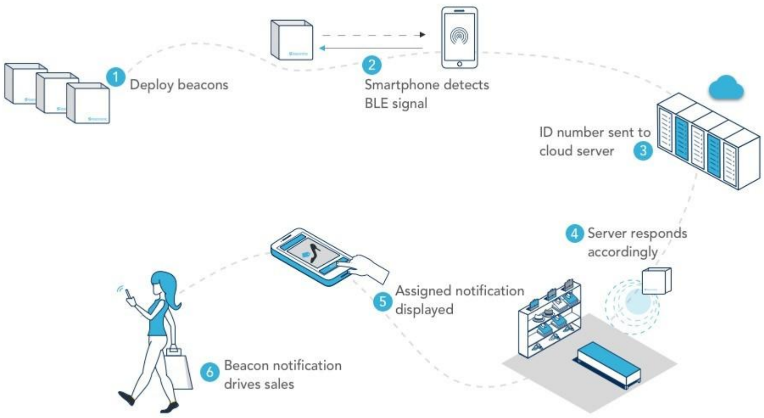


Figure 2.15: BLE communication (Adarsh, 2020)

Application of beacons in transport and logistics includes better data analytics, more efficient storage, and fewer delivery errors. For instance, as the vehicles can be easily and reliably tracked, there is no need to always place them in a predetermined, precise, specific location. BLE devices enable increased flexibility in choosing the most convenient location at the moment where cars can be stored and to find a car's location easily when required. Moreover, beacon tags could be equipped with sensors that detect temperature measurements, car movement, battery level, engine start and stop events to monitor movement, speed, and condition of the vehicle (Figure 2.16).

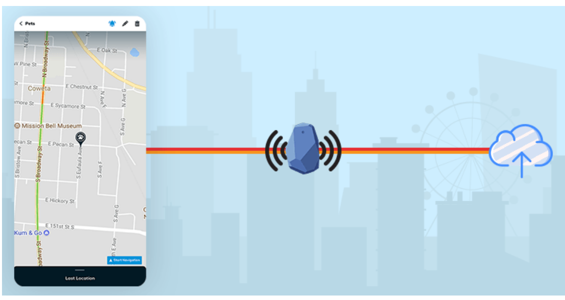


Figure 2.16: Different measurements' identification by using BLE beacons (BLE Mobile Apps, 2019)

2.6.4. Automatic License Plate Recognition

The car license number plate recognition (LNPR) identification places a significant role in the Intelligent Transport System (ITS) and Electronic toll collection (ETC).

Nowadays, License Plate Recognition System is applied for parking lot management, parking lot vehicle and license plate recognition, card license plate recognition parking fees, card charge, and management. The system supports many languages from different countries.

The automatic license plate recognition system (LPRS) is an image processing and character recognition technology that is used for vehicle identification by reading automatically the license plates (Hermawati and Koesdijarto, 2010).

This technology is used in various security and traffic applications. LPRS is widely used in traffic management to find theft vehicles, whose drivers violate traffic rules (Singh and Vaidya, 2019).

As LPR is based on image processing a computer technology, it constructs a vehicle's feature model and distinguishes different vehicle features like color, a model of the vehicle or number plates.

The goal of the system is to automatically extract and recognize the register numbers of the vehicles from car images, divide characters, and then identify characters. It is a special computer vision system focused on a special goal. Recognition of vehicles by license plate numbers is designed specifically for vehicle access control when it is difficult or impossible to use tags. The reader can be installed both in conjunction with the barrier and in the place of free passage. ALP Reader is a unified identification system that consists of a video camera with IR illumination and data processing unit integrated into a compact and rugged outdoor housing (Hermawati and Koesdijarto, 2010).

In the parking lots, the system works this way: when the vehicle enters the parking, the system recognizes the license plate number of the specific car. All the car details are taken at the entry time and when the car leaves, at exit time the parking price is automatically calculated rules (Singh and Vaidya, 2019).

Automatic License Plates Verification is done with an LPR camera or UHF reader and UHF tag. A more detailed description is shown in Fig 2.17 and Fig. 2.18 accordingly.

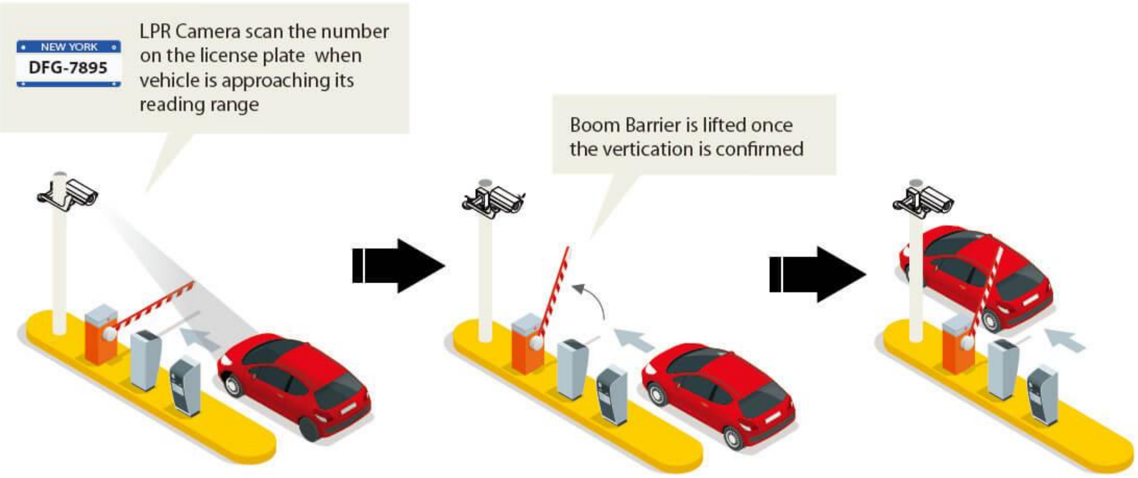


Figure 2.17: Automatic License Plates Verification (with LPR camera) (ZKTECO, 2018)

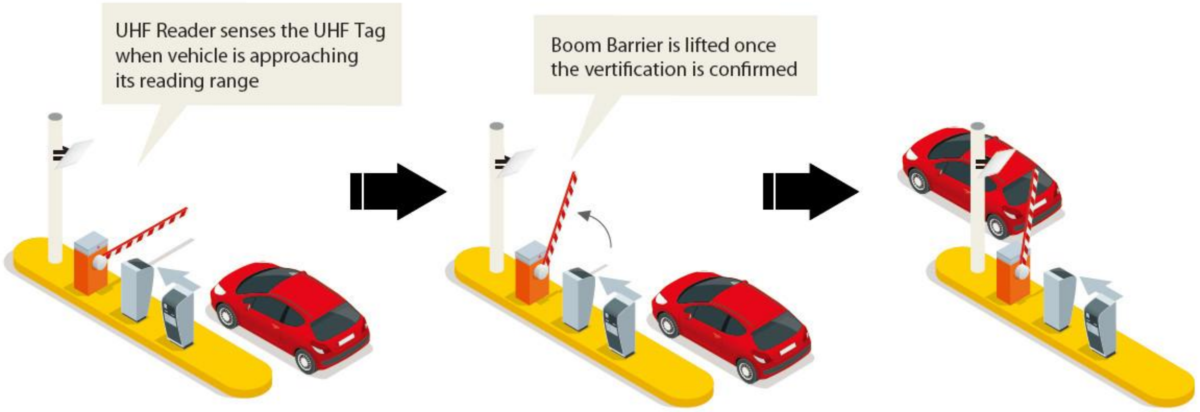


Figure 2.18: Automatic Vehicle Recognition (with UHF reader and UHF tag) (ZKTECO, 2018)

The main components of the LPR system are:

— LPR Camera;

— Ultra-high Frequency Reader;

— UHF tag that can be fixed either on the upper or lower edges of the license plate (3a) or on the windshield (3b) (see Figure 2.19).

Figure 2.19: The main components of LPR system (ZKTECO, 2018)

License Plate Recognition system has six primary algorithms.

First of all, the image of the car has to be captured. Then the system has to extract the vehicle's license plate separately for character segmentation. A big percentage of license plate localization is defined using an algorithm that is based on combining morphological operations sensitive to specific shapes in the input. The complexity appears in differentiating the license plate and other areas because the vehicle has many rectangular objects on it. Algorithms look for geometric shapes of rectangular proportion, for the similar background color of uniform proportion and contrast as a means of distinguishing between objects on a vehicle, for the characters with equal color and similar font structures. Therefore, when the vehicles are moving, their speed creates complexity. In conclusion, the system has to be adapted to the velocity because the image of the license plates is skewed under the angle and can be reflected from light changes.

License plate recognition system consists of 5 main phases (Figure 2.20): image input and acquisition, binarization, noise removal, image processing, database storage, and bill generation. Before the stage of the vehicle number plate's extraction, the captured image should be converted into binary format. After the number plate is extracted, the characters are segmented vertically and localized in the binary image. Optical Character Recognition (OCR) is applied to recognize a character with the condition that the background of an image has no noise or just a bit of noise.

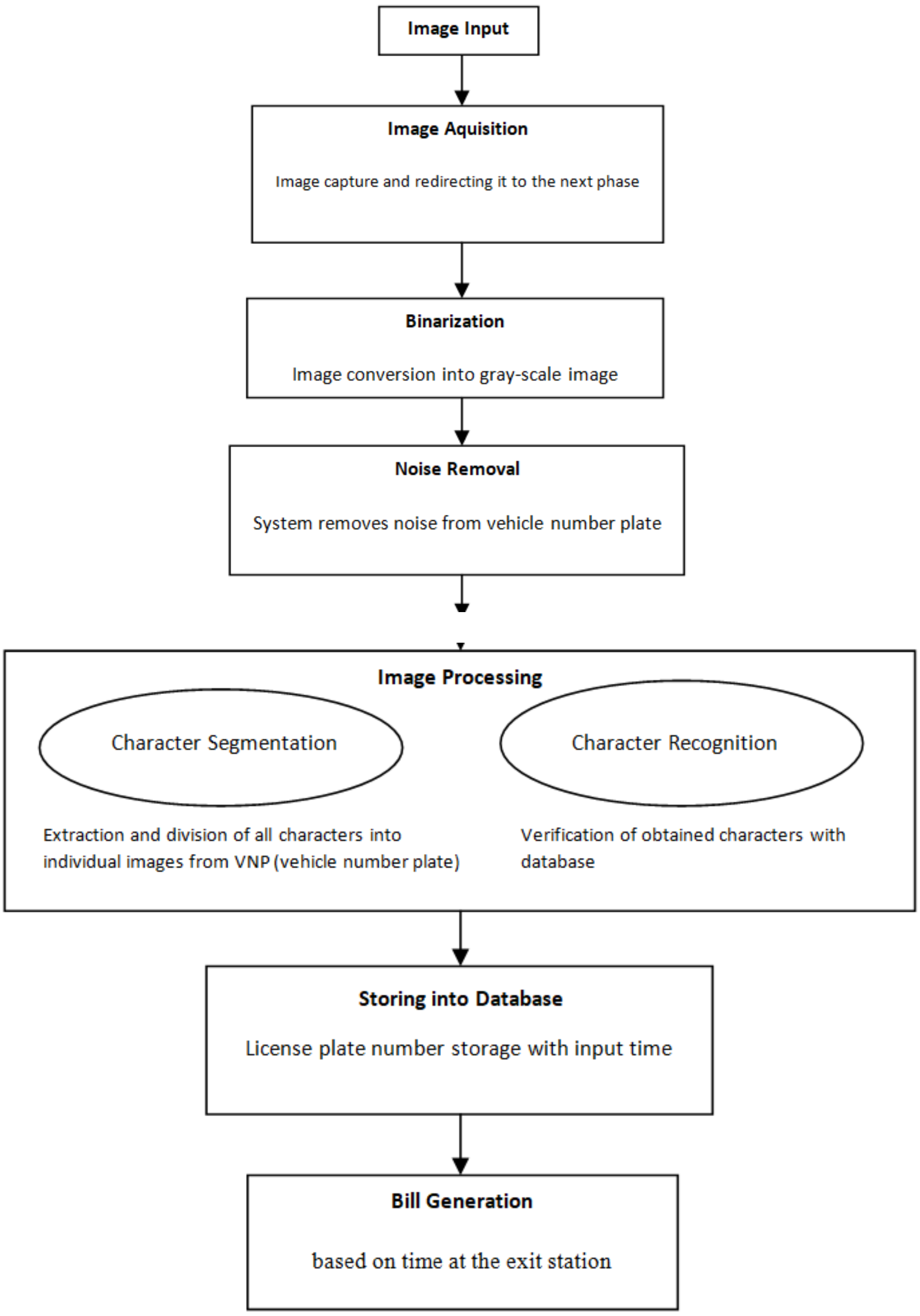


Figure 2.20: Parking Management System Architecture

The aim of the system is algorithmic recognition of a car license plate in a parking area and the implementation of parking and billing operations without the use of magnetic cards.

Benefits of the LPR system:

— *Less Manned Surveillance*

This system provides very high accuracy and traffic personnel can get all the information provided by the automatic license plate recognition software.

— *Monitoring and Surveillance*

This type of recognition replaces the manual process of recording license plate numbers. It is almost impossible for a person to determine the exact registration number when the car passes by. However, an automatic LPR system can do it, even in real-time. This function helps to view clear traffic statistics on the road and at the parking.

— *Still and Video Footage*

Many ALPR systems have still and video footage. They are designed to take snapshots in a situation when the car passes on a red light, speeds up or takes a wrong turn. The recording is done at different weather conditions under different angles and positions of the camera.

— *Improved Security*

It is useful to detect stolen vehicles.

Disadvantages of the LPR system:

— *Extreme Weather Conditions*

Despite the popularity of license plate recognition systems, one should always be taken into account that the weather can affect their effectiveness. During bad weather conditions, the system could work not complete effectively. That is why there is a need for manned surveillance.

— *Privacy Concerns*

As records and images are stored, there is a possibility that somebody’s whereabouts in the footage could be misused.

2.7. Vehicle tracking techniques

Nowadays, the safety of public and private vehicles is the main concern. As result, the accessibility of the vehicle tracking system in the car provides safety.

Apart from theft-prevention, vehicle tracking is commonly used in logistics and transport.

