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5th EAI International Conference on Management of Manufacturing Systems

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Preface

We are delighted to introduce this publication, which is results of fruitful cooperation between the European Alliance for Innovation, Faculty of Manufacturing Technologies with a seat in Prešov of Technical University of Košice and The Department of Information and Communication Traffic, Faculty of Transport and Traffic Sciences, University of Zagreb.

Our ambition is to establish channels of communication and disseminate knowledge among professionals working in manufacturing and related institutions. Therefore, we cordially invite experts, researchers, academicians and practitioners in relevant fields to share their expertise from the field of management of manufacturing systems at the Conference. This publication aims to provide the most comprehensive and useful exchange of information on current developments in the management of manufacturing systems and Industry 4.0. Manufacturing systems tend to be developed mostly based on lean or agile approaches to reach a high level of competitiveness in the global environment.

This publication encompasses a total of 38 selected research contributions by 143 worldwide authors.

In light of the latest knowledge and findings from scientific projects, the authors present actual R&D trends in the given field. This issue not only defines state of the art in the area, but it additionally explores related topics for future research.

Our ambition was to establish channels of communication and disseminate knowledge among professionals working in manufacturing and related institutions.

This publication is a collection of invited experts, researchers, academicians and practitioners in relevant fields, to share their knowledge from the field of management and manufacturing systems.

Big thanks to our all authors and co-authors and reviewers for their significant contributions during a specific worldwide pandemic COVID-19 situation. We appreciate your work much.

Stay safe and healthy!

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Contents

Chapter 1
Review of Automatic Passenger Counting Systems in Public Urban Transport

Ivan Grgurević, Karlo Juršić, and Vinko Rajič

1.1 Introduction

The assessment of the number of passengers in public urban transport (PUT) is of crucial importance for the organization of public transport in urban environments, which is of special assistance in planning and managing the transport services. Currently, there are diverse implementations of technologies and methods for the counting of persons/people, with the aim of collecting data for the optimization of operation. The counting of persons, that is, passengers as a method of optimizing the provision of transport services in PPT is infallible as part of the passenger transport logistics. The passenger transport logistics is focused on creating the transport demand in accordance with the requirements and needs of the PPT users. Therefore, it is important for the information to be accurate and timely since PPT should be the primary transport mode in urban environments because it has numerous advantages such as economy, ecological acceptability, reduction in the number of road vehicles, realizing a reduction in traffic congestion, and so on. Special attention while planning the transport services is added to PPT services and urban planning also has to be taken into consideration. For efficient planning as well as the realization of the service, accurate, precise and reliable as well as timely information must be provided, which includes the service area—wider urban area (which does not always coincide with the city limits), population density [inhabitants/km^2]—ratio of the number of inhabitants to the number of km^2 and the population—number of inhabitants in the area of PPT service [1].

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Passenger counting determines the flow in the vehicles (buses, trams, etc.) according to single PPT lines, and it is carried out on several predefined points along each line and the busiest lines have to be taken into special consideration. The basic form of passenger counting is performed by observers at defined locations or it is carried out based on the methods that depend on the number of tickets sold. Neither of the two methods can give accurate data due to the traffic dynamics as well as the large number of passengers since they depend on the factors such as the fatigue of the observer, their expertise and experience, engagement, weather conditions, part of the day, and so on. Errors occur, thus, for various reasons and vary from observer to observer. In order to maximally reduce the human factor, automatic passenger counting systems are increasingly used [2].

Automatic passenger counting (APC) systems are increasingly used in order to avoid the human influence on the results, reducing thus the error to a minimum and eliminating the variations in the results. This paper studies the different used methods in the APC system and presents an overview of the existing studies, their results, that is, measurements that are presented in a table for better clarity (Sect. 1.4, Table 1.1). The motive for researching this topic arose during previous research of wireless telecommunication networks on board vehicles of public urban passenger transport in the city of Zagreb [3]. The problem of determining the number of passengers in tram traffic at all levels (daily, weekly, monthly, and yearly) was observed, and one of the ways that was then considered was counting of passengers via a wireless telecommunication network (Wi-Fi based systems). In addition to the above, the paper analyses various independent and integrated automatic passenger counting systems.

1.2 Automatic Passenger Counting Systems

As already mentioned, proper planning is needed when developing and optimizing the PPT resource allocation strategy. Also, as with any other strategy, it is necessary to set rational goals defined by S.M.A.R.T. (Specific, Measurable, Attainable, Relevant and Time-Bound) methodology. For these goals to be achieved, one of the items that must be implemented is the passenger counting. The automatic passenger counting systems provide numerous advantages in relation to manual passenger counting and are a desirable substitution when passenger counting is done on board PPT vehicles. Figure 1.1 shows a flowchart of a simplified presentation of the automatic passenger counting (APC) operation.

Automatic Passenger Counting (APC), although a relative novelty on the market, is available for sale and use in the form of various designs that will be explained in more detail in the paper. APC thus helps in route planning and in the optimization of resources and represents a backbone for the integration into the modern Smart City concept. The main advantages offered by the APC systems include:

- elimination of human error factors when counting passengers

Table 1.1 Overview of studies related to the designs and methods of automatic passenger counting

Paper title	Authors	Used technology	Design and methods	Transport means (vehicle)	Accuracy
Novel vehicle mass-based automated passenger counter for transit applications; Minnesota; 2015 [10]	Kotz, A.J., Kittelson, D.B., Northrop, W.F.	IR sensors and on-board cameras with measuring pressure inside the vehicle suspension system	Measurement was carried out using IR sensors and the existing cameras on board vehicles in combination with the already installed sensors on suspensions. The data about the pressure from the vehicle suspension are gathered in order to calculate the additional vehicle mass, thus assuming the number of passengers.	Bus	Just IR and cameras 82.50%
					Just pressure 71.70%
					Combination 97.62%
1-6 An echo state network-based pedestrian counting system using wireless sensor networks; Sankt Augustin; 2008 [11]	Mathews, E., Poign, A.	IR sensors	It is designed and implemented in the form of hardware and software components that apply novel machine learning techniques. It is used for learning motion patterns and claims to excel other counters in price (except simple ones using beam breaking principles).	–	80.4%
Concept validation of an automatic passenger counting system for trams; Budapest; 2009 [13]	Kovács, R., Nádai, L., Horváth, G.	Measuring pressure inside the vehicle suspension system	The estimate of the passenger number according to the mass in trams with a large number of passengers and uncoordinated entry/exit from the tram. The mass of a single passenger is taken as an average value per gender (in kilograms). The concept is that the total mass of the vehicle is calculated via dynamic ride, haul and vehicle energy data. This makes it possible to calculate the passenger mass and to accurately estimate their number.	Tram	–

(continued)

Table 1.1 (continued)

Paper title	Authors	Used technology	Design and methods	Transport means (vehicle)	Accuracy
Estimating passenger numbers in trains using existing weighing capabilities; Copenhagen; 2014 [14]	Nielsena, B.F., Frølicha, L., Nielsenb, O.A., Filgesc, D.	Measuring pressure inside the vehicle breaks system	Passenger counting by means of the already existing system of measuring pressure in the railway vehicles' braking system. The method compares the obtained results with the results of manual counting and IR system.	Train	–
Research on counting method of bus passenger flow based on kinematics of the human body and SVM; Tianjin; 2018 [15]	Zhu, F., Gu, J., Yang, R., Zhao, Z.	Kinematics of the human body and support vector machine (SVM)	The system analyses continuous kinematic characteristics at the entry of passengers into the vehicle in the form of pressure between the floor and the foot and processes them using SVC (*Support-Vector Machines*).	Bus	93.98%
Clustering method for counting passengers getting in a bus with a single camera; Xi'an; 2010 [16]	Yang, T., Zhang, Y., Shao, D., Li, Y.	RGB video where RGB colour model is an additive colour model in which red, green blue lights are used together to reproduce a broad array of colours	One camera by using KLT (*Kanade-Lucas-Tomasi*) monitoring mode.	Bus	96.5%
Real-time passenger counting in buses using dense stereovision; Paris; 2013 [17]	Yahiaoui, T., Khoudour, L., Meurie, C.	"*Stereo vision*"	Counting of persons passing beneath the camera where the first image creates a block for calculating the disproportion, then the segmentation block identifies the height of the person's head via round shapes with the constant height value. The paper uses modules that reconstruct the head trajectories by means of stereo pairs.	Bus	97%

iABACUS: a Wi-Fi-based automatic bus passenger counting system; Cagliari; 2020 [21]	Nitti, M., Pinna, F., Pintor, L., Pilloni, V., Barabino, B.	Passenger tracking via Wi-Fi	Observation and analysis of mobility in the urban environment following passengers during their travel in PPT, not needing any intervention apart from Wi-Fi on board vehicle (bus).	Bus	94%
Robust people counting system based on sensor fusion; Seoul; 2012 [23]	Dan, B.-K., Kim, Y.-S., Suryanto, J.-Y.J., Ko, S.-J.	"*Video-plus-depth*"	First, the image of the depth is processed via a morphological operator for the elimination of the optical noise. Then human objects are drawn out using the already processed image. Finally, the trajectory of the detected object is determined by the application of the two-way overlapping algorithm.	–	90.57%
Automatic passenger counting system for bus based on RGB-D video; Beijing; 2016 [24]	Li, F., Yang, F.-W., Liang, H.-W., Yang, W.-M.	RGB-depth video	Combination of RGB and the depth of the image in order to determine the size of the passenger's head.	Bus	95.4%
Automatic passenger counting system using image processing based on skin colour detection approach; Padang Besar; 2018 [25]	Nasir, A.S.A., Gharib, N.K.A., Jaafar, H.	RGB video	RGB in hue, saturation, value (HSV) coloured image, segmentation by means of threshold method, and elimination of noise and/or unwanted items for passenger counting.	Bus	90.64%
Measuring bus passenger load by monitoring Wi-Fi transmissions from mobile devices; Warsaw; 2014 [26]	Oransirikul, T., Nishide, R., Piumarta, I., Takada, H.	Passenger tracking via Wi-Fi	The system collects periodically "*probe*" requests and data about mobile devices that are located in the AP environment. According to the performed survey, Wi-Fi activity is in correlation with the number of waiting passengers, as well as the number of riding passengers.	Bus	–

(continued)

Table 1.1 (continued)

Paper title	Authors	Used technology	Design and methods	Transport means (vehicle)	Accuracy
Counting public transport passenger using Wi-Fi signatures of mobile devices; Trondheim; 2017 [27]	Myrvoll, T.A., Håkegård, J.E., Matsui, T., Septier, F.	Passenger tracking via Wi-Fi	It is based on discovering Wi-Fi signatures in 2.4 GHz spectrum by collecting "*probe*" requests broadcast for all APs within the area. According to the survey, Wi-Fi activity is in correlation with the results of manual passenger counting.	Bus	–
People counting by means of Wi-Fi; Prague; 2017 [28]	Kalikova, J., Krcal, J.	Passenger tracking via Wi-Fi	An approach to the detection of mobile devices by recording the version of the operating system and producer with other important information about the device (MAC, RSSI, etc.). The device should be detected immediately upon entry into the observed area.	–	73% (for 180 s)
Occupancy estimation using Wi-Fi: a case study for counting passengers on buses; Melbourne; 2019 [29]	Mehmood, U., Moser, I., Jayaraman, P.P., Banerjee, A.	Passenger tracking via Wi-Fi	Wi-Fi system for assuming the occupancy of PPT vehicles which is proposed by the algorithm for the estimation of occupancy with the aim of reducing overestimation in the estimates (based on Wi-Fi).	Bus	67%
Mobile device detection through Wi-Fi probe request analysis; Rio de Janeiro; 2019 [30]	Oliveira, L., Schneider, D., De Souza, J., Shen, W.	Passenger tracking via Wi-Fi	The proposition is to use a technique for estimating the number of mobile devices through analysis of Wi-Fi probe requests. The goal is a solution that is immune to media access control (MAC) address randomization strategies by using information propagated in the environment, without the need to know the real MAC addresses of the devices.	–	Sherlock method 0.087
					Linear regression method 0.383
					Support vector regression method 0.0298; where results value are expressed in mean relative error form.

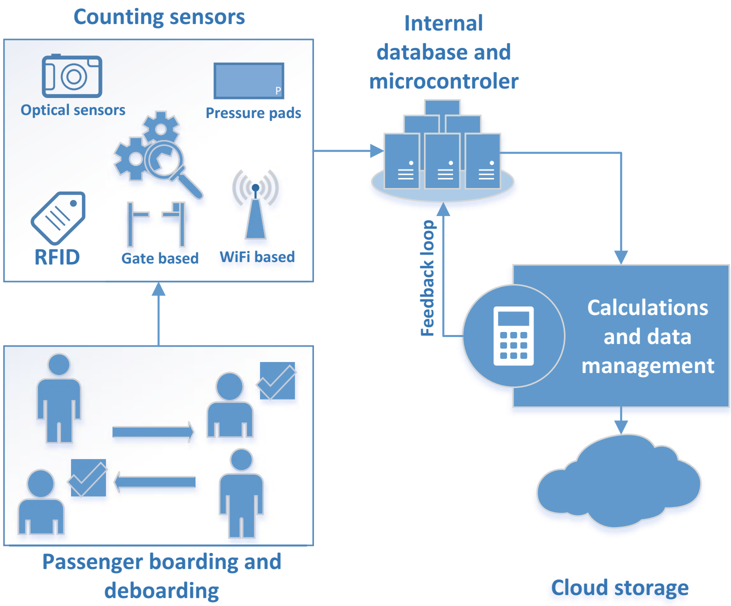

Fig. 1.1 Flowchart of simplified general presentation of APC operation

- fast and up-to-date data collection and processing
- constant accuracy and reliability of results compared to manual counting where the accuracy/reliability varies
- allows work in all weather conditions
- possibility of consecutive counting for several days in a row on the same line and
- gathering information and making conclusions for the optimization of PPT [4].

In spite of numerous advantages offered by the automatic passenger counting systems, there are also many drawbacks that can make it impossible or difficult to use:

- a large initial investment is required when integrating the APC system into the PPT vehicles
- accuracy is not 100%—it often happens that the number of boardings and deboardings of passengers does not match and
- APC systems cannot identify the emergencies [4].

There is no universal APC solution, and for passenger counting on board PPT vehicles, it is necessary to select an appropriate technology and methodology taking into consideration the possibilities and paying attention to the possibilities and limitations of (traffic) infrastructure. Figure 1.2 shows the distribution of APC systems.

The presented breakdown of the APC system (Fig. 1.2) can be divided in the first step into integrated systems, where there is direct interaction with passengers

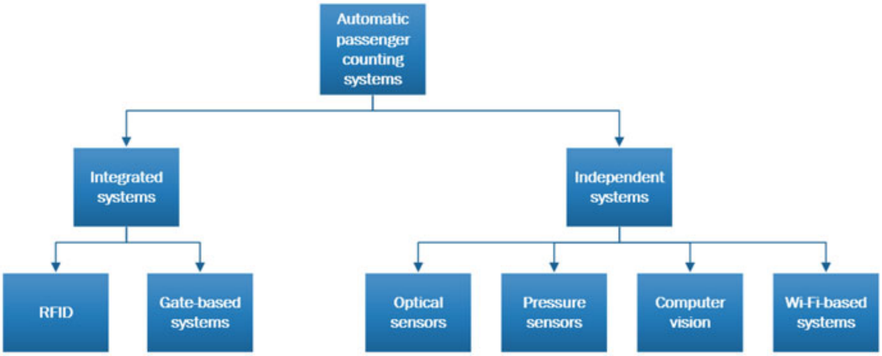

Fig. 1.2 APC system breakdown

and independent systems or independent passenger counting, where there is no direct interaction with passengers. Before introducing the mentioned systems, one should make an analysis of the possibility of implementation as part of the existing infrastructure and technology with the aim of reducing the costs. Therefore, it is necessary to make an overview of the technologies that can be integrated into the already existing system of PPT vehicles' validation. Therefore, in the system for integrated passenger counting the system of verifying the passenger tickets or some other types of identifiers are used in order to determine the number of passengers who accessed the traffic infrastructure or the PPT vehicles. The advantage of RFID in relation to other technologies is that it does not have any mobile parts and it is easily maintainable. RFID device uses radio signals that are sent to the transponder—RFID tag, which gives feedback in the form of identification code and/or a series of data that are stored in the transponder memory [5–7].

In the papers [5–8], the authors use RFID technology as the base for the validation system. Regular tickets are substituted by smart cards that contain data about the user of a certain PPT service. Smart cards contain data about the passengers and based on these data one can follow the movement of single passengers, as well as a group of passengers according to different demographic data (gender, age, education, profession, material status, etc.). Demographic data are often used as the basis for the segmentation of the market and/or users. After studying various demographic factors, the demographic profiles of users can be created, on the basis of which attractive transport alternatives for single groups of users can be determined. The system of smart cards functions so that after boarding the vehicle, the passenger registers and based on the number of passenger registrations the number of passengers on board the vehicle is determined, as well as the number of free places. The research described in the paper [9] has been carried out in controlled conditions (experiment); 40 volunteers carried RFID tags in backpacks, banknotes, pockets, and so on, through the vehicle door model with four antennas installed. Volunteers passed through the model in pairs and individually. The authors showed accuracy for various scenarios depending on where the RFID tag was located (backpack, pocket, in the hand, etc.). The average value of recognition for four scenarios amounted to 91% for single-tag cards and 82% for dual-tag cards, and single-tag cards are the size of credit cards that contain an Electronic Program Guide (EPG) Generation 2 tag whereas dual-tag cards contain MIFARE tags which are common for contactless smart cards [9].

The "Gate-based" methodology is integrated and connected with the validation system, and as a rule, it is used in subways and at airports. The advantage is the ticket validation with simultaneous passenger counting. The main advantage is accurate and reliable information about the actual number of passengers on the PPT infrastructure except in emergencies. This is because passengers have to go through a physical barrier located at the entrance and/or exit on PPT infrastructure (vehicle door, to the station, etc.) where they are validated. The main drawback is the impossibility of boarding passengers without previous validation at the planned "gate checkpoint". This greatly reduces the possibility of implementation in a more dynamic environment of the traffic system, such as bus and tram traffic. However, there are systems that practice a similar approach in public surface traffic (bus and tram), but it refers to fenced passenger stops, and this method in this environment is very inconvenient for passengers because of the waiting queues and requires large financial investments by public urban transport operator, that is, city administration.

Therefore, in the case of integrated APC in a dynamic traffic environment, it is difficult to avoid non-registering of passengers without applying a kind of "gate" technology, but this requires large financial investments, and the mentality and behaviour of passengers who are not used to it is always questionable. For this reason, the integrated APC systems in case of no "gate" are very unreliable, so there is a need to implement some of the technologies of automatic passenger counting on board vehicles, independent of passenger validation.

1.3 Independent Passenger Counting

The ticket validation systems that are integrated into the infrastructure are often not a real indicator of the condition in the traffic so that other direct methods of passenger counting are sought. Independent passenger counting is unrelated to the validation, and contains various counting technologies and methods and serves to find an adequate and unobtrusive way to monitor the number of passengers on board vehicles due to the optimization of traffic processes. In order to take into account the dynamic behaviour of the traffic system and passengers, the counting methods can be divided as shown in Fig. 1.2.

1.3.1 Optical Sensors

The most used optical sensor is infrared (IR), and it is the simplest in the context of the APC system. The main advantages are affordable price and simple implementation, and the IR sensor design requires a minimum of two sensors in order to avoid intersecting of IR beams. Two designs can be highlighted, the active and the passive one. Active IR sensors include in their design a receiver and a transmitter, where the transmitter generates the IR beam that has the purpose of detecting the passing through the cross section of the counter. The main characteristic of passive IR sensors is pyroelectricity, which understands that they are designed so as to emit one IR beam which is divided into beams. Detection occurs when a passenger passes through the beam and during implementation in the vehicle; the receiver/transmitter is installed at the entry and/or exit parallel to one another. The reason is to avoid interrupting the beam only from one side and to reduce errors. IR sensors are often used in combination with some other types in order to raise the level of accuracy as done by the authors of the paper [10].

The authors of the paper [11] tested the APC system which uses Passive Infrared Sensors (PIR) sensors, and they reported an accuracy of 80.4%, but the biggest advantage is the low costs and price of implementation. The authors of the paper [12] used the passenger counting system at airports, and the presented deviations are 3.6% for a 5-min interval when there is no passing of passengers in both directions. In papers [10, 12], IR sensors are used in combination with other types of sensors in order to increase the level of accuracy in passenger counting.

1.3.2 Pressure Sensors

Pressure sensors are often very easy to implement and use, and are divided into several different types. Two types have been singled out in this paper, and the first is the simplest and uses a pressure sensor in the form of a mat to determine the number of passengers. The mat is most often used in the PPT for the purpose of checking passengers when entering/exiting the vehicle so that the door can be closed, and to a much lesser extent for counting. It reacts every time a passenger steps on it and must be made of durable materials to be resistant to mechanical wear and vibration. Thus, it is usually metal and covered with rubber, but when installing it should be taken into account that the edge parts do not have the ability to detect and it is necessary to act accordingly in order to reduce erroneous readings. It is not optimal to use in heavy traffic jams because some of the passengers usually stay standing on the sensor. This causes erroneous readings and thus affects the final results. In such situations, it is advisable to use other technologies to reduce the possibility of error, as was done in [10].

The second type is more complex and expensive and refers to the calculation of mass in motion and can be used in two ways. The first method is integrated and does not require large investments outside the purchase and implementation of sensors. This method has various versions, and each of them brings different results as seen in papers [13–15]. The second way is the implementation in the infrastructure and requires large investments and significant interventions during the implementation. The conducted research determined that there are few papers on this topic, and the assumption is that this is precisely because of the need for large investments.

1.3.3 Computer Vision

Computer vision uses optical sensors as the main component, and according to the characteristics offered, this technology is almost equally or more accurate than some of the already mentioned technologies and does not usually require any additional investments. Computer vision has no mobile parts nor does it require any special maintenance, and the installation can be done with only one sensor. The biggest drawback of optical visual counting is the implementation of software support since the operation method is very simple. It starts by identifying the shape of the passenger and their distinction from the background and other elements in the environment. It can detect their direction of movement, and thus, whether they are entering or exiting the vehicle.

A potential problem is security, that is, from the passenger's perspective, since any visual "software" for detection in public causes fear that results from ignorance and lack of understanding. Thus, during implementation, it is necessary to pay additional attention to the psychological aspect of the passengers. The basic technical design uses one or two cameras, which can be or do not have to be stereoscopic. The cameras are usually installed above the entry and/or exit of the PPT vehicle and an integrated LED is used which enables visibility in almost all ambient light powers. The possibilities depend most on the software support and artificial intelligence which is used in a certain case. Papers [16, 17] provide descriptions of certain simpler technical designs.

1.3.4 Wi-Fi-Based Systems

APC systems that use Wi-Fi methods are based on the number of detected mobile terminal devices within the Access Point (AP) radius or based on the number of connected mobile devices to the access point. These methods can be used on board PPT vehicles if the vehicles are equipped with a wireless access point. In this way, a frame estimate of the number of passengers on board PPT vehicles can be made according to the number of active mobile terminal devices.

However, there is a problem when determining the exact number of mobile terminal devices, and the reason lies in the fact that the access point on board vehicles will detect also the devices that are outside the vehicle, and this will produce inaccurate, that is, unreliable results. One of the problems is the number of mobile terminal devices per passenger also, since there is an increasing trend in persons having 1–2 mobile devices, and this will continue, especially in the context of the development of the 5G mobile telephony, IoT artificial intelligence (AI) in the context of the Society 5.0 environment. The research in paper [18], is based on the increasing number, that is, penetration of mobile terminal devices, and refers to the young people and their need to be connected at every moment. The authors of papers [19, 20] connect the increase with the ever larger number of available smart mobile terminal devices as well as the reducing prices. The most frequent design of Wi-Fi APC systems greatly depends on whether the passengers have the Wi-Fi component on their devices switched on during the ride. Besides, there is yet another problem that affects the reliability of this method and occurs in the form of randomisation of “Media Access Control” or MAC address [21]. Wi-Fi on board vehicles in the future is inevitable, so this method will certainly be used more and more frequently despite its drawbacks.

1.4 Analysis of the Results of Existing Research

Accuracy, that is, precision of the system is frequently checked by manual counting as a preliminary counting method, but this method brings along its problems due to various factors such as the time of implementation, reliability, that is, experience of the examiner, greater possibility of error due to human factor, and so on [22]. By developing various new APC systems, their accuracy (and precision) of measurement results is increasing, that is, it is about 95% in some designs and excludes the influence of human factor in performing the passenger counting.

Conceptually, the principle of using various technologies in the function of automatic passenger counting does not differ a lot between the analysed available relevant papers presented and quoted in Table 1.1. However, the application and the used methodology are not the same due to the different needs of public urban carriers as well as the possibility of the traffic infrastructure in a certain area, and the financial power of the transport service provider. This means that there is no unique solution since different PPT service providers have different challenges that have to be approached in different ways. Therefore, for the sake of clarity, Table 1.1 shows relevant papers on the topic of automatic passenger counting, their authors, used technologies, designs and methods, types of transport means in which the measurement has been performed and the precision percentage indicated in the analysed paper.

It is obvious that in a large number of carried out research the determined measurement accuracy is greater than 90%. Of course, this is not the only important factor, but the used technology, method or design are very important information, as well as the conditions in which the measurement was carried out. A large number of papers use bus subsystem of public urban transport, that is, bus as a reference vehicle for the implementation of a certain automatic passenger counting system, and the reason is the outspread and numerous use of this type of transport means in urban environments. Light-rail—metro, has not been present to such an extent, and it often uses some kind of integrated verification methods (usually "gate-based"), whereas tram traffic is the least present in the presented analysed studies (Table 1.1), but it is possible to apply similar, if not equal, technologies and methods as with buses.

During the research process, apart from the papers mentioned in Table 1.1, a large number of other papers/studies have been analysed, which performed a series of measurements using various technologies and methods of automatic passenger counting but have not been listed due to the lack of relevant data about the quality of the performed measurements, such as accuracy, precision, and finally the reliability of the obtained measurement results. Also, some measurements have been carried out in laboratory conditions on very small samples, so that as such they fail to be comparable without performing additional measurements in the real PPT environment.

According to the carried out research, it can be seen that there is a wide spectrum of APC technologies and methods, and the criteria for selecting a certain technology and method depend on the possibilities of the investor (public urban carrier), available financial means, and the desired level of accuracy and precision of the obtained results.

1.5 Conclusion

According to the set item of research and with the analysis of available relevant scientific papers, it can be concluded that the need for passenger counting in PPT is a universal problem and the solutions are different and numerous. Many authors have performed their research on PPT of a certain city and the results are various and depend on the type of transport means (bus, tram, light-rail—metro, etc.) as well as on the already existing technologies on board vehicles that may be used, in order to reduce the costs of implementation. Although passenger counting is a universal problem, there is no universal technology or method of automatic passenger counting. This paper provides an overview of the most frequent modern passenger counting methods, with the aim of defining a comparison according to the obtained measurement results related to the accuracy, that is, precision of passenger counting and the values of the results of analysed papers range even up to 97%. With the development of innovative information and communication services related to the development and implementation of different IoT devices, it will make possible the detection of events, objects and passengers, real-time data transfer, and being linked to various information and communication systems and devices. The expected implementation of such IoT service in Society 5.0 environment is very large and it will refer to numerous automations and simplifications apart from living also of traffic processes. For instance, activation of numerous measuring devices by detection of movements, temperature and other conditions, surveillance on demand, and real-time presentation, as well as optimization of traffic processes based on the collected analytical data. This leads to the expectation of fast development of the automatic passenger counting systems in various PPT vehicles.

Future expectations of the authors' research will include the development of an initial passenger counter by using the possibility of Arduino platform and the trial testing will be done in closed spaces (entry into a certain facility or building) and public urban transport vehicles, mainly trams. The tests, in terms of counting persons entering a certain facility or building, are expected to use at least three different counting methods, and the determination of the level of accuracy, that is, precision.

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Chapter 2
Technology Transfer and Foreign Direct Investment in the Light of Innovation Management on the Example of Poland

Magdalena Byczkowska, Janusz Soboń, and Anna Majzel

2.1 Introduction

2.1.1 Thesis, Aim and Methodology of Research Concerning Technology Transfer by Polish Companies

In today's world, technology has become the "key" to innovation and the competitiveness of businesses. Investing in and disseminating new technologies has been recognized as a driver of economic growth for many years now. New technologies provide a wide range of benefits for businesses and open up new perspectives for human activity. They accelerate more efficient working methods, initiate improvements in the quality of products/services and increase production efficiency, shorten the time to market and, consequently, provide opportunities for increased competitiveness and business development. However, the scale of these benefits and their extent depend to a large extent on companies' innovation policies and the financial resources allocated to R&D activities. An important role in this respect is attributed to foreign direct investment (FDI), which is carried out mainly by pro-innovative international companies (transnational corporations). Thanks to their involvement, technology transfer is carried out, consisting in the transfer, but above all, the use of technical and organizational solutions of international companies by the companies of the country.

Countries whose development capacity is limited have become one of the key factors in their economic development. With a negligible level of domestic savings and low accumulation capacity of domestic enterprises, the supply of external

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capital has become one of the main conditions for the countries of Central and Eastern Europe, including Poland, to improve the competitiveness of their economy.

It should be stressed that the inflow of FDI is not limited to supplementing the internal accumulation of capital, but brings about such an important transfer of technology and knowledge. The importance of this process is a component of several aspects. Firstly, technology transfer increases the available production factors. These may include, for example, foreign workers providing technical services or holding managerial positions in local companies, imported machinery and equipment, foreign raw materials, components or parts not available in the country and accompanying technology transfer contracts. Secondly, foreign technology contributes to economic growth by using existing resources. They can create additional employment opportunities for the unemployed, reduce unused potential in certain sectors of the economy. Finally, the transfer of foreign technology can result in a significant increase in the productivity of existing production factors.

The above reflections gave rise to the main thesis of the article, which is that insufficient equipment of technology and knowledge of companies from less developed countries is a premise for seeking external sources of "power" in the form of foreign direct investment. However, the aim of the article is to identify the issues related to the scope and effects of foreign capital impact on innovative activity, including technology transfer by Polish companies.

The article uses descriptive and comparative methods and a literature review. The choice of these methods was determined primarily by the type of research materials available. The descriptive method was used, among others, to characterize the nature of the inflow of foreign direct investments to Poland. The comparative method was used primarily to confront different points of view related to the role of foreign capital. Whereas the literature review was carried out in order to characterize the latest achievements related to the undertaken issues, which were presented in the scientific publications in question.

The measurement tool was a survey questionnaire, which contained both open and closed questions. In the case of the majority of closed questions, it was possible to add own answers to the proposed variants, not provided by the author. Entrepreneurs marked their chosen answer variants with an appropriate sign or assigned them a specific scale of importance by assigning the given values. The data obtained in this way were developed on the basis of the number of answers given to a given question.

The questionnaire consisted of three main parts and the so-called tag, where respondents were asked to provide basic information about the company.

The main parts of the questionnaire are:

– Part I—Cooperation of undertakings.
– Part II—Innovative activities and technology transfer.
– Part III—Transfer of knowledge.

The research process included the following methodological approach:

1. Desk research—It included the collection and analysis of available information and a review of previous research on the state of innovative potential of entrepreneurship in Poland, as well as the activities of companies with foreign capital in this respect; the research also provided information used in building research questions.
2. Questionnaire survey—In order to maximize the effectiveness of the survey, the designed survey tool was previously checked in a pilot study, which allowed to verify the accuracy and comprehensibility of the questions included in the questionnaire, as well as to verify the correctness of its general structure.

2.1.2 *Implementation of the Study*

As a result of the actions taken, 45 correctly completed research questionnaires (out of 120) were returned, which means a return of 37.5% and allows the results to be generalized to the whole community. Among the 45 companies that took an active part in the survey were large companies with an average employment of 565 people. In the surveyed sample, the majority of companies with foreign capital and those with a majority share of foreign capital (more than 80%) prevailed. Information on the share of foreign capital in the surveyed group of companies is presented in Table 2.1.

The vast majority of investors who engaged in capital in the surveyed companies came from the European Union (81%). The majority of them were investors from the European Union (81%): Germany, France, Sweden and Holland. From outside the EU structures, capital came from Switzerland and the United States (Table 2.2).

Due to the large diversification of locations of enterprises with foreign capital participation in Poland, the number of questionnaires per each voivodship was drawn with a probability proportional to the number of active enterprises in a given layer. The number of conducted interviews in particular voivodships is presented in Table 2.3.

Table 2.1 Share of foreign capital in the surveyed group of enterprises

	Number of enterprises	
Share of foreign capital	Absolute	w %
Up to 50%	1	2.2
51–75%	2	4.4
76–90%	4	8.9
91–99%	16	35.6
100%	21	46.7
No answer	1	2.2
Total	45	100

Table 2.2 Country of origin of foreign investor of enterprises constituting the research sample

Number	Country	Number of enterprises	
		Absolute	%
1	Germany	17	37.8
2	France	8	17.8
3	The Netherlands	6	13.3
4	Italy	4	8.9
5	Switzerland	3	6.7
6	United States	3	6.7
7	Denmark	1	2.2
8	Spain	1	2.2
9	United Kingdom	1	2.2
10	Austria	1	2.2
	Total	45	100

Table 2.3 Percentage distribution of the surveyed enterprises in particular voivodships

Voivodships	%	Voivodships	%	Voivodships	%
Lower Silesia	8	Mazowieckie Voivodeship	17	Świętokrzyskie Voivodeship	2
Kuyavian-Pomeranian	3	Opolskie Voivodeship	2	Warmińsko-mazurskie Voivodeship	5
Lubelskie Voivodeship	4	Podkarpackie Voivodeship	4	Wielkopolskie Voivodeship	11
Lubuskie Voivodeship	5	Podlaskie Voivodeship	2	Zachodniopomorskie Voivodeship	4
Lódzkie Voivodeship	7	Pomorskie Voivodeship	5		
Małopolska Region	8	Śląskie Voivodeship	13		
Total	100				

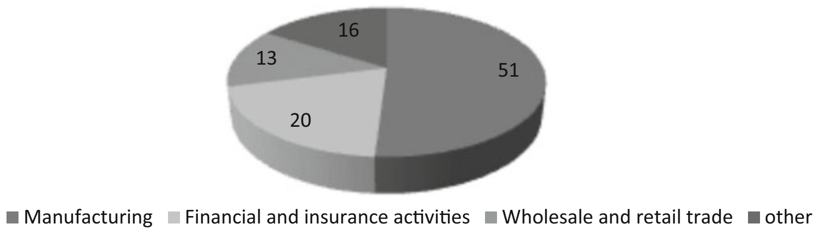

Fig. 2.1 Structure of the surveyed enterprises by sections of the Polish Classification of Activities (in %)

Foreign enterprises surveyed represented mainly the industrial sector—industrial processing (51%), financial intermediation (20%) and trade and repairs (13.3%). The activities of the remaining 15.7% of respondents focused mainly on transport, warehouse management and communications, construction and hotel and catering activities (Fig. 2.1).

Taking into account the above, foreign companies representing the following sections of the Polish Classification of Activities took part in the survey (Table 2.4).

Among the surveyed foreign entities, the vast majority were new enterprises, created from scratch. They prevailed both in the industrial and service sectors,

Table 2.4 Structure of the surveyed enterprises

Section D	Manufacturing
Section F	Construction
Section G	Trading and repairs
Section H	Hotels and restaurants
Section I	Transport, storage and communication
Section J	Financial intermediation
Section K	Real estate, renting and services related to doing business

Table 2.5 Form of entry into the Polish market

	Number of enterprises	
Description	Absolute	w %
Greenfield investments	31	68.9
Joint venture	7	15.5
Acquisition	2	4.4
No data	5	11.1
Total	45	100

dominating the sections of the economy represented in the study. Much less often foreign investors built new enterprises together with Polish capital, creating the so-called joint venture. The form of entry into the Polish market is presented in Table 2.5.

The obtained results allow for the implementation of the set objectives and in particular the cooperation of foreign enterprises with the entities of the country of deposit, the innovative activity of enterprises with foreign capital and the transfer of knowledge and skills by them.

2.2 Technology Transfer as a Result of Foreign Direct Investment

Transnational corporations play a key role in international technology transfer. The great importance of multinational companies in the process of technology diffusion results from the fact that these corporations are the source of the majority of technological innovations and have the largest share in research and development work carried out in any industry. The technology transfer through international companies is accompanied by the effect of diffusion of knowledge, production technology, marketing management methods and techniques, the effect of demonstration, often accompanied by the effect of the mobility of the labour factor and the so-called permanent learning in the country of capital investment [1].

The liberalization of foreign economic policy, high costs of innovation and control and protection of intangible assets have made FDI one of the main channels of access to valuable technology, especially in developing markets [2]. Being

Table 2.6 FDI effects related to innovation and competitiveness of enterprises

Positive effects	Negative effects
1. Acquisition of modern technology not available on the domestic market. 2. Taking over new, positive patterns of organizational and management culture. 3. Acquisition of new skills, for example, marketing, cost control. 4. Upgrading and training of staff. 5. Penetration effects to improve the efficiency and competitiveness of other sub-actors. 6. Increased demand for local R&D services. 7. Limiting the role and negative effects of national monopolies.	1. Transfer of undesirable technology. 2. Cutting domestic companies off from foreign markets and displacing them from the domestic market. 3. The dissemination of negative cultural patterns. 4. A higher level of market focus and therefore stronger competitive pressure. 5. Risk of unfair competition in relation to domestic companies. 6. Limiting the development of local companies by specializing in highly processed products. 7. Reducing the level of exports and increasing imports. 8. Limitation of national R&D facilities.

Source: Ref. [4]

an important external source filling the gap of capital shortage, they finance the structural transformation of the Polish economy, create an opportunity for its modernization as well as replacing the depleted productive assets with new ones [3]. FDI effects related to innovation and competitiveness of enterprises are presented in Table 2.6.

It should be noted that the impact of FDI on the competitiveness of the country of investment depends largely on the type of investment undertaken—therefore it cannot be assessed unequivocally positively. A list of results possible in this case is presented in Table 2.7.

This article will present the results of a survey concerning: innovative activity of foreign enterprises and initiating technology transfer by them. The results of innovative activity obtained by enterprises are assessed in terms of [6]:

- quantitative by the number of product, process, marketing, organizational innovations introduced to the market or implemented, but also by the number of protection rights to inventions or trademarks filed by the company
- value by value and share in total sales of new products or services
- quality, which requires determining the degree of novelty (modernity) of products, technologies, their environmental performance, level of complexity, types of new or significantly modernized products or processes, the possibility of diffusion of innovation, the scope for improving the quality of new solutions
- the impact of the innovative activity on the company's financial results—in this case, it is assessed primarily the change in revenue from sales of new solutions, the amount of cost reduction after the application of the innovation and the determination of changes in financial results in the short (up to 1 year), medium (up to 3 years) and long term.