A vehicle tracking system allows companies and organizations to realize the main benefits, including improved safety, increased productivity, and lower costs.

Every vehicle tracking system has to have these features:

1. Real-Time Location Tracking

Tracking of location is at the heart of fleet management. Knowing the current location of the drivers, vehicles and equipment at any given period of time enables to respond faster to emergencies. Additinally, the tracking system helps to make sure that the vehicles are sent to the right location. The main reason transport companies need real-time tracking is for an anti-theft system. However, not every tracking system provides real-time tracking. Some of them make a periodic update of the tracking devices and send information every certain period of time (afew minutes or longer).

2. Customizable Alerts

The must-have feature of the tracking system is alert. Different real-time notifications about vehicle diagnostics or driving behavior enable to improve efficiency and reduce the risk.

Customizable alerts can vary from: speeding alerts, when the vehicle is driving over a speed limit of the road or its specified speed; alerts about vehicle maintenance (vehicles inspections, oil change or tire rotations); long idle times; up to odd-hours alerts, when the vehicle is driving during a specified range of time (for example: between 11 pm and 7 am).

3. Vehicle Maintenance Scheduling

By detection of new maintenance issues, they have to be resolved immediately ensuring timely planning and execution of preventive maintenance. It is important to make sure that cars get the service they need on time. This will prevent minor problems from becoming catastrophic so that nobody is going to perform repeating maintenance on unaccounted problems.

4. Route Optimization and Scheduling

Modern vehicle tracking systems save businesses from manual planning of driver's route with pen and paper. Before the introduction of vehicle tracking technology, companies had problems with drivers that took longer way or overlapping routes.

Automatic vehicle dispatching allows drivers to know at the start of each day where they go and which route they will take. Vehicle tracking systems allow organizing routes in the most cost-effective way.

Route optimization of the route is a natural outcome of vehicle tracking systems. It considers many factors that could make an impact on the route such as accidents, bridge height, traffic patterns, and road works. Consequently, travel time can be improved and fuel consumption and kilometers are driven are decreased.

Up-to-date data for current conditions give a possibility for quick, aware decisions that maintain efficiency.

5. Driver Behavior Monitoring

Vehicle tracking systems provide an overview of many different driving behaviors. This analytic data includes data on speed, fast acceleration, and hard braking up to the average time. The reports can show the start and end times of the days, which can confirm timesheets or show extended hours (Automotive Fleet, 2019).

2.7.1. Intelligent Vehicle Monitoring Using Global Positioning System

GPS vehicle tracking system appeared with the need to get information about vehicle location outdoors at time for numerous reasons.

Global Positioning System (GPS) is an embedded space-based satellite navigation system that is used for tracking and positioning of the vehicles, navigation and time dissemination, location, time information during different weather conditions and other research purposes (Vatsal et al., 2019).

GPS is attached to the vehicle in a suitable compartment or a hidden part and moves continuously along with the car and subsequently calculates the coordinates of each position it covers. It is not visible to anyone because of the fitness of its vehicle (Keerthika et al., 2017).

It traces the vehicles anywhere at any period. Whether it is a fleet of hundreds of cars or a truck with expensive cargo, the GPS can help to keep an eye on it and will give the current information without a physical presence on site. This tracking system can be used in the consumer vehicle as retrieval device and theft prevention.

GPS system is applied to any type of vehicle (car, truck, boat, motorbike) for many purposes:

- to ensure vehicle security and smooth fleet management;
- to track vehicles, if they are moving or stationary and define their position;
- to easily find a stolen vehicle using a mobile phone without additional cost;
- to monitor trucks that carry valuable goods, keep updating the status of delivery and truck’s location;
- to define current location while traveling locally or in a foreign country;
- to keep a tab on the driver based on data protection rules (Vatsal et al., 2019).

The main disadvantages of GPS are atmospheric effects, signal multipath, no GPS signals in the indoor environment, underground, and underwater (Maurya et al., 2012).

2.7.2. BLE-based Vehicle Tracking

BLE technology provides significant benefits for indoor tracking, while GPS is not suitable for reliable distances within 5 to 20 meters inside the closed area. Furthermore, BLE technology is a diverse system that can be employed with traditional GPS for outside tracking. This method is a perfect solution for a combination of indoor identification and outdoor tracking in one technology.

The special type of beacon is applied for the notification of the current location of the vehicle to the Smartphone or tablet devices. For the outdoor tracking, additional BLE-based GPS locators have to be attached to the objects for monitoring the location (Fig. 2.21).

Figure 2.21: BLE-based GPS locator (Comarch, 2020)

All the information about the position of the vehicles is gathered in one system. Tracking is performed through a Bluetooth-based device that is nearby the beacon's equipped vehicle or via an app in the gadget through Wi-Fi or Bluetooth. Additional mobile location technologies can be used to identify the current location of the vehicle or to add the location context.

The tracking can be applied by attaching a beacon with GPS inside the vehicle for different purposes such as monitoring of location during the transportation from point A to point B when the vehicle is outside from the warehouse or at any destination location to ensure vehicle security and smooth fleet management.

Application of this type of tracking takes some advantages:

- battery drain minimization by using location services only when required;
- no disruptions when moving from indoor to the outdoor environment and vice versa;
- usage of existing location services.

The main drawback of using this type of tracking is a dependency on a mobile application on devices (TEAM Software, 2019).

Chapter 3

3. Methodology and Analysis of proposed systems

This Chapter represents a deep analysis of RFID and BLE technology and their application in the parking and warehouse. Then, both systems are compared based on their benefits and disadvantages. Finally, the most relevant technology for vehicle identification and tracking is provided for the research study.

In the previous chapter, various types of identification systems were overviewed.

The study aims at assessing the feasibility of applying vehicle identification technology at the parking area and warehouse with the possibility of tracking. As the main focus area is the identification of historical vehicles (including those without license plate) at the parking area and garage and tracking of the objects outside from the territory, the two most suitable technologies will be considered and analyzed in the following chapter.

RFID exist on the market for a long period of time and is the best application for check-in/check-out point detection. However, it is not an appropriate option for real-time location tracking. Furthermore, it enables the contactless location of the objects in the warehouse. Why are BLE beacons replacing RFID tags nowadays? And which features do beacons have that RFID-based technology cannot accomplish?

To give the right answer, both technologies will be analyzed and compared based on their features and drawbacks.

3.1. Analysis of RFID technology

3.1.1. Application of RFID in the industry

RFID technology is applied diversely in the transportation domain: traffic and fleet management, electronic toll collection, electronic vehicle registration, access control, car parking, positioning, theft prevention, and automatic vehicle identification. In the automotive industry, the appeal of RFID technology lies in security protection and real-time visibility (Landt, 2005).

Vehicle identification

RFID technology is applicable for a variety of purposes, including vehicle identification and tracking. RFID is a ready-made solution for parking, garage, yard, residential complex (Jayalakshmi, 2016).

Accounting for vehicle entry-exit for vehicle fleets

There are several main applications of radio frequency identification for tracking entry and exit into the territory (enterprise, parking and warehouse):

i. A radio tag is a kind of electronic pass for a car. By reading the data from the tag, the access control system can identify the vehicle that belongs to the company's vehicle fleet. This means that the tracking system can give a command to open an automatic gate or raise a barrier.

ii. The fact of reading means that the vehicle has returned to the garage, or, conversely, is leaving for the route. The fleet management system, thus, automatically enters the vehicle code into the list of those who are now on the territory of the vehicle fleet or excludes the vehicle from the list of "present" if the vehicle was already there.

iii. Gate is not the only place where RFID can be applied. For example, a reader system can be installed at the entrance of a repair shop to automatically track vehicles that are in service.

Thus, RFID-reading systems make it possible to fully automate the tracking of how many objects are in a garage and which of them can be quickly accessed for the next destination point (Asupro, 2020).

Advantages of the new automatic pass system:

- no need to leave the vehicle interior;
- automatic vehicle entry and exit occurs without delays;
- vehicle registration: the system registers the entry/exit of vehicles;
- access control to the territory;
- low cost of equipment and RFID cards;
- additional savings: no need to hire an employee;
- Versatility of use: the RFID module system can be applied to gates and barriers of various types;
- Functionality and simplicity: plastic cards with RFID-chip are temperature tolerant, moisture resistant, and have a long service life without the need to recharge.

RFID parking

RFID parking is a system for monitoring vehicle access and parking space management, which simultaneously performs several functions: identification of vehicles using RFID tags (radio frequency identification) cards, control of vehicle entry-exit, and opening of barriers and gates. It speeds up the access control process, and most importantly, makes it cheaper. RFID reader for parking quickly solves all problems of control and accounting instead of a person.

When approaching a gate or barrier, the tag is detected by an RFID reader, which automatically opens the barrier or gate (Figure 3.1).The RFID tag cannot be forged due to the use of digital coding of the tag.

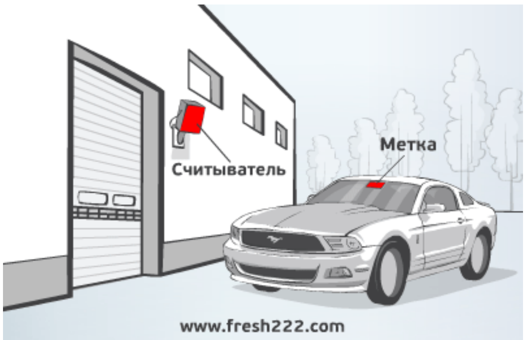


Figure 3.1: Parking access point (Fresh222, 2020)

3.1.2. How does the system work?

Check-in process

The vehicle arrives at the parking lot and tries to register with an RFID tag, the system checks if the vehicle is registered in the database. If the object is registered the system lets it enter. Upon the entrance stage all the vehicle identification system, entrance time, and date are recorded and it checks if the object was check-out from the previous parking. In case, if the vehicle made an unauthorized check-out from the parking lot, the system would not register the vehicle at any of the RFID-enabled parking lots. The only solution for the vehicle owner is to cover the fine. That is why the check-in information plays great importance. After receiving permission, the barrier lifts up and precedes the check-in process (Fig. 3.2).

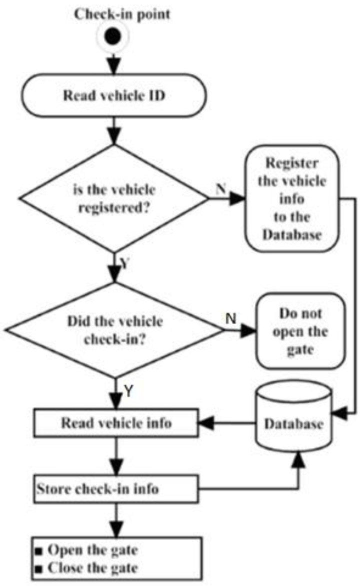


Figure 3.2: Parking-lot check-in process (Pala and Inanc, 2009).

Check-out process

During the check-out process at a parking lot, identification information of the vehicle is queried on the database. If the object performed the correct check-in process with authorization, the check-out process is initiated. The check-out time and date are fixed by the system and, based on the calculation of the total time spent on the parking lot; the total fee has to be paid. In case, when the vehicle made an unauthorized entry to the parking area, the system will block the check-out. In this situation, firstly a fine has to be paid and after a driver can turn back to the check-out again. After completing the process, the barrier is lifted off (Fig. 3.3).

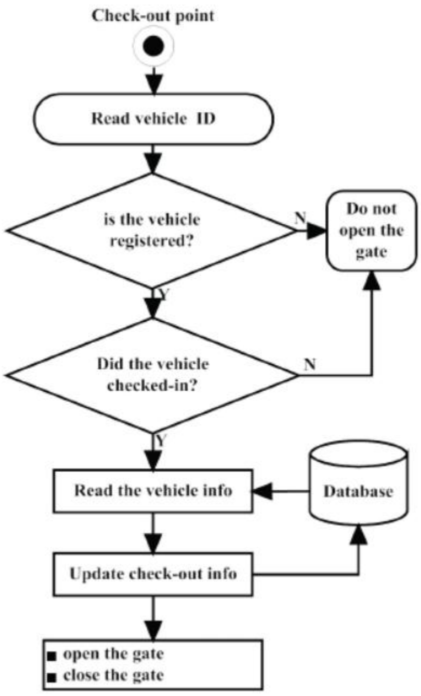


Figure 3.3: Parking-lot check-out process (Pala and Inanc, 2009).

3.1.3. Implementation of RFID technology in a parking lot

RFID technology is a contactless identification technology that perfectly suits the parking system. It does not require personnel since vehicles are recognized automatically and fees are collected via the system. This type of technology enables check-in and check-out processes under secure, fast and convenient conditions. RFID readers control check-in and check-out. Additional sensors and timing of gates let one-by-one circulation and it helps to prevent multi check-ins or check-outs at the same time.

After analysis of RFID technology, the results will be summed up in the benefits and drawbacks of using RFID.

Benefits of using RFID:

- Each object has an individual unique vehicle code.
- A plurality of tags can be read simultaneously.
- Non-line-of-sight communication.
- The wireless storage and automatic retrieval of data.
- Manually executed workloads are significantly reduced by the use of RFID.
- Tags can be used repeatedly.
- Low maintenance costs.
- No physical contact between the data carrier and the communication device.
- RFID technology is universal, useful and efficient.
- It has a high degree of product authentication and is more secure compared to other networks.
- Ancillary data infrastructure allows data retrieval and vehicle tracking anywhere as long as the reader is close enough to the tag.
- Each tag can be unique; it can act as a means of protection in the event of loss or theft.

RFID has some disadvantages:

- Reader collision. It occurs during the overlap of the signals from two or more readers.
- Tag collision. This type of collision appears when many tags are present in a small area (Pala and Inanc, 2009).

3.2. Analysis of BLE system

BLE infrastructure is the ideal solution for the indoors and outdoors. To define the accurate position of the vehicle, it is sufficient to have a combination of three indoor beacons.

3.2.1. Application of BLE in the industry

Bluetooth Low Energy (BLE) system is the center of indoor location technologies. It is one of the newest innovations available on most devices today that has evolved and become an industry standard. It utilizes so-called BLE beacons that are affordable, lightweight, have long battery life, and do not need an external energy source (Locatify, 2020).

Bluetooth Low Energy beacons can be applied in different scenarios: theft protection (attachment to the valuable objects); indoor tracking; process optimization; indoor tracking; personnel and vehicle tracking and inventory management. BLE technology can improve the efficiency of the objects' operations, reduce labor costs by automating data collection, and optimize capacity and monitoring. By using beacons, objects can be placed in any free location without concern of getting lost.

How is it used for Tracking?

BLE is used in two ways. Firstly, tracking beacons send location information and sensor data of the object. The second way is that beacons have a unique identifier assigned to each tracking object. It is also possible to read BLE devices automatically, so there is no requirement to scan manually tags and move them through checkpoints. This makes them much more effective for automatic data collection than technologies such as RFID.

How long do these beacons last?

The lifespan of a beacon battery is affected by three categories of factors:

1. Hardware factors.

The lifetime is driven by the capacity and number of batteries. The bigger size or the higher amount of batteries, the longer is the lifespan.

2. Environment-specific factors.

Such environmental conditions like temperature or humidity affect battery life. For the specific areas bigger beacons built to withstand an impact have to be used.

3. Configuration-specific factors.

The consumption of the battery is influenced by:

— Transmission power, defining the signal strength and spreading distance.

— Advertising interval, determining the frequency of broadcasting the signal by the device. The shorter is the interval, the faster is the device broadcasting and the more energy used.

3.2.2. How do beacons work?

Beacons broadcast signals, also called identifiers, on short, regular intervals. When beacons are active, they send signals in small intervals; otherwise, the tact is longer (Figure 3.4). Identifiers are picked up by any other Bluetooth-enabled devices being in the range and once connected; the current location will be tracked and transferred into the software. After the processing of the given information, all the current data will be represented in the system.

The identifier is a unique ID number that the Bluetooth device recognizes as unique to the beacon. The beacon, which is sending the signal repeatedly, could be movably attached to some vehicle or stationary, mounted on the floor or wall (Adarsh, 2020).

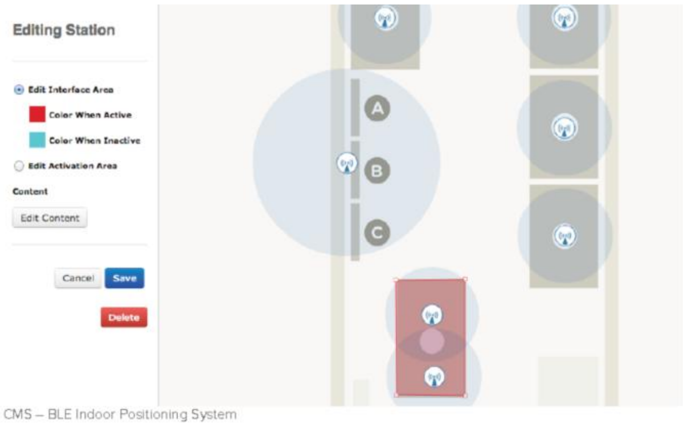


Figure 3.4: BLE indoor positioning

BLE tracking gives the exact information about who and when interacted with which vehicles without paperwork fulfillment. All the details about the movements of the vehicles, the path they took along the way are documented automatically in the system. As a result, it provides more transparency over manual operations (Kontakt, 2020).

3.2.3. Implementation of technology in a parking lot

By implementing the BLE technology at a parking spot, it turns into a smart parking system. The system can be accessed from any wireless device (Smartphone, tablet, computer).

Each parking spot is paired with a unique BLE beacon that is registered in the system (Figure 3.5). The system itself provides drivers with real-time information on available parking at any given time.

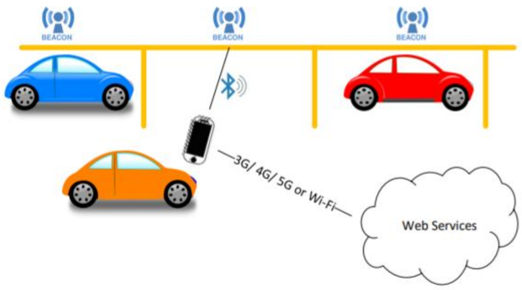


Figure 3.5: Smart parking system overview (Mackey, 2020)

It guides to a free parking space and provides a secure, automated payment based on real-time usage of the parking space. In addition, there is a possibility to reserve a remote parking space via app in advance. Arriving at the destination parking, the driver can use indoor navigation to be guided to the allocated space (Figure 3.6). The app can provide other services such as electronic payment or car finder function.

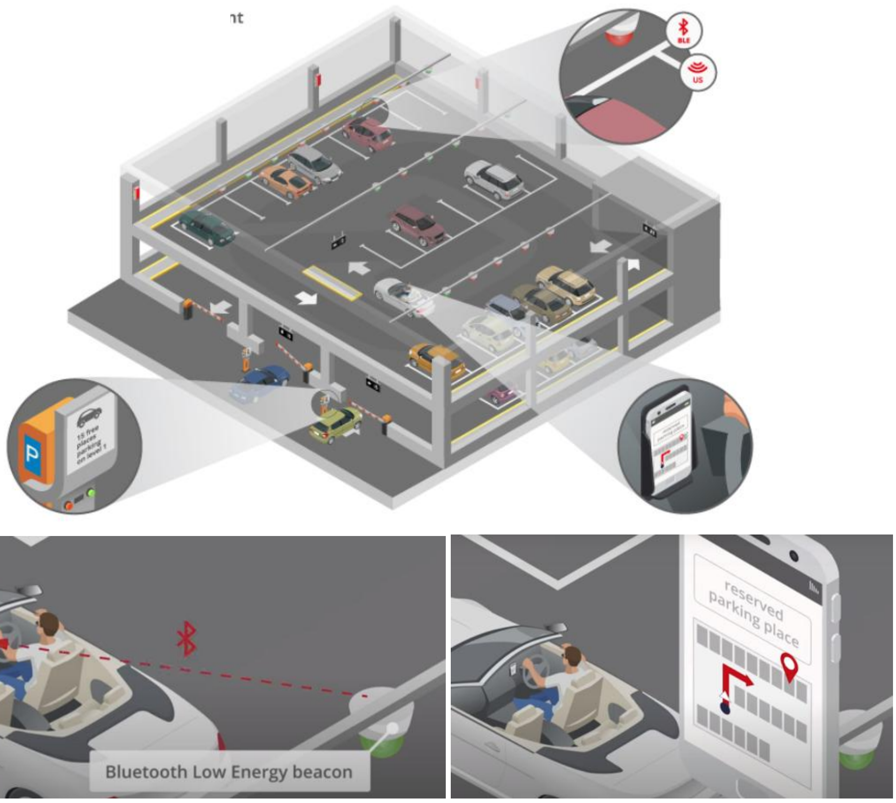


Figure 3.6: Intelligent vehicle parking management (Infsoft, 2020)

Benefits of BLE technology:

— Cost efficiency and high Return of Investment (ROI);

This technology cannot be counted as cheap but is cost-effective. The bigger amount of beacons is installed, the more accurate information is received.

— Real-time tracking;

— Low power consumption;

Between transactions, beacons are ‘sleeping’ and use less power. Hence battery life can last longer.

— Versatile tags;

The integration and installation of beacons are flexible with the existing infrastructure, while BLE does not require additional infrastructure. BLE tags are versatile for indoors and outdoors.

— High coverage range;

With the implementation of high coverage range, less hardware can be installed and it will reduce expenses.

— Improved security;

— Fast data transfer speed.

BLE beacons deliver data two times quicker than other methods. This faster data update makes the operations managers' job much easier.

Every technology has its drawbacks. BLE is not the exception. Here are the main ones:

— Relatively small range;

It can operate only up to 100 meters.

— Low bandwidth;

It does not suit the transmission of big data applications.

— Communication problems;

Difficulties exist to eliminate problems, especially on long distances and interference.

— Additional hardware.

The gateway device is needed to connect end devices to the Internet (smartphones, dedicated gateway devices) (Asset infinity, 2019).

The Analysis shows that both technologies can be applied for indoor positioning and identification of vehicles (including those without LPN). One of the main differences between the two technologies is that BLE vastly simplifies the identification process in cases where Bluetooth-equipped devices are used for the real-time location system. RFID has different drawbacks that BLE can help to address. As RFID has a low reading range, the entire warehouse has to be covered with RFID readers, which incur high servicing costs. In contrast, the warehouse can be divided into zones and each zone will be equipped with a BLE reader. Due to the energy-conserving nature of the BLE technology, beacons have a high read-range. Finally, RFID technology is incapable to provide real-time location and tracking outdoors. The readers do not have GPS and GSM triangulation capabilities. As opposed to RFID, the user can determine the location in real-time using a GPS chip in a GSM device or using cellular triangulation (Plum, 2020).

To define the most suitable technology for our specific case, first of all, these technologies are compared in the following Table 3.1.

Table 3.1

Benefits and drawbacks of RFID and BLE technologies

Technology	RFID	BLE
Benefits	- High accuracy - Immunity to interferences - No battery needed - Low maintenance costs - Each tag is unique - No-light-of-sight communication	- High accuracy (up to 1 m) - Real-time tracking - Cost-effective, unobtrusive hardware - Low energy consumption - Flexible integration into the existing infrastructure (battery-powered or power supply via lamps and the domestic electrical system) - Works where other positioning techniques do not have a signal - No IT integration - Easy deployment
Drawbacks	- Short range (< 1 m) - “point-in-time” location - Installation requires significant planning - Infrastructure can be expensive (the readers are very expensive) - Complexity in setting up - Inability to provide real-time location - Reader and tag collision	- Relatively small range (up to 100 m) - Additional hardware - Instability with layout changes and radio interferences - BLE can also be prone to some interference from other devices - Low bandwidth

BLE tracking offers the versatility of all the variations in any sphere where the stream of individuals and things has to be followed. The information is read anywhere, unlike RFID physically reading with a scanner or when the object passes through a certain checkpoint. This type of technology benefits in gathering information at a level of detail that would not be possible with other systems (Kontakt, 2020).

The integration of BLE technology into other systems is easier and cheaper. The use of such a wireless real-time location system within the warehouse replaces manual operations and personnel does not require making manual tagging, data entry, and managing positioning information, the system will do everything by itself (Sainathan, 2018).

Result: While RFID reached its prime, it also reached its peak. The growth in globalization requires a more cost-effective solution for operational efficiency improvement. BLE technology will be this solution for smart warehousing and parking.

Future warehouses are relying on real-time tracking technologies to simplify and improve coordination between the many moving parts in the warehouse with the help of real-time data analysis. Management operations in smart warehouses streamline space management, logistics processes, and inventory. Implementation of such real-time tracking technology as the BLE system improves operations, facilitates processes, accountability, and even replaces slow, error-prone manual human actions at a warehouse (Sainathan, 2018).

BLE technology is used in diverse case studies in the warehouse or parking area. The application of the technology varies in the amount of the hardware, depending on the main purpose of the object identification and tracking: from precise location identification to the general location. Below are described some examples.

Case 1: Zone-precise location in the technical services station:

Fixed Beacon locators are installed at the entrances and exits of the workshop, as shown in the following Figure 3.7.

Entrance: The vehicle drives through the gate into the maintenance station and the system shows the vehicle location in the maintenance area.

Exit: The vehicle leaves the technical services station through the gate and the system displays the vehicle position outside the station.

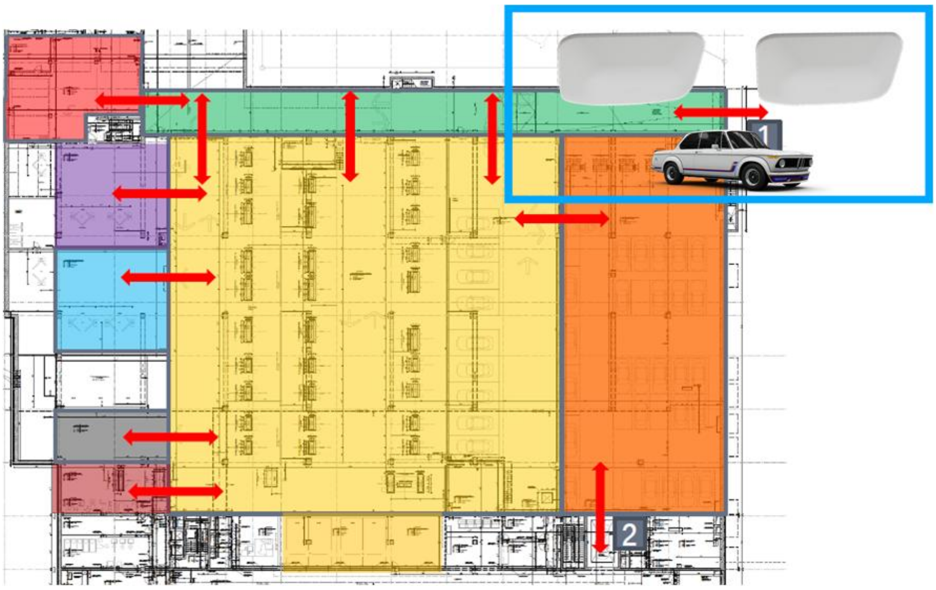


Figure 3.7: Location example of beacon locators at the maintenance station

Case 2: General location in the parking deck area

Three fixed beacon locators are placed across the area to detect the moving objects. When a vehicle enters the coverage area of one of the beacon locators, the system detects this event and displays the car in this zone as “Last Seen Position”.

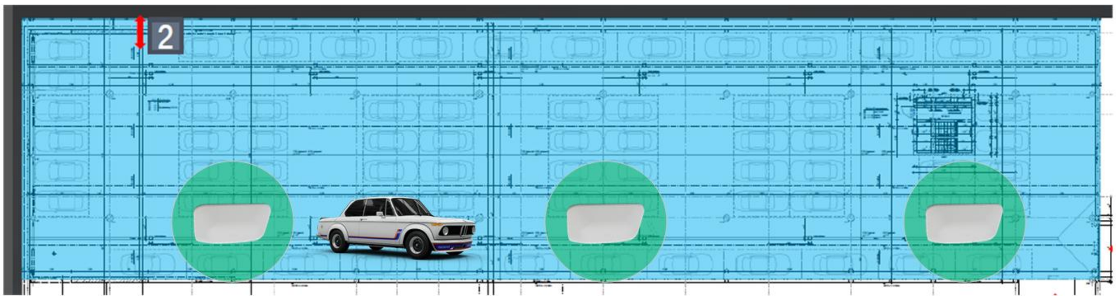


Figure 3.8: Example of location of beacon locators in the parking deck area

Case 3: Parking space exact location in the parking deck area

Fixed beacon locators are mounted on the ceiling or wall. When a car drives into the parking lot, the locator over the parking lot detects the vehicle with the attached beacon. The parking space is determined as the position of the vehicle.