Table 2.7 Types of FDI and their impact on competitiveness growth in the country of the deposit

Type of investment	Impact on the competitiveness of the country of deposit
Resource-oriented investments	– Provide complementary resources in the form of technology, organizational and management techniques – Provide access to foreign procurement and sales markets – Generate a local spin-off effect, that is, the development of related processing activities – They increase the quality of products manufactured so far – Can, but do not have to, contribute to the development of industries producing intermediate products for sectors where FDI has been carried out or which are recipients of their products.
Market-oriented investments	– Provide complementary resources in the form of technology, organizational and management techniques – Develop cooperation with local sub-suppliers – They increase the quality of the products manufactured so far, at the same time increasing the requirements imposed on local companies by domestic customers – Stimulate local entrepreneurship and competition among local companies.
Investments aimed at improving productivity	– Improve the international division of labour and contribute to a more efficient international production network – Provide access to foreign markets and sources of supply – Develop cooperation with local sub-suppliers – They increase the quality of products manufactured so far – At the same time, it increases the demands placed on local companies by national customers – Accelerate structural adjustment.
Investment oriented towards strategic resources	– Provide financial capital and complementary resources in the form of technology, organizational and management techniques – Provide access to foreign procurement and sales markets – Stimulate local entrepreneurship and competition among local companies – Improve the international division of labour and contribute to a more efficient international production network.

Source: Ref. [5]

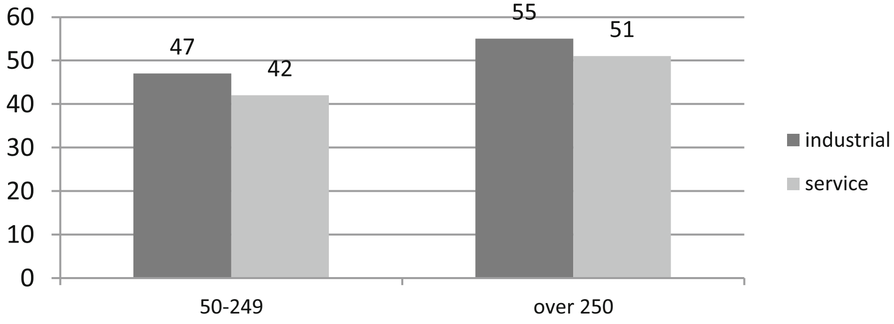

Fig. 2.2 Innovation of the surveyed foreign enterprises (in %)

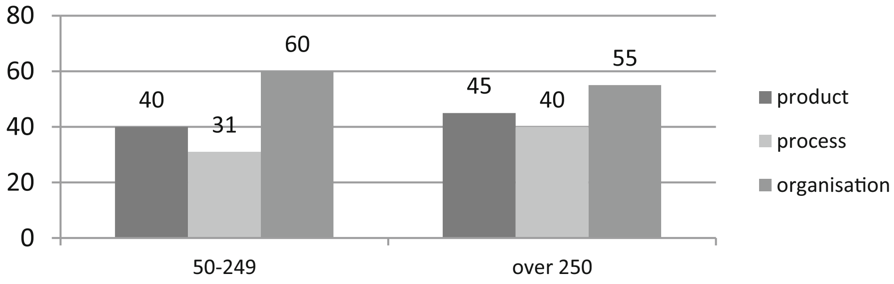

Fig. 2.3 Innovation of the surveyed foreign enterprises (in %)

Foreign enterprises operating in Poland were active innovatively, that is, they introduced or tried to introduce at least one innovation. The research showed that innovations were most often introduced by entities with 250 employees and more in the sector of industrial and service enterprises. These entities implemented both product (40% and 31% respectively), process (45% and 40% respectively) and organizational innovations (60% and 55% respectively) (Figs. 2.2 and 2.3).

The above data indicate that the number of implemented innovations is higher in industrial or service enterprises employing more than 250 people, and the profile of activity has a significant impact on the innovative activity of these enterprises in case of introducing a product, process and organizational innovations.

The largest number of product innovations was implemented by industrial enterprises (22%). They gained an advantage over service companies also when introducing process innovations within new or significantly improved product manufacturing methods (20%). There was also relatively high interest in introducing new methods on the principles of organization among industrial enterprises (16%). Slightly less frequently, new methods of division of tasks and decision-making powers were introduced by enterprises from the service sector (9%). Whereas in the last group of marketing innovations, industrial enterprises implemented innovations in significant changes in the design/construction or packaging of products and

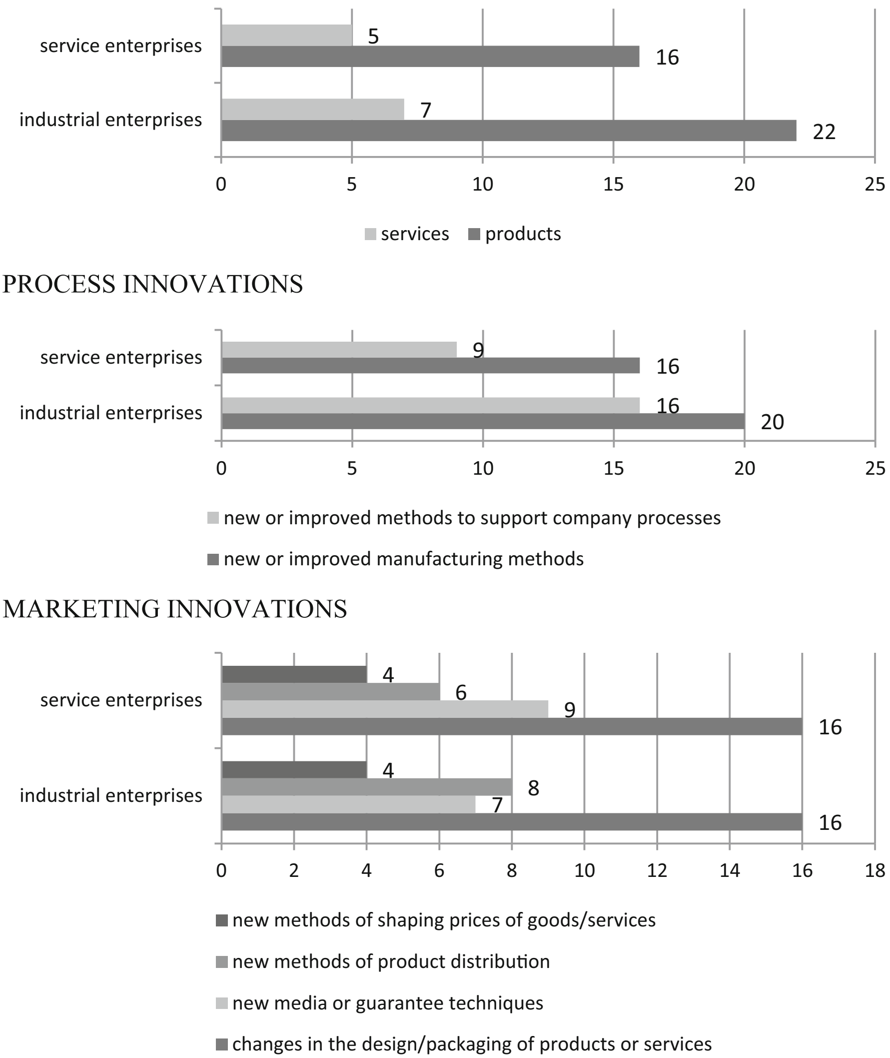

Fig. 2.4 Share of companies introducing innovations (%)

services (16%). The same percentage of innovative activities was introduced by service companies in the field of new media or media guarantee techniques (Fig. 2.4).

The dominant type of innovative activity carried out by the surveyed foreign companies was investment expenditures in tangible assets: purchase of machinery and equipment, computer equipment, means of transport, as well as buildings (61% of the total number of companies active in innovation). Next, foreign companies incurred outlays on: employee training (nearly 50%), purchase of software related

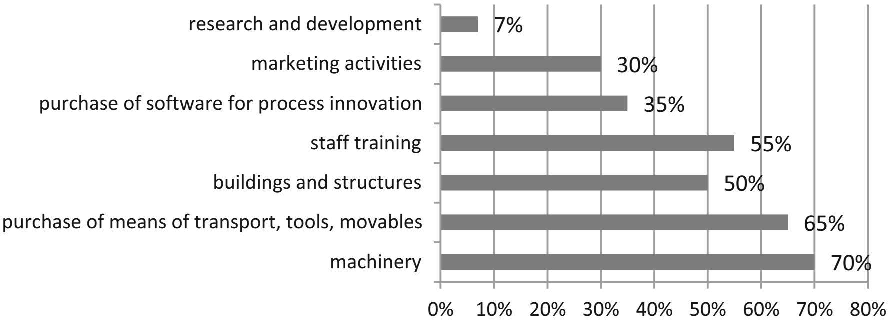

Fig. 2.5 Innovative activity in the group of examined foreign companies. (Source: Own study based on the findings of the survey)

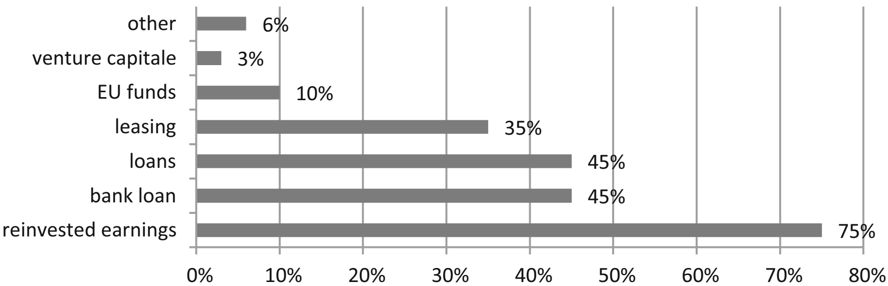

Fig. 2.6 Sources of financing for investments of enterprises with foreign participation—completed and planned investments

to the introduction of product and process innovations (nearly 40%) and marketing activities related to the introduction of new or significantly improved products (nearly 30%). Incidentally, innovation activity among foreign companies was related to research and development works. Only 7% of innovatively active enterprises took action in this respect (Fig. 2.5).

The implementation of the above-mentioned investment plans required considerable financial resources (they could be obtained both from internal and external sources).

Most of the surveyed foreign companies financed the planned investments from their own resources (75%). Moreover, in order to carry out innovative activities, external sources of financing were used, such as bank loans, loans or leasing, funds from EU funds, funds from risk capital funds and other than European funds (Fig. 2.6).

According to the group of the surveyed enterprises active in innovation, the main benefits from the introduction of innovations were general development of the enterprise (nearly 70%), improvement of the quality of products and services (60%), improvement of the organization and working conditions (60%) and increase

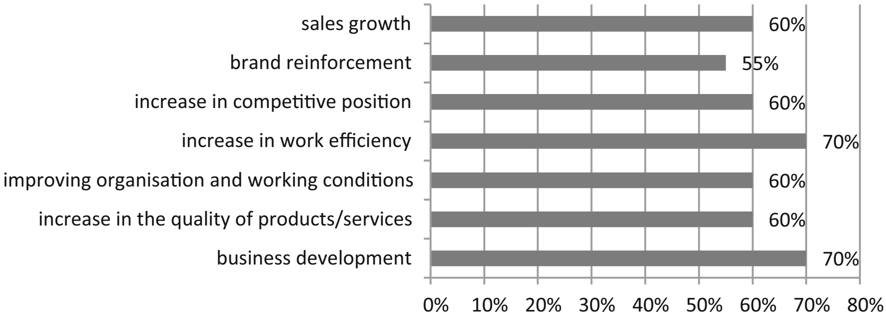

Fig. 2.7 Benefits of innovation

of work efficiency (70%). The benefits were also visible in terms of financial results achieved and competitive position (Fig. 2.7).

An important factor conditioning the achievement of the desired level of absorption and diffusion of innovations by enterprises is the development of attitudes characteristic of innovation management in these organizations, where innovation management is understood as a process aimed at continuous development of the organization through new products and processes [7], and whose tools are innovation and technology and R&D strategies. Therefore, in order to maintain the level of innovation desired by enterprises, it is necessary to make a decision in the area of innovation development, which concerns the choice of one of the following alternatives [8]:

– the possibility to create innovations on one's own, which means that the company carries out its own research and development work, conducts inventive and rationalizing activities or hires researchers
– acquiring innovations from external sources, which involves the purchase of external R&D services, new technologies and manufacturing techniques, or even the acquisition of another company
– combining the production of innovations with purchases, that is, implementation of joint ventures of an innovative nature, as well as conducting research and development works
– purchasing for manufacturing purposes, which in turn aims to purchase a manufacturing technique or technology for the company's research.

The main sources of knowledge about new technologies of the surveyed international companies were: fairs, exhibitions and specialist industry conferences (68% of indications), professional and popular science literature (52% of indications) and knowledge gained from competitors or suppliers (42% each). Next, technological knowledge came from scientific research units and universities (14% of responses). The importance of the institutional environment was marginal and constituted only less than 5% (Fig. 2.8).

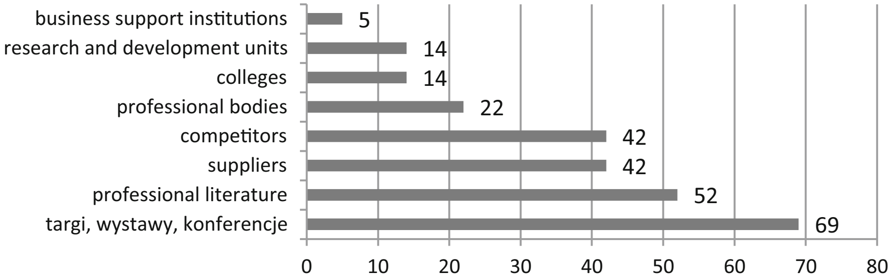

Fig. 2.8 Sources of knowledge about technological changes

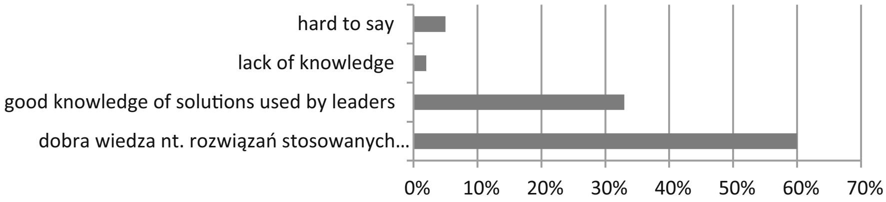

Fig. 2.9 Level of knowledge of the latest technologies

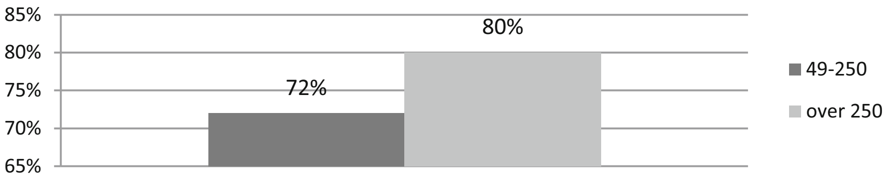

Fig. 2.10 Companies of different sizes that have recently completed a technology transfer

The main point of reference for the level of knowledge of the latest technological solutions, foreign entrepreneurs were the main industry competitors (60% of companies). In turn, for more than one in three companies, these were industry leaders. Only about 2% of companies admitted to a lack of good knowledge of the latest technological trends in a given industry (Fig. 2.9).

Most foreign companies (76%) have made a technology transfer in recent years involving the purchase of machinery or equipment needed to implement a new or modernize an existing production or service process or have acquired new knowledge to implement new solutions in the company (Fig. 2.10).

The most common form of technology transfer was purchase of machinery and equipment (78% of indications) and consulting services (32% of indications). Next, foreign companies indicated: purchase of licenses (20% of indications) and purchase of scientific research results (9% of indications) (Fig. 2.11).

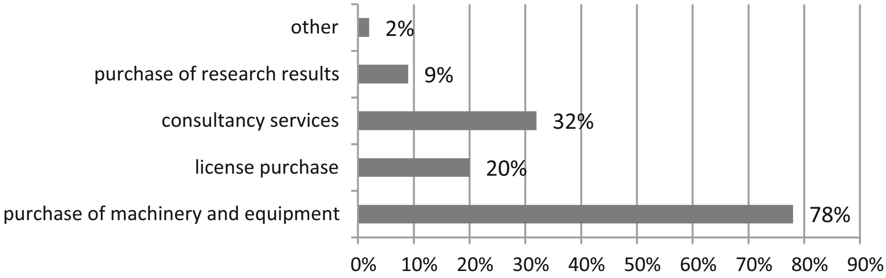

Fig. 2.11 Method of technology implementation

2.3 Conclusions

The following conclusions can be drawn from the analysis above:

– the innovative activity, regardless of its type, is correlated with the size of the company: the bigger the company, more often different types of innovative activity are conducted and outlays for this activity are incurred;
– foreign capital in enterprises was, in most cases, connected with undertaking investment undertakings in those enterprises, however, these were not one-off initiatives, but continued in subsequent years;
– investments made by enterprises with foreign capital participation were most often related to the purchase of fixed assets, training of employees and modernization of buildings and structures;
– the main source of financing of innovations were own funds of companies;
– the basic external source of funds for innovation were traditional financial institutions and European funds.

In addition, the studies carried out showed that:

– The entrepreneurs had a good understanding of new technological solutions in the industry;
– Knowledge of technological changes in the industry was mainly derived from literature and popular science as well as fairs, exhibitions and conferences;
– Most of the surveyed companies have recently implemented innovations by purchasing technology, mainly machinery and equipment;
– The role of technologically imported goods was important for the productivity of domestic industrial companies;
– The choice of the source of technology transfer was influenced by both the type of innovation implemented in the company and the support from business environment institutions.

To determine future trends in cooperation between domestic and foreign companies and the effects of corporate cooperation, the author plans to expand the research for subsequent periods and update the issues raised.

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Chapter 3
Material Efficiency and 3R Objectives for Sustainable Industry Applications

Lucia Knapčíková, Patrik Kaščák, Jozef Husár, and Matej Hrabčák

3.1 Introduction

The European Union Directive is strictly given, until the year 2030, waste that is suitable for reuse/recycling should not be accepted at a landfill, except for waste where landfilling provides the best environmental result. By the year 2035, we should reduce the amount of waste deposited to 10%, or less, of the total amount of municipal waste generated [1]. If we announce a postponement of the deadline and prepare an action plan that the Commission accepts, the period of 10% will be extended, but we must take measures to reduce the amount of waste deposited to 25% by 2035, however, limiting landfilling to 25% by 2035 is ambitious [1, 2]. And this is our primary goal of the proposed manuscript, reduce, recover, and recycle of windscreen foil. PVB foil is one of the essential parts in the interlayer of car glass or safety glass. Laminated glass, commonly used in the architecture and automotive industries, contains a protective interlayer, usually PVB, which forms a kind of fuse between two glass panes. From a study presented on Transparency market research [3], it is known that land transport was the largest for the end user of the PVB film segment on the market, representing more than 45% use as in 2014 [2, 4]. Figure 3.1 shows in detail the deposition of polyvinyl butyral film in the windshield of a car. It is the PVB foil that ensures that the glass does not break; it just shatters and sticks

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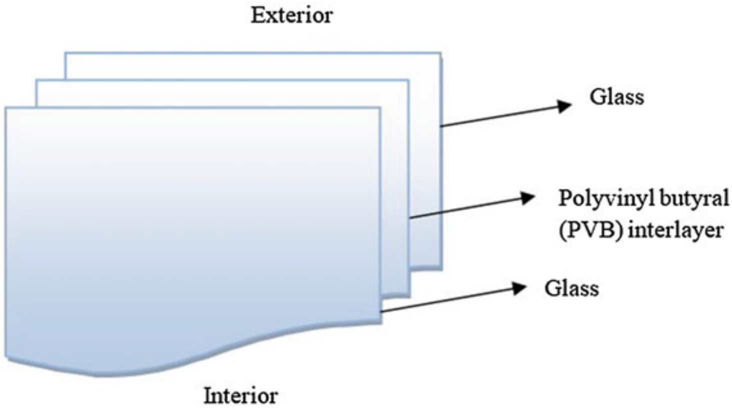

Fig. 3.1 Polyvinyl butyral foil as interlayer into windscreen (authors own processing)

together [5, 6]. The material that holds the layers of glass together is just polyvinyl butyral foil. Recycled polyvinyl butyral was contaminated (dust, glass fragments), so it was necessary to wash and dry the material before starting laboratory work thoroughly.

As part of the work, PVB in the form of flakes was used for research. Figure 3.2 shows the types of recycled PVB in different embodiments. Polyvinyl butyral is a thermoplastic material that is soluble in ethanol, butanol, ethyl acetate, butyl acetate, in mixtures of chlorinated hydrocarbons, and insoluble in aliphatic hydrocarbons (in gasoline) [5]. The density of the polyvinyl butyral used in the research was 1.07 g cm^{-3}, and the selling price of the recycled material is 0.25€ to 0.50€ per kg.

When using 3R objectives [6], specifically in the material recycling of plastic waste, either technologies used in the processing of "pure" plastics are used, which require pretreatment of plastic waste (crushing, grinding, washing, etc.) or modified technologies taking into account specific requirements in processing mixed plastic [7, 8]. If conventional plastics processing technologies are used in the material recycling of plastic waste, they allow the production of products with parameters comparable to products made of pure materials [8, 9]. The disadvantage of this approach is the requirement for a high degree of separation, that is, to be the input plastic waste is identifiable, and it was possible to classify it at least in the appropriate group of polymers [6]. Another problem is the requirement for high purity of the material, which means that this plastic waste must be not only mechanically treated (crushing, grinding, etc.) but also be freed of impurities before processing [4]. All these requirements must be met to ensure the quality requirements for products produced in this way from recycled plastic and to ensure the stability of the production process [3].

If the goal is to produce products with high-quality parameters, only a limited amount of recycled waste can be used. In this fall, the recycled plastic can be used in the volume up to 20%.

Fig. 3.2 Types of recycled polyvinyl butyral (PVB) (authors own processing)

3.2 Material Characterization and Problem Definition

The general definitions of composite materials say that the composite materials are composed of at least two or more chemically different components. Where one of the components is referred to as a matrix (it is continuous) [9, 10]. The second component—filler, is dispersed in the matrix [11]. Table 3.1 provides general information on the suitability of the choice of matrix in the manufacture of a composite material. When choosing the type of matrix and filler in the composite material, it is important to know and define the basic factors [12] from which the method of preparation and subsequent application of the material is derived.

Recycled polyvinyl butyral [1, 13, 14], used in the research, has the following parameters (Table 3.2).

Table 3.1 The differences of matrix types [13] (authors own processing)

Material properties	Thermoset	Thermoplast (PVB)
Viscosity	Less	High
Elongation modulus	Less	High
Material strength	Less	High
Storage stability	Limited	No–limited
Efficiency (manufacturing efficiency)	Less	High
Recyclability	Bad	Good

Table 3.2 Material characterization of recycled polyvinyl butyral [13] (authors own processing)

PVB-polyvinyl butyral, recycled	
Form	Flakes
Color	Colorless
Size	20–30 mm
Purity	More than 97%
Impurity content	Less than 3%
Residual humidity	ca. 2%
Portion of glass particles	Less than 2%

Table 3.3 Results after tensile test for recycled PVB and resin PVB [14] (authors own processing)

Material	E-module (MPa)	σ_{max} (MPa)	ε_{max} (%)
PVB resin[a]	7.50	13.7	49.50
PVB recycled	5.000	17.5	145.96

[a]PVB resin—as a reference from Du Pont company [1, 2]

3.2.1 Mechanical Characteristics of Composites Smart Materials

The composite material, which is created by homogenization of recycled polyvinyl butyral and reinforced by high-strength fibers, is called “Composite material with long unidirectional fibers” [5, 15, 16]. The tensile test was used to evaluate the tensile strength of the material according to DIN EN ISO 527-1. Table 3.3 contains a comparison of tensile test results for commercial polyvinyl butyral and recycled polyvinyl butyral [17]. E-modulus and tensile stress are comparable, at relative elongation ε_{max} the values were different, due to the effect of internal forces and the method of homogenization.

3.3 Results and Discussion

By our research we used the fibers that were unidirectional oriented. Their important feature is the dependence of the physical properties of substances on the direction of the force [18]. It is known from the definitions that the strength of composite materials in the direction of fiber orientation, for example, longitudinal, is substantially higher than in the direction perpendicular to the fiber axis [19, 20]. The following figure (Fig. 3.3) shows an overview of the mechanical properties of selected fibers (Table 3.4), as reinforcement, in a composite material.

Polymer composite materials [21] have advantages over metal and ceramic composites, mainly in terms of high specific strength, available processing technologies, corrosion resistance, better dynamic and damping properties, and high dimensional stability [22]. An important factor is the possibility to produce complex parts in one go or the possibility of assembling them [23]. At present, 3D printing of plastic products also plays an important role, which represents a huge potential for usability [24]. Among the key reasons for the applicability of reinforced plastics (Table 3.5) is their high specific strength [25, 26]. Table 3.5 is compiled on the basis of processed

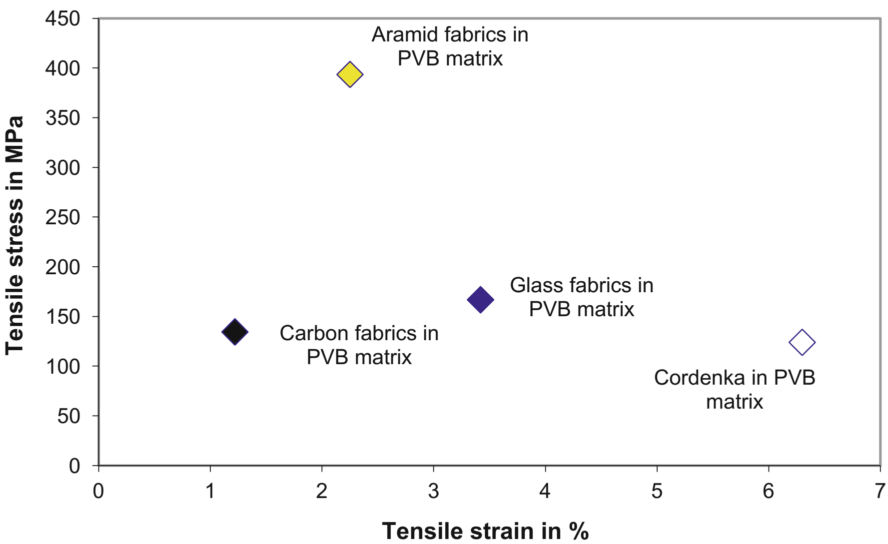

Fig. 3.3 Comparison of mechanical properties of composites materials (authors own processing)

Table 3.4 Results after tensile test for composite materials (matrix PVB and filler) (authors own processing)

Filler in the matrix	σ_{max} (MPa)	ε_{max} (%)
Aramid fibers	393.6	2.25
Carbon fibers	134.3	1.22
Glass fibers	166.8	3.42
CordEnka	124.0	6.30

Table 3.5 Compilation of key usability factors for materials from recycled polyvinyl butyral (authors own processing)

Material	Key factors				
	PVB without filler	Composite with aramid fibres	Composite with carbon fibres	Composite with glass fibres	Composite with cordenka
Material strength	–	+++	+++	++	++
Shape memory	+++	+++	+++	+++	+++
Elasticity of material	+++	++	++	++	+++
Dynamic and damping properties	+++	+++	++	+	++
Transparency	+++	–––	–––	–––	–––
Corrosion resistance	+++	+++	+++	+++	+++
UV stability	++	+++	+++	+++	+++
Possibilities of surface treatment	+++	++	++	++	++
Available technology process	+++	+++	+++	+++	+++
Low input cost	+++	+++	+++	+++	+++
Non-toxicity	+++	+++	+++	+++	+++
Recyclability	+++	+++	+++	+++	+++

Legend: – low, –– limited, ––– unacceptable (material properties) + good, ++ good (with the application possibilities), +++ excellent

mechanical properties and general properties of usability [27] of individual types of material with their direct application in practice.

The fact that the following years will revolutionize the use of composite materials plays an important role in the selection of factors.

3.4 Conclusions

The new product, which in this case is a composite material of recycled polyvinyl butyral, generally has several stages of development. Only by constantly increasing the professional knowledge and practical experience of employees and, last but not least, by constantly improving the processes of innovation and development, the company leads to the development of new products, with their application possibilities. Application of traditional material like wood, or plastics without filler, with a comparison of our new composite brings a possibility to respond to customized customer's requirements. The coloration, using color pigments, is extremely resistant to weather conditions, and therefore, the appearance of the material does not change fundamentally even after years.

The use of composites material in the exterior conditions has advantages in the followed areas:

- Does not rot
- Does not corrode
- Does not absorb moisture

Advantages over of the sustainable composites materials:

- Newly created material
- Cheaper inputs
- Mechanical properties are common with other similar material
- Harmless

By using a composite material made of recycled polyvinyl butyral and reinforced with glass, carbon, aramid, and Cordenka fibers, it also prevents the penetration of soil moisture into the fencing. The advantage of 3R objectives by windscreens, especially by polyvinyl butyral foil we see in a material lifetime, vibration absorption, and fire resistance. Definitely, this composite material we can consider to be a future material.

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Chapter 4
Parametric Evaluation and Cost Analysis in an e-Axle Assembly Layout

Muaaz Abdul Hadi, Markus Brillinger, and Martin Weinzerl

4.1 Introduction

Since the beginning of industrialisation, manufacturing of products has been moving towards digitisation. With digitisation, the products are manufactured much faster and cheaper and, moreover, in large quantities. However, products with lower batch size are yet being manufactured without the techniques of automation due to high costs. On the other hand, the products manufactured in Europe cannot be compared to low-wage countries in terms of price. Hence, in order to counterbalance the increased production costs in Europe to the customer, additional benefits must be generated for the customer, such as high quality, shorter delivery times, etc. Adaptive production systems can be one such approach to reduce the production costs. They make it possible to manufacture different types of products with the same production equipment at relatively low costs.

In this project, a novel, highly flexible assembly system was developed for various electric drive systems in order to manufacture them inexpensively and with

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high precision. The strengths of man and machine have been optimally combined. While the assembly worker can act instantly with smartness and flexibility as the changes in product occur, machines such as robots, on the other hand, are very well suited for repetitive tasks. In this project, the best of these two sides were combined so that the varying activities can be implemented quickly by the worker.

Equipping the assembly line with cognitive features allows the inexperienced workers to be quickly trained. This is achieved by analysing the assembly activities that are and will be performed by workers in the vicinity (assembly stations) and, if required, support them with informative and assistive systems. These informative and assistive systems are, for example, pick-to-light, pick-to-voice, screens, etc.

The implementation of a completely automated assembly line for a small batch size and high-variety products such as e-axles can have many drawbacks, mainly because of the tiresome programming and initial setup of robots and the high costs associated with it for an automated assembly line. Hence, the aforementioned technologies act as a counterbalance to increase the adaptivity as well as maintaining the costs of the assembly line. Moving forward, this paper presents the results in the form of case study where three selected adaptive technologies have been implemented and their impacts on the assembly line with respect to various parameters. This paper corresponds to stage C of the study from Fig. 4.4. The final results have been presented which denotes the research output of the initial implementation of study.

4.2 State of the Art

In this section, research findings along with the state of the art are briefed. The study of e-axles is presented in the first section. As this paper is a continuation of previous papers, the next section briefly describes the previous publications. This section explains the research and initial results in previous papers that could be linked to the current paper. The next section explains the selected adaptive technologies for the first full implementation into the assembly line. Finally, the state of the art with respect to the basic cost model in an e-axle and the simulation approach is followed and is briefed in last section.

4.2.1 The Product: e-Axle

Prior to explaining the technologies that have been selected for implementation and further study, it is necessary to explain the product, e-axle in brief. As described in Fig. 4.1, an electric powertrain as a whole combines the e-axle and energy storage system. The focus area of this assembly layout is only the e-axle. e-Axle further involves the energy and torque conversion systems. Moreover, the form of energy transformation from one module to another is shown.

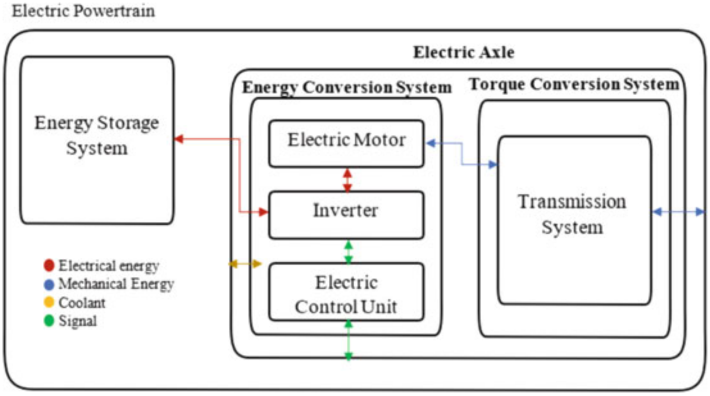


Fig. 4.1 Functional modules of e-axle

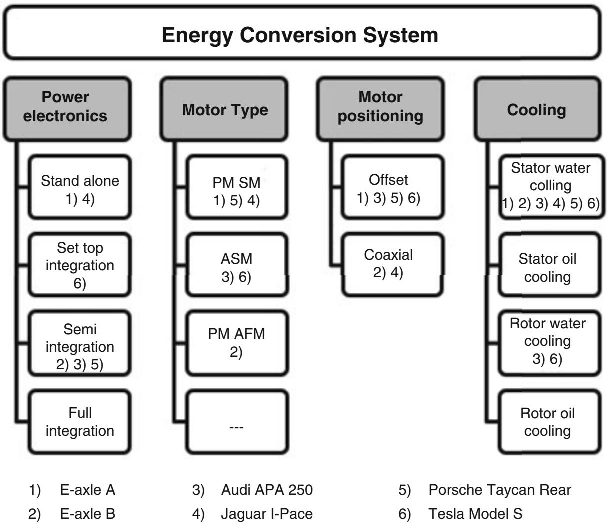


Fig. 4.2 e-Axle classification based on energy conversion

The e-axles can be derived on the basis of energy conversion (Fig. 4.2) and torque conversion (Fig. 4.3) system. Two such e-axles (A and B) that are assembled on this layout along with e-axles of acclaimed manufacturers are depicted in these figures. The flowcharts have also been explained in [1] by the author.

As the variety in e-axles is distinctly understandable from the figures, further variety can also be generated. However, with respect to the current e-axle market, majority of which fall under these classifications. The next step for ideation is to generalise the assembly steps with respect to this variety which is followed in the next section.

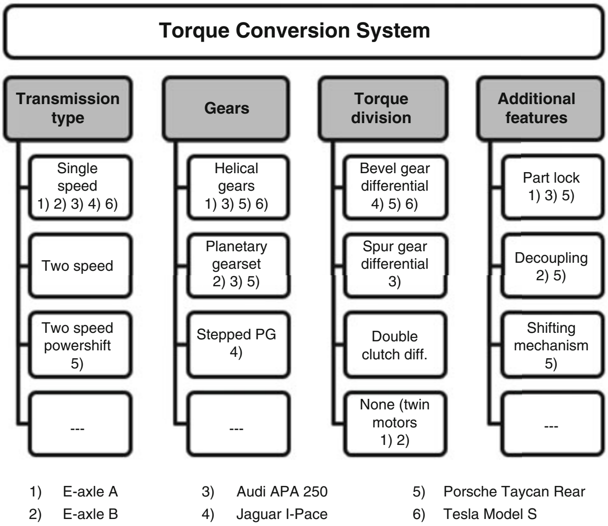


Fig. 4.3 e-Axle classification based on torque conversion

4.2.2 Continuation Study

For a successful implementation of an adaptive assembly line, suitable technologies must be implemented. These technologies must be chosen to using criterion based on their automation, adaptivity (i.e. flexibility) and cost levels. Abdul Hadi et al. describes these technologies and concepts in [2]. Four concepts have been derived with sub-technologies that have been clustered into a LoPA (level of practical application) matrix. These concepts were further honed during the implementation phase by building the system architecture for respective technologies. As seen from Fig. 4.4, paper 1 represents this study of deriving the concepts and technologies and hence building a LoPA matrix. Moreover, the assembly layout prior to initiation of study and the product were analysed in this stage. The initial results of which are presented in [2].

A step-by-step approach was followed to implement the first few technologies into the assembly line. Paper 2 from Fig. 4.4 was the focus of study in this paper. Initially, only one station was equipped with human-machine interaction and an another station for data-driven bearing test rig (BTR) in an e-axle. The human-machine interaction involved a collaborative robot, i.e. cobot. The cobot performed the high-variety assembly of bearings in an e-axle, the sealing application and bolting operations for combining the two sides of e-axle housing. The bearing test rig is a reliable method to analyse the durability, noise vibration harshness (NVH) behaviour, thermal behaviour and prediction of other properties based on the quality and assembly tolerances of the bearing in an e-axle. Both these case studies are being published in the paper titled “Implementing cognitive technologies in an

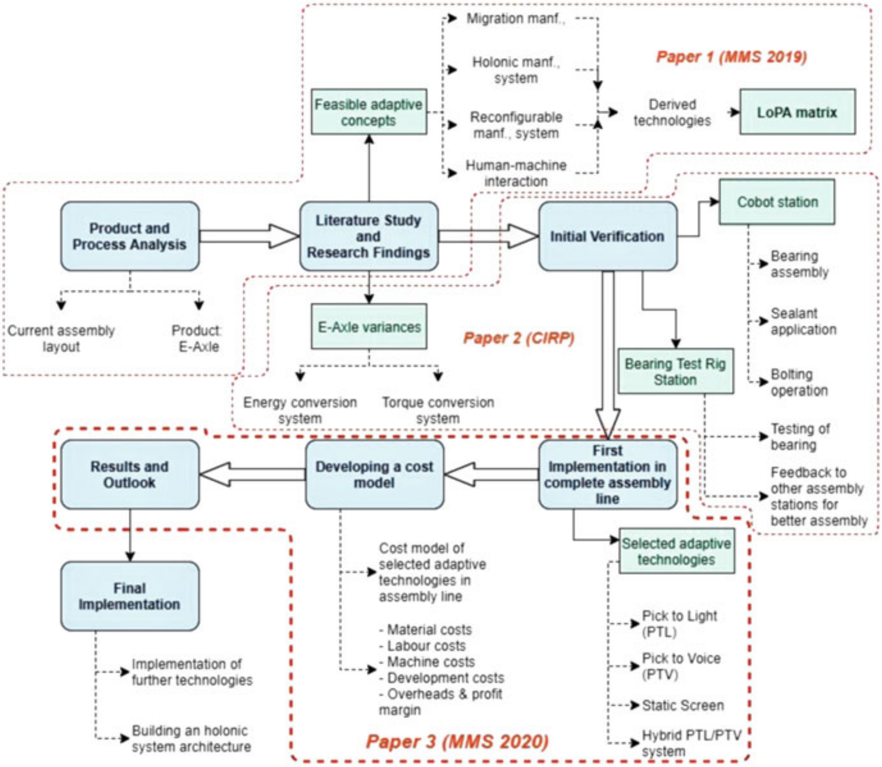


Fig. 4.4 Approach of study

assembly line based on two case studies" under the Procedia CIRP 2020 proceedings [1]. This paper depicting the detailed two case studies is a follow-on to the previous publication by Abdul Hadi et al. in [2].