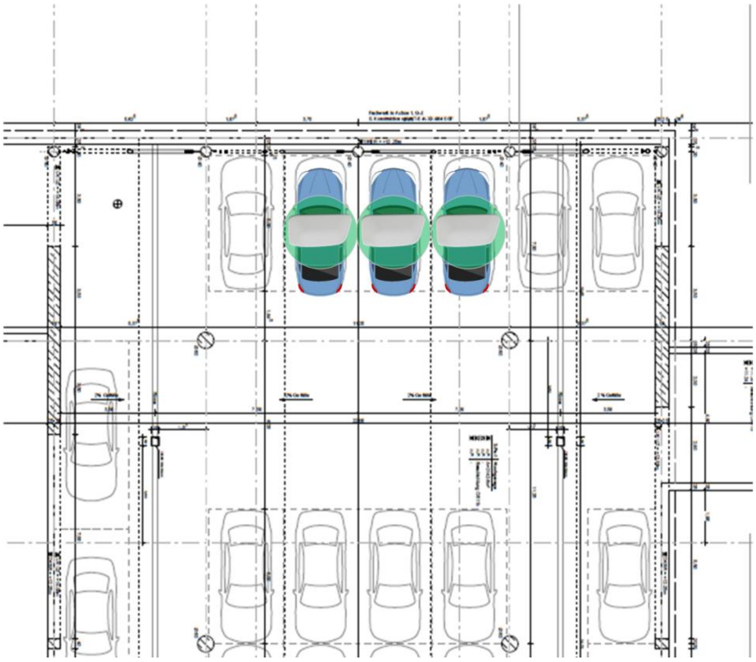


Figure 3.9: Parking space exact location in the parking area

With the integration of the new vehicle tracking technology into the existing system, an important part plays the analysis of a period of time, during which all the invested capital will be covered and after which estimated profit or savings will be done. This type of analysis is called the Payback period (PBP).

What is the Payback Period?

The payback period refers to the period of time (months, years) required to recoup an investment. This type of analysis allows companies to analyze opportunities of the project, make a comparison between few alternative investment opportunities and make a decision based on a project that returns its investment in the shortest period of time (CFI, 2020).

The following formula can be used to find when payback occurs:

$$Payback\ Period = \frac{Amount\ to\ be\ initially\ invested}{Estimated\ Annual\ Net\ Cash\ Flow}$$

The Payback period is suitable for different areas of business:

— For investment;

In this context, the payback period is the period of time after which the income from the project becomes equal to the amount of money invested. When investing in any business, the payback coefficient will show how long it will take to return the invested capital.

— For capital investment (the possibility of modernizing or reconstructing production processes);

With capital investments, the time period for which the savings or additional profit received from the modernization becomes equal to the amount spent on this modernization becomes important.

— For equipment.

The coefficient will show how long this or that device, machine, mechanism (and so on), on which money is spent, will pay off (Zvyagin, 2017).

Chapter 4

4. BMW Group Classic as a Study Case

The general characteristic of BMW Group Classic and analysis of the current situation in the warehouse of the company as a study case is proposed in this chapter. The challenges faced in the company lead to the integration of vehicle identification technology. BLE technology is integrated into the current system. Finally, the analysis and all evaluation costs represent the effectiveness of the implementation of innovative tracking technology.

4.1. General Information about BMW Group Classic

BMW Group Classic is the branch of BMW which is responsible for all activities related to the history of the company and its four brands: BMW, BMW Motorrad, MINI, and Rolls-Royce Motor Cars. It is working as a central point for owners of classic BMW vehicles and includes such services as restoration, repair, parts sale, purchase, and sale of cars. All the information about the product, brand and company history can be provided by the BMW Group Archive. BMW Group Classic is preserving and managing a collection of the old classic, series, prototypes, concept, and unique vehicles from the early 1930s up to nowadays.

4.2. Analysis of the current situation

As mentioned before, all vehicles of BMW Group Classic are historical, which means that most of them are not equipped with modern technologies (GPS, sensors, or parking assistance).

The complete car park accounts for around 1400 historical vehicles including motorbikes. All of them are registered by inventory number in the BMW system, called Festus.

Festus is an internal logistics - software system specially created for BMW Group Classic. It has been used for:

- Estimates;
- Order entry and placing orders;
- Booking, locating and dispatching the vehicles;
- Accounting orders.

Whenever the vehicle changes position, the latest vehicle location details have to be documented in the Festus.

How does it work?

The vehicle can be searched by different criteria (Figure 4.1): inventory number, brand, vehicle identification number, type of vehicle, color, or construction year.

Figure 4.1: General view of the software system

After searching for the specific vehicle by one of the criteria mentioned above, the vehicle characteristics and information about the current position of the vehicle (Figure 4.2) will be represented in detail. If the position of the vehicle is changed (f. ex. replacement from level A to level B, transportation to the event), it has to be documented in the system (Figure 4.3).

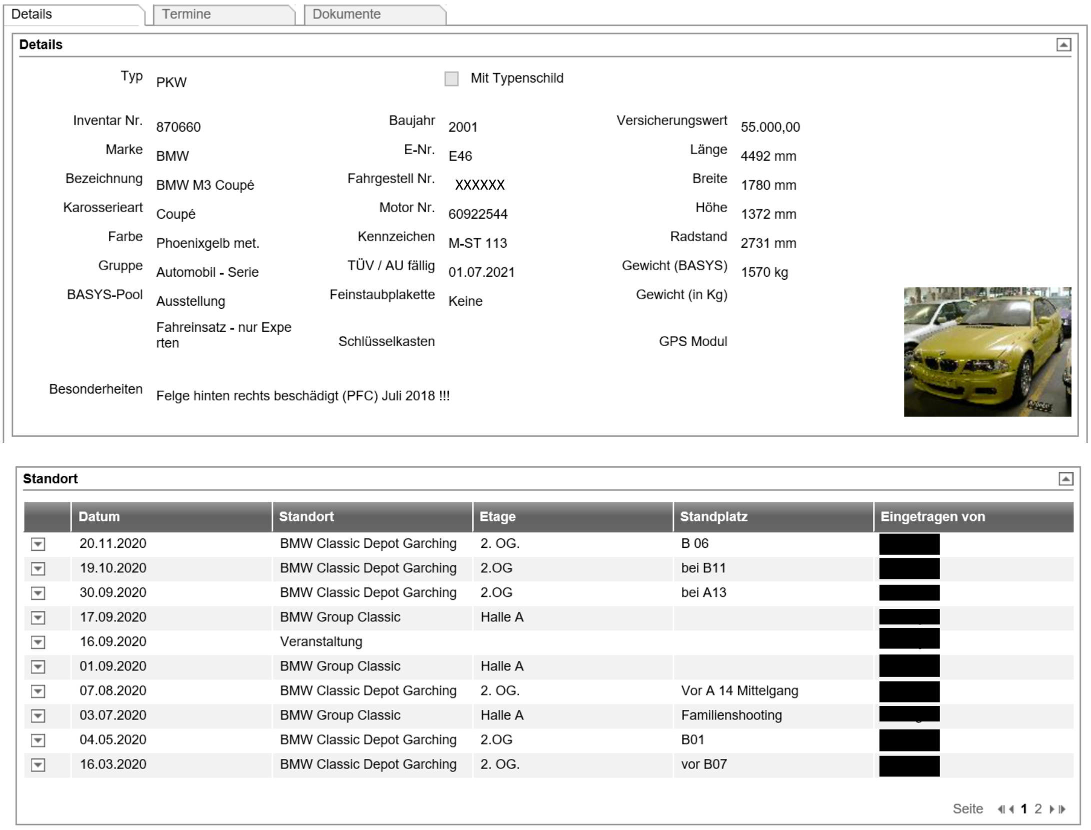


Figure 4.2: Description of vehicle characteristics and position identification

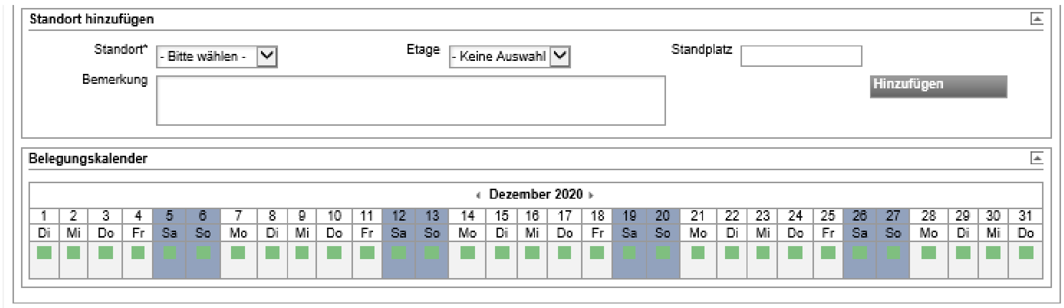


Figure 4.3: Alteration of vehicle location data

The vehicles from the historical collection are transported and shipped worldwide. This is done either by external freight forwarders or by BMW's transports. The latter is carried out by BMW's employees. The most common way to find out their current position during transportation and at the location is through communication with a responsible person.

Another possibility, rarely used, is the application of a tracking system to the valuable vehicles that are transported to a distant destination. BMW Group Classic accounts for a limited number of GPS devices that have to be installed in the historic vehicles to be able to locate the vehicles, which are of considerable value, in the event of theft. The employees also carry out other work tasks in addition to their freight forwarding activities. Technically, the tracking system is expected to take place via a GPS transmitter.

There is a part of vehicles without any license plate number. They are used for museums, exhibitions, driving tests, are transported with the truck, could be installed in media, shootings, or movies, or they are gathered for the restoration and collection in the warehouse, stay on preservation without movement.

All the vehicles are stored in a multi-stored warehouse. The warehouse description is represented in Table 4.1.

Table 4.1

Characteristics of the warehouse

Total Area	XXX m^2 *
Number of floors	5
Total number of vehicles	1400
Number of rows at 1 level	7 (from A to G)

* – due to the confidentiality restrictions by BMW Group Classic, the total area cannot be officially published.

The warehouse consists of 5 levels with the same dimensions and each level is divided by rows and blocks. In one block can be located from 2 up to 6 vehicles (Figure 4.4). A more detailed overview can be seen in Figure 4.5.

Figure 4.4: Vehicle location in the warehouse (Own photograph)

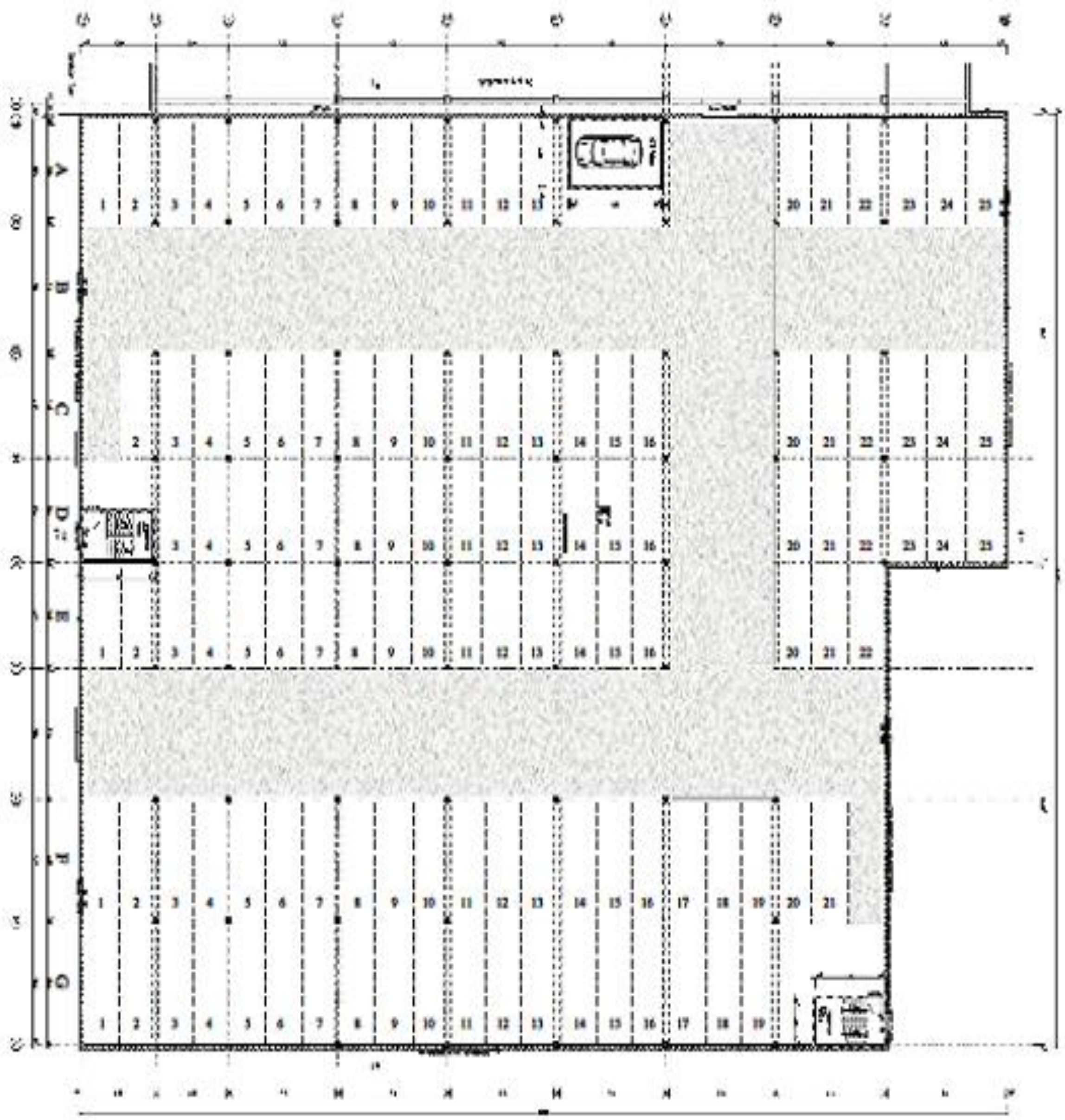


Figure 4.5: Warehouse plan (2 level as an example)

Between levels, vehicles are transported by elevator (Figure 4.6). There are multiple areas in the facility used for the purpose of car preparation, delivery zone, charging, and cleaning (Figure 4.7).

Figure 4.6: Elevator (Own photograph)

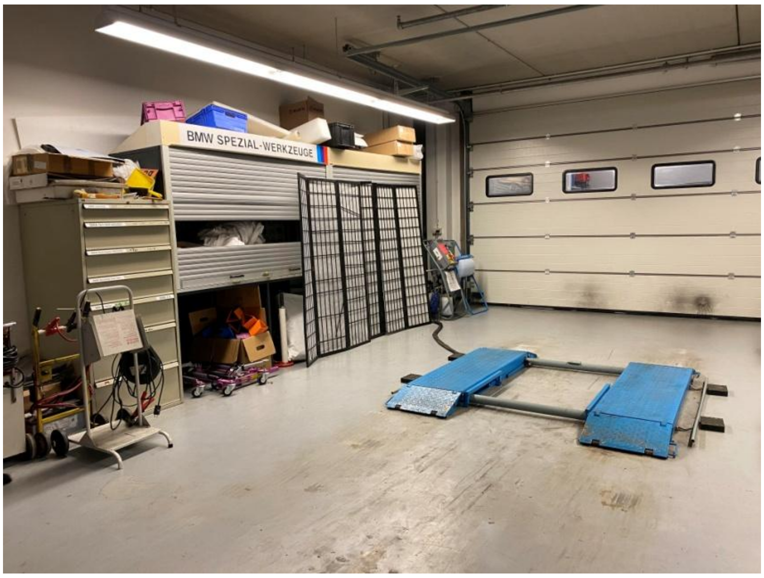


Figure 4.7: Preparation zone (Own photograph)

All the operations are done manually by BMW employees. The general process looks like:

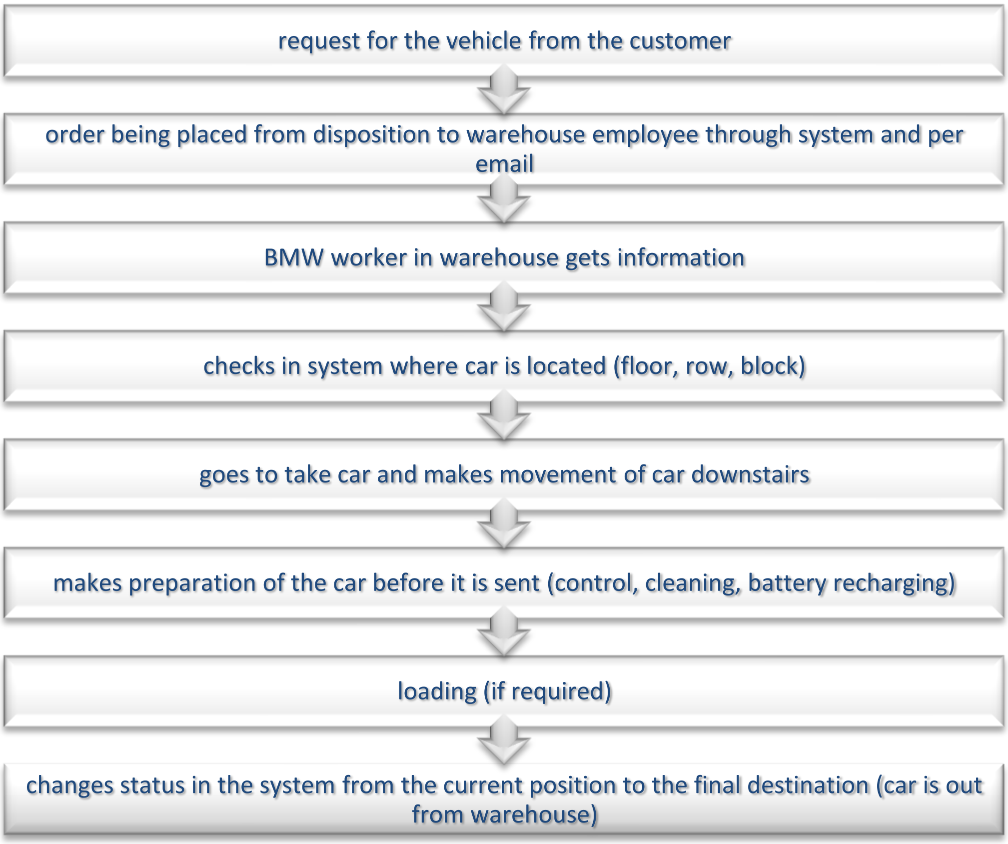


Figure 4.8: Car dispatch process overview

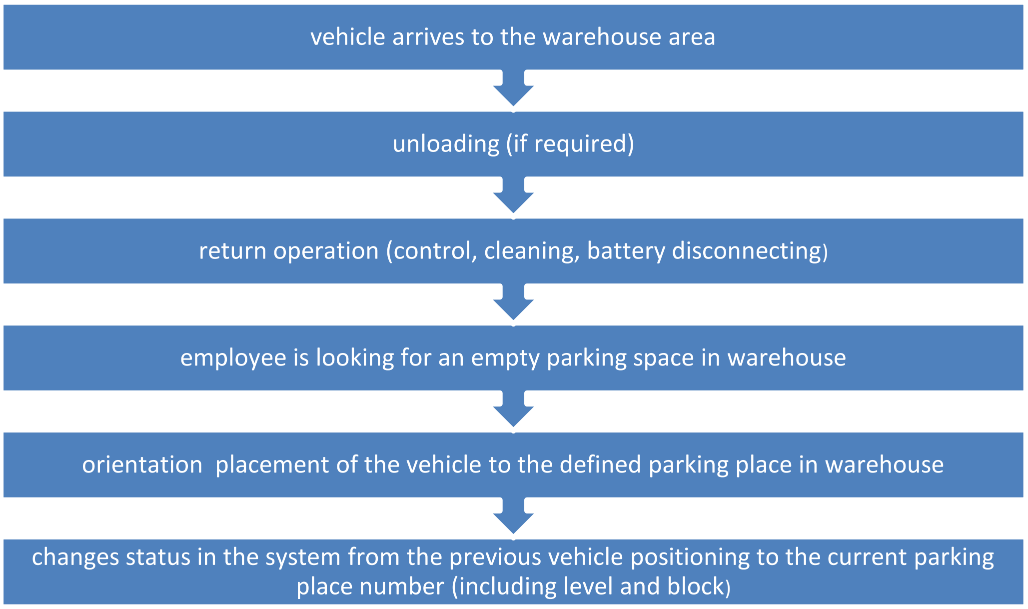


Figure 4.9: Car arrival process overview

In 2019, 1500 vehicles were dispatched from and arrived in the warehouse. During the year all the movements of vehicles inside the warehouse are done manually. Around 5 % of vehicles are being placed in the wrong position in the system due to human error. It costs time and money to find the vehicle in the warehouse and replace it in the correct position after some period of time. To place the vehicle back on the position, it could take around 1.5 hours: firstly, to find car location (level, row, number place), then move to the correct position and finally, change in the system.

The main objective is to track and trace 1400 historical cars and motorbikes (including those without license plate number) located in a multi-story warehouse and to decrease human error to the minimum, to be able to find out the location inside the warehouse and track it outside the area.

Table 4.2

Overview of the current processes in the warehouse

Salary of the BMW employee in warehouse *additional costs: health insurance + pension insurance + vacation + premium	13,8 €/hour +59%*
Vehicle movement and replacement in warehouse in 2019 year	1500 vehicles
Error done concerning wrong vehicle position during the year	5 %
Time needed to search for position of 1 vehicle in the warehouse	10 min
Time needed for vehicle movement and replacement in warehouse (including upload/unload)	50 min
Searching time for 1 vehicle that is wrongly placed	60 min
Time needed to replace 1 vehicle placed on the wrong position	30 min

4.3. Challenges faced in the warehouse of BMW Group Classic

The main issues are:

- Manual check-in and check-out of the vehicles.
- Human errors. During the car arrival or dispatch, all operations are done manually. As a result, some human errors could appear. It could include the wrong position of the car in the warehouse or wrong data given in the system after placing the vehicle. Parking places in the warehouse are dependent on employees. The employees need to maintain data of all the vehicles by physically entering the information. Later it leads to problems related to determining the location of the vehicle, which affects time and price.
- Identification of the exact location of a specific vehicle or motorcycle in the parking lot, including unregistered vehicles (without license plate).
- Vehicle tracking absence during transportation to a specific event (exhibition, museum, round trip, repair, photo shooting).

4.3.1. Cost evaluation

— Costs spent to solve 5% of employee's error during the year:

The number of cars that could be placed in the wrong position during the year (5%):

1.500 vehicles/100% × 5%=**75 vehicles**

Costs/year spent to search for the vehicles that are wrongly placed in the warehouse (5% error):

75 × 60=4.500 min=75 hours/year

75 hours/year × 22 € = **1.650 €**

Costs/year to replace 1 vehicle placed in the wrong position (5%):

22 € + 59% = **11 €**

Costs/year for replacement of wrongly positioned 75 vehicles and their movement in or out from warehouse (including load/unload):

11 € × 75 = **825 €**

Complete costs spent to solve 5% of employee's error during the year:

1.650 + 825 = **2475 €**

— Costs for vehicle position determination, replacement and movement in or out from the warehouse:

Costs/year needed to find the position of the vehicle correctly positioned in the warehouse during the year:

1.500 cars - 5% =1.425 cars/year

1.425 cars/year × 10 min = 14.250 min/year = 238 hours/year

238 hours/year × 22 € = **5.236 €**

Costs/year for vehicle replacement and movement in or out from the warehouse (including load/unload):

1.500 × 50 min × (13.8€ +59%) = 75.000 min/year = 1.250 hours/year

1.250 hours/year × 22€ = **27.500 €**

— Complete costs/year spent for vehicle preparation and movement in or out from warehouse including 5% of error:

1.650+825+5.236+27.500= **35.211 €**

4.4. Solution Approach

The goal is:

— To be able to locate cars inside the warehouse and zones quickly without the need of BMW employees to input information about the change of the last position of the car.

— To track the vehicles at any period of time on demand when they are transported from the warehouse to another location (museum, exhibition, event) and vice versa.

The idea is to get rid of human errors, wrong and not actual information that could be placed into the system.

By the implementation of vehicle detection and tracking technology in the warehouse, the human error will turn to zero, which will result in time and cost-saving (Table 4.3).

Table 4.3

Description of the processes during the current situation and with the implementation of identification technology

Process	**Scenario 1**	**Scenario 2**
	Current process overview (min)	Process overview with the implementation of identification technology (min)
Vehicle dispatch		
Search for the specific vehicle parking location in the system (Festus)	5 min	5 min
Vehicle replacement, preparation (control, cleaning, battery recharging) and moving out from the warehouse	50 min	50 min
Alteration in the system to the current position (out of warehouse)	5 min	-
5% error made by an employee	30 min	-
Vehicle arrival		
Search in a system (Festus)for the empty parking lot to place the arrived vehicle	5 min	5 min
Vehicle movement to the warehouse, preparation (control, cleaning, battery disconnecting), placement on the free parking spot	50 min	50 min
Alteration in the system to the current position (store, row, block)	5 min	-

After a comparison of 2 Scenarios, we come to the conclusion that with the implementation of the vehicle identification technology the process will become half automated which affects time decrease. During the dispatch, around 35 minutes will be saved as the system will automatically track all the movements of the vehicle in the warehouse and change the position of the vehicle. That means that all information about vehicle position is presented correctly in the system (no 5% error during the year) and BMW employee does not need to search for a wrong vehicle position.

During vehicle arrival, 5 minutes will be saved due to the automatic change of the vehicle position in the system. The time savings will decrease costs.

— <u>Implementation of the identification technology in the warehouse:</u>

Costs/year needed to find the position of the vehicle in the warehouse with the implementation of identification technology:

1500 cars/year × 50 min = 75.000 min/year = 1.250 hours/year

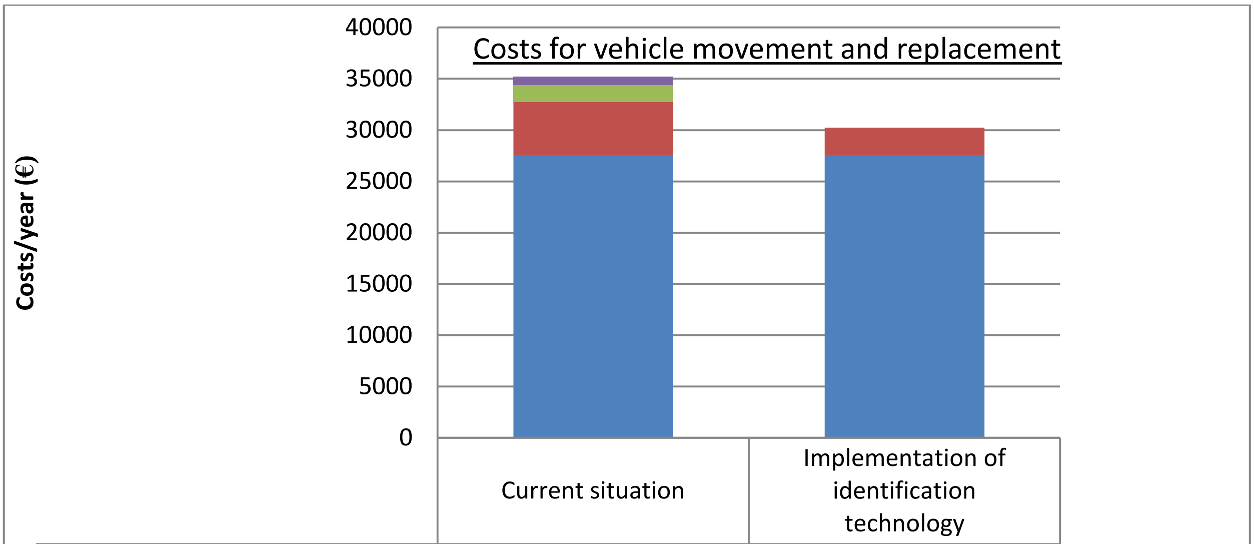
1.250 hours/year × 22 € = **27.500 €**

Costs/year for vehicle replacement and movement in or out from the warehouse (including load/unload):

1500 cars/year × 5 min = 7.500 min/year = 125 hours/year

125 hours/year × 22 € = **2.750 €**

Figure 4.10: The cost analysis of the current situation and after implementation of the identification system



	Current situation	Implementation of identification technology
5% error- Vehicle replacement, preparation and movement	825	0
5% error - Vehicle location determination	1650	0
Vehicle location determination	5236	2750
Vehicle replacement, preparation and movement	27500	27500

The results show that with the implementation of the identification technology the whole process will cost 30.250 € during the year. During the current situation, 35.211 € are investigated for the dispatch and arrival works.