4.2.3 Selected Adaptive Technologies

The LoPA matrix depicted in [2] classifies the technologies based on practicality in the assembly line. These technologies have also been categorised on their technology readiness level (TRL) [3]. Of the classified technologies, some of the technologies under the highest level of practical application are selected for initial implementation into the assembly line. These technologies are:

- Pick-to-light (PTL) technology
- Pick-to-voice (PTV) technology
- Static screen
- Hybrid PTL/PTV system

These technologies are chosen to follow a linear move towards automation from a complete manual assembly. Studies have shown that a failure of the assembly line occurs when a sudden transition is made from manual to a completely automated system [4]. Hence, three technologies along with the already existing cobot and BTR station are implemented into the entire assembly line of e-axle.

Pick-to-Light Technology

The PTL system has increasingly become more common over time. The market of pick to light was estimated at \$304.1 million in 2016 and is depicted to increase up to \$538.2 million by 2023, at a rate of 8.84% [5]. These have progressively been acceptable in all warehouse logistic activities and enhancing the level of automation [6]. However, for their implementation in the area of assembly processes, the design and architecture must be restructured. The current e-axle assembly has over 25 assembly steps in each station. As shown in Fig. 4.5, the multiple boxes in the assembly station are monitored via infrared (IR) sensors and LED light arrays which indicate the part to be picked. They are controlled via a micro controller and monitoring to pick the right part is calculated by the distance *x* and signal to the receiver. Moreover, the boxes are classified into ABC principle based on their usage in the assembly [7, 8].

The levels of the PTL architecture are as follows. Level 1: The DDC (display data connector) receives information of the logic process order of picking from the host system. This DDC receives the orders and transfers the prepared data to the multiplexer or EMUX (Electrical Multiplexing System). Level 2: The EMUX is the link between the assembly stations and the DDC. At one hand, it sends the received data from DDC to the stations, and on the other, it transfers the done operations to

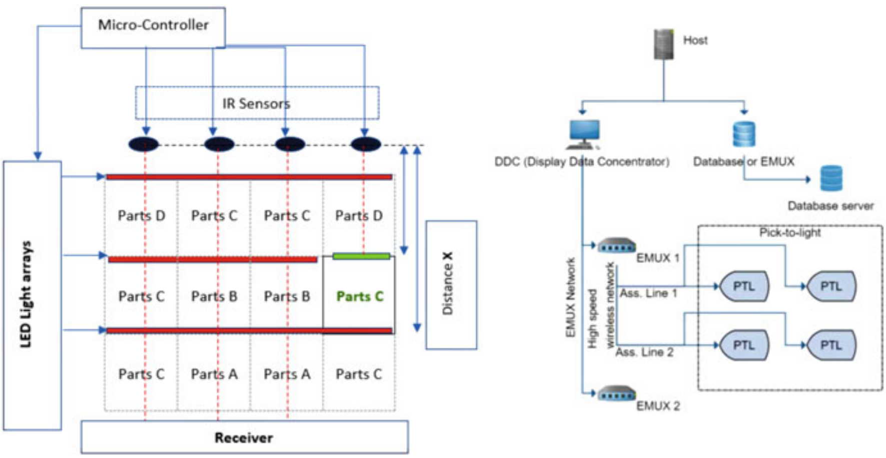


Fig. 4.5 PTL system and its architecture

the DDC and the database, which triggers the next set of operation. Level 3: These are the light displays (or just displays) which denote the next assembly operation to be performed.

Pick-to-Voice Technology

The use of smart devices in production has increased over time. Many smart devices are entering the market, and it is expected to increase at a rate of 11.9% until 2023 [5]. As in the PTL system, the architecture is built on the same model. However, there are multiple access points in an assembly area. These access points then wirelessly communicate with each individual at a workstation. Through this technique, it is possible to instruct, guide and monitor the worker even when his/her view is elsewhere. Also, these devices are a promising technology for visualisation of technology and knowledge transfer [9]. There are several benefits for usage of such technologies. Most importantly, no initial training is required. A constant monitoring and feedback are an additional advantage with such a system.

Static Screen

Most of the industries have the process steps or instructions placed close to the worker. Among these are those that still have a hard copy of these process steps fixed onto the workstation. However, utilisation of a digital method such as static screen is quite scarce in an assembly line. This modality is quite useful and important to transport complex information and decisions via text, images or also video sequences [10]. The detailed process steps and information can be displayed at a static/movable screen placed ahead of the worker [11]. Fasth describes that by using a “mobile information carrier” for assembly processes increases the productivity and quality [6, 12]. Moreover, it is beneficial on the perspective of costs. The information is consistently within reach, and the cost to look an additional time is much lower if the instructions are at a visible height. It also enables a proactive work environment. The static screens are positioned on a special rack system in a way that the screens can be maneuvered along the axis (vertically) and an angle depending on the worker setting.

Hybrid PTL/PTV System

A combination of the aforementioned PTL and PTV system was experimented during the simulation study. With an additional investment of having both technologies, the productivity gain was much higher and overweighed these investment costs. The productivity as well as rework of the products has considerably reduced which is explained in detail in further sections. The hybrid system has a high potential for increasing the productivity with 5.7%. Moreover, static screen increases productivity by 3.4% and finally PTL with 3.7%. The reduction in rework percentage by implementing static screen is 3.6%, PTL system reduces by 1.5%, PTV system reduces by 1.8% and finally the hybrid system reduces the rework by 3.2%.

4.2.4 Basic Cost Model and Simulation Study

Implementing these aforementioned adaptive technologies into an assembly line for e-axle for increasing adaptivity will raise the initial costs of the assembly line. As seen in Fig. 4.6, beside labour, machine, material and development costs, the costs for adaptive technologies need to be considered. The costs of each position cannot be shown due to confidentiality.

On the other hand, the higher adaptivity of the assembly line leads to higher variances of e-axles which can be assembled on the line which thereby reduces the specific adaptive technology costs per axle. In addition to this, the reduced possibilities for failure occurring with manual assembly operations must be considered. To do so, an FMEA analysis of an adaptive assembly line with and without these technologies will be carried out and compared.

The third important issue is the throughput. It determines the costs strongly. Due to the assembly of different types of e-axles, such as A and B, at one assembly line, many bottlenecks may occur. Hence, a tecnomatix simulation model of the adaptive assembly line will identify the throughput with respect to the product mix of e-axles A and B.

Furthermore, a simulation of the assembly layout with all the parameters and constraints is a step closer to digital twin. The simulation model can be used

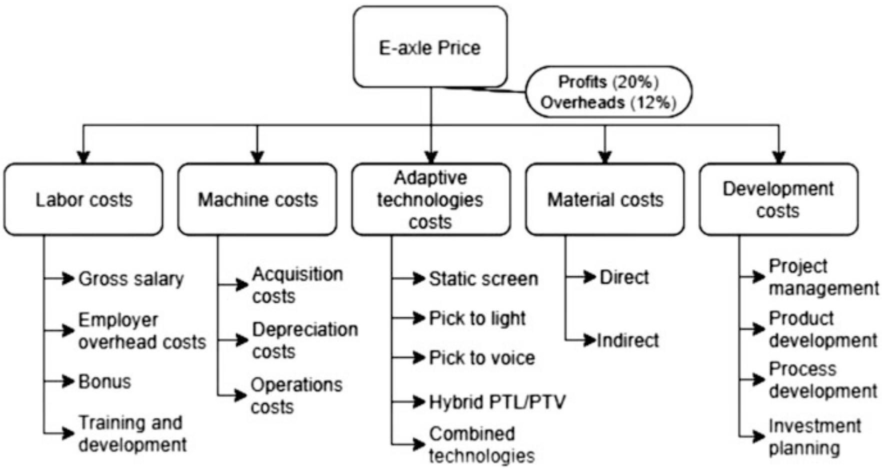


Fig. 4.6 Cost model

to visualise the assembly in real time [13, 14]. Tecnomatix plant simulation was utilised for building the assembly model. In this respective case study, with the help of simulation approach, many criteria were determined:

- The order in which various e-axles must be assembled
- Determining the implementation of specific adaptive technologies at specific stations
- Calculation of throughput of individual e-axles

Moreover, the cost analysis, simulation study, FMEA and LoA (level of automation) study depict the improvements of an assembly line post the implementation of adaptive technologies. Also, the initial simulation study and FMEA performed in [2] indicate the results of only one e-axle being assembled on the manual assemble line. However, the current analysis considers the higher variety of e-axles with considerations of improved assembly layout, implementation of technologies and a better cost model.

4.3 Research Gap

With the product being explained in Sect. 4.2.1 and its variances, it was necessary to determine the befitting technologies to implement into the assembly line. Section 4.2 explains the technologies involved for initial implementation along with one of the architecture. The next phase is the implementation of these technologies in a generalised assembly layout. The linkage between the two must be formed for building the assembly layout.

Much literature and methodologies are not available in this scientific field as the concept of e-mobility, specifically e-axles, is an emerging one. And developing an assembly layout for high variety is a challenging aspect. Hence, this paper depicts a successful approach in creation of an interrelationship between the technologies, adaptivity, automation and quality. Moreover, the low-volume and high-variety assembly line which can generally be used even for a prototype e-axle assembly would be an outcome of this research.

4.4 Methodology

The methodology or an approach in developing the assembly layout with the said technologies followed a straightforward approach as seen in Fig. 4.7. Post the product and feasible technologies analysis, a feasibility check is performed to indicate if the researched technologies fit into the assembly line for the product, e-axle. Initial implementation is followed where a trial run is performed by implementing technologies on two stations. An assembly layout is ideated for assembling this high variety of e-axles, i.e. high flexibility.

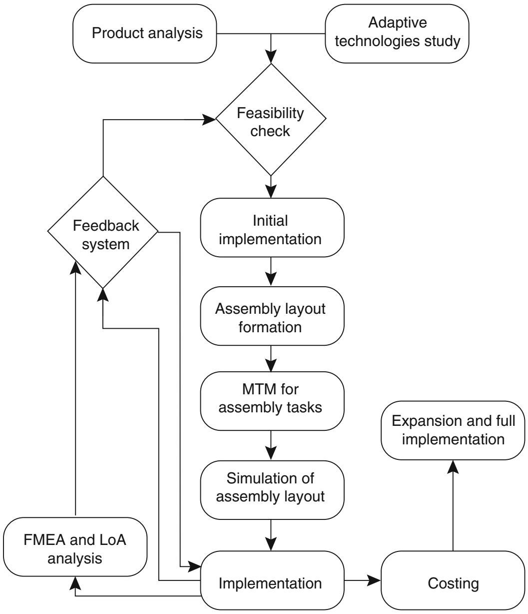


Fig. 4.7 Methodology

Methods-time measurement (MTM) is followed for calculation of ideal assembly time required for each task. With the help of these timings, a simulation model is built. This is done prior to implementation of further technologies in assembly line to denote the throughput and alter the scheduling of e-axles. The said technologies in Sect. 4.2.3 are implemented in the assembly stations. A cost model is built based on these technologies and throughput. This serves as a basic model before the implementation of further technologies. Evaluation procedures such as LoA, FMEA, etc. are followed to monitor the assembly line. A feedback system from the technologies is also generated and monitored for anomalies. This feedback system helps in further honing of the e-axle assembly to increase the throughput and quality.

4.5 Assembly Layout Formation

Similar to the ICE (internal combustion engine), an electric powertrain, thence e-axles, can have a huge variety. Hence, e-axles with similar product structure must be ideated and clustered, which thereby follows a same sequence of assembly process. The assembly steps common to most of the e-axles are derived which have been explained in this chapter. Further, a suitable layout is ideated for assembly of this immense variety of e-axles. The adaptive technologies that were selected for implementation into the assembly line have been explained in the previous section and have been implemented. These technologies impact the assembly line tremendously in improving the process which has been explained going further.

Table 4.1 Clustering of assembly tasks

No.	Station	Tasks involved	Necessary equipment	Complexity
1	Pre-assembly station	Interference fitting, placing snap ring	Hydraulic press, heating device	Medium to high
2	Motor pre-assembly	Interference fitting, placing snap ring, small part installation, bolting and sealing application if necessary	Hydraulic press, heating device	Medium
3	Rotor-stator housing assembly	Fitting rotor and stator, fitting shaft if necessary	Centring device	High
4	Main transmission assembly	Installation of shaft, actuators, park lock, shifting mechanism and small parts	Hydraulic press, measurement tools	Medium
5	Closing station	Apply sealant, bolting and inverter mounting	Cobot station	Low
6	EOL test station	Connect and disconnect	EOL equipment	
7	Universal station	Special operations, buffer station and rework		

4.5.1 Generalisation of Assembly Steps

The e-axle assembly follows a similar pattern of assembly tasks that is required. However, some of the e-axles have additional tasks that must be performed and vice versa. In case of additional tasks, the e-axle or product moves to a universal station. The detailed aspects of each station has been explained in the Table 4.1. The assembly is classified over seven stations along with the end-of-line (EOL) test.

As shown in Table 4.1, each station also indicates the assembly tasks it involves. The necessary equipment and the complexity level have also been determined. The complexity level is determined with the time taken for assembly due to its complexity of the tasks. These levels have also been verified through simulation. Station 6 is an EOL test station where one in ten e-axles at random is tested for its performance. The universal station, i.e. station 7, as mentioned prior, performs special operations or acts as a buffer station.

4.5.2 Formulation of New Layout

With the aforementioned seven stations, a layout must be ideated for the assembly process. Several layout concepts were generated that could be implemented for the assembly of e-axles. Also, the mentioned four concepts in [2] were to be implemented in this assembly line. The holonic communication was achieved via

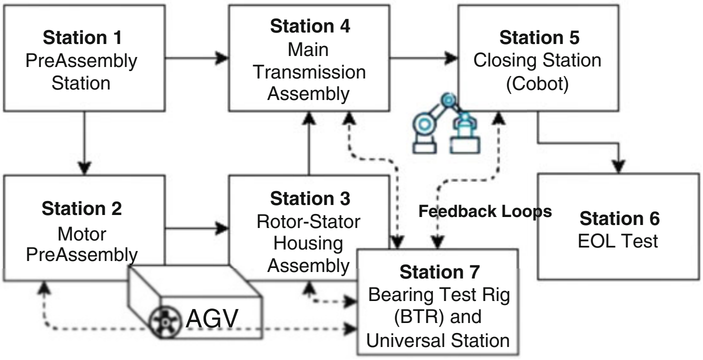


Fig. 4.8 Assembly layout

the AGVs (automatic guided vehicles), where they interact with the universal station wirelessly [2]. The mentioned adaptive technologies in Sect. 4.2.3 were implemented with the concepts [2] to generate a highly flexible assembly layout.

Value benefit analysis [15, 16] is a technique used for evaluation and detection of functions of products, systems or organisations. It validates these functions and characterises and structures the outlining functions of the system. Further, it also involves cost analysis for accessing the cost of this system. Finally, a number is generated which depicts the value of the system. The higher the number, the greater the value of the system.

The ideation of the layout was done along with the representatives from the company. Over six layout concepts were derived, and the value benefit analysis for each was followed to derive one final concept. The sketch of layout has been described in [1] and shown in Fig. 4.8. Here, the bearing test rig station, which is placed along with the universal station for depiction purposes, has feedback loops to the stations involving bearing assemblies as this is a crucial assembly in an e-axle. Use cases of BTR and cobot station (station 5) are well explained in [1].

4.6 Simulation Study and Costs

In this chapter, the results of the simulation study are seen with respect to each technology and combination of these technologies. Also, the sequence of assembly of e-axles is described. The technologies have been iterated in the simulation study to best suit the individual assembly stations and also to mitigate the error indicated by FMEA of the considered assembly line. The next section describes the costs in brief for the implemented e-axle assembly layout. Moreover, the detailed costs of individual technology are not shown due to the reason of confidentiality as indicated before.

4.6.1 Simulation Study

Initial Simulation

The initial study for the assembly layout, prior to implementing adaptive technologies and layout variations, revealed few loopholes. The initial layout was only designed for one type of e-axle. The throughput was 3895 e-axles per year. This simulation results showed a negative deviation of 0.5% with the actual implemented output. This possible potential for this deviation was the walking distance of the worker which was not considered and the moving of parts from one station to another. However, this deviation was later reduced in the further models.

Sequencing

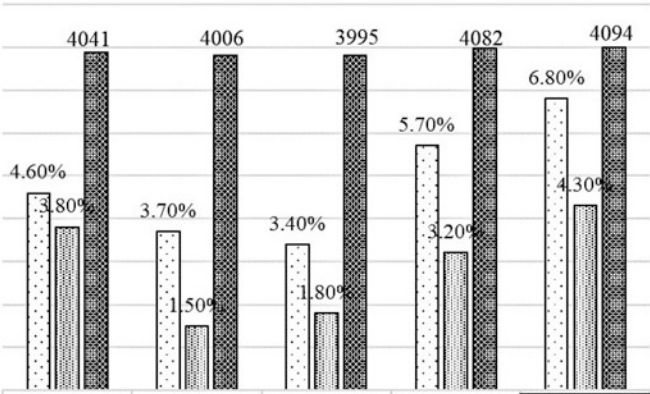
Since the variety of e-axles assembled is more than one, sequencing them is an important aspect to achieve higher and faster throughput. The simulation approach has aided in identifying the best quantity of an e-axle to assemble prior to moving to the next set of e-axles. As the batch size per day is quite low, e.g. 10–20 e-axles per day for each variety, it is necessary to determine the minimum number of e-axles to assemble before the switch to another e-axle. Considering two varieties of e-axles are assembled in a day, the minimum number of e-axles to be assembled is four. Once four e-axles have been assembled, a switch can be made to another variety. However, this is the least number for assembly of one variety. If only one e-axle is assembled per day, the throughput is higher. But since the goal is to depict an adaptive assembly line, the former variance is used. Figure 4.9 depicts the results considering this sequence approach of four e-axles per variety before a change is made to another one. [2] describes the three types of e-axles and their assembly times utilised for the simulation approach.

Adaptive Technologies

Abdul Hadi et al. describe the RPN numbers of the assembly process prior to implementing adaptive technologies in [2]. The considered three adaptive technologies, explained in Sect. 4.2.3, have been implemented in the assembly line. The benefit of each technology in the assembly line is shown in the table below.

Results

With the help of a simulation model, individual increases in productivity and throughput were determined. The technologies were combined to determine the increase in throughput. Figure 4.9 depicts the results of study. Also, sequencing of



	Static screen	Pick to light	Pick to voice	Hybrid system (PTL/PTV)	Combined technologies
Increase in productivity	4.60%	3.70%	3.40%	5.70%	6.80%
Decrease in rework	3.80%	1.50%	1.80%	3.20%	4.30%
Total throughput	**4041**	**4006**	**3995**	**4082**	**4094**

Fig. 4.9 Results from simulation study

e-axles is also explained to achieve maximum throughput. With the help of these studies, the rework has also reduced which is an important aspect to depict the qualitative improvements.

4.6.2 Costs

The cost of building a flexible assembly line is usually considered to be higher. It is much higher than a dedicated assembly line for assembly of a single product [17, 18]. Moreover, utilising automation technologies for a flexible line further adds to the costs of assembly. Hence, it is crucial to explain the costs of e-axle including the technologies involved to depict the cost advantage of an adaptive assembly line over flexible and dedicated lines.

A cost model is an elaborate topic comprising of many aspects and considerations. As indicated from the Fig. 4.9, the considered technologies have a positive impact on the productivity, rework and, hence, throughput. Generally, the calculated breakeven point between the investment of these technologies and the returns generated is between a year and a year and a half. Considering the lifetime of these technologies to be over 3 years, these technologies best fit into the cost-effective adaptive assembly line. The further considerations that have been made are the access points for these wireless devices, database systems and the initial implementation costs. The central warehouse execution system (WES) monitors and controls these devices along with knowledge and information transfer to the assembly stations. Moreover, there are further several subtopics under each of the sections in cost model which are not depicted due to complexity.

As the throughput of e-axles has increased along with the flexibility, costs have been reduced by a certain percentage. Approximately, for e-axle A, a 2% reduction in costs is seen indicating the benefit of adaptive technologies in the assembly line. Elaborative results with the percentages can be seen in Fig. 4.9.

4.7 Results and Outlook

The paper begins with explaining the e-axle market in Europe. It depicts the importance of this study as the e-axle market is an emerging one in the field of e-mobility. Moreover, this paper is a continuation of previously published two papers [1, 2] as explained from the Fig. 4.4. The technologies derived and the concepts generated have been verified over the course of study. Three technologies have been selected for the initial implementation and to develop a cost model. This is done to determine the impact of these technologies on the assembly line prior to implementation of further adaptive technology models. This approach is also followed to negate the technology jump that would cause disruption for the workers and assembly process.

An e-axle can have vast variety similar to that of ICE and mostly depending on the automobile manufacturer. This variety generally depends on the energy and torque conversion systems as shown in the Figs. 4.2 and 4.3. This variety was analysed, and assembly tasks in each e-axle were further clustered. They were clustered into stations, and the necessary tasks and equipment involved were derived. Finally, a new assembly layout was formulated with the help of value benefit analysis. A rough overview of the layout is shown in Fig. 4.8. The feedback loop is generated, most importantly from bearing test rig and the end-of-line testing station to constantly improve the e-axle assembly. The evaluation study is followed in the next section. A simulation model has been built up to determine the improvements in the assembly line. Simulation in tecnomatix proves that with the implementation of the selected technologies, there is an impact on productivity, rework and throughput as shown in Sect. 4.2.3. Moreover, an FMEA of the after implementation was also done to determine the decrease in the risk priority number (RPN), i.e. the errors in the assembly line. The initial study of this FMEA prior to implementing the adaptive technologies is shown in [2]. The FMEA done after the implementation of assembly technologies is shown in extracted Fig. 4.10. As it is depicted, the RPN numbers have significantly reduced indication an increase in quality of the assembly line. Further, an increase in level of automation, i.e. physical and cognitive automation levels, is significantly noted.

The cost model developed for the e-axle assembly depicts the investment required for implementation of an adaptive assembly line. As predicted, the cost of implementing an assembly line of this type is much easier and cheaper when compared to an automated line. The devices and technologies used in an

	Before-study		New Values				
Process Step/Input	**Potential Failure Mode**	**RPN**	**Action Recommended**	**SEVERITY (1 - 10)**	**OCCURRENCE (1 - 10)**	**DETECTION (1 - 10)**	**RPN**
Information/ Assembly operations	Poor or missing documentation - Process description	*162*	Static screen, BUS system, Data transfer systems	*3*	*3*	*5*	*45*
Assembly operations/ Manufacturing operations	Operating errors	*336*	Cobots and adpative technologies for monitoring	*3*	*3*	*6*	*54*
Assembly operations/ Information	Longer assembly times than allocated	*540*	PTL, Static screen, Ear devices, Watch, HMD, Turntable, Reconfigurable systems, Cobots, AGVs, Multi-function station	*4*	*3*	*3*	*36*
Person related/ Assistive operations/ Information	Distraction of the worker	*294*	PTL, Static screen, Monitoring techniques	*3*	*3*	*4*	*36*
	Wrong decisions for basic worker operations	*189*	Static screen for guidance, Reconfigurable systems, HMI's	*2*	*7*	*3*	*42*
Ergonomics/ Assistive operations/ Information	Lack of prevention measures	*120*	PTL, Static screen, Ear devices, Watch, HMD, Monitoring techniques	*2*	*3*	*2*	*12*
Maintenance	Equipment failure	*360*	Informative sensors/systems, Multi-function station, Sensors system predicting the failure (predictive maintenance)	*1*	*4*	*1*	*4*
	Wrong tools, broken tools, missing aids	*252*	PTL, Screen, Ear devices, Watch, HMD, Reconfigurable systems, Cobots	*2*	*7*	*6*	*84*
Quality	Error in quality inspection	*336*	PTL, Screen, Ear devices, Watch, HMD	*3*	*3*	*5*	*45*

Fig. 4.10 Post-implementation FMEA (extracted)

adaptive assembly line are mostly assistive and informative systems. Thus, the costs are cheaper than implementing robots and automated machinery. Moreover, the flexibility is much higher in the case of these systems.

Further study must be done for developing a holonic communication system, i.e. wireless communication, between the stations. A system architecture must be built at first, tested and then implemented. Since further adaptive technologies must be implemented, the holonic architecture system is necessary. Moreover, the use of collaborative robots (cobots) must be increased, which is currently being used for bearing assembly, sealing and bolting operations. This would further decrease the qualitative errors and increase the productivity.

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Chapter 5
Design of Simulation Workplace for Quality Evaluation Using LEAN Principles and Vision System

Stella Hrehova and Darina Matiskova

5.1 Introduction

Industrial automation systems are mostly designed to check known objects in fixed positions, characterize item defects, and take steps to report and eliminate these defects and replace or remove defective parts from the production line [1]. Industrial vision systems are one of such systems. They are described as computer systems, where the software performs tasks to acquire, process, analyze, and understand digital images. They are usually focused on industrial quality assurance, defect detection, part recognition, and so on [2, 3]. They are like "eyes" that capture the process and recover the analyzed digital image with image processing software. These systems are used in all industries and are an essential part of achieving efficiency and high standards of quality (Fig. 5.1).

This paper presents a design of an experimental workplace using a camera system for monitoring the achieved quality of the production system. In order to ensure greater efficiency in the design, we will use the LEAN approaches to decrease the losses.

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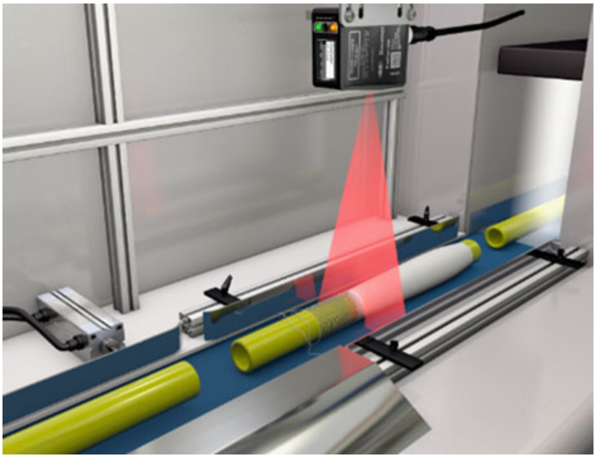

Fig. 5.1 Diameter measurement via vision system [4]

5.2 Methods and Tools

5.2.1 Statistical Process Control

In this paper, we will use methods and tools of statistical process control (SPC). SPC is the application of statistical methods to monitor and control the process to ensure that the process is stable. According to SPC, the process behaves predictably to produce the most satisfactory product with the least possible waste [5]. The quality of the production process can be characterized from several points of view. From the point of view of the production process, we can characterize quality as a set of all product characteristics that satisfy the customer. The product manufacturing is based on technical documentation, where are defined all product dimension and their specification limits. We can define a product's dimension during the manufacturing process, which is very important to them. If the observed value is outside the tolerance limits, the product is classified as noncompliant as waste [6]. The result is a loss for the company, and therefore, the emphasis is on keeping the required limits values. During the production of the product, the individual production forces interact with each other and this can cause deviations from the desired value. Common causes of variation result from natural factors in the process and occur randomly. Deviations due to common causes cannot change except for fundamental changes in the process itself [7]. These variations make it impossible to produce two identical products. Producers, therefore, seek early detection and prevention of problems.

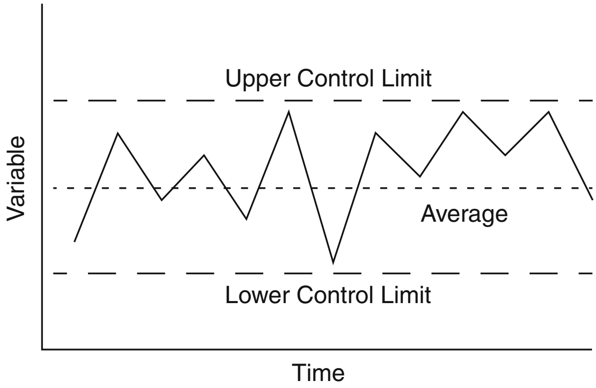

Fig. 5.2 A typical control chart [9]

Determination of Control Limits

Based on the decision-making process to eliminate noncompliant products, we chose the principles of Shewhart diagrams. Shewhart control charts utilize the principle of statistical significance tests and graphically display process variability. They allow to separate random causes from definable causes [8].

Central line (CL) in the Shewhart control chart is characterized as parallel to the x-axis. It is the distance of the reference value of the displayed characteristic. For the processes, it is most often the mean of the average of the individual subgroups x or the average of the range R (Fig. 5.2).

The regulations borders (limits) are called:

- the lower control limit (LCL)
- the upper control limit (UCL).

If the borders are crossed, it is necessary to analyze the causes and implement the corrections. Assuming the process is in a statistically stable state, approximately 99.73% of the final values will be within control limits.

The values of the individual control limits were determined based on the following equations [9]:

Upper control limit:

$$\text{UCL} = D_4 \times \overline{\text{MR}} \tag{5.1}$$

Central line:

$$\text{CL} = \overline{x} \tag{5.2}$$

Lower control limit:

$$\mathrm{LCL} = D_3 \times \overline{\mathrm{MR}} \tag{5.3}$$

where the difference among data point x_i for m individual values are calculated as:

$$\mathrm{MR} = |x_i - x_{i-1}| \tag{5.4}$$

the arithmetic mean of these values is calculated as:

$$\overline{\mathrm{MR}} = \sum_{i-2}^{m} \frac{\mathrm{MR}_i}{m-1} \tag{5.5}$$

The upper control limit (UCL) and lower control limit (LCL) for the individual values are calculated by adding or subtracting 2.66 times the average moving range to the process average.

In the proposed workplace, UCL and LCL values will serve as limit values for product quality assessment.

5.2.2 Lean and Chosen Methods

Lean manufacturing is a direction of management that ensures the competitiveness of a business by producing products (providing services) in the quantity needed for the customer, with high quality, minimal resource costs, and low costs. It is primarily the effort of the whole organization to continuously improve in all areas and avoid unnecessary waste. The main goal of lean manufacturing is to reduce or eliminate all types of losses in the production process. Losses are characterized as all shares that do not create value for the consumer.

Brief Description of JIDOKA

Jidoka is one of the strong pillars of the TPS (Toyota Production System). It helps prevent errors in the manufacturing process, identifies error areas, and suggests solutions to ensure the elimination of problems and not to occur the same fault again. Jidoka is used to ensure quality, reduce raw material costs, and spend time and resources to eliminate errors.

The idea of Jidoka is stopping the system. We get an immediate opportunity to improve or find the root cause, instead of letting the defective product go down the line and not solve it [10]. The implementation of this method can increase the quality

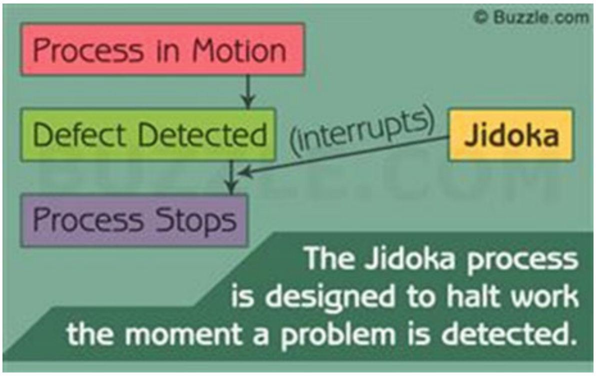

Fig. 5.3 Principle of Jidoka [13]

level of product production. This system consists of two components. The first is the separation of man from machine. The second part is the concept of creating 100% quality at any time throughout the process without the need for further control. This means that key product parameters are checked and evaluated during the process. In order to eliminate errors of operators and other participants in the production process, it is also possible to use additional LEAN techniques—POKA-YOKE [11]. It means to use various technical devices that can detect operator or machine errors and signal with a light (sound) instrument or stop the machine. Because of this, we can describe Jidoka as a technique that gives machines and operators the ability to detect when unusual conditions have occurred and stop work immediately [12]. With an effective Jidoka system in place, companies can ensure that errors are not passed on to the customer, to prevent equipment failures and reduce losses, so that operators do not have to waste time watching machines or processes, but they can work on multiple machines (Fig. 5.3).

Andon

The Andon device is traditionally used in the manufacturing industry. This visual management tool shows the status of operations in an area and signalizes the occurrence of abnormalities [14]. It emits electronic signals depending on the state. If the signal is negative, the machine stops immediately until the error in the process is cleared. The fact that an error has been detected is indicated by signals.

The alarm can be activated manually with the button or can be activated automatically by the production facility itself. The system may include tools to stop production until the problem is solved. Some modern warning systems include audible alarms, text, or other displays.

The implementation of these systems in production can reduce the number of noncompliant products. Individual signals for the use of Andon will be based on specified control limits calculated according to statistical quality control procedures.

5.2.3 Tecnomatix Plant Simulation

Computer simulation is a powerful method for designing and analyzing manufacturing processes in the industry. Today, within a relatively short period of time, it is possible to design or redesign a manufacturing system to improve it or add new components [15]. The most suitable software is Tecnomatix Plant Simulation which allows the modeling and simulation of manufacturing systems.

It is an object-oriented 3D program used to simulate discrete events, which allows to quickly and intuitively create realistic, digital logistic systems (e.g., production), and thus test the properties of the systems and optimize their performance [16]. A very important feature of the program is the possibility to model and simulate processes following the paradigms of object-oriented programming. In this paper, we use the OPC UA interface between Plant simulation and control and automation technology systems for accessing and exchanging data. It allows access to process monitors, such as PLC controls via the *OPC Unified Architecture*. Because we can run the simulation in real time, as controls work with a real-time timer and do not provide a fast forward function. When the PLC sets the value of a variable to right, then *Plant Simulation* calls a callback method in which you can react to the value from the external application [17].

5.3 Design of Workplace

These are the following assumptions for workplace design:

- We assume repeated production.
- Tolerance limits (USL, LSL, UCL, and LCL) are available for individual product types. Therefore, they can be loaded into the system.
- The production process is under the statistical control, no significant fluctuations are expected.

For our workplace, we will use a smart vision system with a USB camera, which process captured data and transforms them into a measured dimension. The parts with dimensions out of tolerance can be signalized to PLC which controls production line. The PLC control system will read and write the parameter according to a preset procedure and decides on the next flow. Figure 5.4 represents the camera part of measurement in the workplace.

We used objects of type *Method* when we can program the actions that we need to take place when the conditions become true. There will be used integrated a powerful programming language. The *Method* also provides a debugger to locate errors and allow us to correct faulty code. In this paper, we use the possibility to create our own entity, which will represent measurement in the workplace.

To simulate the decision process, we used in the tool *FlowControl* in the model, which moves the parts on to their successors according to an attribute of the part.

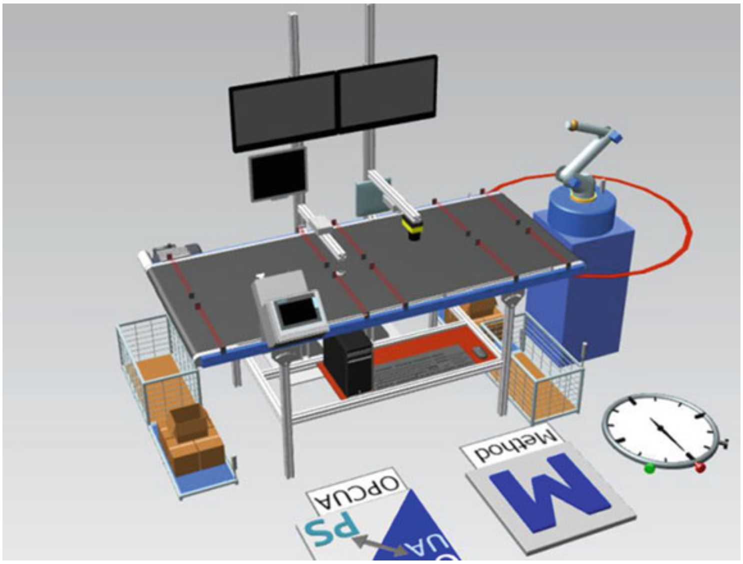

Fig. 5.4 Camera part of the workplace

For the output from the Measurement block, the “Percentage” strategy was selected. It should simulate common division based on statistical estimates. This setup represents the following figure (Fig. 5.5).

```
s6 := OPCUA.getItemValue("MyObject|MyVariable6");
//Vision Sick/Cognex
s7 := OPCUA.getItemValue("MyObject|MyVariable7");
//Empty
s8 := OPCUA.getItemValue("MyObject|MyVariable8");

print s1;
OPCUA.setItemValue("MyObject|MyVariable1",2);
print Drain2.NumPartsSinceSetup;

if s1 = 49
    //EventController.reset //EventController.start
    Source1.Pause := false  //Drain2.Pause := false
    Drain1.Pause := false
else
    //Source1.Pause := true //EventController.p
    //EventController.stop
    Drain2.Pause := true
    Drain1.Pause := true
    //DeleteMovables;
end
```

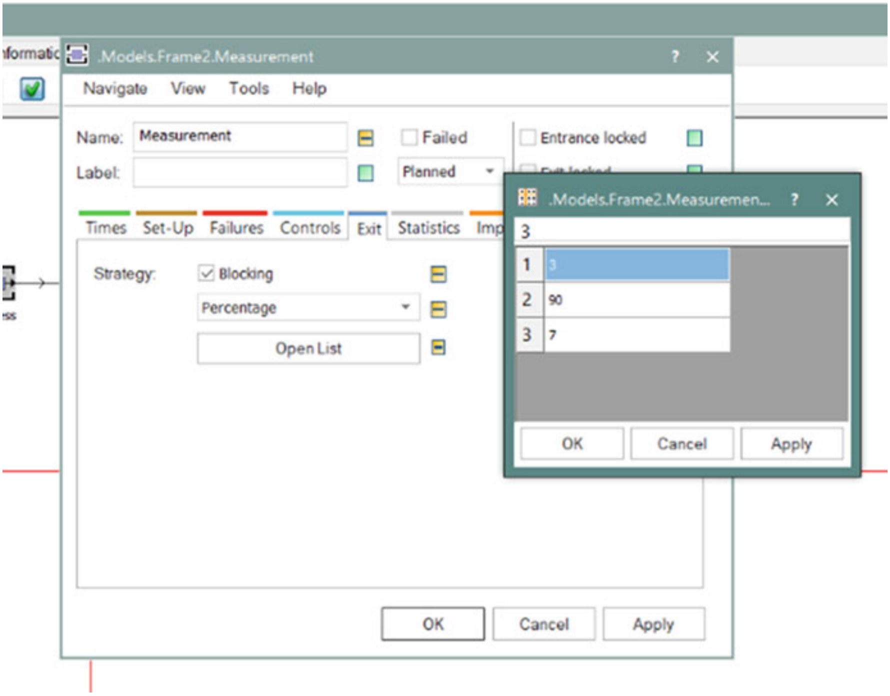

Fig. 5.5 Set the strategy

5.3.1 Proposed Activities of Workplace

The computer model of the workplace is based on the following activities:

- The workpiece passes through individual workplaces according to the technological procedure. The measuring station is located after the production operation of the key parameter for the overall product quality.
- The monitored parameter is measured and the value is compared with the desired value. If a deviation is detected, the workpiece is moved to the appropriate workstation as a rule.

  Based on the obtained result, the product is moved:

- If the measured value is within the control limits, it will go to the next operation (Line1) or the process will end.
- If the measured value exceeds the upper or lower control limit, the product passes through the Line2 conveyor and is stored in the Store. Exceeding the upper or lower control limit does not mean that the product is not within the required tolerances, but there is a risk that it will not meet customer requirements. It would also be advisable to set a counter to count the number of such deviations. In

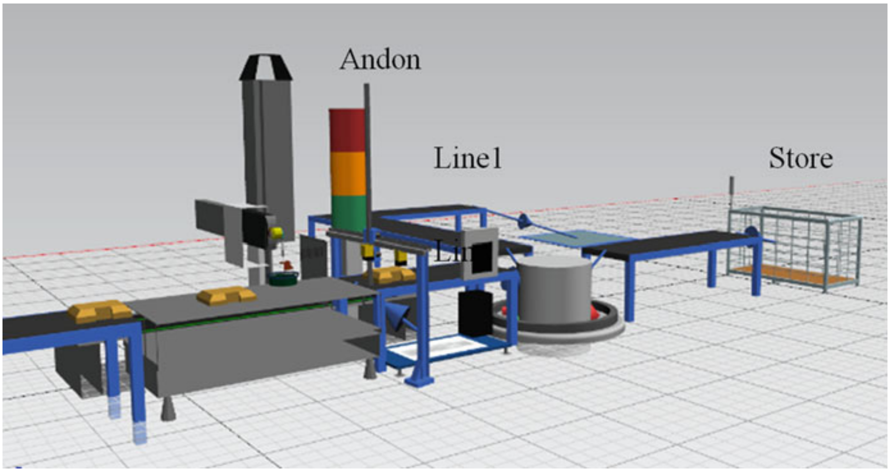

Fig. 5.6 Scheme of workplace

case they occur in a larger number, it is advisable to stop, respectively signal process error. These deviations may occur, for example, by blunting the tool or by changing the stability of the machine assembly.

- If the measured value is outside the upper specification limit—USL or lower specification limit—LSL (exceeded deviation according to the technical documentation), this means that the product does not meet the customer's requirements. In this case, the machine stops and the red light comes on. It is a signal to the operator to determine the cause of the fault (Fig. 5.6).

The possibility to stop the machine (principle of Jidoka) reduces losses. If should it happens more often in a short time, it is necessary to check the machine setting, or too.

5.4 Conclusions

Computer simulations performed by available software tools using IT tools optimize the work and performance of production lines as well as other production and logistics processes. Computer models enable businesses to run simulations without disrupting real-world systems and find optimal solutions to problems. It is possible to choose the best strategy by testing different scenarios to increase efficiency and quality and eliminate losses.

This paper describes the design of the workplace, which, based on the use of the camera system and the principles of statistical quality management, could be able to decide whether the measured values are below the control limits. Tecnomatix Plant Simulation tools can be used to test the management of individual system elements such as the machine itself, the camera system, the PLC, and Andon. This would ensure online monitoring of the quality of the required indicator and thus the fulfillment of production quality requirements. The advantage of introducing the philosophy of LEAN and Andon in the compilation of the control in the workplace, which can be considered, to ensure that the following conditions are met:

- Machine operators are not tied to one machine but can provide control of several machines. The system itself signals a deviation from the normal state.
- The required parameter values are monitored directly during production. When the limits are exceeded, Andon signals this condition or the line is stopped.

In order to meet the required goals, it is necessary to precisely specify the method of evaluation of the required parameters and the interconnection of all components of the workplace. In the initial phase, this can be time-consuming to run and test a given workplace.

After debugging all the expected situations and creating a precise procedure for each situation, the workplace can become highly efficient and flexible.

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Chapter 6
Employee Training Programs for Small- and Medium-Sized Manufacturing Enterprises

Angelina Iakovets, Michal Balog, and Stella Hrehova

6.1 Preparing of Employees

6.1.1 Introducing

The development of engineering and technology always requires retraining of the workforce, therefore, to investigate the effectiveness of teaching methods and organize training courses for employees is the task of all enterprises and schools. The research had shown that a lot of secondary and high schools actively apply and implement the latest technology and equipment for the training and education of students. On another hand, schools cannot prepare students for real specific conditions of every enterprise, therefore, the graduate will be instructed again, according to the specifics of the enterprise. One cannot reject the fact that a pretrained student, especially a young one, will easily and quickly perceive information than a adult and unprepared one. That is why it is important to turn to the modern trends of personnel education and training.

In a recent study by BambooHR, the importance of onboarding was clear. Losing a newly hired employee costs nearly two times the employee's annual salary in wasted hiring and rehiring activity.

Effective onboarding is not just the responsibility of HR, managers must also take an active role. Survey respondents said they wanted more time with their hiring managers during onboarding and identified some common ways companies could improve in their new hire processes [1].

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One of the main directions of every manufacturing enterprise is not only the implementation of the newest technologies but also reducing the production cycle as well. The main tools for reducing production time and time losses are:

- improvement of technology
- the use of more productive equipment, tools, and technological equipment
- automation of production processes and the use of flexible integrated processes
- specialization and cooperation of production
- organization of in-line production
- flexibility (multifunctionality) of staff
- trainee programs for stuff
- controlling the processes and machines
- many other factors affecting the duration of the production cycle.

6.1.2 Staff Training Approaches

Each manufacturing enterprise has its own special technology and equipment, which accordingly directly affects the type of work performed. Thanks to such features, the training of personnel for a certain type of work is often carried out directly at the enterprise or the training centers of the enterprise.

Small- and medium-sized enterprises often cannot afford to develop preparatory course programs and open training centers. Despite the size of the enterprise, it is important not to stop the production process, therefore it is essential to develop training courses for personnel rationally to ensure a reduction of production downtime associated with this.

A lot of managers and scientists continuously study trainee programs for manufacturing enterprises. Dr. G.S. David Sam Jayakumar and a group of scientists in their research say that all tests confirm that: "strategic goals and mission of the organization are to continuously improve the training and development system" [2]. This idea is especially relevant since it is very important to motivate employees to develop and be adapted to all technical innovations.

Referring to existing research and forecasts of specialists in this industry, it is obvious that most of them see the future for new technologies that will be widely used for staff training. Personalized learning will boom in 2020, thanks to the ability of artificial intelligence and machine learning to assess a learner's needs and offer customized learning content, predicted Celeste Martinell, vice president of customer success at BenchPrep. A Chicago-based company, BenchPrep works with large training and credentialing organizations to improve the employee learning experience [3].

Also, Martinell said: "There are a number of companies that are employing recent graduates, paying them salaries and providing benefits to train them in the latest technologies, development or data science skill sets, and then staffing them at their client sites. They also provide ongoing professional coaching for them so that their clients are confident they are receiving a high-quality employee, albeit a contract employee. It's an innovative model that removes a lot of the friction in the education and training space" [3]. According to the quotes presented, it becomes obvious that specialists understand that using the latest types of training is more suitable for the young generation, recently graduated from institutes.

Employees have to be trained in new technology in automated manufacturing facilities. They always won't have the time for classroom training due to their regular work.

"Myautomation solutions's" representative Lavanya, says that augmented reality (AR) and virtual reality (VR) technologies are improving training programs in plant facilities and bridging the skills gap with more efficient training for the incoming workforce—training new workers at 30–40% more efficiently and reducing assembly time. Also, advancements in AR for creating and documenting work procedures for training have shown a 37% reduction in time spent training and a 75% reduction in time required to document work instructions [4].

Introducing such technologies into the learning process, it is noteworthy that the equipment is expensive and requires a specialist for creating and maintaining such systems. Not every small- and medium-sized enterprise that does not have enough financial resources for such investments and also has a small group of permanent staff will not be able to implement such a technology. It is also worth considering that such enterprises often take students and temporary employees during the seasonal growth of orders, and then the speed and quality of training of such personnel is especially important.

6.2 Solutions for Small- and Medium-Sized Enterprises

6.2.1 Selecting Criteria for Employees Preparing

Due to the fact that technology is rapidly developing, knowledge very quickly lose relevance, therefore, it is important to maintain the level of knowledge required in the labor market. Since the whole world is in crisis due to the coronavirus pandemic, this factor should also be taken into account.

To justify the need for personnel training courses, one should turn to the existing problems:

- loss of knowledge due to quarantine compliance
- a decrease in the relevance of acquired knowledge due to unemployment
- lack of practical implementation of the knowledge gained due to lack of work experience in a certain working position.

For the experiment, two medium-sized enterprises were selected. Both have similar features:

- number of permanent production employees up to 50 people

- mass production, which depends on the season
- in the season of a large number of orders hires temporary staff
- the age group of production workers 25–70 years
- 1–2 employees are engaged in training and preparation
- working day lasts 8 h (30 min for lunch)
- a large range of products that constantly changing.

Geographically, the proposed studies were conducted on the territory of the Slovak Republic, so further statistical data are from the study area.

In order to choose the appropriate method of training, it is important to determine the target group of trainees.

The purpose of each state is to eliminate unemployment, therefore, training and advanced training of the unemployed. Due to the fact that both enterprises take temporary employees, it means that most of them will be from the group of unemployed.

Among all EU countries—Slovakia is in the 12th place among 24 countries (Fig. 6.1). This is a pretty good result, but do not forget that the statistics were made in February 2020. Now the situation has changed because of the virus, so unemployment will increase and the state will not be able to provide financial support for small enterprises, that were closed due to quarantine. Due to this fact, it becomes apparent that these enterprises will not be able to pay for training for their employees or even hire new highly qualified employees due to lack of financial resources.

From Fig. 6.2, it can be seen that the overall unemployment rate is 5.05% and this indicator fluctuates significantly, this is especially evident in the period starting from January 2020, when the COVID-19 began [7]. To pick up the appropriate way of training it is necessary to study a target group of future workers of the studied enterprises (see Table 6.1).

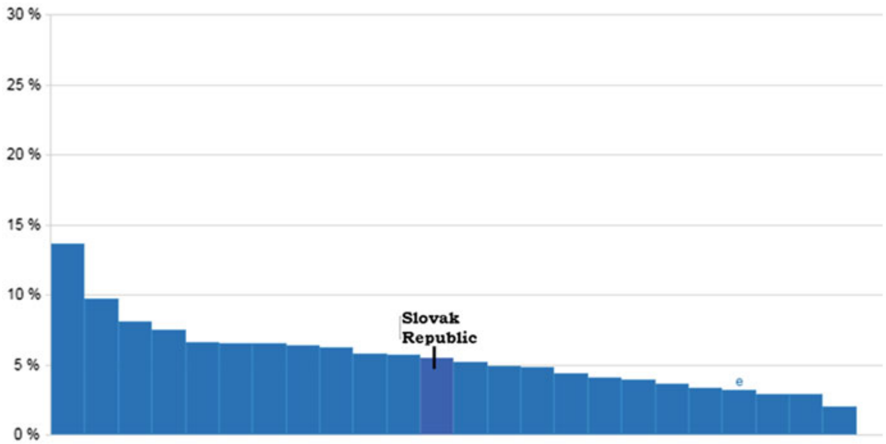

Fig. 6.1 Unemployment of EU countries 2020 year [5]

March	168865	▲	+108	5,05%

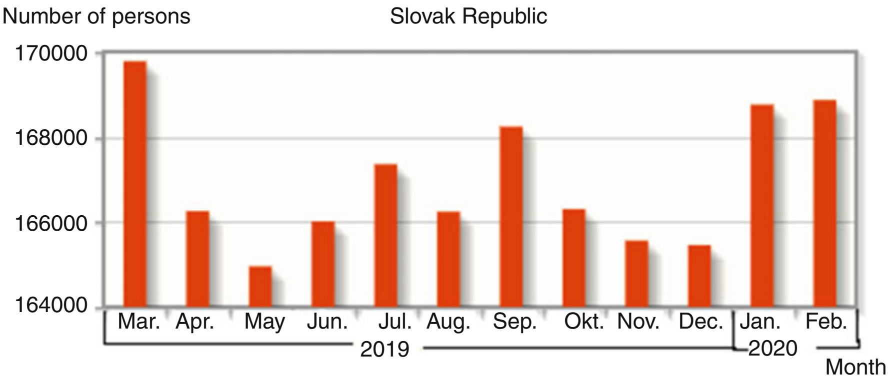

Fig. 6.2 Unemployed of Slovak Republic [6]

Table 6.1 Age structure of employed population in Slovakia [8]

People pending employment	Age groups					
	Less than 25 years		25–54 years		55 years and more	
	Less than 20 year	5024	25–29 years	18,912	55–59 years	21,042
			30–34 years	19,678		
			35–39 years	20,555		
	20–24 years	16,389	40–44 years	20,626	60 years and more	10,646
			45–49 years	19,131		
			50–54 years	18,864		
Total amount	21,413		117,766		31,688	

Table 6.1 shows that the largest number of unemployed people are in the age group of 25–54 years. Such people have long graduated from institutes and schools, therefore, they need initial training to begin to perform official duties. Since the group members have a difference in age up to 24 years, it is worth considering the level of their erudition and technical readiness when developing training programs. Programs using virtual and augmented reality for such a group of people will be difficult to perceive.

According to Gregory's theories, for most people, it is more convenient to perceive visualized information in the form of pictures, videos, as well as visual demonstrations [9]. The research of Kevin Larson of Microsoft and Rosalind Picard at MIT showed that text information is more difficult to perceive if it is not accompanied by graphic images because not everyone can focus on the text to the right extent [9]. These facts should be taken into account for design effective solutions, for investigated enterprises.

6.2.2 Practical Side of Research

Both enterprises carry out production and non-production operations. The speed of production operations primarily depends on the machine where employees make only servicing.

Nonmanufacturing operations of both enterprises include product assembly, visual inspection, technical control, revision or elimination of product defects, and packaging.

Training at both enterprises was conducted on the basis of technical documentation and drawings, where the workshop master was a trainer and showed on his example what and how to do. This approach took a lot of time for additional consultations of the employee, also it was impossible to clearly standardize processes and accurately calculate the lead time.

In order to maintain the established level of product quality and provide qualitative training seasonal staff as well as create comfortable conditions for permanent staff, it was proposed to create the appropriate type of instructions.

Based on the research of scientists [3, 4, 9] and current trends [3], the criteria for the educational material were determined:

– minimum text
– visualization of actions
– the ability to have training materials at hand
– ease of use
– with the possibility of modernization

In 2020, the most modern and relevant method of training is argument (AR) and virtual reality (VR) simulating the work processes. Such types of training are widely used by a huge volume of big corporations from all economic fields [10, 11]. According to literature resources, the price of implementation of AR or VR assembling courses will take 3–6 months, where the price of developing in Western Europe is from $80 to $150 per hour, and Eastern Europe from $25 to $100 per hour [10] (Fig. 6.3).

Such characteristics of VR application will cost $15,854 [12] but it should be noted that studied enterprises have a lot of products, which are constantly changing and adding new components will be expensive. AR assembling program will be cheapest and easier because it requires a mobile phone or tablet and a 3D model of the product. As written by Bocevska a Kotevski: “Marker based augmented reality technologies represent quite useful tools that can be used for creation of interactive visualizations of 3D CAD models. The advantages of this type of application are the opportunities to display a 3D CAD model in a real world scene, while enabling the user to interact with it in the manner of translation, rotation and scaling of the overlaid model by the simple usage of a printed marker placed in the camera viewing field. Presented visual graphics enable viewers to comprehend the core concept and features behind the design of the assembly, even if they are not from a technical background. Besides, this paper presents the possibilities to use augmented

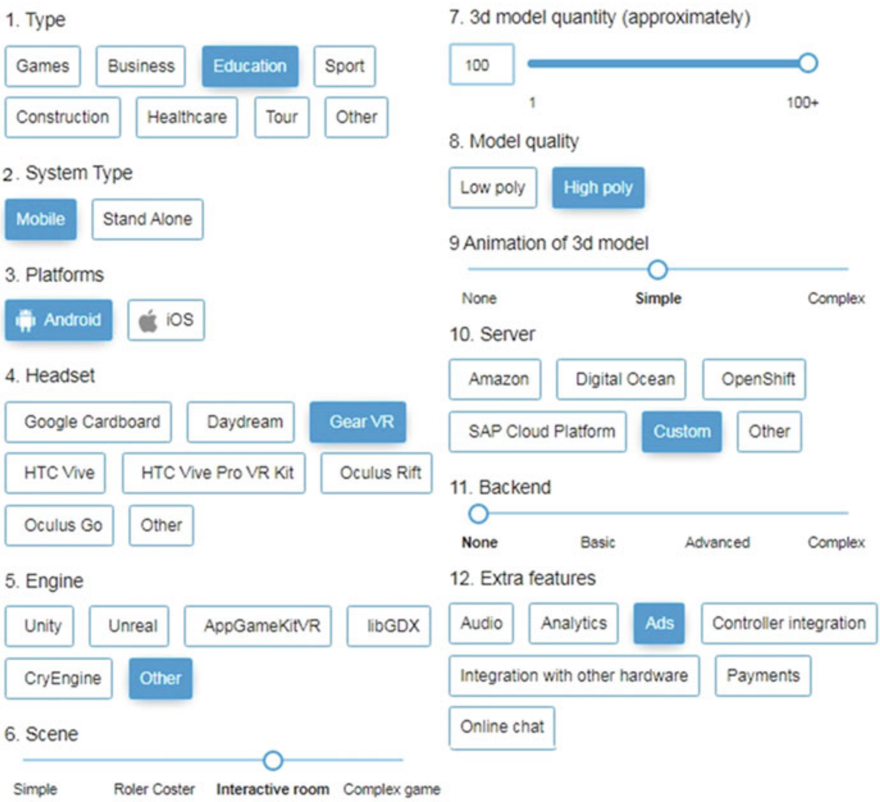

Fig. 6.3 Online calculator [12]

reality technologies in CAD assembly design supplemented with animations i.e. the possibilities to view the virtual object and its constituent parts in the real world using a marker based AR system. Such product animations also provide better overview of the final product, its performance and overall efficiency" [13].

This type of technology is very useful but it requires visual contact with object or marker and source of software as mobile phones or AR glasses—that is why it will be uncomfortable for persons with poor eyesight. If we are talking about AR glasses, it should be maintained that their workability is very poor.

In order not to demotivate the staff by setting standards, a modernization was carried out in two stages:

The first step was the introduction of photo instructions with accompanying text, where, the master explained according to the instructions and on a practical example how do this kind of job.

At the second stage, the average time of the operation was calculated. At the second stage, there was calculated the average time of each operation.

EWH [hours] = Working hours − lunch-preparing time − time for natural needs − consultations

Effective working hours (EWH) of employees were calculated in this way:

$$EWH = 8 - 0.5 - 0.5 - 0.5 - 1.5 = 5\ \text{h}$$

All times for EWH were taken for a new employee and permanent staff.

Where the consultation time included the training time, time for consultations linked with work process, and the waiting time for a mater to fix the defect of the product components.

According to this calculation, multimedia instructions were made with time limits. Where time limits were equal to the average operation time for one process. Each employee in one process performed an average of five operations (exceptions occurred when a defective component appeared).

For example, an operation lasts 1 min—this means that the video animation will loop and last a minute, after which it will switch to the next operation and this will continue until the employee stops the program.

To reduce the downtime associated with training, consultation, and photo-fixing of defects, it was proposed to integrate mobile devices to combine these processes. For convenience, a tablet with a 7-in. display diagonal was chosen, which was a tool for creating instructions and as a result, became its carrier, and was also used for photo-fixing defects [14, 15].

The device's camera, a GIF Maker-GIF Editor application [16], and PowerPoint application [16] were used to create video instructions. Thanks to the simple management interface of multimedia instruction, there were no problems with switching between animations and stopping the instruction. The instruction's program window had only four buttons: wreck, back, stop, exit. GIF pictures provided an easy perception of the workflow, and comments on images replaced additional consultations. Also, the worker was able to carry out photo-fixing of defects. Testing showed reducing of downtime from 1.5 h to 30 min and waiting time from 30 to 10 min. There was a decrease in low-quality products, the pace of assembly work improved due to the fact that the instruction was always in front of the employee and the number of errors associated with negligence also reduced.

Price of such a solution was 120 euros per worker (100 euros for tablet and 20 euros for holder). Instructions design did not require special skills from the instructor and it took one week to create the instructions for an entire current product range. Another advantage of mobile devices is that the main applications for installation workers do not consume much memory and do not require a high-performance processor, which means that the price of such devices will start from 100 euros/device.

The third stage of budget modernization of small and medium enterprises will be the use of a mobile application, where the basis for such solutions is already provided at the second stage of modernization.

The benefits of training can be summarized as:

- improves the morale of employees
- less control
- fewer accidents
- odds of promotion
- productivity increase

Functions and opportunities of mobile devices are limitless. On the third stage of modernization – permanent staff will be able to use more options of mobile devices. For example, scanning processed components (for checking how many parts were used), collect data about processes, and to get feedback from employees, reporting, and so on.

So-called mobile learning is the best ground for small- and medium-sized enterprises because it will help to provide other components of Industry 4.0. As experts in this field say: m-learning is the next step in e-learning and the future in employee training [17].

6.3 Conclusions

The main advantages of managing the plant using mobile devices are better monitoring of the workload of employees, improving the accuracy of the information, real-time shipping and order tracking, quality assurance and control, data mobilization, faster data collection, and processing. During the investigation of the problem, appsFreedom magazine found in electronic form that a regular production company prints 10,000 papers a year for one employee, which in money terms is $80 a year for one employee [18]. Properly selected programs and equipment will reduce time losses, optimize the management process, and in general, increase the level of the company in the market compared to competing companies in the market. Perspectives of implementation of mobile devices in the learning process:

- self-guided learning on worker's own schedule
- online learning when workers don't have desktop computers
- pre-training (the "flipped" model of instruction)
- post-training and spaced practice
- field-based skill demonstrations and evaluations
- on-the-job performance support
- training for employees who work remotely
- quick, nearly instant updates for employees

The use of mobile devices can reduce the time of reports, training, as well as informing employees. The phased modernization of small- and medium-sized enterprises is very important since such enterprises are very valuable to their employees and do not always have the finances for large investments in the latest technologies.

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Chapter 7
Modeling and Management of the Technical and Technological Potential for the Agriculture Sector

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7.1 Introduction

Climate change and growth of world's need for foodstuff issues new challenges for Agricultural Science. Mostly the resources of agricultural manufacturing (earth, water, and agrometeorological conditions), which is a must for each country, should be stocked by this country to make-up the deficit of foodstuffs in other countries, so that the country doesn't have to lower its internal quality of foodstuff. Unfortunately, this scenario progress is specific for Ukraine because its agricultural manufacturing is mostly resource consuming and harmful for the earth cover of productive resources (agricultural land). The main reason for this is the faulty managing department system along with the national and agricultural producers. In particular, real production management systems are characterized by subjectiveness, and deficit of reliable information resources of decision support system on the basis of information technologies [1].

The effectiveness and competitive ability of agriculture largely depend on the technical and technological potential. It is defined by the condition of technologies and the technics, which are used in processes of some manufacturing. Every year farmers solve many management problems. They are the nomenclature of cultivated and harvesting crops, their varieties and hybrids, production technologies, timely (in special agronomic terms) and qualitative implementation of mechanized operations, and their technical and resource support, and so on. Trying to solve this problem is trying to make true management solutions. With the help of this, manufacturing will be successful. Unfortunately, experience has shown that these project tasks are decided intuitively, without a special substantiation. The main problem is the

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absence of scientifically grounded methods which decide these tasks, and make some scientific and applied problem.

7.2 Literature Review

Nowadays, knowledge management is developing exceedingly, particularly in agriculture, especially, [2] collecting knowledge of projects management in the last 30 years. This knowledge aims to create different standards in some activities. The publications of management production on basics of using the Decision Support Systems appear more and more often. But in most cases they refer to its separate parts [2]. Analysis of these publications allows us to assert that the tasks of production management in agriculture are researched but unsolvable not only in Ukraine but also in the world.

Agribusiness is investigated by many domestic and foreign scientists [3]. We must seek and promote ways to manage and protect the resources that generate the world's agricultural productivity and wealth. Many researchers also assist people whose goals are to increase agricultural productivity, farm profitability, and environmental quality around the world.

So they developed methods such as: (1) the substantiation of the need for fertilization with the help of forecasting the crop yield [4], (2) the determination of the efficiency of production technologies in agriculture, and (3) the substantiation of the need of farmers in technical means [5]. The groups of the other technical and technological problems are solved intuitively. However, as we think, developed systemic and project foundation of the modeling and the technical potential management in agriculture can find new management and technical and technological problem solutions.

7.3 Research Methodology

The farmers consider agricultural manufacturing on the basis of the system approach. It includes two main systems (1) technical and technological system (Z), and (2) organizational and technical system (management system) (U) (see Fig. 7.1).

Every component executes some functions, which altogether provide agricultural manufacturing. In this case, the technical and technological system (TTS) makes qualitative transformations of labor objects (ground, seeds, fertilizers, and harvest), and the organizational and technical system (OTS) provides the forming of conditions for qualitative and efficacious transformations of these objects. Qualitative transformations of these labor objects take place organized, with the help of some technologies. They make separate projects, programs, and portfolios in the section of separate fields, agricultural crops, and kinds of project work [6]. The

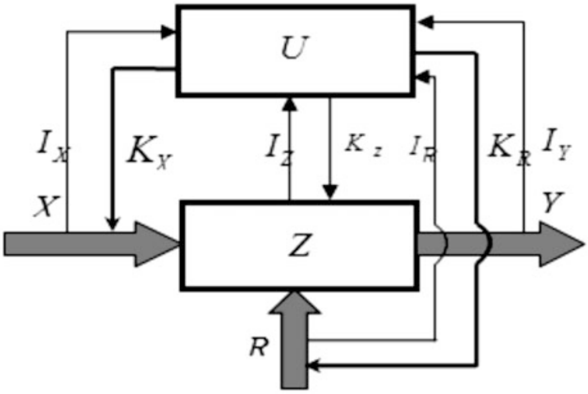

Fig. 7.1 Scheme of the system for the agricultural manufacturing: X is the characteristics of the input stream of the manufacturing contract for agricultural projects; Z is the parameters of the technical and technological system; R refers to the characteristics of resources' provision for projects; Y is the rates of the manufacturing production; I_X, I_Z, I_Y, I_R characteristics of the input information; U parameters of the technical and technological system (management system); K_X, K_Z, K_R rates of output orders

managing of these projects, programs, and portfolios are realized by management subsystems (U), which consist of managers and Decision Support System (DSS). Managers make decisions and managing difficult situations with the help of DSS, and they prove decisions in reference to the initiation of some commands for doing agricultural projects on the basis of issues. These commands can concern input streams of the manufacturing contract for agricultural projects (X), parameters of TTS (Z), and the resources' provision for projects (R).

Ongoing into the matter we can confirm that parameters of systems Z and U have some connections between them which must be allowed in the creation of agricultural projects. These connections will be called internal system connections, which we can write down in the implicit aspect:

$$Y = f\left(X, Z, R, I, U, K, T\right), \tag{7.1}$$

where Y refers to the rates of the manufacturing production in the agriculture, X, Z characteristics of the input stream of the manufacturing contract for agricultural projects and parameters of the technical and technological system for their doing(making), R refers to the characteristics of resources' provision for projects, I, U, K are the characteristics of the input information, parameters of the organized and technological system (management system) and rates of output orders, T is the duration of operation for agricultural systems (projects, programs, and portfolios).

This expression shows the systemic task of synthesis for a set of arguments that determine parameters (the function) of some agricultural outputs. Problems of analysis and synthesis are solved for defining parameters of TTS (Z) and OTS (U). Separately, one of the first problems (tasks) of the analysis is the task that determine compliance between characteristics of input streams of the manufacturing contract for agricultural projects (X) and parameters TTS (Z). The determination of this compliance is one of the main functions of OTS (U). In this case, we don't deeply prove the method to determine compliance between X and Z, so here the cause (argument) is X, and the result (function) is Z. That's why we can write down the compliance of parameters TTS (technical and technological potential) from the characteristic X in the implicit aspect:

$$Z = f\ (X, \mathrm{T})\ \text{ providing } Y = \text{exstr.} \tag{7.2}$$

This compliance is revealed on the condition that all systemic parts are fixed and they are included in the expression (7.2), and the attainment of the extreme value (rational value) Y. Simultaneously it identifies requirements to information flows I_X, I_Z, I_Y, and causes parameters OTS (U):

$$U = f\ (X, Z, Y)\,. \tag{7.3}$$

The managing of the technical and technological potential is possible on the condition that the identification of agricultural projects, programs, and portfolios will be based on many features. For the identification of agricultural projects, programs, and portfolios and disclosure of these features at first, we must show that they are objectively determined by meteorological conditions that aren't controlled by people. They are cyclically changed over time and cause their life cycles. In this case, meteorological cycles are one of the reasons, which determine the kinds and deadlines of projects, programs, and portfolios. So, kinds of agricultural projects are one of the features of their identification.

The next feature of the identification of agricultural projects is crops that are grown and gathered in some natural production conditions. These cultivated plants are characterized by their biological features that determine requirements to conditions of the growth and development [7]. The differences between biological characteristics of cultivated plants are based on requirements to the time and the content performance of corresponding projects in agriculture. They are based on the division of cultivated plants into kinds and classes.

The agricultural manufacturing is carried out on separate fields, which are characterized by the type of the soil, and many geometrical (physical) parameters (area, configuration of the external circuit, the average length of the hon (hon—a length of the plowed field in Ukraine), slope of the horizontal line, etc.). The content of operations in agricultural projects is determined by some fettle. This fettle depends on any calendar moments with regard to agricultural fields. This fettle regards to the soil environment of fields. It can or cannot permit performing mechanized works in agricultural projects. In addition, the soil environment of such fields is characterized by some type of soil, the nutrient content, and it determines the feasibility of growing crops and their potential yield [8]. So, we can consider fields as an important identifying feature in agricultural projects.

Thereby, crops, fields of these crops, and types of projects works, which are determined by meteorological (agrometeorological) conditions (cycles), are characteristic features that can identify agricultural projects, programs, and portfolios.

7.4 Results

In our research, the set of agricultural projects using crops is called "programs" because they are technologically dependent. In this case, project works are divided into seven types (1) soil tillage, (2) fertilization, (3) sawing, (4) care of crops, (5) harvesting, (6) transporting, and (7) postharvest handling and crop storage. Each of these projects is technologically connected with the previous and next project. So, they all together make a program of agricultural manufacturing according to the preset field. These projects are created gradually over time.

According to manufacturing programs (cultivation and harvesting) of agricultural products in separate fields, we can point out the portfolios of projects. They are created with the help of the merge of projects in sets in relation to different fields. In this case, each of these projects is independent from others. The peculiarity of each project is the start time of its creation that is determined by the biological features of crops and meteorological conditions of each year.

Let us approach each agricultural project as a system. We can separate its security (S_s). Indexes of this security are determined as indexes of outputs, and consumptions of resources, and the energy of its manufacturing. These features are dependent on many factors that reflect all main system parts of projects, programs, and portfolios. In this case, these factors are united factors groups [9]. Separately there are main factors: (1) objective soil (O_s); (2) objective plant (O_p); (3) agrometeorological (A); (4) manufacturing (M); (5) technological (T_l); (6) technical (T); (7) organizational scale (O); (8) social (S); (9) material resources (M_r); (10) energetic resources (E); (11) standard quality (Q); (12) financial (F); (13) management (M_n).

$$\{S_\mathrm{s}\} = f\left(O_\mathrm{s}, O_\mathrm{p}, A, M, T_\mathrm{l}, T, O, S, M_\mathrm{r}, E, Q, F, M_\mathrm{n}\right). \tag{7.4}$$

Let us determine the essence of each factor group of measures of project worth, programs, and portfolios in agriculture. The objective soil factor group (O_s) represents the quality of the soil cover every field. Additionally, there are important things too: the area of fields, their configuration, slope, the average length of the hon, the presence of wetlands, artificial obstacles (power pillars), and natural obstacles (trees, bushes), which hinder the motion of machine units. These features and the distance between the field and the place of postharvest grain crops or the temporary storage for harvested crops belong to the manufacturing factor group (M).

The objective plant (O_p) is a necessary part of the objective soil (O_s). It is determined by the kinds and classes of crops, which are in fields and their yield capacity.

The important factor group of measures of agricultural project worth, programs, and portfolios is the agricultural factor group (A). It changes the condition of labor objects (soil cover every field and crops), and it is variable (stochastic) during the project, program, and portfolio life cycle [10]. This group is changed during seasons in the year and every season in the year (summer, winter, etc.). It determines the expediency and possibility of doing the mechanized work in the fields in agricultural projects, and their start time.

The social factor group of the value is represented by the number of workers (operators) and their qualification in agricultural projects, programs, and portfolios. It shows the rate performance of mechanized works and their stops (breaks) through the physiological needs of operators.

The technological factor group (T_l) is the necessary part of factor groups of measures of agricultural project worth, programs, and portfolios. This group determines the nomenclature, content, and sequence of doing operations (works) in agricultural projects. Different technologies of doing mechanized works are the important feature of the difference of their factor groups of measures of agricultural project worth.

Technical means which are used for realizing works in agricultural projects represent the technical factor group of measures of agricultural projects worth (T). Technical means are different from the type and productively. There is a possibility of doing mechanized works that are different from the content with the help of changing technical means and technologies.

The organizational scale factor group (O) represents scales of the agricultural production of some farmers. These scales are usually represented by agricultural areas that are controlled by manufacturers.

The material resources factor group (M_r) is characterized by the nomenclature and volumes of material and technical and material and technological resources that are necessary for manufacturing.

The energetic resources factor group (E) is represented by energetic resources, which are used for the realization of agricultural programs and projects.

The quality factor group of value (Q) consists of the security of quality agricultural outputs. Every farmer aspires to have a quality production. This production must be competitive on the market.

The management factor group of measures of project worth (M_n) belongs to the main factor group too. It is represented by many features, separately the number of management personnel (managers), and the availability of technical means, etc., which are parameters of OTS.

The system (7.1) and factor (7.4) models of technological agricultural systems (projects, programs, and portfolios) represent two important conditions of their modeling. The third condition is the event reflection of system components [11]. At this stage, there are determined events, which are predetermined by these factor groups of measures, of a project worth in technological processes of the project realization.

Organizational scale factor groups (O) determine the amount (the number of farmers' fields) which help in the agricultural project realization. This set can be the main cause of their effective reflection in agricultural projects, programs, and portfolios. Every field of this set characterizes the objective soil factor group (O_s). Every year some crop is grown in some field and it is characterized by the objective soil factor group of measures of project worth (O_p). Separately we can consider each field (O_s) that helps to separate the manufacturing factor group (M) (geometrical parameters of the field and its distance to the place of postharvest grain crops). So, the organizational scale factor group (O) determines the set of fields (O_s), which are based on agricultural projects, programs, and portfolios. That's why the availability of fields forms some set of possible projects, available programs of the growing crops in every field.

Events of the start time of these programs are determined by some set in fields for each program of the crops growing. The first projects are projects of the preparation of fields to the seedtime of crops. The start time of these projects is determined by the physical condition of the soil (if it can be made for these projects), and the season that causes optimal agrotechnical terms of project creation. So, we can determine three typical events for each separate field: (1) the crop which can be grown in the field, (2) the optimal agrotechnical term preparation of the soil to the seedtime, and (3) the moment beginning of the soil condition which is acceptable for doing the mechanized operation (to start cultivator projects).

The cultivator projects are closely connected with seedtime projects of crops. In this case, the next action is the cultivator project end time. This action determines the start time of seedtime projects. We can point out different cultivator projects that are dependent on the applied technology (T_l). They can be organic fertilizers projects and cultivator projects or they can be complex projects (cultivator band projects with the simultaneous fertilization and the seedtime of crops). So, the content of projects and events of the preparation of soil and the seedtime is determined by the definite technology (T_l) which is allowed by other models.

The projects are based on mechanized technological projects, which are done by operators (executors) with the help of some technical means. So, events that are in these processes, belong to the social (S) and technical (T) factor groups. Separately, there are these events: (1) stoppages through physiological needs of executors, (2) the launching of processes after these stoppages, (3) stoppages through technical and technic abandonments of machine units, (4) the launching of these processes after eliminating abandonment; (5) stoppages of processes for technological refills of machine units; (6) the launching of these processes; (7) stoppages of processes for the unloading bunkers of combine harvesters; and (8) the launching of these processes.

Besides these processes, mechanized technological processes determine such components as the movement of machine aggregates on the field and their reversals at the end of "hons". These components provide processes of doing which are realized in projects of the soil preparation and seedtime of crops, care of crops, harvesting, postharvest handling, and yardage. The modeling of each of them has some peculiarities that are caused by applied technologies and technical means.

Each agricultural project happens (creates) with the help of some agrometeorological conditions (A). They determine the start time of crops growing in separate fields in programs and their growth and development which need the creation of technologically conditioned projects which are created after the seedtime. There are care of crops, harvesting, postharvest handling, and yardage. The stochastic character of agrometeorological conditions determines a probabilistic character of the start time for separate agricultural programs (they start with the soil preparation) and the next of their projects. So, models of agricultural projects comprise the events which are caused by agrometeorological factor groups (A). There are: (1) the start time of projects and (2) pauses of mechanized technological processes. These events are not only the function of agrometeorological conditions (A) but also objective soil (O_s), objective plants (O_p) factor groups, and the technical and technological potential of farmers. We don't reveal this function in detail in this article. We only notice that the management of this potential can't be successful without the consideration of the stochastic action for agrometeorological conditions that determine the change of the soil condition in fields and their crops.

Mentioned events and operations, which are done in agricultural projects and mechanized technological processes, are justified by agronomic and engineer sciences. At the results, they predetermine the timeliness of the creation for separate agricultural projects. It is determinative in crop forming. So, the dependency of this crop capacity from the timeliness of the creation of each separate project for programs of their growth is an integral part of knowledge for the modeling of agricultural projects, programs, and portfolios which are made by agronomic science. The amount of the untimely fulfillment of mechanized works in agricultural projects is one of the most important criteria for management problems solving with technical and technological providing of agriculture.

The stochastic action of agrometeorological conditions predetermines the possible character of the majority of events and mechanized works in agricultural projects. So, the model adequacy of agricultural projects, programs, and portfolios is achieved through using the method of statistical and imitation modeling. It provides the multiple implementations (iterance) of different agricultural projects with the help of the stochastic influence for agrometeorological conditions and possible occurrence of main events and given parameters of technical and technological equipments. The number of realized models of projects is based on the analysis of theoretical laws of distribution of random variables that characterize possible events.