4.4.1. BLE technology implementation

Proposition: application of new automated vehicle identification technology – BLE technology.

With the challenges mentioned above, the solution is based on Bluetooth Low Energy technology to track vehicles with the following three objectives:

- To design a system for tracking the location of the vehicle in the warehouse;
- To automate check-in and check-out;
- To avoid errors appearing while placing the cars on the positions in the warehouse and updating the tracking system;
- To track the position of vehicles shipped outside the warehouse.

4.4.2. General system architecture of tracking solution

4.4.2.1. BLE system architecture in the warehouse

The proposed BLE system will consist of BLE beacon devices (type E7 plus), locator beacons and beacon nodes for indoor identification, and BLE Beacon devices with GPS for outdoor tracking.

Each beacon will be assigned to a particular car (Figure 4.11) kept in the BMW parking and will transmit its ID constantly so there is an unambiguous identification about the car location. Locator beacons will be fixed to each parking position and 2 beacon nodes will be placed per each floor.

Figure 4.11: Location of the beacon in the vehicle (BMW Niederlassung, 2020)

Additionally, beacon nodes with two-way communication shall be installed in every zone. Thanks to that approach it would be easier to locate the car inside the floor since the parking block (4-6 cars) with an existing naming scheme (f. ex. A23). Every time a car is being moved to a zone, a two-way beacon node detects the beacon signal inside the car and sends information to the cloud application. Asset tracking application updates the status and location of a particular car.

IoT gateway class devices gather data from all beacons installed across the BMW warehouse. The device is equipped with Bluetooth Low Energy and LTE/4G modules. Such configuration allows sending the data in real-time to the Asset Tracking cloud application every time there is a change in a car location or there is a new car within the defined zone (Figure 4.10).

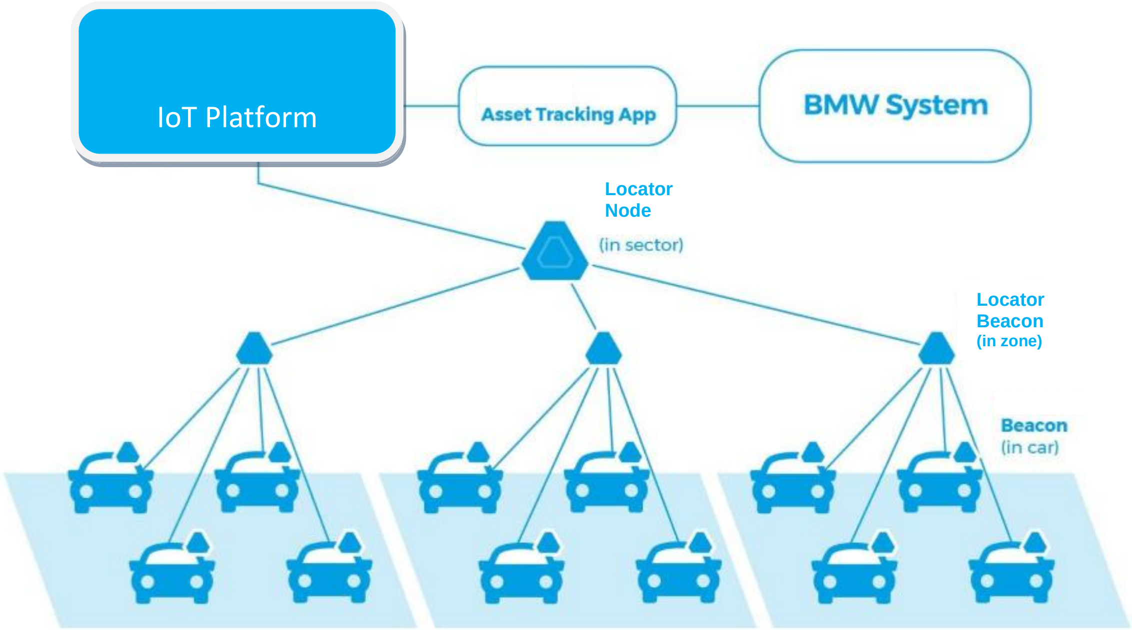


Figure 4.12: BLE system implementation in the warehouse (Comarch, 2020)

4.4.2.2. BLE tracking outside the warehouse

Indoor and outdoor tracking have to be interrelated. To facilitate the process of using an additional GPS device, BLE Beacon with GPS will be paired with every vehicle that will leave the BMW warehouse and will provide global connectivity. The BLE Beacon with GPS in the vehicle will have to be connected with a wireless device (phone, tablet) that will transmit all the tracking information to the system.

According to General Data Protection Regulation (in German: DSGVO) represented by BMW Group Classic, the equipping of historical vehicles with BLE Beacons with GPS is permitted from a data protection point of view, provided that the employees are informed about the measure, the purpose of the data collection and the storage period. As part of the admissibility check, a proportionality check must be carried out (weighing the employer's interest in information against the employee's personal rights). Only event-related tracking will be tracked. The geodata is always recorded and stored in an access-protected location. The access protection is only lifted if the valuable cargo is stolen.

The tracking may only take place if the employee is aware. Secret tracking is not permitted. In this respect, the employee should be informed of the purpose of the data collection and any storage period. The collected transport data must be deleted immediately as soon as they are no longer required.

Asset tracking application will provide a simple interface to assign the particular GPS tracker to the object and provide accessibility to follow and show the location of the vehicle on the map in real-time. That means that the most valuable cars shipped outside the campus are going to be tracked with GPS locators and with location information on demand.

After the implementation of BLE technology vehicle dispatch (Figure 4.13) and arrival process (Figure 4.14) is simplified and improved.

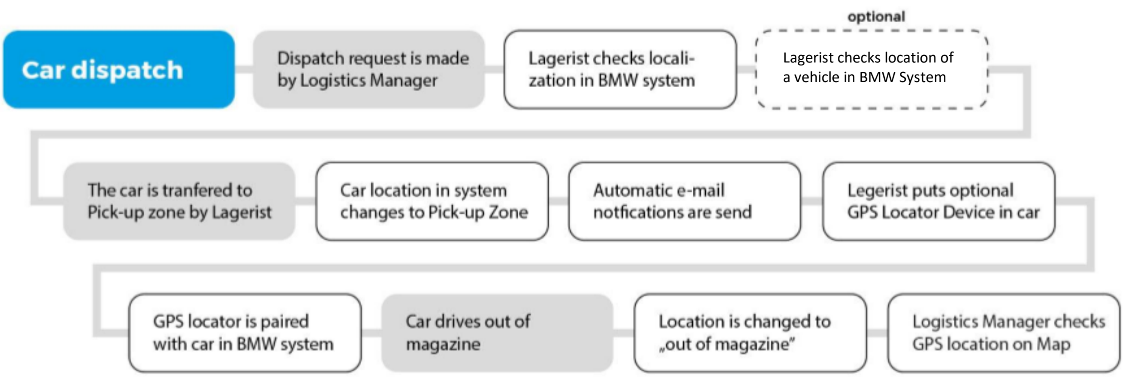


Figure 4.13: Car dispatch process overview by using BLE technology (Comarch, 2020)

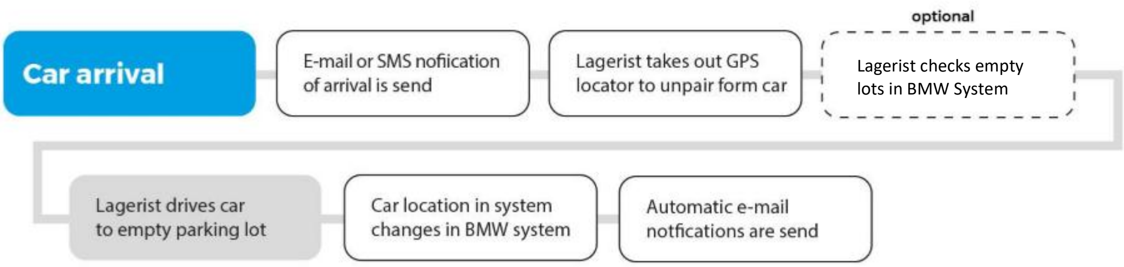


Figure 4.14: Car arrival process overview by using BLE technology (Comarch, 2020)

BLE technology can also provide a more sophisticated solution providing additional features to enable smart-car-like functionalities including:

- car battery power level sensor;
- car battery low-level alerts;
- engine start and stop events;
- car movement alerts;
- temperature measurements.

4.5. BLE implementation in BMW Group Classic as a Study Case

To find out the best suitable proposition different companies were considered: Zebra, Infsoft, Comarch, Estimote, LinTech GmbH. Various offers were proposed, discussed and analyzed. Below (Table 4.4) is represented as one of the Offers with a detailed description of hardware and software elements needed for system implementation in the warehouse.

Focus area: 5 levels of warehouse.

Table 4.4

Hardware and software elements for the implementation of BLE technology in the warehouse

	Description	Unit price	Number of items	Total price
	Hardware | one-time costs			
1	**Locator node** Requires power supply and internet connection; Detection of BLE beacons	130 €	10	1300 €
2	**Mounting bracket for locator node** Wall / ceiling bracket for Locator Node Magnet holder	18 €	10	180 €
3	**Locator Beacon** Dimensions: 72mm x 72mm x 18mm; 4x AA battery (replaceable); BLE broadcast for indoor navigation	20 €	390	7.800 €
4	**Mounting bracket for Locator Beacon** Wall / ceiling mount for Locator Beacon; Magnet holder including hole	8,20 €	390	3.198 €
5	**BLE Beacon E7 Plus** including motion sensors Dimensions: 39mm x 15.5mm (disk) Weight: 21g Temperature range: -20 ° C to + 60 °C Battery (replaceable) 	9 €	1000	9.000 €

Continuation of Table 4.4

	Description	Unit price	Number of items	Total price
6	**BLE Beacon with GPS** Incl. Man-down, button interaction and SIM card slot (separate SIM card required) Dimensions: 44mm x 43mm x 20mm Weight: 40g Temperature range: -25 ° C to + 55 ° C Battery (rechargeable)	49 €	20	980 €
Software and licenses | annual costs				
7	**Tracking per year** (max 200 receivers, max 1,000 transmitters simultaneously) - Tracking based on Locator hardware - Search function using different criteria - Filter groups – Real time view (including map) of current positions - History of individual positions	11.700 €	1	11.700 €
8	**Automation per year** (max 50 scripts, max 1,000 transmitters simultaneously) - Location-based alerts - Emails - Access to third-party systems via web services	3.000 €	1	3.000 €
9	**Interface inventory management per year** -Operation, maintenance and hosting	2.250 €	1	2.250 €
Services | one-time payments				
10	**Flat rate deliveries** Postage, packaging, customs clearance, insurance	1.200 €	1	1.200 €
11	**Project management** Setup subscription in the platform Hardware configuration & management System introduction and training with the customer Remote installation support general project management	840	40	33.600 €
12	**Digitalization** Digitization of the building plans	750 €	1	750 €
13	**Customizing scripts** Adaptation of the tool scripts based on an approved catalog of requirements	840 €	7	5.880 €
14	**Goods management interface** Implementation of a bidirectional interface with average complexity.	9.000 €	1	9.000 €
Support level | annual costs				
15	**Standard support level per year**	0 €	1	0 €
Total one-time payments:			**72.858 €**	
Total annual costs:			**16.950 €**	

There exist some restrictions:

— Average accuracy of approx. 5m in open spaces. Accuracy depends on the reflection and shielding characteristics of the environment.

— Transmission interval of the active component of ½ second in the event of movement.

— Tags send their signal in an average radius of 8m. The range depends on the reflective and shielding properties of the environment.

— Each tag signal must be received at least by the Locator Node or Locator Beacon to enable an assignment to the nearest Locator component based on the signal strength.

— If the tag signal is received by 3 locators at the same time, it is possible to determine the exact position, taking the specified accuracy into account.

— Locator Beacons send the received data every 2 minutes to the nearest Locator Node. There is no intermediate storage for detections during the transmission intervals.

— The Locator Nodes and Locator Beacons require a wall or ceiling mounting in max. 6m high.

— The installation of the Locator Node and Locator Beacon hardware at the specified installation points as well as the asset tags is carried out by the customer.

The detailed implementation of the BLE technology in the warehouse of BMW Group Classic is represented in Appendix A. The second floor was taken as an example.

Payback period (PBP) analysis

With capital investments, an important role plays the period of time, for which the savings or additional profit received from the modernization will become equal to the amount spent on this modernization. The payback period is a period of time after which the income from the project becomes equal to the amount of money invested. When investing in new technology, the coefficient of the payback period will show how long it will take to return the invested capital.

This type of analysis allows the company to analyze opportunities and find out if a project returns its investment in the shortest period of time. The payback period is expressed in years.

Every year personal costs grow by 2%. By the implementation of the BLE system, the first-year total one-payment costs are paid over, every next year only total annual costs have to be covered.

Note: the implementation of the BLE identification system will not lead to full automation in the warehouse. The BMW employee will still perform vehicle replacement and movement. Nevertheless, the system will help to save 35 minutes/ vehicle.