If we don't deeply stop paying attention to the features of this modeling, we can single out three main steps (stages), which were developed by us. There are system and design step, value factor step, and system and event step. These steps are a methodological basis of this modeling [12].

As the results of statistical and imitation modeling, we can get some functional indexes for the realization of projects, programs, and portfolios. There are amounts of timely and untimely executed mechanized works, project lifetime cycles, operational expenses of human, energetic, material, and technical resources, and using a coefficient for fund of time for machine units. Each of these indexes is characterized by some theoretical division and appropriate assessments of its parameters. The dependency assessments of these parameters and assessments of mathematical expectations from parameters of technical and technological equipment in agricultural projects are the main basis to substantiate management decisions for changing parameters of this equipment (potential). Opposing trends such functional indexes change of projects as amounts of untimely executed works, and a using coefficient for fund of time for machine units help to determine rational (optimal) parameters of this equipment. To this end, each said functional indicator is assessed in the value or energy equivalent. The minimum percentage (which belongs to 1 ha/1 cwt), total loss value through untimely executed mechanized works, and costs of carrying out mechanized technological process correspond to the rational (optimal) parameters of technical and technological equipment in agricultural projects.

7.5 Conclusions

The management of technical and technological potential is carried out mainly on the basis of deterministic models, which do not take into account the stochastic effect of agrometeorological conditions. It has necessitated the development of new principles of modeling and management of agriculture.

Projects, programs, and portfolios are considered as technological systems in agricultural modeling. The systemic view could determine tasks of analysis and synthesis of these systems. The second stage was the definition and conceptual disclosure of the factor model of the value for agricultural projects, programs, and portfolios.

Determined three stages of the process of making a model of agricultural projects, programs, and portfolios are the methodological basis of the corresponding research and they can minimize the risk of the subjective managing decision from their technical and technological equipment. The disclosure of methodological peculiarities of the creation of projects, programs, and portfolios on each step of their research makes it possible for the substantiation of methodologies of the creation models for corresponding mechanized technological processes and systems. Stochastic influence of agrometeorological conditions on the start time of programs for cultivation and harvesting, growth, and development of crops is the basis for the choice of the statistical imitation method of modeling for agricultural projects, programs, and portfolios with the purpose of managing their technical and technological potential. Results of this modeling are functional indexes of projects, programs, and portfolios. Their cost and energetic value can prove rational (optimal) parameters of technical and technological equipment, and make many managerial decision problems.

The feature direction of the research is the disclosure of system principles of creation of automated organizational and technical systems in Agricultural Project Management. The creation of organizational and technical systems of an automated project and program management should be based on research results of management objects (technological systems) and management systems (organizational and technic systems). These researches are based on the relationships between technological and organizational and technical systems. These systems depend on their functional purpose and intersystem interactions. The systematic disclosure of interaction technological and organizational and technical systems could identify intersystem interactions, which are determined by management objects and the content of management tasks.

Solving project management problems of technological systems requires that their modeling must be based on the Monte Carlo method for projects of technological systems in agriculture.

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Chapter 8
Customization of BIM Educational Process During the COVID-19 Crisis at Department of Technology, Economics and Management in Construction at Faculty of Civil Engineering in Košice

Peter Mésároš, Jana Smetanková, Tomáš Mandičák, and Annamária Behúnová

8.1 Introduction and Problem Statement

Information and communication technologies are important in several industrial areas and sectors of the economy [1]. Innovations in materials or specific technologies are very much needed [2, 3]. These are all components necessary for growth in industries of any production. The current time, however, requires a little more. The current uncertain situation in the world requires much more innovation in every area than ever before [4, 5]. The current time is marked by the impact of the COVID-19 pandemic, which has paralyzed the functioning of several sectors. Several European countries have taken various measures to prevent the spread of COVID-19. This situation is very sensitive also because this change and circumstances have occurred very quickly. The change in conditions did not only occur in industrial areas and in the management of manufacturing companies. This current situation and development have also affected ordinary people and day-to-day operations. As already mentioned, each country has taken different measures, which have resulted in the problematic functioning of several spheres. Under the conditions of the current situation in Slovakia, industry and production areas were largely paralyzed.

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This resulted in the temporary cessation of production in selected companies. An example can be the great impact on the automotive industry, which is largely developed in Slovakia and has a significant share in GDP in Slovakia. Not only the industry itself but also other sectors are paralyzed. For example, construction is also showing signs of a slowdown in production and is also beginning to have a negative impact on unemployment and other macroeconomic indicators. Education and training is another area where the situation around the COVID-19 pandemic has brought widespread restrictions and changes. This whole situation has brought new requirements to achieve a state of basic functioning. This situation resulted in the interruption of the full-time form of study at each level of study, which represented complications, but at the same time new challenges for setting up the functioning of the given processes. The consequences of this situation resulted in the educational process of students from home, which means a huge change in the current functioning of education. The need for ICT training for industry has been of great importance over the last few decades [6]. In the situation caused by the pandemic, COVID-19 only emphasized these needs. The field of construction has long demanded the teaching of BIM technologies for practice. The implementation and expansion of BIM technologies begin with the implementation of teaching BIM technologies at faculties. This need stems from several surveys carried out in the construction industry. Several studies and researches address this issue. They also map the use of BIM technologies at the University of Zagreb [7–10]. The issue of BIM technology and the educational process is also solved by international research, in which participants from Slovenia, Germany and the Czech Republic and Croatia also participate [11]. This issue was also addressed in the framework of cooperation in research by Slovakia in cooperation with Croatia. The current global situation around COVID-19 only multiplies the need to implement information and communication technologies in all areas (industry, education, services, etc.). The Faculty of Civil Engineering at the University of Technology in Košice has long sought to imply the maximum possible level of ICT from the educational process. He also tries to bring BIM technologies closer to students. They have previously tried to customize the teaching process to the real needs of praxes and students. However, the situation during the COVID-19 pandemic has more demanding requirements for this process. Customization in education is of great importance. Students get what they need for practice and at the same time it reflects their individual requirements. Of course, the degree of customization must be acceptable by the set processes and functions of the faculty or department. The level of customization in the field of BIM technology education must intensify during the current situation. On the contrary, this also applies to the construction industry and its needs. The degree of customization of teaching the given technologies acquires a much greater meaning and need. The main goal of the research is to describe the customization of teaching BIM technologies at Department of Technology, Economics and Management in Construction at Faculty of Civil Engineering in Košice.

8.2 Mass Customization and Educational Process

The term mass customization was first defined in 1987. The term represents the way in which one type of product is produced. Production is tailored to customer specifications, regardless of the economics of production [12]. Mass customization is characterized by high flexibility in the production process. Customers directly influence the properties of the product [13]. Mass customization is the ability to design and manufacture customized products while maintaining the same level of efficiency and speed of the production process as in mass production [13].

The aim of this method of production is to bring the consumer a product or service in the required form and quality, without increasing the selling price. Mass customization is characterized by:

– Rapid response to consumer demands
– Taking into account individual requirements in the supply of goods and services
– A high degree of modularization of components (support for meeting individual requirements)
– Individual approach to the production of products and the provision of services
– individualization of services for standardized products and services [14, 15].

We know several types of mass customization, specifically (see Fig. 8.1):

– Transparent customization—the aim of this method of customization is to deliver products to measure, while the customer is not aware that the products are adapted directly to him
– Adaptive customization—the aim of this type of customization is to adapt the standardized products to the needs of producers or consumers. The settings of the product are additionally changed, without changing the final product or the final presentation
– Collaborative customization—this type of customization represents the most perfect strategy. The customer acts directly into the production process and precisely specifies his needs
– Cosmetic customization—a type of customization in which the product itself does not change, only its presentation changes [16].

Types of customization	Product		Presentation	
	change	without a change	change	without a change
Transparent customization	X			X
Adaptive customization		X		X
Collaborative customization	X		X	
Cosmetic customization		X	X	

Fig. 8.1 Types of customization

8.3 Customization of BIM Educational Process at the Study Program of Technology and Management in the Building industry

Competition is increasingly being perceived among educational institutions as well. The aim of universities is to provide the best possible environment for increasing the expertise and experience of their students. For this purpose, several innovative approaches and strategies are introduced into the educational process, which individual universities implement and incorporate into the educational process. The aim of individual universities is to adapt education to the needs of students as much as possible. It is therefore very important to support student willingness in improving and adapting the educational process. The level of quality of the educational process is directly proportional to student satisfaction, so it is important to look for ways to improve services and how to differentiate as much as possible from competitors, therefore from other universities and educational institutions [17]. Despite the growing competitive environment, schools manage their education system in the same way as they did 50 years ago. The education system is made up of traditional ways, which do not provide differentiation in order to satisfy the needs of students and maximize their potential. These “traditional” universities are increasingly fighting for their “client” with emerging subsectors—virtual universities, development companies and others [18].

There are many ways to differentiate and individualize education as much as possible. In the United Kingdom, several studies have been carried out to differentiate the guidelines and to monitor their impact after their implementation. Based on the research, four elements (see Fig. 8.2) in the class were defined:

- Content—what the student must learn and how to obtain this information (access to information)
- Process—a set of activities in which the student is involved in order to manage and understand the content
- Product—project outputs. Their aim is to stimulate students—practicing, applying and disseminating knowledge
- Learning environment—creating an engaging way of teaching and creative environment [18].

Education is during a historic shift towards a less centralized model oriented primarily to students. The implementation of innovative ways in the educational process is constantly increasing; students require the implementation of innovative technology in the educational process.

The study “The Future of Education” brought the following findings:

- 50% of students do not need to be physically present in the classroom (they prefer online teaching)
- 53% of students prefer the so-called online education
- 39% of students expect the start of the so-called virtual education

Fig. 8.2 Four elements in the classroom

– Up to 84% of students use PC when studying
– 19% of students use a tablet and a mobile phone to study
– 43% of students state that online education is education of the same or higher quality as traditional higher education
– 78% of students state that online learning is more demanding than education in a traditional classroom
– 63% of students would be interested in the so-called online internships [17].

The Faculty of Civil Engineering of the Technical University in Košice has been providing education in the field of construction for 43 years. The faculty offers 18 study programs in three levels of study—bachelor, master and PhD studies (see Fig. 8.3). During its existence, the faculty has educated more than 8000 graduates who work in various positions as successful protectants, construction managers, general managers, scientific research and pedagogical staff. The faculty is one of the leading educational institutions. As many as 89.5% of graduates will find employment within 1 year after graduation.

Students are provided with basic knowledge in the field of business management, law, principles of teamwork and coordination of specialists.

Many innovative teaching methods are used in the educational process. Undoubtedly, such innovative teaching methods include the use of mass customization, transparent customization. The aim of transparent customization is to provide students with products and services that are "tailor-made" for them, while students are unaware of the targeted profiling of education. Faculty supports the use of progressive tools such as 3D laser scanning, 3D printer, virtual reality tools and new innovative software solutions. Students of the study field of Technology and management in construction participate in the preparation and implementation of constructions. Building information modelling technology is increasingly being used in this phase.

Building information modelling is the process of creating and managing digital characteristics. Building information models are files that can be extracted, exchanged or networked. The aim is to connect and support decision-making. BIM is a source of knowledge and information that forms the basis for decision-making during the life cycle of a building [19].

BIM is a process for creating and managing information about a construction project throughout the project life cycle. One of the key outputs of this process is

Level of study	Study programs
Bachelor study	Building construction and architecture
	Civil engineering and transport construction
	Technology and management in construction
	Reailzation of transport construction
	Construction with environmental determination
	Buildings for sustainable water management in the country
Master study	Building construction
	Load-bearing structures and transport construction
	Technology and management in construction
	Technical equipment of buildings
	Load-bearing structures
	Reailzation of transport construction
	Construction with environmental determination
	Buildings for sustainable water management in the country
PhD. Study	Theory of building and environment creation
	Theory and design of civil engineering
	Theory of technology and management in construction
	Environmental engineering

Fig. 8.3 Study programs of Faculty of Civil Engineering, Technical University of Košice

the building information model. The model is based on information collected and updated in the key phases of the project. BIM collects all the information about each part of the building in one place. The technology helps to effectively integrate various aspects of the design, reducing the risk of errors or inconsistencies and minimizing costs [20].

The result of work in the environment of information modelling of buildings is a model of an object that contains graphic and non-graphic information. Individual information can be considered as individual dimensions of information modelling of buildings. The 3D model is the carrier of graphic information of the object. The model has time parameters (4D-time), cost parameters (5D-cost), information on sustainability (6D sustainability) and information on building management (7D-facility management) (see Fig. 8.4).

Education at the Faculty of Civil Engineering changed its form during the COVID-19 crisis. The faculty moved from the full-time form of study to the

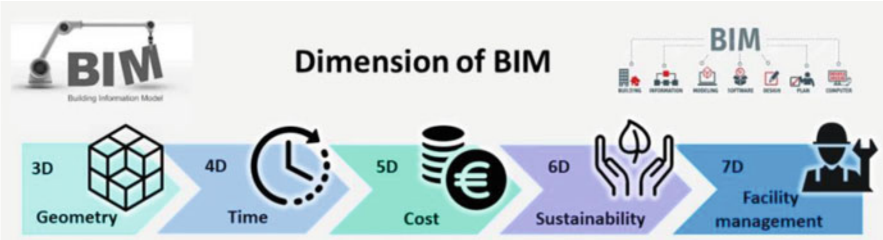

Fig. 8.4 Dimension of building information modelling

distance form of study. The use of various cloud technologies, shared databases, social networks, teamwork between students and the faculty is supported to a greater extent, the use of BIM software applications, creates online training of these applications and provides students with school licenses for selected applications.

The whole educational process has moved to the online space. The faculty has created an online account for each teacher in the Cisco Webex portals, through which all subjects are taught. Cisco Webex allows to virtually schedule lessons, create virtual rooms, virtual meetings and video conferences. The application allows you to create online exercises. The teacher creates the video metering, determines the topic, date and time. After creating the meeting, the application automatically generates a link, access code and allows to send this information to students to their student email accounts. Information about the created meeting is also shared on the portals Moodle Tuke, which represents the Learning Management System—LMS. LMS are applications that integrate various online tools for communication and study management (discussion forums, chat rooms, records, etc.) and make available to students teaching materials and online or offline teaching tools [21].

Teamwork is encouraged for students. In the last years of master studies, the study subject Team project is created in which students of individual fields of study cooperate with each other. Within the subject, students solve the assignment, the project. The aim of the faculty is to support the connection of study with practice. Therefore, projects are selected from external contractors, whether private companies or the public sector. Currently, students are working on a project to restore the House of Culture in Svidník. Members of the team project are the assignors (the town of Svidník), project coordinators (tutors within the study fields) and students—solvers of project documentation—design of structures of the building, static design, design of construction site equipment and other (see Fig. 8.5).

Individual team members work up their part of the project in BIM software applications. Teaching takes place online, individual team members (students, investors and tutors) communicate and share their solutions and ideas through the Webex platform. As part of the consultations, a meeting room is created, where students and tutors share their plans and explain their solutions. The advantage of a given online conversation is the ability to record video and audio, which leads to a perfect

Fig. 8.5 Structure of team project

recording of all stimuli, whether by students, investors or tutors. The research team is divided into four areas of design: design, static solution, consideration of the environmental aspect and preparation and implementation of constructions. The result of this cooperation is the preparation of project documentation for the construction, technical equipment of buildings, static solutions, environmental assessment of the building and at the same time a work schedule, construction budget and construction organization project are compiled.

The faculty is increasingly supporting the implementation of information modelling of buildings in construction processes. Within the subject Technological project, students are creating an information model of the building. Students are provided with 2D project documentation, which then model in selected BIM software applications such as AutoCad Revit. Within the mentioned subject, students are provided with student licenses for selected software applications. As part of the exercises, online tutorials are prepared on how to work in the given software environment.

In addition to supporting the creation of 3D models, students are also acquainted with the time and economic planning of construction. Students create construction budgets and time schedules. Within the subject Technology of construction of buildings and units, students are explained through online meetings various forms of time planning—schedules, cycloramas, histograms of materials, machines, workers and the other. Subsequently, students are presented with information in which BIM software applications it is possible to create the same time schedules and what is their creation process (see Fig. 8.6).

The customization of the teaching process was also at the course Economic Information Systems. This course was the first to start online teaching since the first week. The online form is suitable for this subject and it was not problematic to provide the entire content to the online environment. During one lecture, students also attended a webinar with the partner company Kros, which is a leading company in the field of development and production of construction and economic software. Enterprise information systems, their modules and BIM technologies that are taught in the subject have been moved to the online environment. The bulk and student versions also allowed access from home. This form of customization for a given subject ensured 100% content for students and at the same time saved their time. The

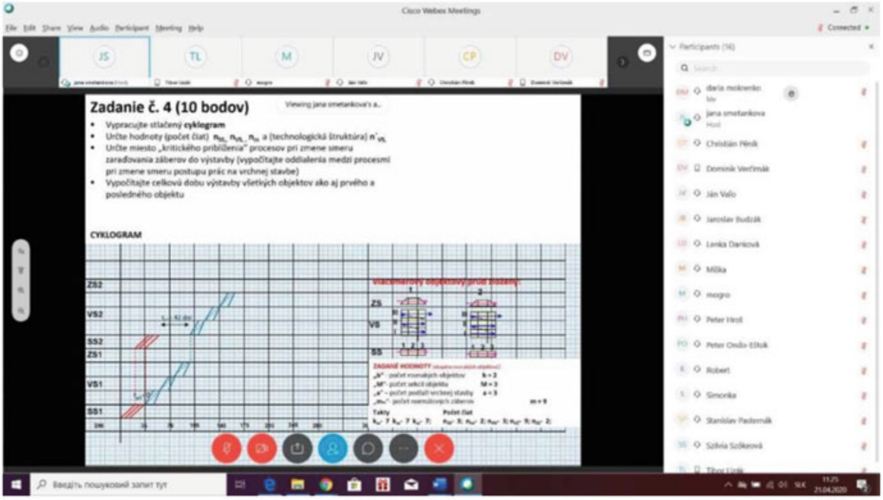

Fig. 8.6 BIM software applications and schedule creating by Webex meetings

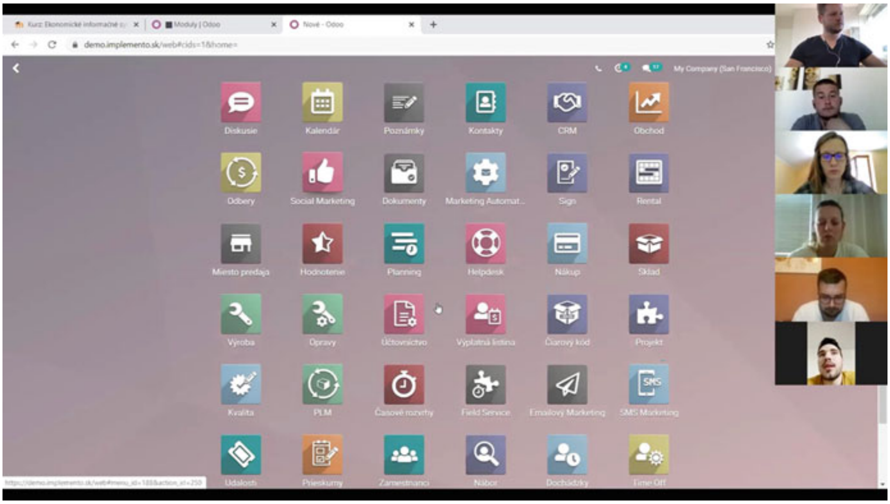

Fig. 8.7 Economic Information System lecture by Zoom platform

online lectures were conducted via the already mentioned Webex Meetings platform from Cisco, or via the Zoom platform, as can be seen in Fig. 8.7. The process of presentation of selected information systems during the lecture and mediation of information content to students can be seen in Fig. 8.8.

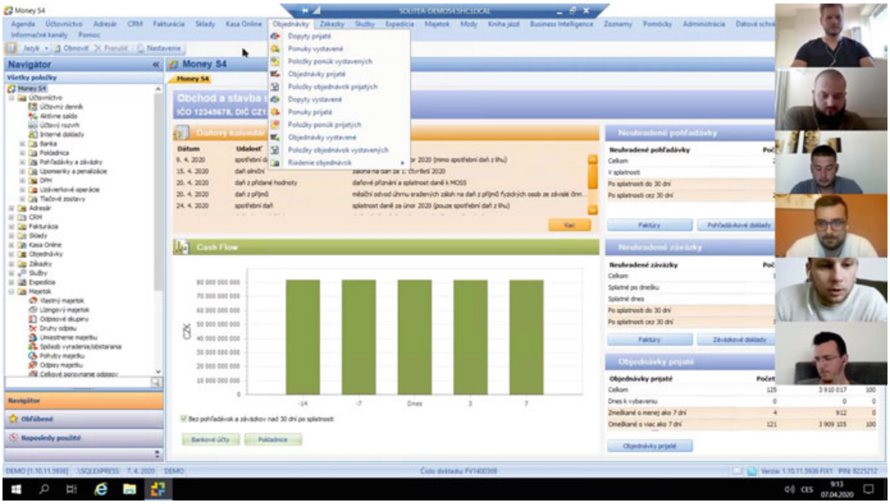

Fig. 8.8 Presentation of economic information software by online platform

8.4 Conclusion

The issue of customizing the educational process is a much-needed topic that needs to be addressed. In general, internships argue that students need to be educated so that the content is consistent with what the internship needs. Customizing the educational process and content is one way to achieve this. BIM technology is one of the most sought after requirements for practice in this area. Mediation and implementation of this process into the teaching process are very necessary for the construction industry in every country. The rate of customization and the needs of construction and students should be as high as possible. This well-started process at the Faculty of Civil Engineering, Technical University in Košice is positively evaluated by practice, but also by students. However, with the current situation associated with the COVID-19 pandemic came a new challenge. The established process had to change quickly as the full-time form of the study was suspended. The construction market, but also students, still demand the content needed for a successful career and work in the field. This situation had to change quickly. The Study Program of Technology and Management in the Building industry study program showed a high degree of flexibility and adaptability. Several subjects, where the customization of content for students was also in the use of information and communication technologies and BIM, had to be adapted to current conditions. It could be said that the degree of customization has increased even more. This situation also confirmed the importance of the implementation of information and communication technologies in all areas and industries. This is an important finding that confirms several previous studies. The rate of customization is slightly higher due to the COVID-19 pandemic and subsequent measures in securing the teaching process. This is where the need for customization and the advantage of its application in the field of education was confirmed.

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Chapter 9
Impact of COVID-19 on the Use of Innovative Technologies in the Construction Project Management

Peter Mésároš, Jana Smetanková, Katarína Krajníková, Tomáš Mandičák, and Marcel Behún

9.1 Introduction

Construction project management (CPM) is a complex process that must be supported by innovative technologies. Innovative technologies have several indisputable advantages that have a positive effect on efficiency and productivity. Implementing innovative technologies is a demanding process and does not always grow as fast as needs [1]. In the process of managing construction projects, we often speak of innovative and information–communication technologies. The current situation is new and the effects of the COVID-19 pandemic are changing the functioning of common areas, but also companies, manufacturing industries. The possibilities offered by innovative technologies are great. On the one hand, their demand may be negatively affected, due to the impact on the reduction of production and the decline of the economy. On the other hand, there is room to move many processes into digital form. In this area, it is assumed that the current situation, on the contrary, will accelerate the implementation and use of these technologies [2].

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9.2 Problem Statement

The current situation has brought many changes that must be taken into account when managing construction companies. Construction project management is a demanding set of activities that has several phases. Effective management begins with the right planning and thus the pre-project phase [3]. This process requires a number of innovative technologies to facilitate and streamline the management of construction projects. In the implementation and construction phase, the need for implementation is equally great. In general, the implementation of these technologies entails certain capital expenditures that the construction sector is not always able to allocate in the required form. Several studies have shown that one of the reasons for the low level of implementation of innovative technologies in construction is the high costs associated with implementation. To this is added psychological barriers in the form of rejection of new technologies and changes in general. Therefore, several studies have pointed to the slower implementation of advanced technologies in the construction sector. On the contrary, larger companies, which often use foreign capital, invest more in these technologies. Innovative technologies in the management of construction projects such as BIM technologies, knowledge technologies, communication technologies, or increasingly the expansion of various types of reality solutions in the long run are an effective tool and their implementation is more than desirable [4]. The implementation and use of new innovative technologies are influenced by several factors. On the one hand, there are the mentioned costs for the implementation and operation of these technologies. On the other hand, it is a personnel issue and the reluctance of people and managers to accept changes and new technologies and materials [5]. The third large group are fundamental and behavioral phenomena and the associated social conditions and situation. The influence of individual factors is addressed by several researches and studies. Their seriousness has often been confirmed and depended to a large extent on the social situation. Investments in new technologies will always be an obstacle to their intensive use. However, the perception of the value of investments changes over time. In a period of growth and expansion, construction companies are more willing to invest in new technologies. On the contrary, in times of crisis and negative situation, it is assumed that these investments will represent a high value and thus a reluctance to invest in new technologies, which results in a lower rate of utilization. There is also a basic scientific question and consideration. What is the impact of the current situation on the use of innovative technologies? The current situation around the COVID-19 pandemic has changed the functioning of several sectors, including construction. Processes set up in management must be modified. On the one hand, there is an assumption that, in view of the above, mainly economic reasons, there will be a reduction in investment in new technologies and thus a reduction in the use of selected innovative technologies. On the other hand, there is pressure to digitize processes and more pressure to use these technologies. It is very likely that this will have a different impact on different types of innovative technologies. This research carried out during the months of March and April, when measures against the spread of COVID-19 are the most intensive in Slovakia, also deals with the use of these technologies. Our assumption is that the utilization rate is different than in the pre-crisis period. Any different results will be evaluated on the basis of exact statistical methods. These differences should also be between the individual phases of construction projects. This means focusing on comparing the results of the project phase and the implementation phase of construction projects.

9.3 Innovative Technologies in the Construction Sector

Developments in the construction project management are influenced by innovative and new technologies. New modern technologies and systems represent innovative solutions that bring several benefits such as shortening the construction time, eliminating unwanted consequences, and supporting the adaptation of complex system solutions.

Among the innovative technologies that are increasingly used is the *Virtual Reality (VR).* Virtual reality represents the next level in 3D modeling (see Fig. 9.1). VR offers a detailed virtual model. The advantage of this technology is that the user is directly placed in a virtual environment [6].

Technology changes the way management and the course of production. In construction, virtual reality is used primarily to support 3D modeling and adaptation with building information modeling (BIM). The easiest way to create a VR model is to combine laser scanning and BIM. Laser scanning is characterized by high

Fig. 9.1 Virtual reality [7, 8]

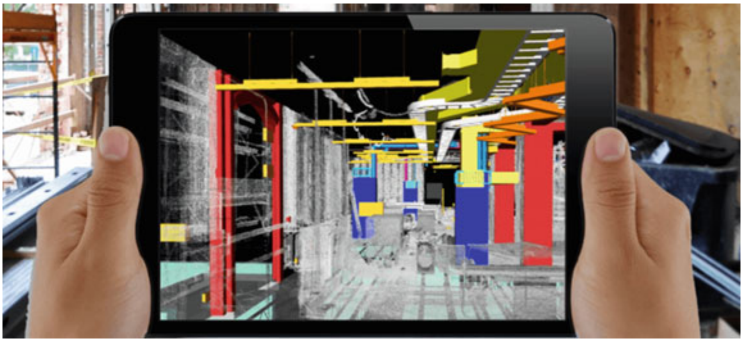

Fig. 9.2 Augmented reality [11]

accuracy, especially with complex geometries and hard-to-reach surfaces. Virtual reality also supports cooperation between individual participants [6].

The use of virtual reality brings several benefits, the most frequent being:

- Fast zoom of models—the VR application enables faster and more accurate creation of a detailed model and supports the exchange of information
- Support and improve collaboration—improve real-time team collaboration in a shared environment
- Improving the "customer experience"—increasing transparency—customers follow a virtual model, thus eliminating the risk of misunderstanding the project documentation. The virtual model is constantly updated. In case of problems or questions, customers can solve them immediately in the VR environment, which reduces the time required for the solution and increases the efficiency of problem-solving
- Support for educational technologies—VR can be used to simulate real situations and to provide the practical experience needed to train staff
- Cost savings—improvement of the planning phase, elimination of incorrect understanding of project documentation
- Improving quality—VR offers a common working space that leads to better decision-making [7].

Augmented Reality (AR) is a technology that integrates virtual elements into a real environment. AR makes it possible to import virtual architectural designs into a real environment (see Fig. 9.2). Technology increases accuracy and efficiency, reducing time, money, and resource management errors. Augmented reality is one of the best technological advances in construction, as it makes all processes more efficient. It supports project planning, enables automated measurements, project modifications, and facilitates team collaboration [9].

The advantages of using Augmented Reality include:

- Accuracy of construction projects—increasing accuracy eliminates time and financial loss. Prior to implementation, the AR will provide an overview of the entire project, including all details

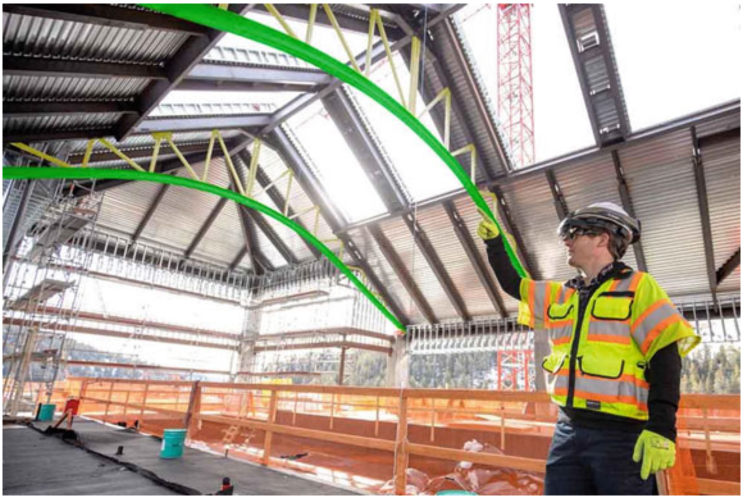

Fig. 9.3 Mixed reality [13]

– Financial and time savings—allows easy modification of the 3D model in the interior of buildings while maintaining the external appearance
– Project management—real-time visualization improves estimation (automated measurement and 3D models) and planning
– More thorough analysis of the project
– Improving construction processes—team members have quick and instant access to virtual models [10].

Mixed reality (MR) combines real-world objects with digital content through interactive real-time tools (see Fig. 9.3). Together with holographic technology, it transfers models from the software environment to the real environment. Technology effectively interprets physical and digital information and the spatial relationships between them. Projected holograms appear alive and can move, shape, and change according to user interaction or the physical environment [12].

The advantages of using Mixed reality include:

– Increase productivity and efficiency—users have easy access to modeling data in a BIM environment. By visualizing and "navigating" projects in the digital world, teams can guide change faster
– Speed up the construction process and identify possible problems faster
– Support for collaboration between the office and the site—site workers can identify exactly what task to perform and can send feedback immediately, thus improving the identification of conflicts or differences between model and reality
– Quality assurance and control—support for quality coordination and elimination of various risks
– Speeding up decision-making and reducing downtime

- Maximizing BIM investments to monitor progress—MR accelerates the detection of irregularities and ensures the quality of production
- Increasing confidence and reducing staff training
- Rejuvenation of the team [12].

Knowledge systems are used to exchange and manage knowledge. Knowledge systems or databases support the collection, organization, and acquisition of knowledge. Knowledge systems are not just a space for storing data but support artificial decision-making with the help of artificial intelligence tools [14].

Knowledge bases are created in software applications for the right knowledge. Knowledge management software helps the user to create, identify, organize, and exchange information assets. The software stores knowledge, information and manages procedures, documents, policies, and databases so that all information is easily accessible, browsable, and consistently updated [15].

The use of knowledge systems brings several advantages in the management and planning of construction production, such as:

- more effective teamwork
- greater certainty and more effective decision-making
- elimination of errors
- reduction of duplication of work
- faster and easier access to the most important and up-to-date information
- improving the connection between partners, projects, and parts of the organization
- support for innovative thinking
- support of communication between individual participants
- increase customer satisfaction [16]

Building Information Modelling (BIM) is a tool that increases the digital skills of individual construction participants. BIM is the process of delivering assets using well-structured digital information. The availability of digital information to all stakeholders is a priority [17].

The BIM model is a multidimensional model that displays graphical and non-graphical information. Individual information can be considered as dimensions of the model. Based on these facts, we recognize seven dimensions, namely 3D—geometric representation, 4D—time parameters, 5D—cost parameters, 6D—information on sustainability, 7D—facility management [18].

The main advantages of using BIM in practice are:

- increasing labor productivity
- time-saving
- elimination of errors
- control of the whole project
- greater competitiveness
- higher profitability of the project [19]

Another innovative technology that most companies use daily is *video conferencing*. *Video conferencing* is a technology that allows users to created so-called long-distance meetings. The joint meeting will take place without the necessary transfer to a commonplace. The advantage of using this technology lies primarily in saving time, costs, and problems that may arise during the business trip. Video conferences are mainly used to organize regular meetings, negotiate business offers, or interview job seekers. A significant advantage of video conferencing is the ability to connect audio and visuals, which can help develop stronger relationships. No special technology is required to conduct video conferences; it is enough to count on a video camera and a microphone or a smartphone. The disadvantage of videoconferencing is the need for a stable and high-quality Internet connection, which can be quite demanding in some cases [20].

9.4 Methodology

9.4.1 Research Aim and Hypotheses

The research is focused on the issue of technologies using changing in project phase and realization phase during the pandemic COVID-19 situation. We focused on six types of technologies—Online meetings, BIM, Knowledge Systems–Databases, Virtual reality, Augmented Reality, and Mixed Reality. The respondent's opinion was found out using Likert-type scale. Based on theoretical background, it was set as the main research aim to analyze the impact of pandemic situation on using modern technologies. This main aim was supported to part aims:

1. Check the normality a dependence of measured data
2. Bulk comparison of changes over all types of technologies and in every phase of construction separately
3. Pairwise comparisons of these groups and results arranged in ranked form

9.4.2 Data Collection and Research Sample

Data collection was conducted by online questionnaire. All participants of construction project created a research sample. Especially, there were 22 companies/respondents as a builder, investor, contractor–main contractor, contractor–subcontractor, designers, and state administration bodies divided into at least two phases—project and realization phase. These companies were divided according to the size of microcompany (0–9 employees), small company (10–49 employees), medium-sized company (50–249 employees), and large company (250+ employees). In Slovakia, there are a few large companies. In our sample, there were only two large companies. With regard to the research sample, it could lead to create incorrect general conclusions. Therefore, a general view on situation, without company size factor, was used.

To determine the answer Likert-type scale ranking was used. The Likert-type scale is commonly used in survey research especially from social science, management, marketing, education, tourism, healthcare, and other disciplines to measure the respondent's attitude by asking insofar to which they agree or disagree with a particular question or statement presented. A typical scale that was frequently applied by majority of researchers might be "strongly agree, somewhat agree, not sure/undecided, somewhat disagree, and strongly disagree." At the outset, survey data using Likert-type scale may seem easy to analyze or to identify the factors involved in the study, but there are other important issues that should be addressed for a data analyst to consider it. This is because the implementation of the Likert-type scale in analysis has become one of the main interesting techniques for each researcher and scholar lately. The extent and interval values for each stage of the scale were thoroughly explained to the respondents [21].

9.4.3 Research Steps and Methodology

First, it was set as problem statement based on theoretical background. It was set as research questions and hypotheses in this issue. Next step was data collection. In sense of statistical evaluation, first, the normality of data had to be tested. The normality assumption needs to be considered for validation of data presented in the literature as it shows whether correct statistical tests have been used [22]. For this, it was used a very common test called Kolmogorov–Smirnov test of normality. It is a test for normal distribution, which is leading to good results even with a small number of observations (respondents). The desired significance level alpha in all used tests in this methodology was used 5%. The desired hypothesis for Kolmogorov–Smirnov test tested if (H_0) research sample does have normal distribution against hypothesis (H_1) research sample does not have normal distribution. Most of research sample did not have a normal distribution. Based on this result, the Kruskal–Wallis test was chosen as nonparametric alternative to ANOVA test and focused on all of the groups at once. If one group has different mean rank, better to say variance rank, the test rejects the null hypothesis, and then post analysis is needed to find out softer differences. All gained results are shown in Sect. 9.5.

To confirm our hypotheses about mean ranks in all of the groups at once, the very common used Kruskal–Wallis test was used. It relies on the rank ordering of data rather than calculations involving means and variances, and allows you to evaluate the differences between three or more matched samples. The Kruskal–Wallis one-way analysis-of-variance-by-ranks test (or H test) is used to determine whether three or more independent groups are the same (H_0) or different (H_1) on some variable of interest when an ordinal level of data or an interval or ratio level of data is available. A hypothetical example will be presented to explain when and how to use this statistic, how to interpret results using the statistic, the advantages, and disadvantages of the statistic, and what to look for in a written report. This hypothetical example will involve the use of ratio data to demonstrate how to choose between using the nonparametric H test and the more powerful parametric F test [23]. When the p value is such that the H_0 that groups have identical variance against H_1 hypothesis that groups do not have identical variance has to be rejected, then at least one sample (or group) is different from another. To identify which groups were responsible for reject H_0, multiple comparison procedure called Wilcoxon sign-ranked test was used. If we are willing to make the assumption that the parent population is symmetric, the Wilcoxon signed-rank test statistic provides an alternative test of location which is affected by both the magnitudes and signs of these differences [24]. For the needs of this article, it is not important to describe the calculation procedure.

The last step was ranking technologies according to mean and according to results of multiple comparisons. The gained ranks of these two approaches were compared and little discussed because of the similarity of these ranks.

9.5 Results: Use of Innovative Technologies During the COVID-19 Crisis

In the first step, all types of technologies were monitored with the respect to every phase. Kolmogorov–Smirnov test was used to determine if the null hypothesis of normality is a reasonable assumption regarding the population distribution of a random sample. The desired hypotheses were that (H_0) research sample does have a normal distribution and (H_1) research sample does not have a normal distribution. In three cases for every phase, the null hypothesis was rejected and the normal distribution was not detected (red-colored numbers). But, generally, it could not be said that research data were normally distributed, so then it had been used nonparametric tests in comparisons of these cases. In Tables 9.1 and 9.2, except for normality, the basic characteristics as mean, standard deviation, skewness, and kurtosis of our samples were calculated.

Table 9.1 Descriptive statistics of samples and the normality test (project phase)

	Online meetings	BIM	Knowledge systems	VR	AR	MR
Mean	0.7273	−0.3636	−0.2727	−2.0000	−1.7273	−1.3636
Standard deviation	2.4155	2.5681	2.2998	1.9069	2.0929	2.1856
Skewness	−0.6951	−0.1173	−0.1219	0.0000	−0.1348	−0.1137
Kurtosis	−0.5120	−0.7753	−0.3408	−2.0834	−2.0769	−1.6259
p Value	0.41531	**0.04658**	0.40026	**0.02417**	**0.00875**	0.05233

Values less than 0.05 mean that we do not reject the HO hypothesis. The data are of normal distribution in these cases.