Table 4.5

Payback period: comparison of the current situation and implementation of BLE technology

Year	Current situation (2% wage increase every year)	Accrued costs for current situation	Implementation of BLE system (2% wage increase every year)	Accrued costs by implementation of BLE system
2020	35.211 €	35.211 €	103.108 €	103.108 €
2021	35.915 €	71.126 €	47.805 €	150.913 €
2022	36.633 €	107.759 €	48.422 €	199.335 €
2023	37.366 €	145.125 €	49.052 €	248.387 €
2024	38.113 €	183.239 €	49.694 €	298.080 €
2025	38.876 €	222.114 €	50.348 €	348.429 €
2026	39.653 €	261.767 €	51.016 €	399.445 €

Result: The project does not have positive outcomes during the next 5 years compared to the current situation and it is not feasible to cover all the investments even within the next 10-20 years.

Conclusion:

With the small vehicle turnover (around 1500 vehicles per year), there is no possibility to cover all the investments in the next 100 years. Additionally, every 5 years a new software update has to be applied and the system details could be improved. As a result, it could also raise investment costs.

In contrast, there exist qualitative aspects such as revision security, improvement of innovation technologies, industry growth trends, transparency in logistic processes, the reputation of the company and change in a company's management. All these aspects will be a competitive advantage for BMW Group Classic.

The main question appears: Which changes should be done to decrease the payback period up to one year?

The answer is: The vehicle turnover/year has to rise dramatically to meet the expectations.

Knowing the break-even point is important in preparing a business plan. It calculates the point where there is no profit or loss.

Determination of the break-even point is shown in the formula below:

$$\textit{Break-even point} = \frac{\textit{Fixed costs}}{\textit{Price} - \textit{Variable costs}}$$

The formula for the calculation of the number of vehicle turnover/year looks like this:

Break-even point in vehicle unit =

$$\frac{72.858\ €+Vehicle\ number\ X*55\ min*22\ €}{Vehicle\ number\ X*1\ hour*22\ €+X*5\%\ of\ wrong\ placed\ vehicles*32{,}9\ €}=\frac{72.858\ €+X*0{,}92\ hour*22€}{1\ hour*22\ €+X*0{,}05*32{,}9\ €}$$

*23, 645 * X = 72.858 + 20,24 * X*

*3,405 * X = 72.858*

X = 21.397 (Vehicle units/year)

The result shows that both scenario 1 and scenario 2 will cost the same amount when 21.937 vehicle unit dispatches and arrivals are done in the warehouse.

Figure 4.15 represents how the vehicle units', turnover/year has to rise to meet the expectations.

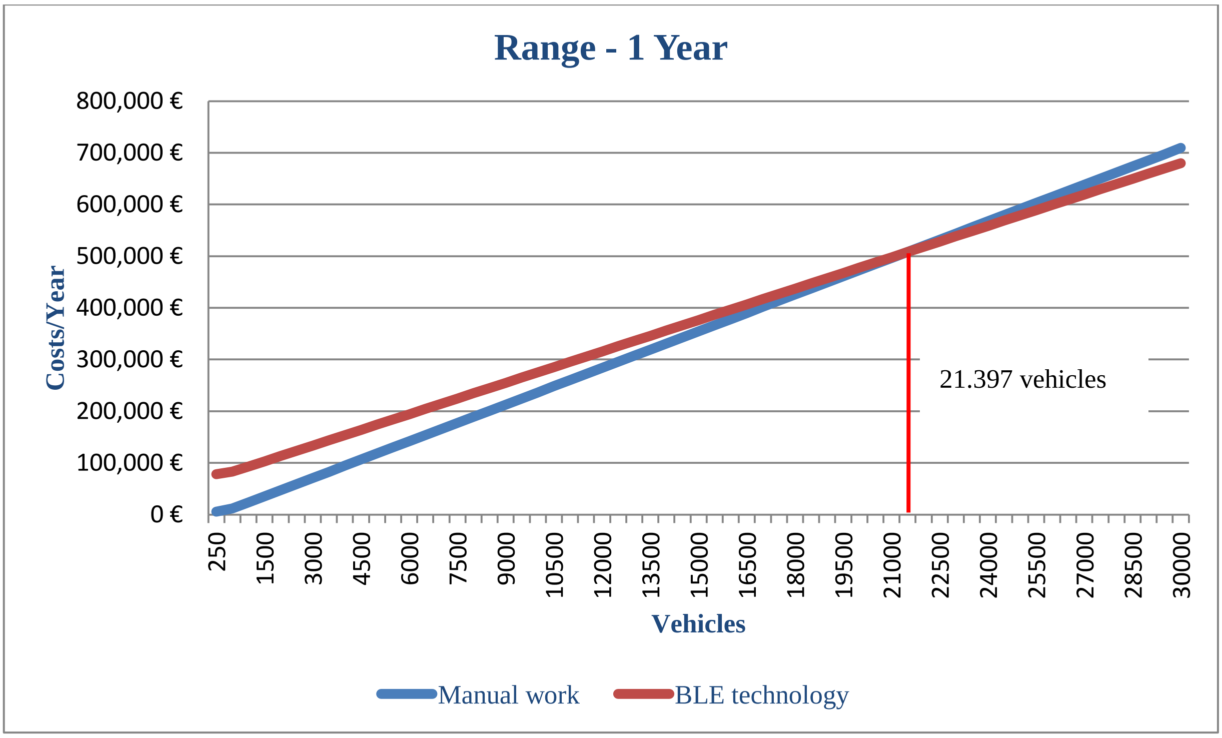


Figure 4.15: Break-even point

Result: The analysis of 2 scenarios represents the break-even point (21.937 vehicles/ year), which means that with this exact amount of units' turnover the investments for both cases are equal. Consequently, with the turnover of > 21.937 vehicles, all the investments will be covered in one year and the implementation of BLE technology will show the efficiency of the number of vehicle units moved in the next years.

Further calculations are done for the upcoming 5 years, to define the break-even point and to reduce the turnover of units' dispatch and arrival during the next years and to decline the payback period up to five years.

The results are represented in Fig. 4.16, 4.17, 4.18 and 4.19 below.

— Range – 2 years:

The formula for the calculation of the number of vehicle turnover during the next 2 years looks like:

Break-even point in vehicle unit =

$$\frac{(72.858\,€ + Vehicle\ number\ X * 55\ min * 22\,€) * 1\ year + (16.950 + Vehicle\ number\ X * 55\ min * 22) * 1\ year}{(Vehicle\ number\ X * 1\ hour * 22\,€ + X * 5\%\ of\ wrong\ placed\ vehicles * 32{,}9\,€) * 2\ years} =$$

$$\frac{(72.858\,€ + X * 0{,}92\ hour * 22€) * 1 + (16.950 + X * 0{,}92 * 22) * 1}{(X * 1\ hour * 22\,€ + X * 0{,}05 * 32{,}9\,€) * 2}$$

47,29 X = 89.808 + 40,48 * X*

*6,81 * X = 89.808*

X = 13.188 (Vehicle units during 2 years)

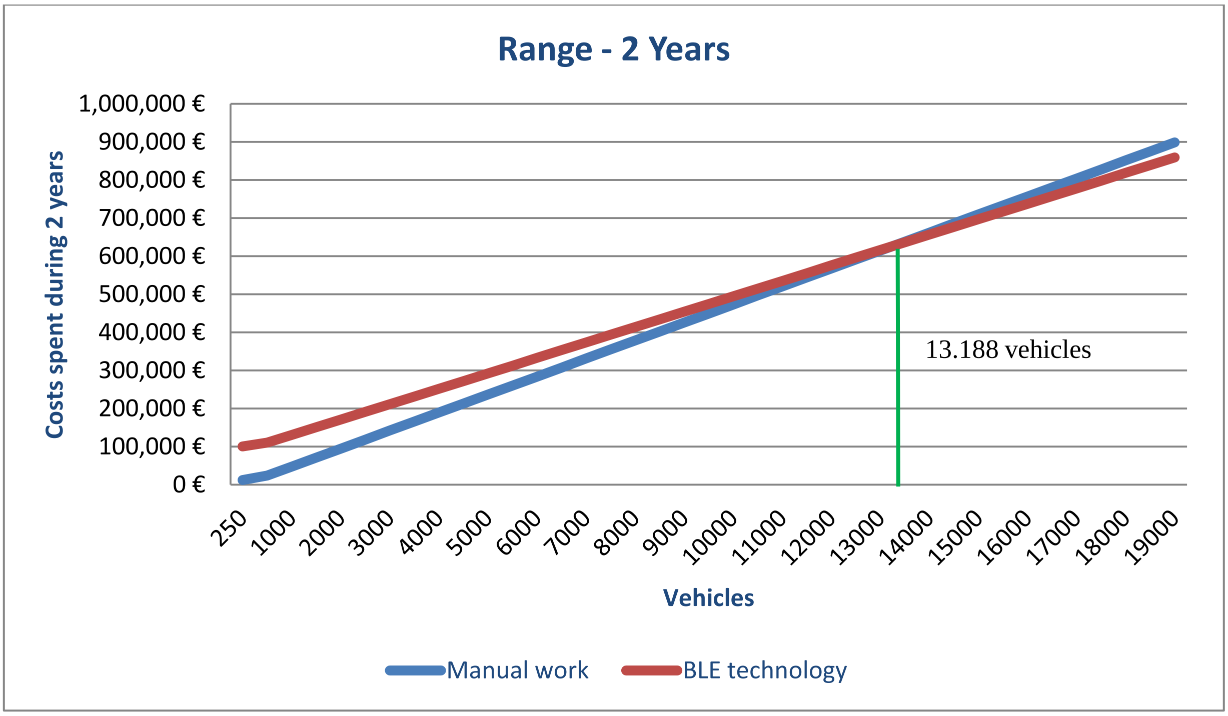


Figure 4.16: Break-even point (range - 2 years)

— Range – 3 years:

The formula for the calculation of the number of vehicle turnover during the next 3 years is:

Break-even point in vehicle unit =

$$\frac{(72.858\ €+Vehicle\ number\ X*55\ min*22\ €)*1\ year+(16.950+Vehicle\ number\ X*55\ min*22)*2\ years}{(Vehicle\ number\ X*1\ hour*22\ €+X*5\%\ of\ wrong\ placed\ vehicles*32{,}9\ €)*3\ years}=$$

$$\frac{(72.858\ €+X*0{,}92\ hour*22€)+(16.950+X*0{,}92*22)*2}{(X*1\ hour*22\ €+X*0{,}05*32{,}9\ €)*3}$$

70,935 X = 106.758 + 60,72 * X*

*10,215 * X = 106.758*

X = 10.451 (Vehicle units during 3 years)

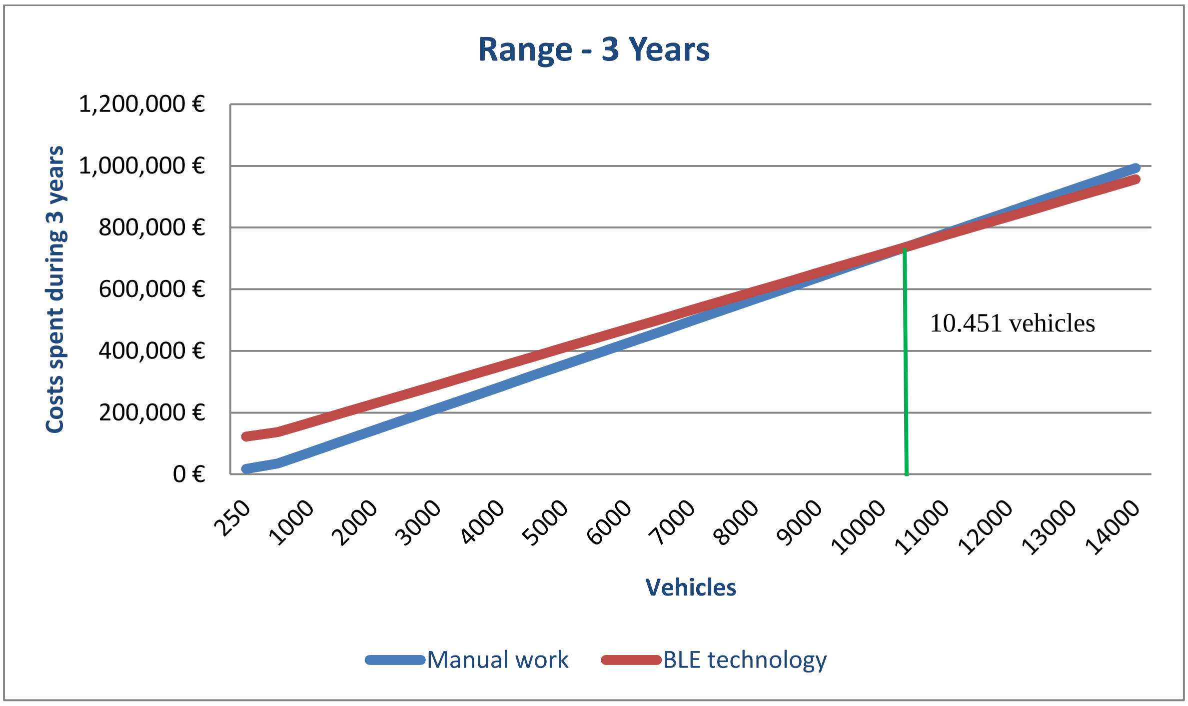


Figure 4.17: Break-even point (range - 3 years)

— <u>Range – 4 years:</u>

The formula for the calculation of the number of vehicle turnover during the next 4 years looks like this:

Break-even point in vehicle unit =

$$\frac{(72.858\ €+Vehicle\ number\ X*55\ min*22\ €)*1\ year+(16.950+Vehicle\ number\ X*55\ min*22)*3\ years}{(Vehicle\ number\ X*1\ hour*22\ €+X*5\%\ of\ wrong\ placed\ vehicles*32{,}9\ €)*4\ years}=$$

$$\frac{(72.858\ €+X*0{,}92\ hour*22€)+(16.950+X*0{,}92*22)*3}{(X*1\ hour*22\ €+X*0{,}05*32{,}9\ €)*4}$$

94,58 X = 123.708 + 80,96 * X*

*13,62 * X = 123.708*

X = 9.083 (Vehicle units during 4 years)