Table 9.2 Descriptive statistics of samples and the normality test (realization phase)

	Online meetings	BIM	Knowledge systems	VR	AR	MR
Mean	0.2727	−0.5455	−0.7273	−2.0000	−1.8182	−1.6364
Standard deviation	2.7991	2.6064	2.2600	1.9069	2.1242	2.1856
Skewness	−0.2750	0.0887	−0.4671	0.0000	0.1107	−0.1109
Kurtosis	−1.4338	−0.9210	−1.3728	−2.0834	−1.9366	−2.0568
p Value	0.30786	0.20772	0.07929	**0.02417**	**0.02791**	**0.01751**

Values less than 0.05 mean that we do not reject the HO hypothesis. The data are of normal distribution in these cases.

Table 9.3 Results of Kruskal–Wallis test

	Project phase	Realization phase
H value	21.3103	13.0716
F	4.35	2.76
p Value	0.0007	0.0126

Table 9.4 Ranks of technologies (two views)

Rank	Mean difference between phases	Pairwise comparison between technologies in every phase separately
1	Online meetings 0.73	Online meetings 91.682
2	Knowledge systems 0.46	Knowledge systems 74.591
3	**MR 0.37**	**BIM 72.5**
4	**BIM 0.28**	**MR 59.227**
5	AR 0.18	AR 53.227
6	VR 0.09	VR 47.773

Based on the tests, the order of use of technologies was determined. Highlighted items indicate discrepancies in order.

The second step was using Kruskal–Wallis test, which (as it was assumed) provided that H_0 could be rejected in both cases (phases) so our groups did not have the identical mean rank (Table 9.3).

The last step also provided rank groups (technologies) according to mean of every considered phase. The obtained ranks were the same. The small differences were only on third and fourth positions in using BIM and mixed reality. Due to the small number of analyzed data, some general conclusions for the use of these two technologies would not be made. All of the technologies were used more in project phase than in realizations phase (positive numbers in Table 9.4 in the second column). In online meetings have seen **the** largest using increase (some boom effect) between phases which is the factor that is observed during pandemic situation generally.

9.6 Conclusion

The issue of using innovative technologies seems to be an important topic. Several researches have pointed out the justification for solving this problem, which leads to the opinion that in the case of determining the real state of use, it is possible to draw conclusions and set processes in the management of construction projects so that they are effective. The current situation on a global scale is characterized by a high degree of uncertainty and change in a short time. This also forces construction companies to be more flexible and willing to adopt new technologies. The results of this research also point to some facts. If there was a presumption of use, a perspective of different use in the period before and during the crisis, then some of these statements proved to be correct. However, it must be said that for some technologies they showed only a trend, but were not confirmed by exact statistical methods. On the contrary, some innovative technologies, such as communication technologies supporting online communication and electronic data interchange, have been confirmed by statistical tests. Their use is really different both in the individual phases of the construction project and at the same time in the period. The use of mainly online meeting solutions is on the rise and it is possible to expect intensive use in the future. The effects of COVID-19 were also noticeable in this area. This probably started the process of digitization and increased use of technologies ensuring the transmission of data and information, support for the electronic exchange of documents. It is appropriate to continue collecting data in this area and to evaluate it at intervals. From a scientific point of view, it will be interesting to examine and analyze research results.

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Chapter 10
UAV Forensics: DJI Mavic Air Noninvasive Data Extraction and Analysis

Siniša Husnjak, Ivan Forenbacher, Dragan Peraković, and Ivan Cvitić

10.1 Introduction

Unmanned aerial vehicles (UAVs), also referred to as drones in the literature, can be defined as an aircraft piloted by remote control or an onboard computer. UAVs can be considered as a part of the broader unmanned aerial system (UAS), which encompasses UAV, ground control station (GCS), controller, and associated applications [1].

The UAS technology is a rapidly emerging technology and it has found widespread usage. According to the report available at [2], the global UAV market will grow from \$14 billion in 2018 to over \$43 billion in 2024 at a CAGR of 20.5%. Considering the increasingly popular use of UAVs, it is evident that there is potential for them to be used in crimes. Also, criminal UAV operations are increasing rapidly and criminals are constantly developing new approaches. This demands a forensics investigation. UAV forensics is valuable for many types of UAVs investigations, including:

- Commercial aerial surveillance
- Disruption of airports and air traffic activities
- Smuggling of drugs, smartphones, knives, or guns—often into prisons
- Oil/gas/mineral exploration and disaster relief
- Delivery of improvised explosive device into public places by terrorists using UAVs
- Invasion of privacy by press or paparazzi
- Espionage of security and intelligence agents

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The camera mounted onto a drone, either as a static recording or a live streaming device, raises significant data privacy concerns for organizations and the public. Also, the ability of drones capturing pictures or videos of operations in designated no-fly-zone areas of airspace, such as airports, military base, and power stations, presents a significant security threat [3]. This urges the research community to develop techniques to detect and prevent illegal activities which involve UAVs.

UAV is an example of a widely used technology that requires the collection of a solid body of evidence to help eliminate potential real-world threats [4, 5]. Despite its increased importance, UAV forensics is still a relatively unexplored research topic. Commercial tools (e.g., Cellebrite, Oxygen Forensic, MSAB) are in their early stages when it comes to UAV forensics. This is because of the different types of drones which require a log parser and visualizer, which support all types of available software [4].

This research paper presents the acquisition and analysis of important digital artifacts found on both the internal memory of the UAV and the controlling application. Forensic analysis of flight logs, media files, and other important files of UAV and controlling application for identifying digital artifacts was done by a commercial forensic tool that meets all the guidelines on the admissibility of evidence.

10.2 Previous Research: Literature Overview

UAV/UAS forensics is a relatively new and less studied domain, in comparison to other popular consumer devices and technologies, such as computers and mobile devices. Only a few research papers performed some type of UAV, UAS, or drone forensics.

Research [6] presents an introductory discussion of UAV analysis and provides the results of a digital forensic investigation of a Parrot Bebop UAV. Further, research [7] performed a forensic investigation of an UAS—the DJI Phantom 2 Vision Plus. Research [8] thoroughly conducted a forensic analysis of the DJI Phantom 3 drone and the primary account for proprietary file structures stored by the examined drone. It also presented forensically sound open-source tool DRone Open source Parser (DROP) that parses proprietary DAT files extracted from the UAV's nonvolatile internal storage.

Authors in [3], presented the extraction and identification of important artifacts from the recorded flight data as well as the associated mobile devices using open-source tools and some basic scripts developed to aid the analysis of two popular drone systems: the DJI Phantom 3 Professional and Parrot AR. Drone 2.0. Further, research [9] presented a forensic analysis of UAV to obtain GPS log data as digital evidence.

In research [10], a forensic investigation on an UAS was performed, specifically the DJI Mavic Air, using an iOS-based smartphone device. This study examined the data that can be extracted from the UAS in addition to investigating and analyzing the logical acquisition of the associated smartphone device created by Apple's iTunes backup utility. Research [4] examined digital evidence and artifacts using the benchmark drone forensic images of the Yuneec, Inc. Typhoon H UAV, and authors in [11] examined and analyzed the data extracted from four DJI drone models.

Most of the mentioned research papers focused on digital forensic investigation involving free and/or open-source software for data acquisition, analysis, and reporting. Further, regarding data parsing and encryption, most of them used open-source tools.

As many research papers, the investigation presented in this paper is focused on the investigation of available DJI UAV, but the main difference regarding other studies involves the usage of commercial forensics tools regarding all of the investigation phases—acquisition, decryption, parsing, analysis, and reporting—thus providing forensically sound and acceptable investigation.

10.3 Sources of Data/Information/Evidence

UAVs are a potential source of evidence in a digital investigation, partly due to their increasing popularity in our society [1]. The artifacts that may be contained by a UAV could be analyzed in two groups such as physical and digital evidence. Physical evidence contains UAV, flight controllers, sensors related with drones, ground control stations, mobile devices and applications, etc. Digital evidence is located on the physical devices and their storage and communications links: the UAVs, batteries, sensors, remote controller, the GCS station, and on any devices used to control the UAV or process its data. In this research paper, the focus is on digital evidence.

After capturing the UAV, a forensic analysis can provide a lot of information about the potential suspect of a crime based on the data gathered from onboard sensors and other electronics that assist with flight and navigation, as well as the camera and digital storage [3, 12].

The sample UAS which was used in this research is DJI Mavic Air, which consists of two main components: the UAV and the GCS; it has four propellers, a stabilized gimbal and a 4K resolution camera, GPS antennas, a MicroSD card slot, and a USB-C port. The aircraft also has 8 GB of internal storage. The GCS consists of the remote controller and the mobile device that is used to run the DJI GO 4 application. The Mavic Air utilizes a Wi-Fi transmission system and can fly for 21 min with a maximum flight distance of 10 km [10]. UAS contains not only the UAV but also the whole system which is used for airworthiness such as GSCs, mobile devices, connected applications, cloud services, communication links, etc.

UAVs will routinely create and store usage logs that can include details such as mission details, time and date of operations, and navigational waypoints during use. This data will generally consist of GPS positions, motor speeds, altitude, and directional information [13]. UASs contain four general types of data that could be presented as evidence, explained further in Sects. 10.3.1–10.3.4.

10.3.1 DAT File(s)

First one of the artifacts that sample UAS (DJI Mavic Air) contained was a DAT extended binary file. This file is located on the nonvolatile internal memory of the UAV (8 GB capacity regarding DJI Mavic Air). It was found in [14] that the UAV creates a new DAT extended file on every startup.

Regarding DJI Mavic Air, these DAT files extracted from UAV are encrypted and encoded, but DAT files extracted from a DJI GO 4 application were not encrypted. The structure of a DAT flight record files, generally speaking (when DAT files are not encrypted and encoded), is presented in Fig. 10.1.

Analysis of these data can reveal the actions of the drone during flight. For example, GPS coordinate can reveal from where the drone took off, or in the event of a crash, battery levels can reveal the time when the drone failed as it can be correlated with time. These data can also be used to reconstruct the flight, which is especially important when the drone has been used in smuggling or other flight-related crime [3].

UAS data, when correctly extracted and accurately analyzed, provide valuable intelligence about launch locations, flight profiles, and logistical and operational linkages, and data packet types which can be found in DAT file are presented in Table 10.1.

The UAV should not be turned on as turning it on changes data on the UAV by creating a new DAT file, but may also delete stored data if the drone's internal storage is full [8].

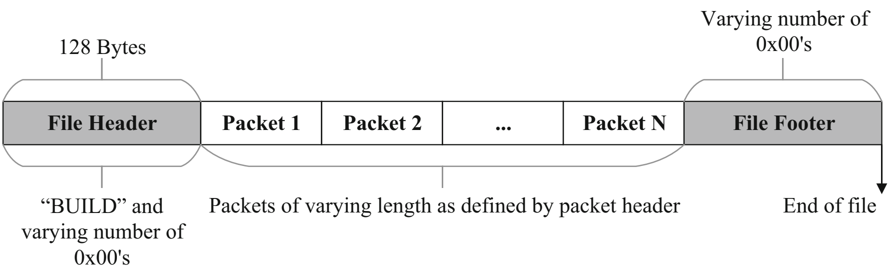

Fig. 10.1 General structure of DAT extended flight record files [8, 14]

Table 10.1 DAT extended flight record file packet type values [14]

Packet type	Value	Packet type	Value
GPS	0xCF01	Home point	0xC60D
Motor	0xDAF1	Tablet location	0xc12B
Gimbal	0x2C34	Remote control	0x9800
Flight status	0x2A0c	Battery	0x1E12
Advanced battery	0x4411		

Table 10.2 TXT extended flight record file packet type values [14]

Packet type	Value	Packet type	Value
On-screen display (OSD)	0x01	Advanced battery	0x08
Home point	0x02	Application messages	0x09
Gimbal	0x03	Application warnings	0x0A
Remote controller	0x04	Remote controller GPS	0x0B
Time	0x05	Aircraft GPS	0x0E
Battery	0x07	Firmware	0x0F

10.3.2 TXT File(s)

Flight logs TXT type of data was stored on the mobile device which runs "DJI GO 4" application. This file is a binary file, has TXT extension, and contains a very detailed flight record. According to [15], the flight logs of TXT files record GPS coordinates, timestamp, motor speed, and other data which are stored in the internal storage of the UAV. General packet type values of a flight record TXT file are shown in Table 10.2.

Authors in [3] emphasize that de-compilation of the DJI GO application revealed the Service Set Identifier (SSID) and password required to gain access to network for the DJI Phantom 3 Professional. According to [14], the TXT file footer contains some specific information about the UAV in plaintext; like flight area and a screenshot of a home point, name and model of the UAV and serial numbers of inertial measurement unit (IMU), camera, mainboard of the remote control, and battery.

Through a flight control system, Wi-Fi information of a drone can be set or modified. The flight data files stored in the drone's internal SD card storage can be downloaded [15].

10.3.3 EXIF File(s)

According to [13], in most cases, the primary and largest source of data stored by either recreational or commercial UAVs will consist of digital imagery or video footage. Photos and videos taken by the drone in flight mode are stored in SD card [15]. Also, our research found that, regarding tested UAV, mentioned storage includes both internal and/or external storage (SD card), depending on the UAV settings.

According to [16], two of the artifacts are log files stored as binary files and the other artifact is the Exchangeable Image File Format (EXIF) header of the images that are captured by the UAV's onboard camera.

EXIF header of the images, which is taken by UAV's onboard camera, contains lots of valuable information, in terms of investigation. There are also lots of tools which can extract the EXIF metadata from the images like location, altitude, creation time and modification times, information about the camera and settings, etc.

10.3.4 Identification, Sensor, and Log File(s)

UASs contain not only DAT and TXT flight information and EXIF files but also other types of files which include valuable information as a digital footprint of the device, user, activity, and involved subjects of the investigation.

These files could include extensions like LOG—which mostly include some log files of application, device, and user's activities; CONF—which generally provides information about configurations and settings; or TXT—which doesn't include extended flight information but involves other information like IDs of the devices, cameras and their sub-elements, firmware versions of software, factory data information, etc.

10.4 Methodology

Detailed methodology of the UAS is described in [1], with set of guidelines for UAS investigations. The study reported in this paper focused on data which could be extracted from different elements of UAS. Regarding that, in this research paper, a general forensic investigation methodology of an UAS was used, which also incorporated principles and elements of proposed guideline to ensure the integrity of the original data. Five-step investigation methodology is presented in Fig. 10.2.

According to [14], in order to investigate a UAV forensically, its hardware and software components should be identified. Besides the investigation of the UAV components, collecting evidence, providing a chain of custody, and media/artifact analysis are important parts of the forensic investigation. Table 10.3 shows the list of hardware and software used in this research.

As a first step, factory reset procedures were performed for the UAV and connected mobile device (Samsung SM-G955F) before performing planned flights. The UAVs storage was formatted by using DJI GO 4 application. This process removes all nonvolatile files that are stored on the internal memory of the drone. Android mobile device was formatted to factory settings by using booting menu.

Fig. 10.2 Five-step investigation methodology used in research

Table 10.3 Hardware and software tools used for the research

Tool	Description	Utilization
Flight system		
DJI Mavic Air	Quadcopter/Model: U11X	Flight scenario simulation
DJI remote controller	Remote controller/Model: S01A	Flight control
Samsung SM-G955F	Android OS/v9.0.0.	UAV control and navigation
DJI GO 4	Heads up display/v4.3.36	Navigation/live video feed
DJI Assistant 2	Software support/v1.2.5	SW update/data verification
Forensic analysis tools		
Forensic workstation	Windows 10 Pro 64-bit	Forensic tools execution
CsvView	Version 3.7.5	TXT data files parsing
UFED Touch 2	Version 7.32.0.68	Data acquisition
Physical analyzer	Version 7.32.0.16	Data analysis and presentation

After the formatting, mobile device was updated to the latest Android version and the latest version of DJI GO 4 application was installed. UAV was updated by using DJI Assistant 2 software, connected to the forensic workstation. SD card located in the UAV was formatted to FAT32 file system.

The second step included scenario creation which incorporated simulation of typical UAS activities like flights in different areas and times, picture footage and video recording, home-point activation, settings adjustment, etc. This research focused on the forensic analysis of a simulation of a captured UAV and a mobile device as a GCS.

Data acquisition phase included a collection of all possible data based on approved forensically sound techniques. In fourth, data analysis phase, the authors investigated data acquired from the UAS and tried to find all relevant evidence about possible cases. The report and presentation phase was a final step of the digital forensics investigation process, partly given by this research paper.

10.5 Data Acquisition

UASs are still in their development phase without any existing commonly accepted standards for their underlying technologies and their forensic investigation [16]. Traditional forensic tools may successfully extract media files; however, flight logs may show as "unreadable." UAS manufacturers may store data in different formats and currently, there is no standardization. Should any data be identified, consideration must be given to checking the data through another tool and confirming that it has been interpreted correctly [1].

Typical digital forensic analysis is normally conducted using commercial forensic tools, which will usually have a proven record for accuracy. Any examination using non-validated tools is considered a risk. However, until commercial forensic tools for all UASs are available, we may have little choice but to rely on open-source

Table 10.4 UASs elements and their description

No.	UAS acquisition part	Description/example
1.	UAV internal storage	Aircraft—main element of an UAV
2.	UAV external storage	SanDisk SD card
3.	Mobile/tablet device	Flight control connected to remote controller
4.	Mobile application	Flight control application installed on mobile device
5.	Remote controller	DJI flight remote controller
6.	Cloud service	Data storage and account for the cloud service
7.	Assistant application	Application for software/firmware update and log files
8.	Mobile/tablet device backup	Backup of a flight control device
9.	First person view goggles	Additional device for flight control options
10.	Network packet data	Communication through wireless networks
11.	SIM card	UAVs embedded or traditional SIM card

tools to extract data of forensic interest. As previously discussed, the capabilities of such open-source tools can vary significantly. In some cases, extracted data can provide significant information, while others may only provide limited data. Examples of such tools include DatCon, DJIFix, st2dash, and DroneLogbook [1].

This research considered data extraction of data sources that do not require invasive or destructive methods (e.g., JTAG, ISP-eMMC, Chip-off). Destructive methods make a risk in future usage of UAS and should only be considered when all other methods fail.

Table 10.4 provides the most comprehensive analysis of the possible elements of a typical UAS and thus possibilities for data storage, transmission, and afterward data acquisition regarding forensics investigations.

Multiple systems are involved in providing the full functionality of DJI Mavic Air UAS and thus, in this research, data acquisition was conducted on UAV and smartphone application DJI GO 4 (parts 1–4 from Table 10.1), as parts of this UAS and primary goal of this research. Commercial forensic tools (UFED Touch 2 and Physical Analyzer) from Cellebrite, Inc. were used to perform data acquisition, analysis, and reporting, providing very unique opportunities regarding the forensic analysis of DJI Mavic Air UAS, involving noninvasive and nondestructive data acquisition as important goals of this research.

UASs elements seen in Table 10.4 and numbered from 5 to 11 are not part of this research paper. Also, our research wanted to emphasize that there are also other UASs elements which could contain valuable investigation data—and this is planned to be analyzed in some future research.

10.5.1 UAV's Data Acquisition

Linux is the predominant OS for onboard UAV systems and it is possible to perform mobile forensic techniques to collect the data from the drone [3].

UAVs data acquisition in this research included:

1. internal (onboarded) and
2. external

storage data extraction, by using mentioned commercial forensic tools and providing noninvasive extraction methods. Extraction methods used in this research regarding UAV device (internal and external storage) were file system and physical extraction. Both extractions were performed by connecting UAV (by USB cable) with the UFED Touch 2 used for data extraction.

UAV's internal mounted storage was a micro SD card (8 GB storage) permanently attached to the main board of the UAV. Extracted files included TXT, LOG, and DAT extension of files which provide information about: ID of the UAV's elements, system log files, encrypted flight logs, Wi-Fi and factory configuration settings, etc.

UAV's external storage was a SanDisk micro SD card (128 GB storage). Recorded media files are stored on a FAT-formatted external micro SD card. Formats used for media are JPEG for images and MP4 for video files. The file names consist of a "DJI" prefix followed by an *n*-digit serial number which increments each time a new file is created (e.g., DJI_0007.JPG).

10.5.2 Mobile Device and DJI GO 4 Data Acquisition

The GCS consists of a remote controller and the mobile device that is used to run the DJI GO 4 application. This application provides real-time image transmission and camera settings adjustments and creates a detailed flight record that is stored on the mobile device. Mobile device Samsung SM-G955F was used for running DJI GO 4 application.

File system mobile forensic extraction method was performed by connecting mobile device (by USB cable) with the UFED Touch 2 used for data extraction. This extraction provided files and potential evidence which can be found on a mobile device with installed DJI GO 4 application.

Both extractions (UAVs and DJI GO 4s) provided many important digital evidence which could benefit potential forensic investigation. Results were analyzed by Physical Analyzer and can be seen in discussion of this research paper.

10.6 Discussion: Data Analysis and Presentation

There are various types of data which assist the investigation of UAS incidents. Data analysis phase included analysis of acquired data from acquisition phase—UAV internal and external storage and mobile device application DJI GO 4 acquired data. Analysis of data was made by commercial forensic software Physical Analyzer and CsvView.

Since data analysis phase provides a lot of valuable information regarding potential digital evidence, it is hard to exclude the most important artifacts. Those files and their value are associated with exact investigation, but the potential of all acquired data is enormous since it gathers other valuable data of a user's activities and devices. Table 10.5 provides anonymous information about potential evidence gathered into categories and provides some details regarding some of the data.

According to data provided by Table 10.5, forensic analysis could provide a lot of useful information regarding the digital investigation.

Table 10.5 Types and examples of recoverable data by UAV and DJI GO 4 acquisition

Data type	Found/extracted	Examples/utilization
Identification	Drone serial number	0K1CGCER######
	Batteries serial number	0K4AH14A######
	Board ID	0K5CGCA0######
	Device ID	0K1CGCER######
	User account(s)	name.surname@gmail.com
	Factory data	Year: 20 month: # Day: 14
Multimedia content	Images—UAV	DJI_####.jpg
	Videos—UAV	DJI_####.MP4
	Images—DJI GO 4	DJIFlightRecord_2020-##-##.jpg
	Videos—DJI GO 4	2020_04_26_18_10_56.mp4
Multimedia activity	Panorama.log	Time: 2020-4-26_18:19:18
	DJI Go 4 DAT	Flight record details
	DJI Go 4 TXT	Flight record details
	Timestamp_check_log	####video start, Sun Apr 26
	Video_drop_frame_log	****video stop, total drop 0 frames
Wi-Fi connection	SSID	ssid=MAVIC_AIR####
	Passphrase	a157####
	Hostapd.conf	channel=7
Flight logs	Longitude	46.226708
	Latitude	16.120406
	Elevation	208,263000488281
	Timestamps	26.4.2020. 16:24:23
Metadata	Camera make	DJI
	Camera model	FC2103
	Capture time	26.4.2020. 18:23:58
	Pixel resolution	4056 × 3040
	Resolution	72 × 72 in.
	Lat/Lon	46.226710/16.120405
Automated usage logs	Power off battery	[L-CMD] power off
	UAV motor log	[L-FMU/MOTOR] read motor
	Takeoff	[L-TAKEOFF] alti: 210.981033
	Battery warning	[L-FMU/LED] battery warning!

Identification of data files provides information regarding devices, their internal components, and users' identities like serial numbers, accounts IDs, etc. Some identification files were encrypted, like UAVs firmware version.

Multimedia content presents information about images and video files and their content, extracted from UAV and DJI GO 4. Depending on the data extraction method, deleted files from unallocated space can also be recovered and analyzed.

Multimedia activity data provided information about details of activities which are involved in creating multimedia content. Those data provide geolocation information for critical locations—launching, landing, and home or return locations; also provided full flight path information and timestamps of involved activities. DAT files extracted from UAV were encrypted and encoded, as mentioned in the previous text. DAT and TXT files available from extraction of a DJI GO 4 application were not encrypted. Research [8] also shares findings on TXT files, which are proprietary, encrypted, encoded on UAV, and also found on the mobile device controlling the drone. These files provided a slew of data such as GPS locations, battery, flight time, etc. Findings indicate that the DJI GO 4 application used to control the UAV contains a significant amount of unencrypted forensic data.

Wi-Fi data like SSID and password were found. Flight logs are very important part of UAS forensics and they were extracted from DAT and TXT files.

Metadata of images and video are available in detail, just like automated usage log files (UAV telematics, diagnostic error codes, power on and shutdown times, system events, etc.) made by UAV itself and correlated with timestamps.

The last phase of the five-step investigation methodology used in research includes reporting and presentation of results. This phase is partially made through this research paper and provided results of data acquisition and analysis, and all other data are available upon request. In UAV forensics, a lot of interest involves flight logs. Figure 10.3 provides visualization of flight records and UAV's journey's, gathered from acquired data, analyzed, visualized, and validated by using two forensic tools.

As mentioned before, DAT and TXT extended flight records extracted from DJI GO 4 application, provided detailed information about UAV's journeys. Those journeys can be seen in Fig. 10.3, which provides a comparative analysis of the results of visualization of two forensic tools.

Fig. 10.3 Visualization and presentation of UAV flight log files; Physical Analyzer (left) and CsvView (right)

Both visualizations are made from one DAT file extracted from DJI GO 4 application. Picture on the left from Fig. 10.3 provided visual information available after analysis by forensic tool Physical Analyzer and his parsing capabilities, while the picture on the right provided visual information available after analysis by tool CsvView. According to [3], there are many online services offering interpretation of DAT files, however, uploading evidence to a third-party server is not appropriate for a forensic investigation or intelligence purposes, so there was a tool designed to interpret and visualize these files—CsvView, used also in this research.

After analyzing similarities and differences, there are minor differences regarding visualization points and flight logs. This also provided cross-verification of forensic tools and thus providing the admissibility of evidence.

10.7 Conclusion

UAVs will have an increasingly more important role in the future of digital forensic investigations. Those devices are becoming more sophisticated and their usage becomes more needed—from legitimate to non-legitimate activities. As a valuable source of potential digital evidence, the use of UAVs could greatly enhance the efficacy of a digital investigation.

Digital forensic analysis of UAVs is increasingly used to determine if a device has been used for a non-legitimate activity. Due to the recent societal use of UAV devices and their services, the need for UAV forensics will become a necessity.

The proposed work in this research presents forensic investigation on a DJI Mavic Air UAV and associated smartphone app DJI GO 4 installed on the Android device. The proposed methodology used five-step investigation process, which included the use of commercial forensic tools that do not require invasive or destructive methods for data acquisition and analysis.

By analyzing acquired data, authors located information about the possible sources of evidence grouped into few categories depending on the type of the acquired data. Also, details about possible digital evidences have been provided. This research also provided a comprehensive overview of elements of a typical UAS and provided a forensic analysis of the most important elements of an UAS.

The outcome of this research study can be seen in a few ways: investigation of possible elements of an UAS for the purpose of forensic analysis, examples of data which are available for the use of a specific UAV (DJI Mavic Air), and possibilities of commercial forensic tools for the purpose of acquisition, analysis, parsing, and visualization of gathered data.

Further research of this should investigate other sources of UAS forensics such as cloud services and remote controller possibilities for the purpose of forensic analysis. Also, there is a need to make a comparative analysis of other commercial and open-source digital forensics software in order to enhance investigation efficiency, verify forensic software, and provide more valuable digital evidence.

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Chapter 11
Possibilities of Using Data Envelope Analysis for Quality Management of Public Services at the Local Level

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11.1 Introduction

The nature of public administration reflects the institutional aspects and principles of governing individual countries [1]. Public administration implements (fulfills) decisions of elected bodies, i.e., deals with the governance of public issues, ensures compliance of practice with law. On the European continent, its activities are carried out only on the basis and within the limits of the law, i.e., its competences are strictly defined by the law. However, its constitution and organization are also subject to law. Public administration addresses the needs of society and operates on the basis of organizational structures, processes, roles, relationships, policies, and programs. It creates sustainable economic prosperity, ensures social cohesion and human well-being [2].

Public administration has very often been seen as a service to the population, a service to the public, which is reflected in the ways in which it operates [3]. Its quality affects not only social confidence in the public sector but also in the whole political system. It therefore also affects the willingness of citizens to respect the guidelines and abide by the regulation enforced by authorities, i.e., to comply voluntarily with decisions of public authorities. The quality of the institutions and the effectiveness of the services they offer play an essential role in identifying the common good, strengthening reciprocity and belonging, enabling long-term prosperity.

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From the economic point of view, public administration represents a managerial structure ensuring mainly the supply of public goods. From our point of view, the allocation function of the public sector and its ability to efficiently provide public goods and public services are particularly important.

11.2 Material and Methods

11.2.1 Distribution of Public Services at Local Level, Czech Context

After the territorial reform of public administration in the Czech Republic at the beginning of the millennium, the attention of the Ministry of the Interior focused on supporting processes aimed at modernizing public administration. It is about increasing the efficiency of public expenditure at all levels of public administration, effectiveness, strengthening the transparency of decision-making, and accountability to citizens. Particularly in recent years, the focus has been on implementing system approaches to quality management. Strategic Framework for the Development of Public Administration, Conceptual Document of the Ministry of the Interior for 2014–2020, adopted by Government Resolution No. 680/2014 on the Strategic Framework for the Development of Public Administration of the Czech Republic and updated by Government Resolution No. 1088/2016 for the period 2014–2020 [4] and the Implementation Plans including annexes, the Czech Republic, through specific objective 3.2, advocates the application of sustainable system approaches to quality management. Attention is focused not only on the institutions of state administration but also on the activities of territorial self-governing units. Services provided by the territorial public administration do not fulfill only the obligatory defined characteristics. Local and regional self-government tries to reflect within its delegated and independent competence also the requirements of stakeholders, which typically include clients of the offices, local citizens, and entrepreneurs and many others [4].

Territorial self-governing units carry out a number of development activities, including the provision of local public goods, which lead to increased satisfaction of the clients of the authorities as well as to the improvement of the quality of life for citizens in their territory. Each unit has its own procedures through which its management manages the organization—planning, organizing, communicating, or controlling the activities carried out. To ensure efficient and effective management of the organization, it is advisable to link the individual activities into a functional management system. The high number of self-governing units at local and regional level makes it possible to compare or develop tools to visualize the comparison.

The issue of efficiency of public services at local level in the Czech Republic is a subject of both professional and political interest. This is due, among other things, to the high degree of atomization of local government, which is represented by 6258 independent municipalities, and the impossibility of their aggregation through administrative mergers or municipalization. This is a consequence of a high degree of autonomy, which is unusual even in the context of the European Union. Municipalities are free to exercise their autonomous powers; they are governed only by laws. The possibility of intervention by the state or state administration is limited to the supervision of legality. Municipalities defend their position very strongly and are highly sensitive to any indications of restrictions or interventions by the state.

All Czech municipalities are obliged to provide basic administrative services to a minimum extent and with regard to their population size and budget also local public services. Public libraries and elementary schools represent traditional public service provided by communities and towns. Their above-average number, compared to other countries, correlates with the high number of municipalities.

According to Ref. [5], public libraries can be defined as organizations that are established, supported, and subsidized by the society, either via local, regional, or national governments that ensure the access to knowledge, information, artworks, and lifelong education via various sources and services. The main services fulfill the mission of public libraries as defined by a specific Library Act [13]; an important feature and a necessary condition of public libraries is their unlimited social–economic accessibility.

The education system provides above all education that we classify as essential human needs. It provides a wide range of knowledge, ideas, attitudes, values, and abilities for life. Education is according to paragraph 2 of the School Act [14] referred to as public service. From an economic point of view, these are net public goods, the purpose of which is to extend positive externalities. It is an important part of the public sector; schools and school facilities are nonprofit organizations of the public sector, typically primary schools [3].

In the Czech Republic, however, a consistent policy for the development of public services is not formulated by the public administration. Unlike in other countries (e.g., Germany, Austria), the availability of public services is not standardized at the territorial level. Facilities are dealt with on an ad hoc basis with a view to ensuring accessibility in the area. The competition between settlements is a significant factor.

The high number of observations makes it possible to investigate efficiency by various statistical methods. The possibility of using the DEA method for the purposes of managing the efficiency of public services is discussed by researchers.

11.2.2 Theoretical Background

DEA is a benchmarking tool in operations research and has a wide range of applications including but not limited to banking, business, agriculture, transportation but also in the field of public services such as health care [6], education [7], public libraries [8], or research [9].

The Data Envelopment Analysis or DEA is a nonparametric method for estimating the production boundary presented in Ref. [10]. DEA measures the technical efficiency of a decision-making unit (DMU) relative to other units. Technical efficiency is therefore relative and depends on the set of all units. Units that lie at the production line are marked as effective, while units that lie below the production line are marked as ineffective. Inefficient units are also assigned an efficiency score between 0 and 1, which indicates how far the unit is from the production boundary. Units with an efficiency rate of 1 are effective and units with an efficiency rate of less than 1 are ineffective. The method was originally applied in the business sector, but later it has been also applied in evaluating the effectiveness of public services or public administration services.

One particular issue many studies face is a heterogeneous operating environment. For DEA to make sense, however, the operating environment should be homogeneous.

11.3 Methodology

In the original DEA model of Ref. [10], all effective units are equal. There are many extension models of the so-called superefficiency in the literature that evaluate and compare the effective units among themselves.

We use the following assumptions when using this method. The output should be homogeneous as the quality of services is standardized by legislation. However, service providers vary widely in terms of population size, number of consumers, amount of resources available, i.e., income of municipal budgets, etc. The consequence is that the smallest municipalities do not provide services to their citizens and use the capacities of larger municipalities. We also consider the impact of the municipality's position on development centers, or their position within the functional agglomeration, on the efficiency of the services provided. Therefore, in the first step, we examine the efficiency of the whole set of municipalities providing the services. Above all, we are interested in efficiency in smaller, more homogeneous groups reflecting the size of the municipality/town and its position in the settlement structure.

The separation approach splits the heterogeneous data sample into several homogeneous subsamples according to one or more environmental variables and performs DEA separately for each subsample. The advantage of this approach is its simplicity and straightforward interpretability. However, it significantly reduces the sample size making it unusable in many studies. The all-in-one model directly includes environmental variables in DEA as inputs or outputs. The two-stage model adjusts the efficiency scores based on the dependence between preliminary efficiency scores and environmental variables using regression analysis.

From the range of DEA models, we selected DEA model with Chebyshev distance (not Euclidean, like classical DEA models) with variable returns to scale (VRS), input oriented, and with superefficiency proposed by Ref. [8]. We choose it because of its robustness and because it is a DEA model with superefficiency so it is possible to compare also efficient units.

All the efficiency results later in the article are calculated by this DEA model in its linear approximation form. Anyway, according to Ref. [8], the inefficient unit order by efficiency scores of DEA model from [8] is the same as in CCR model [10] with VRS.

11.3.1 Variable Selection

When evaluating the efficiency of public libraries, we utilize ten variables in total. All variables except the town distance are strongly positively correlated, while the town distance is moderately negatively correlated with the others. For the efficiency analysis, we consider the following $r = 3$ input variables:

- Total expenditures: The total expenditures in CZK by the municipality on library activities (class 3314 in the sectoral classification of budget structure) in 2016 and 2017. We aggregate the expenditures in 2 years to capture long-term investments and smooth out annual budget changes. The data source is the information portal MONITOR of the Ministry of Finance of the Czech Republic.
- Employees: The number of full-time equivalents of library employees in 2017. Note that 64.07% of libraries have no own employees as very small libraries are run either by employees of the municipal office or volunteers. The data source is NIPOS.
- Collection: The total number of book units owned by the library in 2016. This variable represents the capital of the library. We use the value from the previous year as we consider the increase in the book collection in the current year to be an output variable reflecting the performance of the library management. The data source is the National Information and Consulting Centre for Culture (NIPOS).

We consider the following four output variables:

- Registrations: The total number of users registered in the library in 2017. This variable captures the size of the reader base. The data source is NIPOS.
- Circulation: The total number of book loans in 2017. This variable captures the main activity of libraries—book lending. The data source is NIPOS.
- Events attendance: The total number of visitors of events organized by the library in 2017. This variable captures the cultural role of libraries. Many libraries do not organize any events while others offer regular cultural program. The data source is NIPOS.
- Collection additions: The positive part of difference between the book collection in 2017 and 2016. This variable captures the increase of the capital of libraries. The book collection of 50.56% libraries remains the same as in 2016 or in some cases even decreases. The data source is NIPOS.

In case of elementary schools, we considered seven output variables and just one input variable for DEA and two segmentation variables. We were very limited by the data availability and quality.

As DEA input variables we chose, due to availability and quality of data, only:

- Current expenditures on primary schools, $E(T)$.

The school year starts on September 1st and finishes on June 30th in the Czech Republic, but the expenditures are for the period 1.1–31.12. So for the analyses, we transformed the expenditures as

$$E(T) = \frac{1}{3}\mathrm{CE}(T) + \frac{2}{3}\mathrm{CE}\,(T + 1) \tag{11.1}$$

where $E(T)$ is the current expenditures on primary schools for the school year T and $\mathrm{CE}(T)$ is the current expenditures on primary schools for the calendar year T.

There were also separate categories for current expenditures on the first- and second-grade primary schools, but most of the municipalities do not fill them in although they had both grades, they just filled in the total for primary schools. So we rather do not use the split. Please note that salaries of teachers are paid from the central budget and not from municipality budgets.

As DEA output variables we considered:

- Primary schools count in a municipality, $S(T)$
- Total number of pupils in primary schools in a municipality, $P(T)$
- Total number of classes in primary schools in a municipality, $C(T)$
- Total number of pupils in the first-grade primary schools in a municipality, $P1(T)$
- Total number of pupils in the second-grade primary schools in a municipality, $P2(T)$
- Total number of the first-grade classes in primary schools in a municipality, $C1(T)$
- Total number of the second-grade classes in primary schools in a municipality, $C2(T)$

Where the first-grade means first five classes (i.e., pupils from 6 to 10 years old as on September 1st, when the school year starts) and the second-grade comprises four classes (pupils aged 11–14). The output variables relate to school years.

As segmentation variables we chose

- Number of inhabitants in a municipality as of January 1st, 2018, $I(T)$. The data source is the Czech Statistical Office (CSO).
- Time to drive by car to the closest municipality with extended competence or regional development centers, centers of regional agglomerations, or metropolitan areas. The data source is the web mapping service Mapy.cz.

Public services are provided by a very heterogeneous spectrum of municipalities, represented by small villages with several dozens of citizens up to big cities. In order to make comparisons in as homogeneous groups as possible, categories of municipalities were proposed that reflect the size of the domestic population and the position of municipalities in the settlement structure. Regarding the hierarchy of settlements, it is based on the Government-approved Strategy of Regional

Table 11.1 Mean efficiency scores within each expert category of local public libraries in 2017

Expert category	Population (*I*)	Distance (*D*)	Units	Mean efficiency (in segments)	Mean efficiency (whole sample)
E01	0–199	≤15	101	0.789	0.138
E02	0–199	>15	545	0.292	0.117
E03	200–499	≤15	354	0.492	0.114
E04	200–499	>15	1113	0.212	0.115
E05	500–999	≤15	343	0.412	0.151
E06	500–999	>15	872	0.376	0.149
E07	1000–1999	≤15	228	0.683	0.213
E08	1000–1999	>15	484	0.583	0.208
E09 (non ORP)	2000+	≤15	359	0.655	0.437
E10 (non ORP)	2000+	>15	123	0.837	0.394
ORP towns			138	0.926	0.801
All			4660	0.434	0.192

Development of the Czech Republic for 2021–2027 (Government Resolution No. 775/2019), which as higher ranking settlements distinguishes regional centers and core agglomerations (essentially regional cities), metropolitan areas (the largest cities of the Czech Republic). Most of them have the role of a municipality with extended competence (a third type municipality, ORP). Thus, the size of the population representing potential local demand and the proximity of the municipality to the municipality with extended competence (third type) or the position of the municipality within the agglomeration, metropolitan area is monitored. The distance of the municipality to these higher centers is monitored by means of time availability when using a passenger car.

On the basis of the above-mentioned data, an analysis of the effectiveness of municipalities in individual expert categories was performed. Due to the small number of observations in the cities with the largest population, these expert groups were aggregated. Prague and Brno were completely excluded as unique cases that are not comparable (Table 11.1).

The efficiency of libraries regardless of categorization by municipalities reaches an average of 0.192. Subsequently, the mean efficiency values for the given expert category were calculated. In the case of the smallest municipalities, the values range from 0.2 to 0.5, which represents a significant inefficiency. The category E01 is an outlier that showed average efficiency within a category nearly 0.8. It happened due to fact that 25% of units were efficient within the category. This high share of efficient units was usually caused by zero expenditures or employees and this happened more often than in other categories. It can be argued that the operation of most municipal libraries is ineffective with respect to the input and output data analyzed. As the size of the settlement increases, efficiency increases on average. The most effective are library services in towns and cities.

Table 11.2 Average DEA elementary schools efficiency calculated on whole sample in distinction by expert-based categories and with different DEA output variables (in columns) in 2018

Segment definition			Efficiency calculated in segments		
$I(T)$	$D(T)$	N	$P(T)$, $C(T)$	$P(T)$, $C(T)$, $S(T)$	$P1(T)$, $C1(T)$, $P2(T)$, $C2(T)$
0–500	≤15	124	0.080	0.080	0.120
0–500	>15	145	0.072	0.093	0.083
500–999	≤15	548	0.224	0.231	0.241
500–999	>15	346	0.207	0.217	0.240
1000–1999	≤15	458	0.240	0.258	0.287
1000–1999	>15	243	0.338	0.366	0.443
2000–4999	≤15	257	0.539	0.569	0.587
2000–4999	>15	166	0.667	0.692	0.704
5000–9999	#NA	142	0.709	0.746	0.741
10,000–19,999	#NA	69	0.869	0.914	0.924
20,000–49,999	#NA	44	0.829	0.880	0.865
50,000+	#NA	18	0.996	1.012	1.006
Total		2560	0.340	0.359	0.380

The influence of the agglomeration, or the position of the municipality in the hinterland of a larger city, is noticeable only from municipalities with more than 500 inhabitants. Easily accessible regional center, metropolises, where the population of the village spend at least a few hours during the day—employment, use of higher public services, reduces the efficiency of the operation of local libraries (Table 11.2).

From the table, we can see that segments with more inhabitants had higher efficiency in general. Only municipalities with inhabitants from 500 to 999 had the lowest efficiency, both with the driving distance below and above 15 min to the closest bigger town.

The results of the DEA analysis can be viewed in the web-based application in the web browser—http://ambis.fd.cvut.cz. The architecture of the application is typical for such applications: three layer one: the database layer is composed by the Oracle DB server, application layer uses PL-SQL, R-language and PHP, final dynamic web pages are created dynamically by PHP on the presentation layer; AJAX is used on the client side. The architecture of the application and the relational model of the database were presented in Refs. [11, 12] in more details.

The configuration on the server and the installed software is concluded in Table 11.3.

The database contains information about 6251 towns/villages in the Czech Republic (the state from 2017). The total count of towns/villages is currently 6258, i.e., we have included 99.88% of them. Financial and statistical data containing budget, number of populations related to each town/village are filed in the range 2014–2018. The disk capacity is utilized at 33%.

After logging to application, splash screen with menu is displayed. The user can display list of town/villages, their statistical data, result of computing, and the comparison. AJAX script "buffers" always part of data. The time from selection

Table 11.3 Hardware and software solution for WebDEAr application

Hardware	
Processor	4 × Intel(R) Xeon(R) CPU E5-2630L v2 @ 2.40 GHz
Memory	8 GB
Disk	161 + 97 GB
Software	
OS	Oracle Linux 64-bit, kernel 4.14.35
DBMS	Oracle DB server ver. 18
Oracle Instant Client	Oracle Instant Client 19.3
R-library	R 3.3.0
WebServer	HTTPD 2.6.4
PHP	PHP 7.3

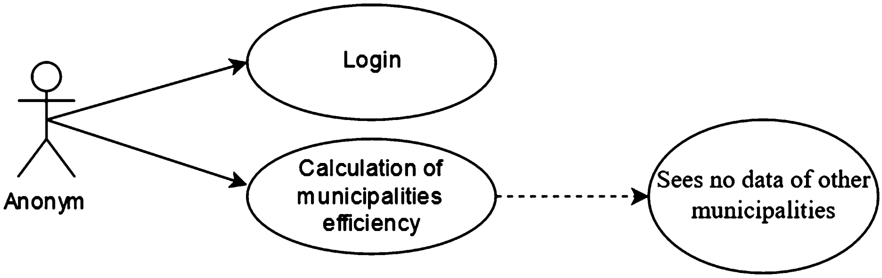

Fig. 11.1 Used by an anonymous user

from menu to display is up to 5 s. The measurement was performed on the local network in one building (two segments) using Google Chrome Browser. When it was accessed using 4G mobile network; the time from selection from menu to display is up to 10 s.

The application can be used by three types of users:

(a) An anonymous user, without the need to register or provide any personal information (use cases see Fig. 11.1)
(b) A registered user with the role of analyst (use cases see Fig. 11.2)
(c) A registered user with the role of administrator (use cases see Fig. 11.3)

An anonymous user can either log in or select the option to use the functionality of calculating the efficiency comparison with other municipalities. For municipalities with which they compare the fictitious municipality with the selected parameters, the user sees only the calculated number, which is used for comparison, not the values of the parameters that were used for the calculation.

A registered user with the role of analyst can see the list of municipalities that contains basic information about each of them. This user can see all information about previous calculations and the value of all parameters used to calculate the municipalities' efficiency.

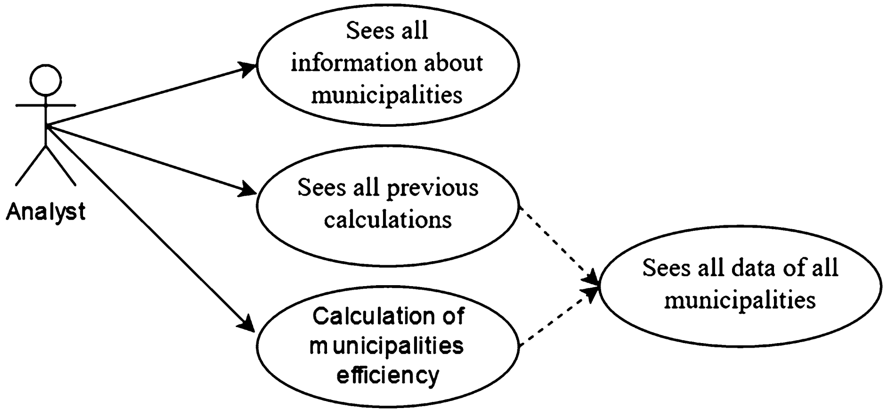

Fig. 11.2 Used by an analyst user

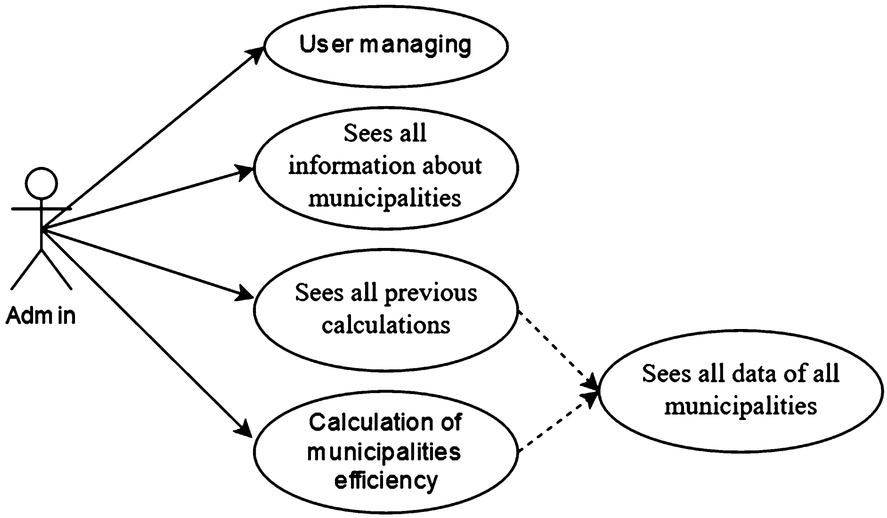

Fig. 11.3 Used by an admin user

A registered user with the role of administrator has the same rights as the user with the role of analyst. His higher rights allow him to edit users, registration, change, and delete data.

11.4 Conclusion

Public services are provided by a very heterogeneous spectrum of municipalities, represented by small villages with several dozens of citizens up to big cities. In order to make comparisons in as homogeneous groups as possible, categories of municipalities were proposed that reflect the size of the domestic population and the position of municipalities in the settlement structure.

The efficiency of libraries regardless of categorization by municipalities reaches an average of 0.4458. In the case of the smallest municipalities, the mean efficiency values range from 0.3 to 0.8, which represents a significant inefficiency. It can be argued that the operation of most municipal libraries is ineffective with respect to the input and output data analyzed. As the size of the settlement increases, efficiency increases on average. The most effective are library services in towns and cities.

The segments with more inhabitants had higher efficiency of elementary schools in general. Only municipalities with inhabitants from 500 to 999 had the lowest efficiency, both with the driving distance below and above 15 min to the closest bigger town.

The findings are important for the discussion on how to set the availability of public services. At present, efficiency does not play a key role in capacity building. The establishment of a municipal library actually depends solely on an independent decision of the municipal council. The funding is conditioned by the willingness to cover the deficit of its operation with regard to the overall size of the municipal budget.

The operating costs of municipal libraries are covered often at the expense of other agendas performed by municipalities (e.g., in the form of sharing staff capacity). This means that some of the costs are not reflected in the financial statements associated with the library service, or are not even monetized. This means that the efficiency of small municipal libraries may in fact be even lower on average.

When it comes to the provision of school education, citizens of a community usually consider this role as a basic function of the municipality. It follows that even small communities, if they already have a school established (either in its entirety or only the first grade), strive to maintain them even at the cost of massive subsidies from their own budget. It is often the case that various exceptions apply, such as small classes, or teaching 2 years in just 1 year in order to maintain schooling. In the case of some rapidly developing municipalities close to large centers (affected by the process of suburbanization), the lagging of capacities behind the current need is observed. Therefore, the capacity of the core city is often used. If the municipality is in debt due to the construction boom, this behavior may be classified as a form of parasitism. The system of shared taxes does take into account the fact that the municipality operates a school when redistributing tax income among municipalities. However, this bonus covers only a fraction of the cost of running a school and is not an incentive to set up new or expand the capacity of existing schools. Some municipalities continue to enforce compensation payments for pupils commuting from other municipalities although this is not entirely in line with the law.

Through the administrative activities of municipalities of the third type (ORP—Municipalities with extended competence), school districts are created, which define the commute area of individual schools. The aspect is the size of capacities and transport accessibility. However, the efficiency of schools does not play a crucial role in this decision-making.

The Ministry of the Interior, as the guarantor of the project, has initiated the introduction of various tools for monitoring and evaluating the efficiency of public administration activities. The created application represents a progressive tool for the application of digital technologies in public administration, it enables further evolution of this tool with regard to data availability.

Representatives of municipalities, as well as civil servants of the Ministry of the Interior, will obtain a tool enabling them not only to compare the efficiency of individual municipalities, but thanks to the extensive database and a map display also a tool for modeling of catchment circuits and service efficiency.

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Chapter 12
Methodology Proposal for Proactive Detection of Network Anomalies in e-Learning System During the COVID-19 Scenario

Ivan Cvitić, Dragan Peraković, Marko Periša, and Anca D. Jurcut

12.1 Introduction

Anomaly represents samples in the data that deviate from the previously defined normal behavior of the observed phenomenon. Observed from the aspect of information and communication systems, anomalies in communication, i.e., network traffic are generally generated by one or several network devices. This is often a result from illegitimate network activities in the system, with the anomalies of network traffic having the potential of negatively affecting the operation of the information and communication system or services [1]. One of the frequent causes of anomalies in the network traffic is DDoS (Distributed Denial of Service) attack. Over the last two decades, numerous studies have been directed to the development of methods, models, and systems that can detect DDoS traffic in real time. Nevertheless, the number of DDoS attacks and the amount of DDoS traffic is constantly increasing, which is the reason for further research in the area of the detection of security threats of this kind [2]. Despite continuous research into network traffic anomalies, cyberattacks such as DDoS attacks are still frequent and can have numerous negative effects on the predicted performance of IC (information and communication) systems and the availability of IC services. The pandemic of coronavirus (SARS-CoV-2) highlighted the importance of the availability of e-learning systems and services. The goal of this research is to propose research

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methodology for the development of DDoS traffic detection models at the attack target in scenario where flash events generated traffic represents legitimate traffic, such as e-learning services during the COVID-19 pandemic.

12.2 Previous Research

Previous researches define several approaches to DDoS traffic detection. Generally, they can be divided into two basic categories, based on the samples and the anomalies [3]. Research [4], apart from the previous ones, identifies also the approach based on entropy, and research [5] mentions the possibilities of applying the hybrid approach to DDoS traffic detection. The methods based on the sample apply the comparison of the incoming traffic with the predefined profiles and samples of the known network anomalies [6]. The detection of DDoS attack based on the sample can be carried out in three ways; based on the signature of the known attacks, the rule (if-then), and the condition and transition [7]. The advantage of this method of detection is a high rate of detection of the already known DDoS attacks with a low number of false-positive and false-negative results. The drawback is the impossibility to detect new and unknown attacks, i.e., those attacks that are not included in the database which is used for the comparison with the samples of the incoming traffic. Because of the dynamics of the problem area, it is of great importance that the detection methods be able to detect unknown samples of DDoS traffic [3].

On the contrary, the approach based on the detection of the network traffic anomalies uses the predefined models of normal traffic which are then used to compare the incoming traffic [5]. This approach to detection has been developed in order to overcome the drawbacks of the detection approach based on the samples [4]. If the incoming traffic significantly differs from the defined model of normal traffic, then the incoming traffic is identified as anomaly, i.e., as DDoS traffic [8]. The advantage of detection of network traffic anomalies related to the detection based on samples is the possibility of discovering unknown attacks. The main drawback of detection based on anomalies is the problem of determining the threshold values between normal traffic and anomaly [5, 9]. The anomalies of network traffic are detected when the values of the current traffic flow or other selected parameters exceed the predefined threshold of the normal traffic model. A low defined threshold results in a large number of false-positive results and high defined threshold leads to a large number of false-negative results [10]. Numerous scientific methods have been used for the detection of DDoS traffic [11]. The current academic literature most frequently applies the statistical methods, machine learning methods, and soft-computing methods [12–14]. In today's big data concept environments, high performances in cyberattack detection and response are demonstrated by machine learning and artificial intelligence methods.

12.3 Methodology for DDoS Traffic Detection Model Development

Despite continuous research into network traffic anomalies, cyberattacks such as DDoS attacks are still frequent and can have numerous negative effects on the predicted performance of IC systems and the availability of IC services. The pandemic of coronavirus (SARS-CoV-2) highlighted the importance of the availability of e-learning systems and services. Crisis situations such as the mentioned pandemic result in the need for isolation of users (students/teachers/administrators) whereby education and supporting processes rely on the reliable work of the e-learning system and all the elements. On March 16th, 2020 there was a DDoS attack on AAI@EduHr system responsible for authenticating users to access various e-learning services (Merlin, webinar, e-learning center, *Dabar*, *Hrčak*, filesender, and others) in the Republic of Croatia [15]. The conducted attack indicated the need to research and find solutions for cyberthreats (primarily DDoS) that are applicable in specific scenarios.

According to data from the Croatian University Computing Center (*Srce*) during March 2020, in the month in which remote education began due to the COVID-19 pandemic, the AAI@EduHr system recorded 11,214,236 successful authentications for 517,453 unique users (Fig. 12.1). In comparison, in March 2019, the AAI@EduHr system had a total of 3,220,212 successful authentications of 252,974 unique users, which can be seen in Fig. 12.2. Authentication through AAI@EduHr was most commonly used to access MS Office 365 systems for schools, Loomen, and *Srce* systems: Merlin—a remote learning system for students

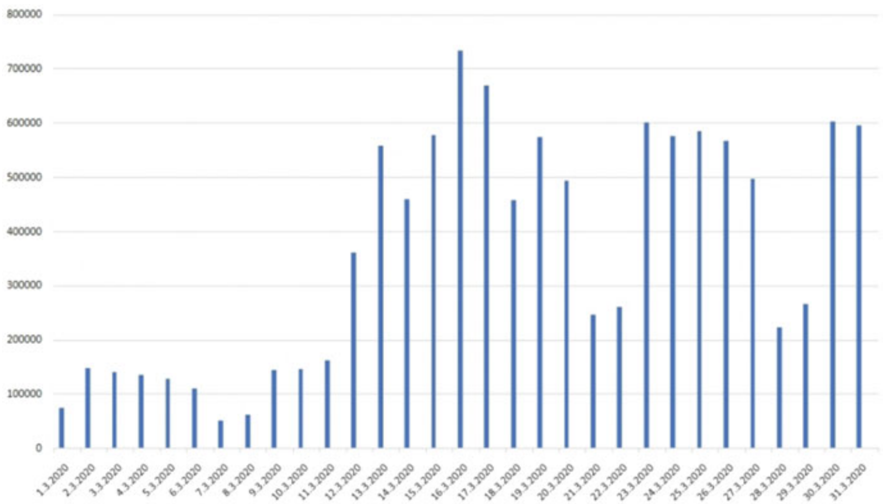

Fig. 12.1 Number of successful authentications in March 2020 by day [16]

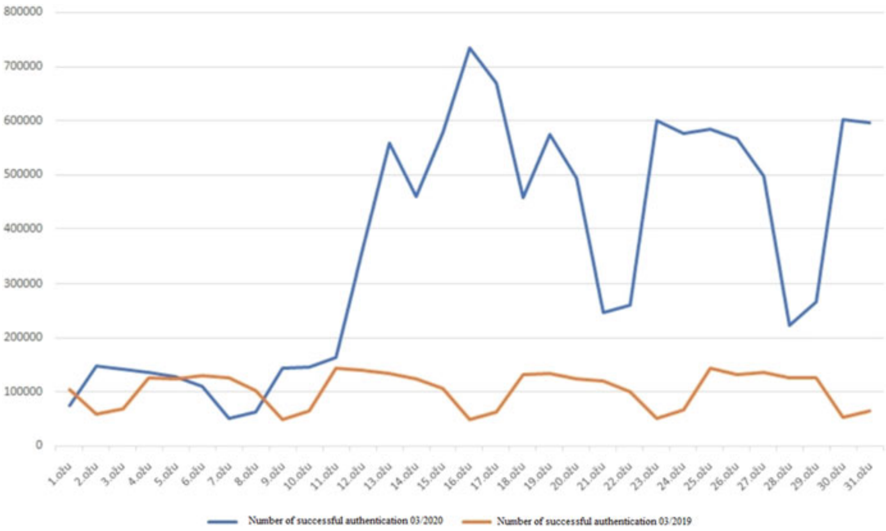

Fig. 12.2 Number of successful authentications March 2019 and 2020 comparison [16]

and teachers, and the ISVU Information System for Higher Education (primary the *Studomat* module) [16].

The presented data indicate the occurrence of the flash crowd phenomenon. This occurs when legitimate requests to access a web-based service exceed the statistically normal number of legitimate requests [17]. Accordingly, flash crowds may adversely affect the performance of DDoS attack detection models based on machine learning methods that use data sets created during the period when the number of service requests is common. Such models are often detecting flash crowd traffic as a DDoS attack traffic, even though it represents a legitimate service request. Some authors are researching solutions that can differentiate flash crowd and DDoS traffic by using human behavior and interaction, but such solutions are not acceptable to users [18].

In order to achieve effective detection of DDoS and thus for reaction to such attacks in specific cases of flash crowd phenomena under crisis situations such as a coronavirus pandemic, the detection model should be based on the ability to distinguish between DDoS traffic and traffic generated under flash crowd conditions. One of the research direction followed by this project proposal is to identify the unique characteristic of flash crowd traffic vis-à-vis DDoS traffic as a basis for the development of DDoS traffic detection model [19].

Implementation of efficient and effective research for dealing with described problem requires well-structured research methodology.

We propose research implementation through four-phase methodology, and activities shown in Fig. 12.3 as follows: (1) analysis of existing elements of the e-learning ecosystem and establishing the theoretical basis and differences between DDoS and flash crowd traffic; (2) forming of a laboratory environment,

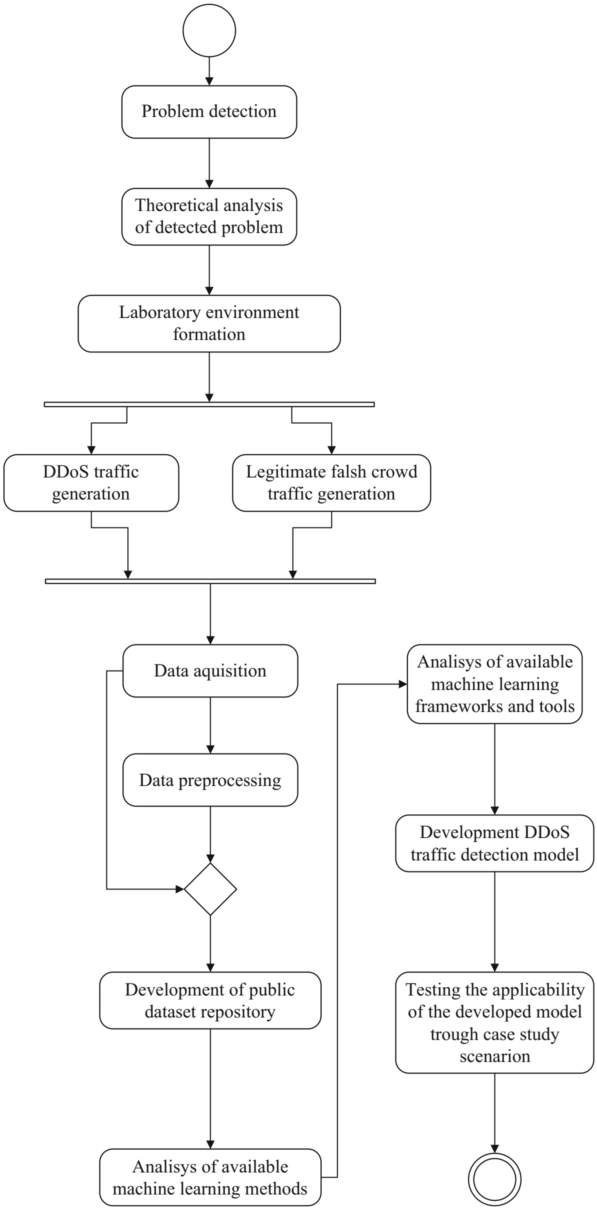

Fig. 12.3 Activities through research phases

the collection of network traffic, processing, and preparation of collected data for further analysis; (3) development of DDoS traffic detection model, validation, and performance evaluation of the developed DDoS traffic detection model; (4) analysis of the applicability of the developed anomaly detection model and the reaction capabilities based on the operation of the developed model.

12.3.1 Establishing the Theoretical Basis and Differences Between DDoS and Flash Crowd Traffic

In the first phase of the research, the current scientific literature will analyze for the purpose of identifying the elements of the e-learning ecosystem, architecture, communication topologies and technologies, and other relevant characteristics of such environments. The purpose of the aforementioned research activities is to provide adequate recommendations and guidelines in the last phase of the research with the purpose of ensuring the availability of e-learning services and minimizing the negative impacts of the emergence and realization of cyberthreats such as DDoS attacks. The analysis of the current scientific literature will also determine the current research findings related to the characteristics of network traffic generated as a result of flash crowd activity and current research achievements regarding the development of models and systems that can distinguish DDoS and flash crowd traffic.

12.3.2 Formation of Laboratory Environment and Data Collection

Second phase should include establishing a laboratory environment for generating and collecting legitimate (flash crowd) and illegitimate (DDoS) traffic. The laboratory environment is planned to be established at the Department of Information and Communication Traffic at the FPZ within the Laboratory for Security and Forensic Analysis of the Information and Communication System (LSF). Flash crowd and DDoS traffic generation are planned with the implementation of the dedicated hardware platform. Such a platform is able to simulate realistic flash crowd and DDoS traffic and also provides advanced management and defining features of the generated traffic at different layers of the OSI (The Open Systems Interconnection) model. The next planned activity is to collect and store the generated traffic on the dedicated computers in .pcap format files, which is suitable for further manipulation in the form of analysis and extraction of the traffic features values. Further research activities in this phase are related to the preprocessing and preparation of data for further analysis. This implies the filtering of the collected data and extraction of the network traffic features that can be used in the network anomaly detection model and adequate labeling of feature vectors. Considered will be exclusively the packet header values, i.e., statistical features of traffic while the packet content will not be considered because of the application of cryptographic methods in the communication processes. In this phase, the independent traffic features will be selected based on which it is possible to differentiate the observed traffic on legitimate and DDoS. Also, the level of connection with the dependent feature will be determined and those independent features with the highest level of connection with the dependent feature will be selected. The selected features will be used for the purpose of defining the model in the next research phase. Final output of the second phase will be datasets containing legitimate traffic generated as a result of flash crowd activities on e-learning ecosystem elements (simulated through dedicated network generator hardware) and DDoS traffic as a network traffic anomaly generated as a result of DDoS attack (simulated through dedicated network traffic generator hardware). By collecting generated legitimate and illegitimate traffic, a unique dataset will be formed. Such dataset will be published on a publicly available server (on FPZ's servers) in original and in the processed form for academic community with the purpose of further research of detection and reaction on DDoS attacks in specific scenarios.

12.3.3 Development of DDoS Traffic Detection Model

Previously carried out activities laid the foundation for the third phase of planned research. This phase encompasses the development of the network traffic anomalies detection model. The first step in this phase is to analyze and select adequate supervised machine learning method from the set of ensemble methods that will suit the solving of binary classification problem. In solving such a problem, the objective is to check the congruence of the generated new traffic sample with the sample of the legitimate traffic. The incongruity of the traffic features values with the values of the features of legitimate traffic above the defined threshold will mean that the device generates DDoS traffic within the observed time. Based on the previous mentioned, following activity is development of network anomaly detection model using supervised machine learning methods. For implementation of the chosen method available, machine learning platform will be used such as TensorFlow, Weka, KNIME, Orange, Hadoop, Apache Spark, Neo4ji, R, or similar. The last step of this phase is to validate the model performances through standard validation measures for classification models (accuracy, precision, specificity, kappa coefficient, rate of false- and true-positive results, confusion matrix, etc.).

12.3.4 Applicability of the Developed Anomaly Detection Model

In the final, fourth research phase, the applicability of the developed model in real scenario through case study will be analyzed. Also, the guidelines and recommendations for response to the anomalies detected with the developed model will be defined. Purpose of this activity is to minimize the negative effects of cyberthreats such as DDoS on availability of e-learning services particularly in crisis situations such as pandemic of SARS-CoV-2 virus when such services are critical for the undisturbedly running of educational and supporting processes.

12.4 Discussion and Conclusion

Using the proposed methodology for developing model of network traffic anomaly detection as well as guidelines and recommendations for reaction to detected anomalies provide the potential for further practical application, as well as strong socioeconomic benefits from several aspects. The research implementation within the framework of the proposed project is significant for the development of the research area since it considers the challenges in a specific scenario of using e-learning services resulted from COVID-19 pandemic. In the proposed research, it is planned to form open and public dataset repositories containing network traffic (in raw and preprocessed format) generated simulating flash crowd scenarios and DDoS attacks. Such repository will benefit other researchers for the purpose of further research of behaving flash crowd traffic, how to distinguish it from other types of traffic such as DDoS or some other type of traffic anomalies. Planned extensive use of machine learning, especially ensemble type of machine learning methods will potentially result in developed anomaly detection model that can proactively detect cyberthreat and adequately react to such a threat. In that way, it will give the possibility to secure availability of e-learning ecosystem and its services when it is needed the most, and that is in the crisis scenarios such as pandemic of coronavirus and similar. Securing the availability of e-learning services that are becoming critical will increase user satisfaction on every level (students/teachers/administrators) and allow undisturbedly running of educational and supporting processes. Furthermore, this kind of research would open a variety of related research problems and it would enable knowledge transfer between various research teams and e-learning system operators as a response to high-risk situations and crisis scenarios that may occur in the future.

There are several results that are expected through implementation of proposed methodology. First expected result is determined theoretical basis of characteristics and main differences between traffic generated during flash crowd events and DDoS attacks discovered by other researchers. Second expected result is formed laboratory environment at LSF for the purpose of generating legitimate and illegitimate network traffic. Third expected result is a collected dataset of legitimate and illegitimate traffic adequately labeled and prepared for further analysis and research. Fourth expected result is repository of datasets of collected legitimate and illegitimate traffic available for further research to academic community. Fifth expected result is developed network traffic anomaly detection model that is based on ensemble methods of supervised machine learning. Sixth expected result is defined guidelines and recommendation for reaction on detected cyberthreats for minimizing negative impact on availability of e-learning services in crisis scenarios (such as COVID-

19 pandemic) when such services are crucial in effective implementation of the educational and supporting processes.

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Chapter 13
The Effect of Non-Wi-Fi Interference on the Throughput of IEEE 802.11 Based Wireless Networks

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13.1 Introduction

In the next few years, IEEE 802.11 or Wi-Fi networks will continue to be one of the main options to meet the ongoing increase of network performance requirements in various industries, such as healthcare, stadiums, and hospitality [1].

IEEE 802.11 networks operate in two frequency bands: 2.4 and 5 GHz with a total of 14 overlapping and 24 nonoverlapping channels available, respectively, depending on the region [2].

However, interference is a perennial issue in IEEE 802.11 wireless networks which can drastically affect network performance, including throughput, if not managed properly. This is primarily because both bands are part of the unlicensed ISM (Industrial, Scientific, and Medical) which is used not only for Wi-Fi but also for non-Wi-Fi communication purposes, as well.

Interference can be categorized into Wi-Fi and non-Wi-Fi interference. The former represents the simultaneous coexistence of various Wi-Fi networks. The latter represents the coexistence of Wi-Fi and non-Wi-Fi devices operating at the same frequency, such as cordless phones, Bluetooth handsets, audio and video transmitters, microwave ovens, or baby monitors.

Both Wi-Fi and non-Wi-Fi interference may result with lower network throughput. This is primarily because the IEEE 802.11 station uses Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) and Clear Channel Assessment (CCA) mechanism before transmitting to check whether the channel is busy or idle [2, 3].

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CCA consists of two related functions: carrier sense (CS) and energy detection (ED). The first is used to detect the presence of other Wi-Fi signals and can clearly determine the amount of time the medium will be busy. This is not possible with ED which is used only to detect the presence of non-Wi-Fi signals on the channel.

The Wi-Fi client uses ED primarily to sample the channel periodically to determine the presence of non-Wi-Fi RF energy [3]. The ED requires a predefined threshold that determines if the detected amount of energy is sufficient to report the medium busy or idle. If detected energy is above the threshold, the channel will be marked as busy, and the Wi-Fi station will have less time to transmit. On the other hand, if the Wi-Fi station transmits while there is another active non-Wi-Fi device on the same channel it may experience a loss of packets or a decrease of latency.

In other words, the network throughput depends on how much time the channel will be busy; the more time it's busy, there will be less time to transmit and, consequently, the lower data rates and/or the number of dropped packets will be increased.

IT managers and network practitioners need to completely understand the effects of non-Wi-Fi interference in order to continually improve their networks. Several researchers emphasize that they often ignore network throughput when deploying networks. For example [4, 5], claim they are often focused on ensuring signal coverage rather than achievable effective data rates, thus underestimating non-Wi-Fi devices and their impact on the throughput of IEEE 802.11 wireless network.

To avoid this, it is necessary to perform comprehensive analysis not only from data or transport layer but also from physical as well in order to detect potential non-Wi-Fi RF energy and understand its effect on IEEE 802.11 network throughput [5].

Therefore, we measured the effect of Line6 Relay G30 wireless audio transmitter on IEEE 802.11 network throughput in experimental laboratory environment. Such type of interferer is often used in various multipurpose environments, yet its impact on the network throughput has been often neglected in the literature. Our results can help network professionals, practitioners, and end users in providing additional understandings in troubleshooting non-Wi-Fi interference in local wireless networks.

13.2 Literature Review

The measurement and analysis of the effect of non-Wi-Fi interference on the performance of the IEEE 802.11 network have been the subject of various studies.

For example, researchers from [6] analyzed the influence of Bluetooth devices on the degradation of performance of IEEE 80.11b network and concluded that their coexistence significantly affects the increase of BER. Authors in [7] studied the impact of unintentional interferers like Zigbee. Their results suggest that throughput can drop by 20–40%. Researchers in [8] explored ways to mitigate the impact of microwave ovens on IEEE 802.11 networks.

More recently, a study from [9] analyzed the impact of various common non-Wi-Fi interferers, such as videophone and Bluetooth device, on network throughput. Results suggested that the throughput of the IEEE 802.11 network can be reduced by 26.5% and 7.5% if the Bluetooth handset and videophone, respectively, are in close proximity to Wi-Fi client. Authors in [10] found that radio frequency noise from a mobile computer platform worsens the performance parameters of IEEE 802.11 network, including throughput.

Researchers from [11] measured IEEE 802.11 network throughput and signal strength by simulating various scenarios that can be found in a home environment. Such scenarios included various distances, interferers, such as home appliances or Bluetooth devices, and obstacles between the access point and client device. They concluded that interferer such as microwave oven or Bluetooth device does not affect download and upload network throughput. However, the interference from such devices tends to decrease Wi-Fi signal strength, as well as the wall between Wi-Fi client and access point.

On the other hand, authors in [5] analyzed the effect of various devices such as microwave ovens, analog wireless video cameras, analog cordless phones, digital cordless phones, Bluetooth handsets, and wireless jammers on the throughput of the IEEE 802.11 network. Their results suggest that the immediate vicinity of the microwave oven can reduce throughput by 100% so that the Wi-Fi network becomes unusable. Similarly, an analog wireless video camera and an analog cordless phone can reduce the network throughput by 90–100% because they transmit continuously, thus occupying the channel for a significant amount of time.

However, previous work has only focused on devices mostly used in a home environment. To the best of authors' knowledge, the effect of a wireless audio transmitter on the throughput of IEEE 802.11 wireless network is not widely understood despite that is often used in various hospitality facilities. According to a recent survey, in such facilities, Wi-Fi is more important than, for example, parking or breakfast [12].

To fill these gaps, we measured the magnitude of wireless audio transmitter Line6 Relay G30 on the throughput of IEEE 802.11 network. We used an experimental laboratory environment in which we configured the IEEE 802.11 network and installed the Line6 Relay G30 wireless audio transmitter. The throughput was measured with two-speed test applications—Internet Speed Test and Speedtest By Ookla.

13.3 Equipment and Methods

13.3.1 Equipment Used

Wi-Fi Client

Mobile phone iPhone SE was used as Wi-Fi client. It was released in 2016 and supports IEEE 802.11a/b/g/n/ac standard, as well as Wi-Fi tethering. Additionally,

Table 13.1 D-Link DIR-615 general settings

Feature	Settings
BSSID	d_8
802.11 mode	b/g/n mixed mode
Band	2.4 GHz
Channel no.	6
Channel width	20(22) MHz

it supports HSPA, GSM, CDMA, EVDO, and LTE. The device falls in Category 4 according to LTE-A standard.

Non-Wi-Fi Interferer

Wireless audio transmitter Line6 Relay G30 was used as a non-Wi-Fi interferer. It was set up to operate on mode RF2 with two channels at 2428 and 2453 MHz which are near to central frequencies of Wi-Fi channel 4 in 2.4 GHz spectrum. Its range is up to 30 m, depending on the surroundings.

IEEE 802.11 Access Point

D-Link DIR-615 access point was used which supports IEEE 802.11b, g, and n standards. It has two fixed omnidirectional antennas with a gain of 2 dBi. Table 13.1 shows access point general settings.

After a quick examination of the area, we opted for channel 6 to minimize the potential effect of Wi-Fi interference. This is because on this channel the signal strength of other Wi-Fi networks was significantly lower (<-80 dBm) compared to the network tested (>-40 dBm). In addition, the channel was idle during measurement with 0% channel utilization from neighboring networks.

Spectrum Analyzer

Spectrum analyzer allowed us to examine the channel utilization and recognize various signal patterns on the physical layer in the monitored RF spectrum.

Hardware. Dual-band Ekahau USB was used to collect RF spectrum data. It has external RP-SMA Antenna, with a range between -100 and -6.5 dBm, and a resolution of 0.5 dBm. It supports both 2.4 and 5 GHz bands.

Software. Metageek Chanalyzer was used for real-time visual representation of collected RF spectrum data.

Throughput Test Application

Speedcheck Internet Speed Test[1] was used to measure the throughput of a wireless network. It is ranked the Apple App Store's top application for measuring network throughput. The application consists of iOS-based client and a worldwide network of high-speed servers for reliable results.

The test is Internet-based and performs through three general steps. First, the client establishes multiple connections with the closest throughput server. Second, the client application downloads or uploads a certain amount of data. Finally, the test ends once the configured amount of time expires and the final results are displayed.

13.3.2 Experimental Wireless Network Settings

An experimental network architecture was established in the Laboratory for Modeling and Optimizing Information and Communication Networks and Services at the Department of Information and Communication Traffic.[2]

Figure 13.1 shows the experimental network architecture settings we used for measuring wireless network throughput. The architecture consisted of the following nodes: iOS mobile phone with preinstalled throughput test client, IEEE 802.11b/g/n access point, a workstation with spectrum analyzer, Line6 Relay G30 wireless audio transmitter, and throughput test server.