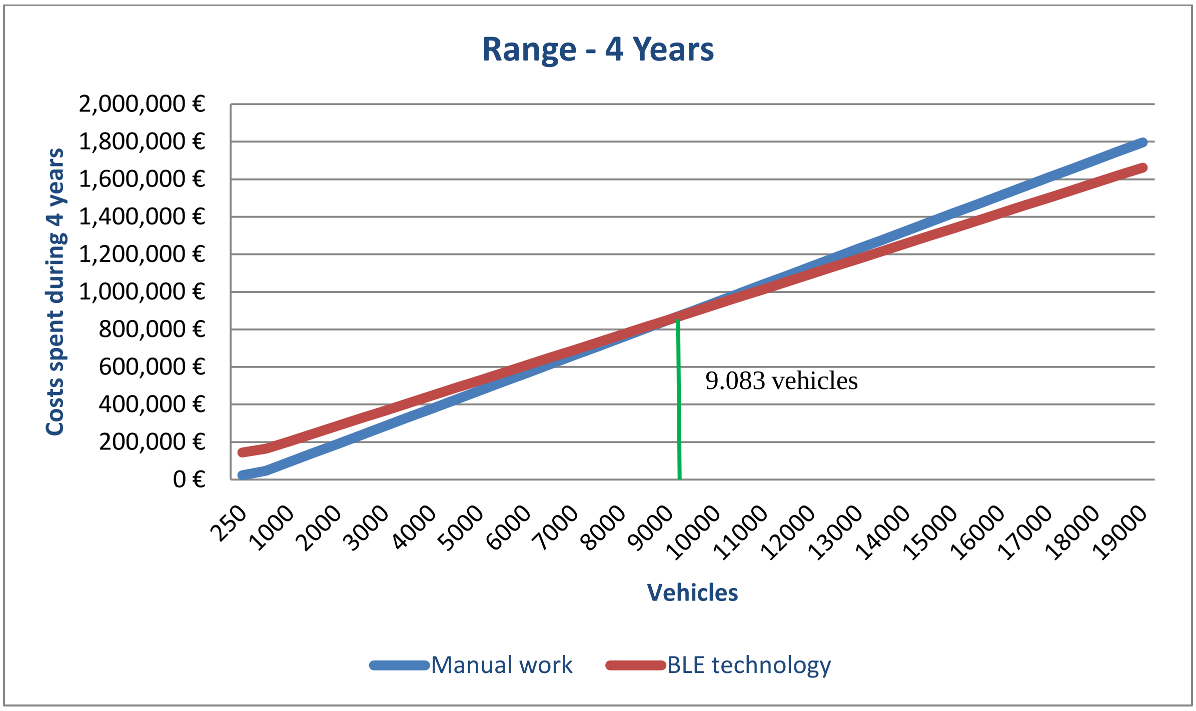


Figure 4.18: Break-even point (range - 4 years)

— <u>Range – 5 years:</u>

The formula for the calculation of the number of vehicle turnover during the next 5 years is:

Break-even point in vehicle unit =

$$\frac{(72.858\ € + Vehicle\ number\ X * 55\ min * 22\ €) * 1\ year + (16.950 + Vehicle\ number\ X * 55\ min * 22) * 4\ years}{(Vehicle\ number\ X * 1\ hour * 22\ € + X * 5\%\ of\ wrong\ placed\ vehicles * 32{,}9\ €) * 5\ years} =$$

$$\frac{(72.858\ € + X * 0{,}92\ hour * 22€) + (16.950 + X * 0{,}92 * 22) * 4}{(X * 1\ hour * 22\ € + X * 0{,}05 * 32{,}9\ €) * 5}$$

118,225 X = 140.658 + 101,2 * X*

*17,025 * X = 140.658*

X = 8.262 (Vehicle units during 5 years)

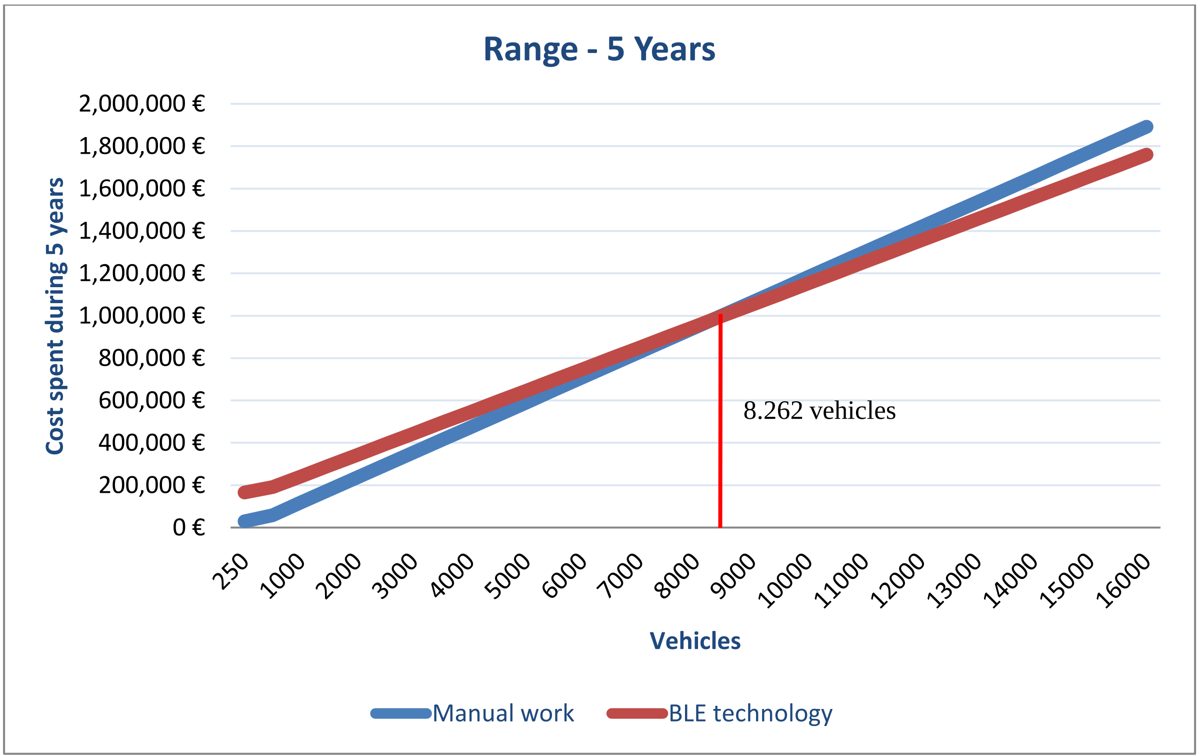


Figure 4.19: Break-even point (range - 5 years)

Result: After the analysis of 2 scenarios during the next 2 - 5 years, the break-even point for each case was defined. Fig. 4.19 shows a decline in the turnover of units' dispatch and arrival up to 8.262 vehicles during the period of 5 years, which could be a good alternative (see Fig. 4.15) to increase the payback period up to five years to meet all the expectations.

As a result, by the implementation of BLE technology, all the investments will be covered after 5 years and a combination of the new technology with employees' involvement will have more benefits compared to the current situation and will meet all the quantitative and qualitative aspects.

Conclusion

Implementation of the BLE technology in the BMW Group Classic warehouse during the current situation will not be cost-effective. Due to the high investment, the payback period will last a long period of time. Despite quantitative aspects, the implementation of the identification system for classic vehicles will bring positive force affecting work in the warehouse and the company itself. Improvement in logistic processes that decrease human errors, saving time, the combination of the innovative technology with the old manual system will be the core element for the decision implementation.

Chapter 5

5. Conclusion

This chapter summarizes the conclusions obtained based on the review work and the implementation of the selected technology along with recommendations for future work.

Summary

The development of Intelligent Transportation Systems has led to innovations in indoor navigation and outdoor positioning technologies. These technologies give rise to different parking facilities based on the new functions they provide. The implementation provides parking slot or warehouse with new services: automation of check-in/check-out, the identification of entering and leaving vehicles in a garage and vehicle parking location memorization, the information related to the availability of unoccupied parking place, the possibility to reserve a parking lot in advance, electrical collection of fee charges for parking, effective security for the safety of vehicles. The goal of such technologies is the improvement of the traffic capacity, reduction of the burden on the employee and driver, provision of reliable, lost vehicle detection, vehicle robbery tracking, and security functions in the garage. The system integrated with RFID, ANPR, UWB, BLE, or GPS contributes to the accurate vehicle position under complex environments.

In this study, the feasibility of using RFID and BLE in the garage is discussed. The results show that both RFID and BLE systems are efficient, accurate, can function properly, and are not dependent on any weather conditions. However, an RFID system is used for vehicle identification and has several limitations regarding materials, reliability, cost, implementation, and readability. As the main focus is to provide indoor identification and outdoor tracking, BLE technology is the best alternative that combines both criteria in one system. BLE devices have the advantages of being portable, widely available, less energy-intensive, and easier to deploy than other methods.

The design of BLE technology for warehouse management systems was proposed in an industrial case. The implementation method was combined with the current enterprise working process. In the analysis of the case study, the proposed system had shown the accurate parking location service in parking lots and the ability to track vehicles in outside environments. BLE supported lower implementation cost, compared to the RFID method. Realization of this method could help the employees to work more effectively and efficiently in the following aspects:

identification of the vehicle location, better operation management, time reduction in finding the position of the vehicles which not being used for a long period, statistics provision for future operation. Beacons provide system control capabilities, ensuring real-time availability.

Based on the results of the study case, BLE technology should be implemented in areas with active vehicle turnover. In cases with small quantitative aspects, an important influence will play qualitative aspects such as improvement of innovation technologies, revision security, industry growth trends, transparency in logistic processes, the reputation of the company, and change in a company's management. All these aspects will be a competitive benefit for the realization of the technology.

Recommendations

Since no technology is 100% reliable, applications requiring the highest possible accuracy should consider implementing a redundant technology. The simultaneous use of two identification technologies can help reduce the risk of error if one of the measurement methods fails.

From the above analysis, it is found that the vehicle tracking system not only facilitates the operations of the warehouse but outside the area as well. In this way, the proposed method is robust and the BLE technology is worth implement. However, more experiments on different BLE equipment have to be done in order to sort out the best one, define the perfect amount for precise detection and future research will be directed towards the high stability and reliability in the future. The method still needs further research, such as how to improve the implementation for low vehicle turnover in the parking lot.

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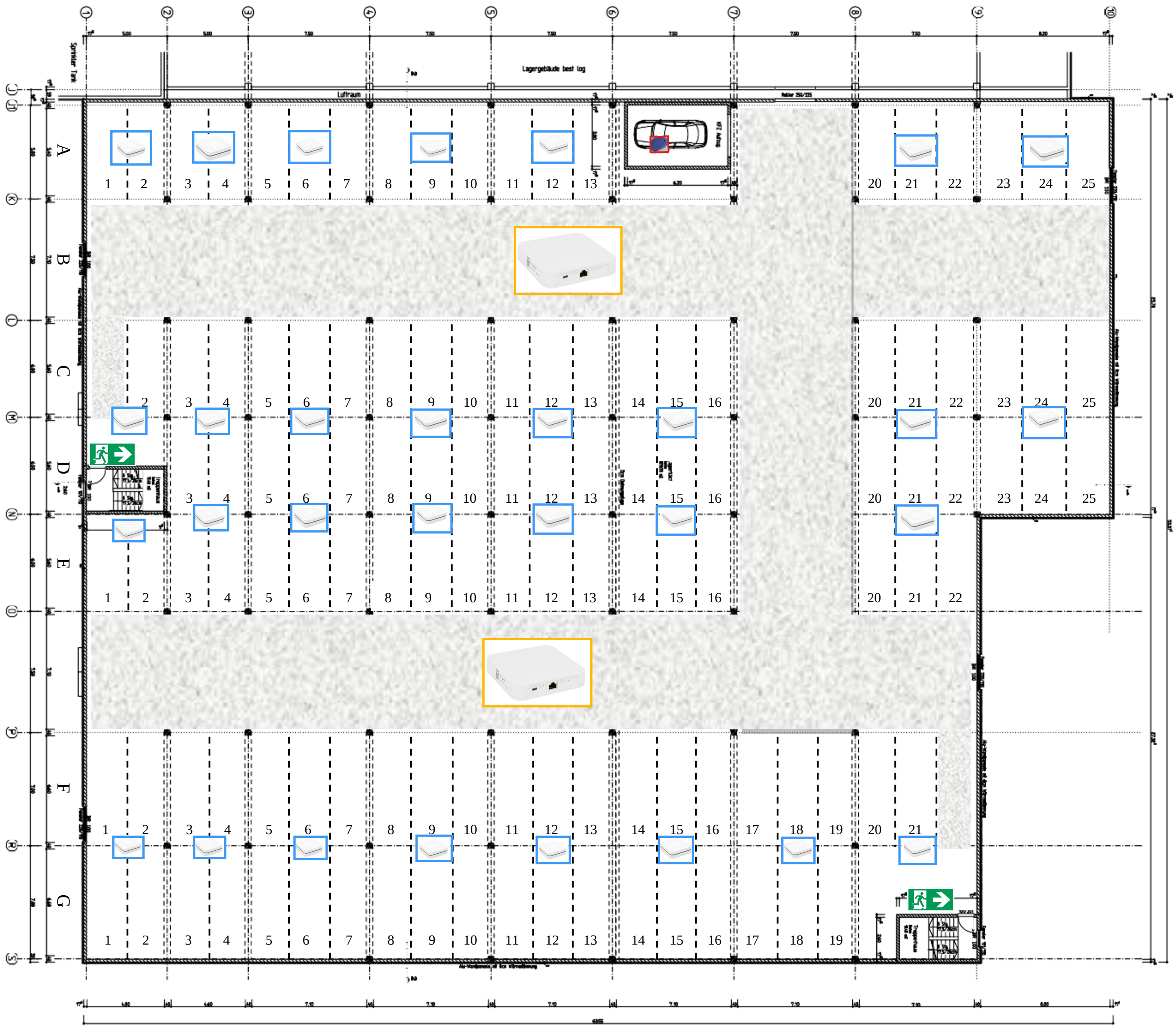
Appendix A: Detailed implementation of the BLE technology in the warehouse of BMW Group Classic



Components of new BLE technology:

- BLE Locator Node
- BLE beacon
- BLE Locator beacon