Since the throughput test uses an Internet-based server, download and upload test path was *iOS Throughput Client → D-Link DIR-615 access point → Internet → Throughput Test Server*.

13.3.3 Methods for Throughput Measurement and Data Analysis

Throughput Measurement

Throughput was measured for previously described experimental network architecture settings. For measurement purposes, we have defined two scenarios:

– *Scenario 1 (control scenario).* Mobile phone is connected to access point (SSID = d_8) without introduced non-Wi-Fi interference. Figure 13.2 shows the settings of Scenario 1 on the physical layer.

[1] More information: https://apps.apple.com/us/app/speedcheck-internet-speed-test/id616145031.

[2] More information: https://www.fpz.unizg.hr/ikp/eng.php.

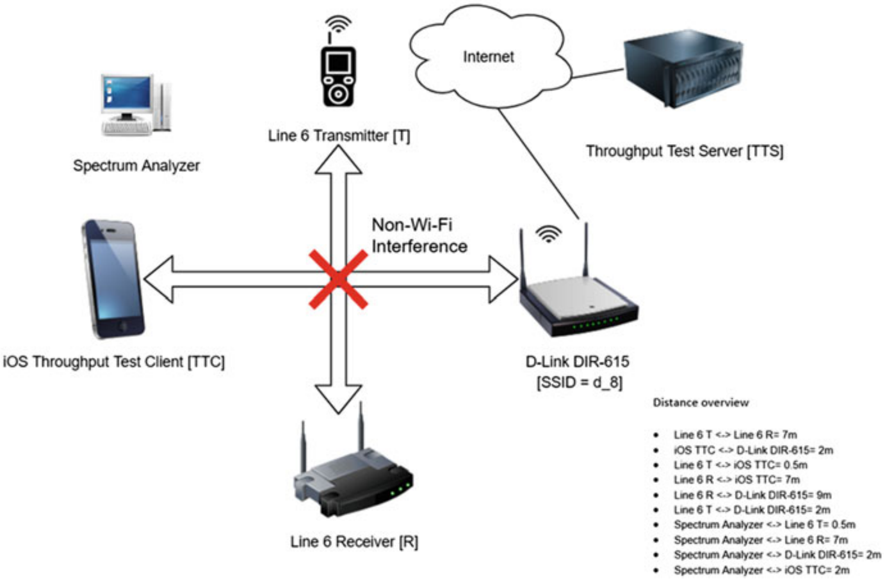

Fig. 13.1 Experimental network architecture settings for measuring the effect of non-Wi-Fi interference on the throughput of wireless network

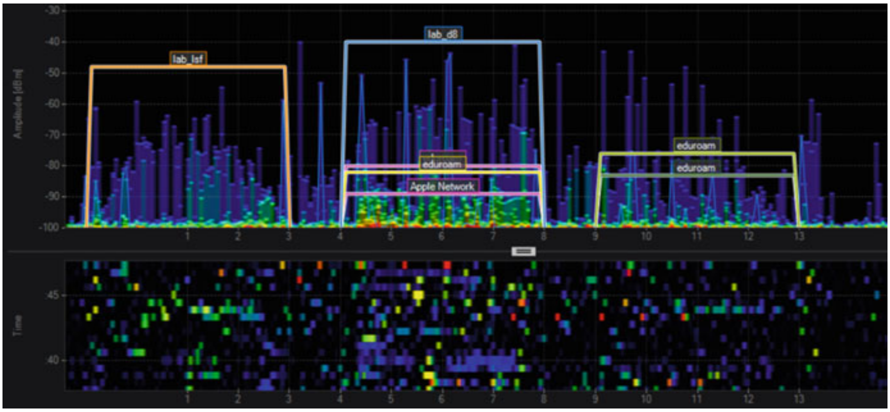

Fig. 13.2 RF spectrum of Scenario 1 in 2.4 GHz band without introduced non-Wi-Fi interference (d_8 is represented by blue line)

– *Scenario 2 (treatment scenario)*. Mobile phone is connected to access point with introduced non-Wi-Fi interference from Line6 Relay G30 wireless sound transmitter. Figure 13.3 shows the settings of Scenario 2 on the physical layer.

Throughput was tested through four steps:

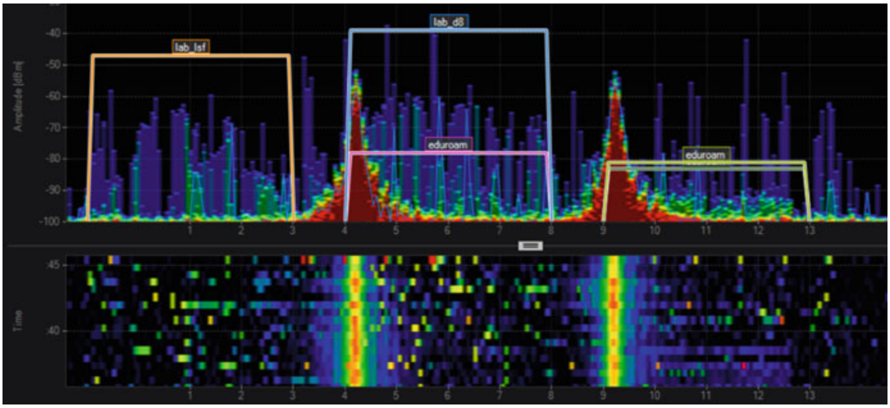

Fig. 13.3 RF spectrum of Scenario 2 in 2.4 GHz band with introduced non-Wi-Fi interference (Line6 Relay G30 is represented by two red peaks)

Step 1: 30 download measurements for Scenario 1
Step 2: 30 download measurements for Scenario 2
Step 3: 30 upload measurements for Scenario 1
Step 4: 30 upload measurements for Scenario 2

This resulted in a total of 60 measurements for download and 60 measurements for upload, or 120 in total. During all steps, all devices in the network were at a constant distance, and measurements were taken exclusively at periods with 0% of channel utilization which was examined by spectrum analyzer.

Data Analysis

Post-measurement data analysis was performed through four steps:

Step 1: Mean values for download and upload data rates for each scenario were obtained.
Step 2: Normality assumption for the data was evaluated.
Step 3: Bartlett's or Levene's test was chosen based on the results from the previous step to test the homogeneity of variances. The test was conducted separately between download and upload data rates obtained from Scenarios 1 and 2.
Step 4: Appropriate two-sample t-test was selected on the basis of the results from the previous step. The test was performed separately between download and upload data rates obtained from Scenarios 1 and 2 to test alternative hypothesis whether the mean difference is:

(a) greater than zero ($H_{\text{alternative}}$: diff > 0)
(b) different from zero ($H_{\text{alternative}}$: diff $= 0$)
(c) less than zero ($H_{\text{alternative}}$: diff < 0).

13.4 Results

13.4.1 Descriptive Statistics

Figure 13.4 shows the mean data rates. For scenario 1, the mean download data rate was 11.0878 Mbps with a standard deviation of 5.8539, while for Scenario 2 mean download data rate dropped to 1.66233 Mbps and a standard deviation of 1.1249.

The mean upload data rate during Scenario 1 was 14.9593 Mbps with a standard deviation of 3.8534 and then dropped to 2.2386 Mbps during Scenario 2 with a standard deviation of 1.8239.

13.4.2 Normality Test

We evaluated the normality of the data in order to select appropriate variance test in the next step. Figure 13.5 shows box plot for measured data rates by scenario. The middle line of the rectangle represents the median, and upper and lower limits represent the interquartile range.

After visually inspecting the box plot, we performed additional normality test based on skewness/Kurtosis to obtain the overall test statistics and test the null hypothesis that Download/Upload variables are normally distributed. Table 13.2 shows the results for normality test.

13.4.3 Variance Homogeneity Test

Since the overall test statistic for download from Scenario 1 (Table 13.2) was statistically significant at 5% level, we opted for Levene's test which is more robust to possible violations of normality assumptions.

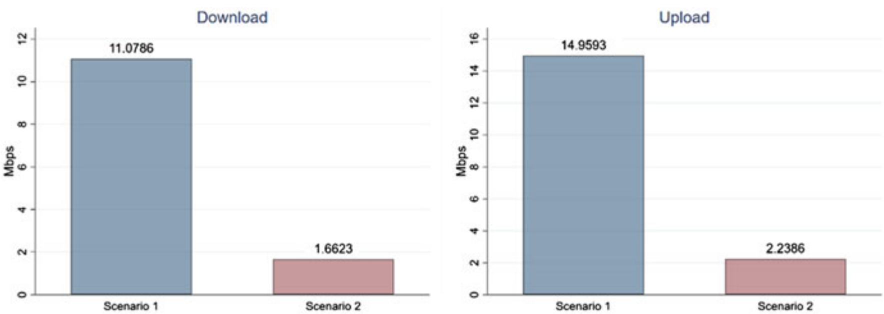

Fig. 13.4 Mean data rates

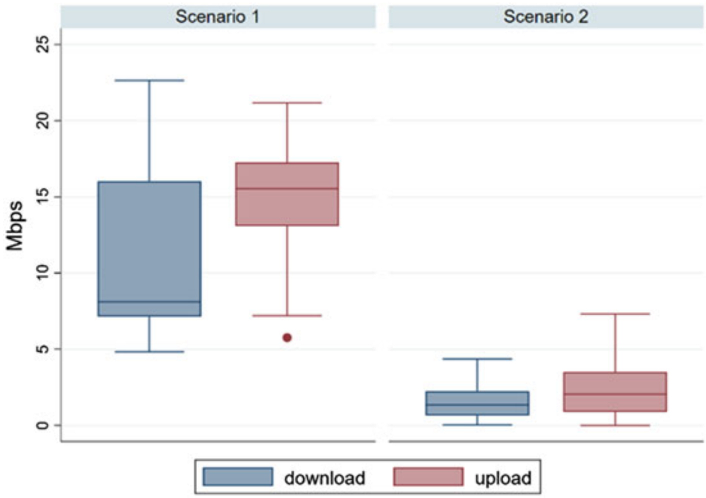

Fig. 13.5 Box plot of data

Table 13.2 Skewness/Kurtosis test

Variable	Scenario	Obs	Pr(skewness)	Pr(Kurtosis)	Overall test statistics	
					Adj chi2(2)	Prob > chi2
Download	Scenario 1	30	0.0265	0.5439	5.16	0.0759
Download	Scenario 2	30	0.0532	0.6844	4.11	0.1283
Upload	Scenario 1	30	0.1362	0.7623	2.56	0.2786
Upload	Scenario 2	30	0.0626	0.3746	4.38	0.1120

Table 13.3 Levene's test of homogeneity of variances for *download*

Group	Mean	Std. dev.	Frequency
Scenario 1	30	5.8539	30
Scenario 2	30	1.1249	30
Total	6.3705	6.3252	60
W_0	45.6455	df(1, 58)	$\Pr > F = 0.0000$
W_{50}	14.7967	df(1, 58)	$\Pr > F = 0.0003$
W_{10}	33.0838	df(1, 58)	$\Pr > F = 0.0000$

Tables 13.3 and 13.4 show statistically significant results from Levene's test with all p values < 0.001. Levene's test statistics W_0, W_{50}, and W_{10} were calculated based on the mean, median, and 10% trimmed mean, respectively.

The final step was to perform the t-test with unequal variances whose results are shown in the following section.

Table 13.4 Levene's test of homogeneity of variances for *upload*

Group	Mean	Std. dev.	Frequency
Scenario 1	30	3.8534	30
Scenario 2	30	1.8239	30
Total	8.599	7.0762	60
W_0	10.2758	df(1, 58)	$\Pr > F = 0.0021$
W_{50}	9.6094	df(1, 58)	$\Pr > F = 0.0029$
W_{10}	9.9085	df(1, 58)	$\Pr > F = 0.0025$

13.4.4 t-Test with Unequal Variances

Tables 13.5 and 13.6 show the results of a *t*-test for mean download and upload data rates, measured with Speedcheck Internet Speed Test.

13.5 Discussion

The main goals of this experiment were to analyze to what extent wireless audio transmitter Line6 Relay G30 affects the throughput of IEEE 802.11b/g/n/ network and to test whether the mean download or upload differ before and during non-Wi-Fi interference.

We found that Line6 Relay G30 caused a very serious degradation of network throughput. Mean data rates (Fig. 13.4) were reduced by 85%—from 11.0786 to 1.6623 Mbps for download, and from 14.9593 to 2.2386 Mbps for upload.

We tested the mean difference with *t*-test with unequal variances, obtaining statistically significant results at 1% level with p values < 0.001. Therefore, we can confirm alternative hypotheses that the mean difference between Scenarios 1 and 2 is not equal to zero ($H_{\text{alternative}}$: diff $= 0$, p value < 0.0001) and that is less than zero ($H_{\text{alternative}}$: diff < 0, p value < 0.0001). In other words, this means that measured data rates from Scenario 1 will be greater than those from Scenario 2.

To evaluate the validity of performing the *t*-test with unequal variances, we conducted two pre-estimation tests. First, we tested the normality assumptions of the data, obtaining results (Table 13.2) insignificant at 5% level and all p values > 0.05. Therefore, the null hypothesis that data don't violate normality assumptions cannot be rejected. Second, we tested the homogeneity of variances with Bartlett test since the normality assumption was not violated. The results were insignificant at 1% level and we couldn't accept the null hypothesis that variances are equal.

Therefore, we can confirm that data rates were seriously reduced during simultaneous coexistence of both IEEE 802.11b/g/n network and active interferer on the same channel in 2.4 GHz band. This is because Line6 Relay G30 wireless audio transmitter transmits continuously, thus occupying the channel most of the time.

Table 13.5 *t*-Test results comparing mean *Download* data rates of both scenarios

Group	Obs	Mean	Std. err.	Std. dev.	[95% Conf. interval]	
Scenario 1	30	11.0786	1.0687	5.8539	8.8927	13.2645
Scenario 2	30	1.6623	0.2053	1.1249	1.2422	2.0824
Combined	60	6.3705	0.8165	6.3252	4.7365	8.0044
Difference		9.4163	1.0883		7.197	11.6356
Diff = mean (Scenario 1) − mean (Scenario 2)						$t = 8.6520$
H_{null}: diff = 0			Satterthwaite's degrees of freedom = 31.139			
$H_{\mathrm{alternative}}$: diff < 0 $\Pr(T < t) = \mathbf{1.0000}$		$H_{\mathrm{alternative}}$: diff != 0 $\Pr(\lvert T\rvert > \lvert t\rvert) = \mathbf{0.0000}$			$H_{\mathrm{alternative}}$: diff > 0 $\Pr(T > t) = \mathbf{0.0000}$	

Table 13.6 *t*-Test results comparing mean *Upload* data rates of both scenarios

Group	Obs	Mean	Std. err.	Std. dev.	[95% Conf. interval]	
Scenario 1	30	14.9593	0.7035	3.8534	13.5204	16.3982
Scenario 2	30	2.2386	0.333	1.8239	1.5576	2.9197
Combined	60	8.599	0.9135	7.0762	6.771	10.4269
Difference		12.7206	0.7783		11.1491	14.2922
Diff = mean (Scenario 1) − mean (Scenario 2)						$t = 16.3426$
H_{null}: diff = 0				Satterthwaite's degrees of freedom = 41.3728		
$H_{alternative}$: diff < 0 $\Pr(T < t) = \mathbf{1.0000}$		$H_{alternative}$: diff != 0 $\Pr(\lvert T\rvert > \lvert t\rvert) = \mathbf{0.0000}$			$H_{alternative}$: diff > 0 $\Pr(T > t) = \mathbf{0.0000}$	

In other words, Wi-Fi station will detect non-Wi-Fi energy from the interferer on the physical layer and will either back-off from accessing the channel or will try to transmit but with an increased probability of dropped packets. In both cases, the network throughput will be significantly reduced.

This is consistent with the results from [5] that suggest that similar devices such as analog wireless camera or analog cordless phone can reduce the throughput of IEEE 802.11 network by a similar amount.

In contrast to other devices, Line6 Relay G30 reduced the network throughput three times more than Bluetooth handset or baby video monitor. For example, according to [9] such devices can reduce the throughput of IEEE 802.11 wireless network by 26.5% on average.

13.6 Conclusion

Interference is an important problem in 802.11 wireless networks. In this paper, we have measured the effect of audio video transmitter Line6 Relay G30 on the throughput of IEEE 802.11b/g/n network in 2.4 GHz band in laboratory environment. Such non-Wi-Fi device is often used in various hospitality facilities and may significantly affect the performance of Wi-Fi network.

To anticipate this, we suggest that it is necessary to diagnose the potential permanent and interim presence of non-Wi-Fi RF energy on the physical layer during network planning and deploying, and its impact on the network. We suggest that solutions for deploying of 802.11 wireless networks should pay special attention to non-Wi-Fi devices, especially in the hospitality industry where low Wi-Fi network performance can result in negative users' reviews (Red Roof Inn., 2020).

Our study may pave the way for similar future studies that should concentrate on interference measurements in different environments and scenarios to get a complete picture about the effects of nonhome and non-Wi-Fi interferers on IEEE 802.11 on wireless network performance.

Taken together, our analyses lead to the conclusion that intensive interference from devices like Line6 Relay G30 wireless audio transmitter may be critical for Wi-Fi communications if located near Wi-Fi stations, and can even interrupt communication or lower data rates to a level where IEEE 802.11 network is unusable.

Our study may help network practitioners and professionals, as well as end users to gain greater understandings of non-Wi-Fi interference landscape which may prove useful during the deployment of IEEE 802.11 wireless networks.

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Chapter 14
Assistive Technologies in Function of Visual Impaired Person Mobility Increases in Smart Shopping Environment

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14.1 Introduction

Continuous development of modern information–communication (IC) solutions and services contributes to the development of functionally efficient assistive technologies. Assistive technologies represent the application of information and communication in easier mastering the everyday living and needs of persons with disabilities (free time, business, and sporting activities, etc.) [1]. Visually impaired persons require adjustment of IC solutions and services because of a specific form of visual damage and methods which they use in moving in the external and internal environment [2]. User requirements represent the starting point in defining the functionality of IC services that are designed for visually impaired persons; therefore, this research was conducted on students with visual impairments, University of Zagreb. The aim of this research is to show the possibilities of IC technology in the function of the increasing mobility of visually impaired persons during daily shopping. With the above solution, it is possible to increase the degree of the user quality of life and their easier integration in society. In this work, Society 5.0 characteristics are also shown as a possible concept of future services of assistive technologies.

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14.2 Previous Research

Research in this area covers the topic of assistive technologies application in shopping processes for visually impaired people. It was also published a patent of smart shopping carts customized for visually impaired people during the shopping process [3]. In the above patent, shopping cart does not have the ability to guide and direct the user to the requested goods, but according to the sensor, user information is performed so he knows if he is on a good route. For obstacle detection, the use of the camera is stated or *Lidar* system and they are installed on the shopping cart. During the detection of the obstacle, via vibrating motors and loudspeakers on the handle of the shopping cart, the user is notified that he must change the direction to avoid obstacle. This mode of operation increases user stress because if he does not change the direction there will be a collision with the obstacle thereby jeopardizing the safety of movement. Proposed solution does not also specify the possibility of shopping cart location when user enters the shop, nor what will happen if the user moves away from the shopping cart during the shopping. Moreover, there is no goods verification system (e.g., product in bulk quantity determination, like fruit and vegetables) and the possibility of scanning of goods when placing in the shopping cart. Product detection on store shelves it is possible to use portable solutions located on the body of the user (finger) [4]. That concept is described in the form of the solution which is implemented on finger or arm in the form of bracelet. Navigation and guidance of user additional aids are used, such as a white cane or guide dog. The survey describes the presentation of different solutions on the market which were represented for the past 10 years [5]. Described solutions: *RoboCart*, *ShopTalk*, *GroZi,* and *iCare* and they base their work on contemporary IC technologies and have the possibility of user navigation and detection of the goods. *RoboCart* represents solutions in the form of shopping cart that enables user navigation across the shop based on RFID labels while for obstacle detection it uses laser sensors. Product search on the shelf takes place using the scanner for barcode, which is mounted on the shopping cart, or connected wirelessly, which user leans on the shelf to find the desired product. Shopping carts have built-in *Belkin* keyboard, which emulates function of classical keyboard for mobile phones by which the user enters next product to which he wants the shopping cart to take him. *ShopTalk* presents system for user navigation in the shop and product detection on the shelf which is based on scanning barcodes on shelves. It is based on the use of MSI type of barcode which represents topological markings for navigation and goods detection, and they are connected in BCM (Barcode connectivity matrix). The solution consists of barcode reader which is connected on OQO portable computer which user carriers in the form of a backpack. A keyboard worn by the user on the shoulder is connected to it. This type of solution is not suitable for users because it requires additional preparation before going to the shop, by putting this type of solution on itself. Also, it is not described in the method of detection and the way of avoiding obstacles, so the user must carry a product basket. *GroZi* represents the solution in the form of a user bracelet, which allows product detection using cameras to record the product on shelf, and via a portable device which the user carries on his back in a form of a backpack, analyzing the image from the camera. When the product the user is looking for appears in the image, using vibrating motors in the glove, the solution signals to the user that the product is on the shelf. Once the product is detected, the solution guides user toward the product by informing it about the direction with vibrating motors. Such a solution requests from the user that using glove constantly records the shelf in front of which it is located. The user can create a list by the website, which is then loaded on the portable device. *iCare* presents the solution that also includes the glove, containing an RFID reader which links to the database via Wi-Fi network. When the customer, with the help of the glove, passes in front of the part of the shelf on which the product is located, he gets the information about product department on which it is located, via PDA (Personal Digital Assistant) device. When the user receives the product, he gets additional information about it based on RFID tag located on the product. The main purpose of this solution is browsing products that are in the store. For the purpose of product detection using mobile devices (MD), it is possible to use photography functionality of different barcodes or QR codes, and through the application on MD perform verification of these codes in code database [6, 7]. In the addition to the possibilities already mentioned for products scanning, detection can be performed using specially designed Barcode Pencil device. The concept also uses specially designed device Barcode *IDBlue Pen* for scanning RFID tags [8]. The buying process can be divided on the preparation of the shopping list, user navigation in the store, and product detection on the shelf [9]. List preparation represents useful possibility for the user because most people with visual impairment prefer to use premade list when shopping.

14.3 Defining User Requirements in the Shopping Process

User requirements during the shopping process are defined on the basis of conducted research among the target population of student-age users. The research was conducted at the University of Zagreb where, according to the official data, the Office for Students with Disabilities has 40 students with visual impairments, who has active student status. Approach to respondents was organized with the help of a coordinator for students with disabilities. In this research, population includes 34 students with visual impairments who were able to access the survey. They are members of the Up2Date association. In survey questionnaire, 34 respondents of which 18 males and 16 women participated. Most respondents are between the age of 18 and 25, 17 respondents are blind, and 17 visually impaired (Table 14.1). The data were analyzed by the IBM computer program SPSS Statistics 21.

To the question “How often do you do the shopping?” 47.1% of respondents responded that they go shopping several times a week, 38.2% of respondents go shopping several times a month, 11.8% of respondents never make purchase in the store. To the question “What bothers you the most while shopping at the store?” 22

Table 14.1 Age of respondent

Age of respondent	Frequency	Percentage
18–24	23	67.6
25–29	10	29.4
30–39	1	2.9
Overall	*34*	*100.0*

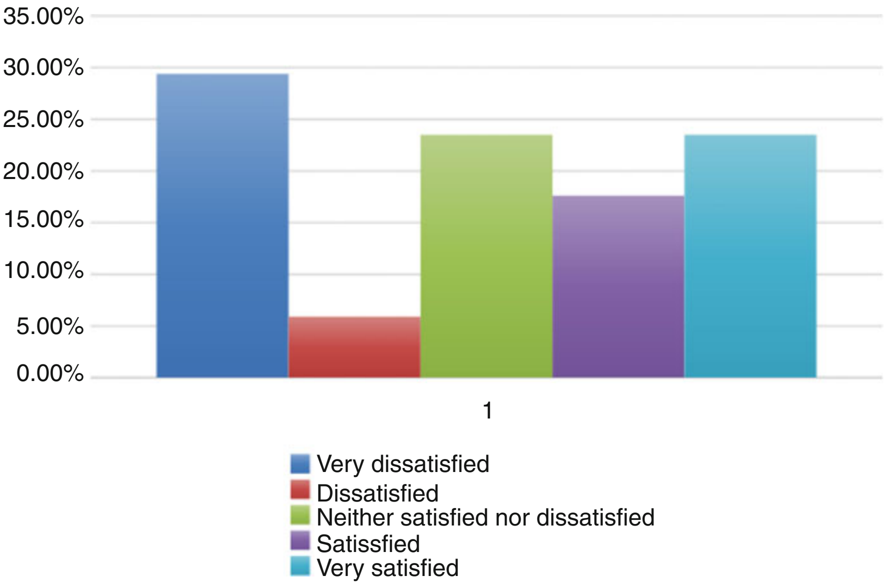

Fig. 14.1 Satisfaction of independent shopping

respondents responded that they are most disturbed by the external disturbances, 9 respondents as the greatest obstacle see misunderstanding by the other buyers, and 7 of them misunderstanding by the employers. Those respondents who independently perform shopping in 29.4% cases claim that they are very dissatisfied by making self-purchase; 5.9% of respondents are dissatisfied while 23.5% of respondents are of neutral status. Satisfaction with the independent shopping expresses 17.6% of respondents, while 23.5% of respondents are very satisfied, Fig. 14.1.

The highest percentage of blind and visually impaired persons (35.3%) is neither satisfied nor dissatisfied by the care of stores for them during the shopping. Still, 29.4% of respondents are satisfied with store care about blind and visually impaired persons and 8.8% of them are very satisfied; 11.8% of respondents are dissatisfied; and 14.7% of respondents are very dissatisfied with the store care for blind and visually impaired persons. Data processing showed that 60.7% of respondents have a habit of shopping always the same product and if there are no desired products, 76.5% of respondents have the habit of shopping a similar product. To the question

"Do you use possibility of product delivery to avoid going to the shop?" 76.5% of respondents answered that they do not use the possibility of product delivery and 23.5% of them use the possibility of product delivery. Of the total number of the respondents who use product delivery, 12.5% of them are very dissatisfied with the service provided, 50% of them are satisfied and 37.5% are very satisfied with the service provided; 20.6% of the respondents use product recognition application and 79.4% do not use those applications. Respondents mostly use *TapTapSee* (83.3%) and *BeMyEyes* (16.7%) applications. Sensor technology is reliable for 76.5% of respondents and 82.4% of the respondents would use the shopping cart based on sensor technologies; 76.5% of respondents use the possibility of contactless bill payment in stores. However, 17.6% of respondents consider very insecure the possibility of linking the mobile phone with the shopping cart, 5.9% insecure, and 14.7% are neutral; 41.2% of respondents consider that the possibility of linking the mobile phone with the smart shopping cart is secure and 20.6% very secure. The highest number of respondents (46%) states the sound as the desired method of obtaining feedback; 33% state an enlarged font, and 21% vibration as desired mode of obtaining feedback.

Considering the importance of feedback (Fig. 14.2), information about obstacles is important for 38.2% of respondents and for 29.4% it is very important. Information about store location is important for the highest number of respondents (47.1%). Route information, location of desired products, and choosing the right type of products, in most cases respondents consider important (41.2%). However, in relation to the three variables, a slight advantage is given to information, which allows them to choose the right type of product (35.3%), then information about desired products location (29.4%) and route information (17.6%). Most respondents take neutral position toward the importance of information about the possibility of

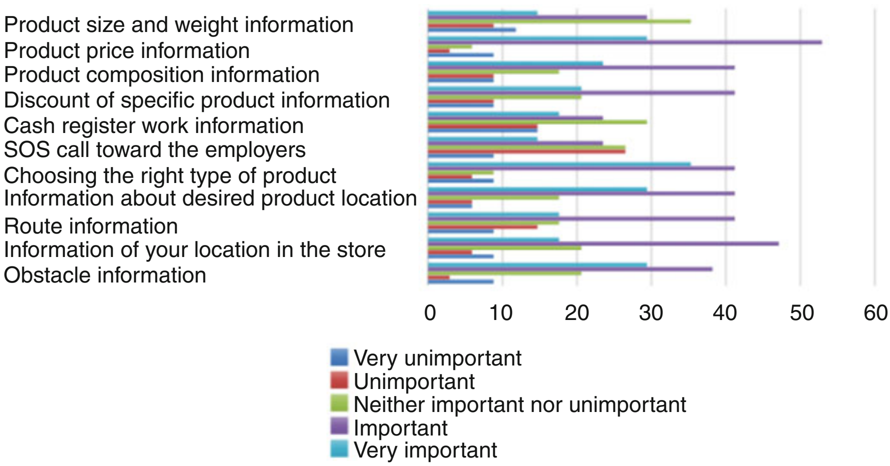

Fig. 14.2 The importance of information during purchase

SOS call toward employers, information about cash register work, and information about product size and weight. Furthermore, discount of specific products information and product composition information are important for respondents (41.2%) as a product price information (52.9%).

For the question "Do you agree that our solution will help you when performing independent purchase?" 20.6% of respondents think that solution will not help them at all when performing independent purchase, while 26.5% of them think that it will help them and 23.5% think that will completely help them while performing independent purchase. Most respondents, 44.8% of them have neutral attitude toward usefulness of education in using smart shopping cart and mobile application; 31.00% of respondents think that education will not be useful at all and 13.8% of them think that education will be useful in the use of shopping carts and mobile application. Respondents would, to the greatest extent, access online education (50%), group education (31.2%), and individually (3.6%); 14.3% of respondents would not attend education. Based on the results obtained, user requirements are defined as well as the information required for navigation system design and information of users during shopping, as shown in Fig. 14.2.

14.4 Proposal for a Conceptual Architecture of the Navigation and User Information System in the Smart Shopping Environment

The architecture of the proposed system is based on *Cloud Computing for the Blind concept–CCfB* that provides the user with the ability to manage the data necessary to achieve all the functionalities of the proposed service [10]. The proposed system consists of a mobile application and specially designed shopping cart equipped with sensor technology. Based on the conducted research, the functionalities of the system were defined. The defined functionalities aim to facilitate the process of independent shopping for visually impaired users. The architecture of the system is shown in Fig. 14.3, and it contains the following elements: CCfB, the users MD on which the required application is installed, a shopping carts equipped with sensors, a user database and a store database, Indoor Positioning System (IPS) for indoor navigation, and a point of sale (POS) device for credit card payments.

Communication between a user's MD and a shopping cart belongs to the Machine-to-Machine (M2M) mode of communication. It is performed by using Bluetooth technology, which represents an open wireless technology standard for data transmission. Communication between the devices works by transmitting radio waves in the frequency range from 2400 to 2485 GHz, better known as the industrial, scientific, and medical frequency band (ISM), for the use of which no payment of a concession is required thus making this standard widespread and accessible to users. Bluetooth 4.0 BLE technology version is used for M2M communication in the Internet of Things (IoT) and Ambient Assisted Live (AAL) concepts. Its

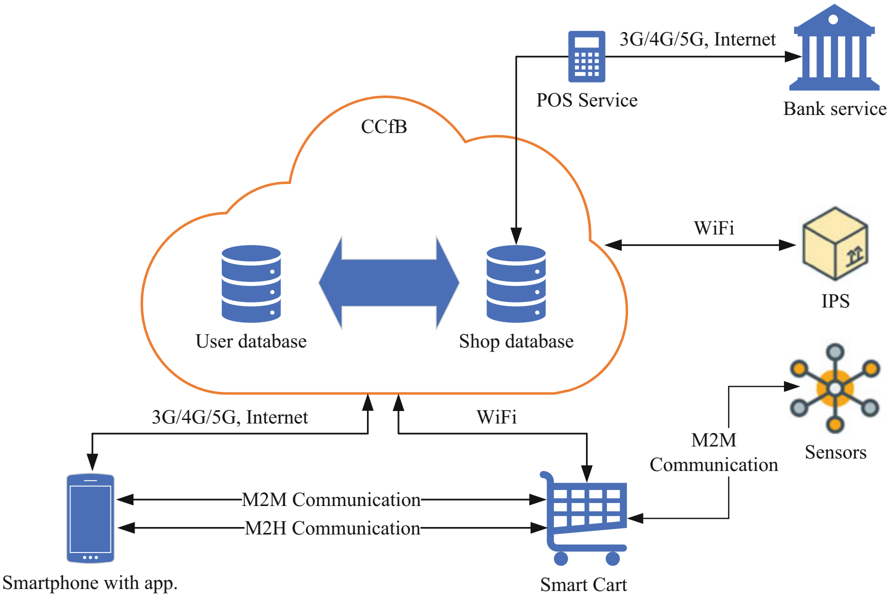

Fig. 14.3 Conceptual architecture of the navigation and user information system in the smart shopping environment

main advantage is the reduced energy consumption when connecting devices and exchanging a small amount of data [11].

In addition to wireless mode, M2M communication can also be performed by a wired connection. This form of connection is used in the communication of shopping carts with built-in sensors because it provides security against interference during data transmission, which can occur in wireless communication. Sensors built-in the shopping cart are used to collect data from the environment in which shopping carts are located. Data are collected and processed in the central processing unit located on the shopping cart, which then performs certain activities based on the collected data.

Communication between the user and the application that is installed on the user's MD and communication of the user with the shopping cart belongs to the machine-to-human (M2H) mode of communication. This form of communication allows the user to receive the right information at the proper time, and the presentation of received information can adapt to his type and degree of disability. The mobile application allows the visually impaired user to receive feedback via a text-to-speech synthesizer (TTS) that works on a combination of application and MD hardware for the artificial reproduction of the human voice. The information can also be displayed with certain design modifications in the form of font and different background and text colors that will make it easier for a partially blind user or users with other visual impairments such as color blindness to read information.

The feedback that the user receives from the shopping cart can be in the form of sound signals of different frequencies. It will signal to the user a certain level of danger, for example, when encountering an obstacle when moving through a store or signaling the successful completion of a certain action such as scanning a product when placing a product in the cart. Obtaining information in the form of sound signals is enabled through the functionality of an MD. After performing a specific action that triggers obtaining audio information, shopping carts signal the application to notify the user.

Feedback in the form of vibration informs the user about the arrival at a certain destination, the way of the turn when moving through the store, and when avoiding obstacles. There are built-in vibration motors on the handle of the shopping cart, one on each side of the handle that can be activated as needed. For example, if it is necessary to make a left turn, the shopping cart will inform the user about that action by activating the vibrating motor located on the left side of the handle. Another example is that when arriving at a destination, the shopping cart can activate both vibrating motors to notify the user of the stop.

User account information is stored in the user database. The data are stored after successful user registration, and once stored, the data can be later edited by the user if necessary. In addition to user account data, the database also contains data on created shopping lists and purchase history. The store database is divided into a part that contains data of products that can be found in a store, a part that's connected to the shopping cart, and a part that stores data on purchases made. The part of the database that is connected to the shopping cart contains a temporarily stored shopping list that is transferred from the user's application and a created shopping bill that updates when a new product is placed in the shopping cart. The user can access the store database with his application, but only to the part where the data about the products are stored. The user needs that data when he is creating or editing the created shopping list. To access the product database with his application, the user must have an Internet connection. He can make that connection by using a mobile data network (3G, 4G, 5G) or wireless networking (Wi-Fi). Shopping carts gain access to the database with wireless networking technology (Wi-Fi), provided to them by the store itself. IPS system is based on the following technologies: Bluetooth BLE, Wi-Fi, NFC (near-field communication—NFC), and RFID (radio-frequency identification). It represents a network of devices like wireless access points, Bluetooth beacons, RFID tags, and NFC tags that are connected to enable users to locate and navigate indoors [12].

14.5 Functionalities of Navigation and User Information Services

14.5.1 The Functionality of Smart Shopping Carts

The functionalities of shopping cart are defined on the basis of conducted research, so as to facilitate the process of self-purchase for visually impaired and provide a new shopping experience for the non-visually impaired people.

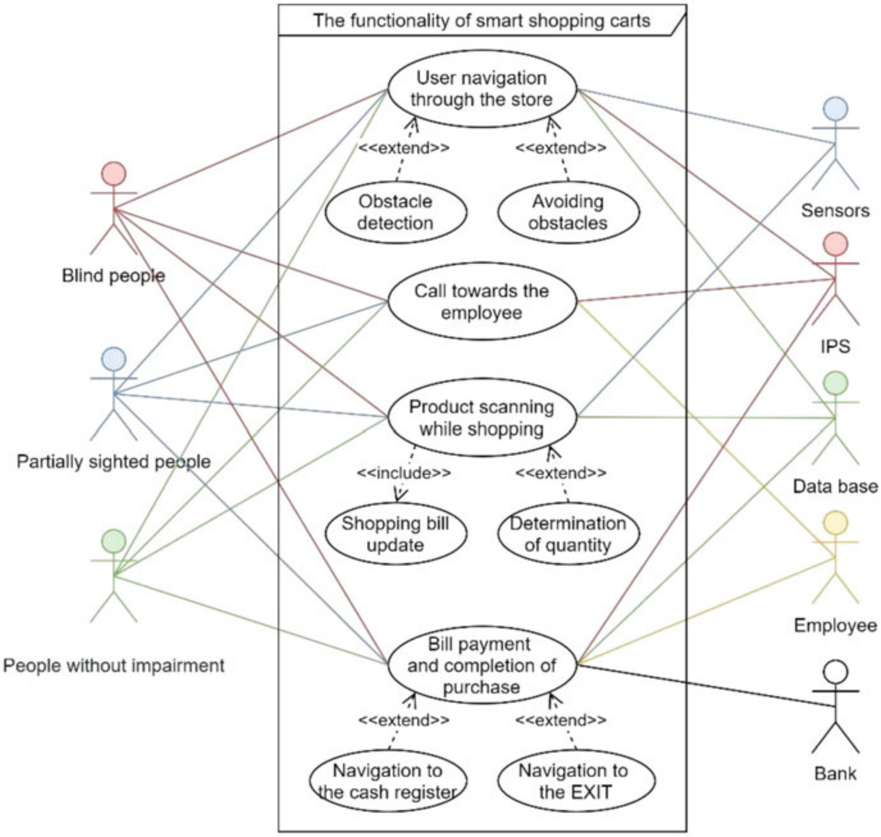

Fig. 14.4 Use-case diagram of shopping cart functionality

According to Fig. 14.4, the following functionalities are shown: user navigation by store to a specific product that includes obstacle detection and avoidance processes, the ability to call an employee by pressing a button on the cart, product scanning when placing a new product in the cart, control of the quantity of products placed in the cart, and navigation of users to the cash register and exit from the store.

User Navigation Through the Store

Shopping cart allows the user to safely and reliable move throughout the store without the use of aids in the form of a cane or a guide dog. The cart moves at a user-friendly speed and performs the processes of detection and avoidance of obstacles and enables the easier finding of products as well as customer orientation within the store itself (Fig. 14.5).

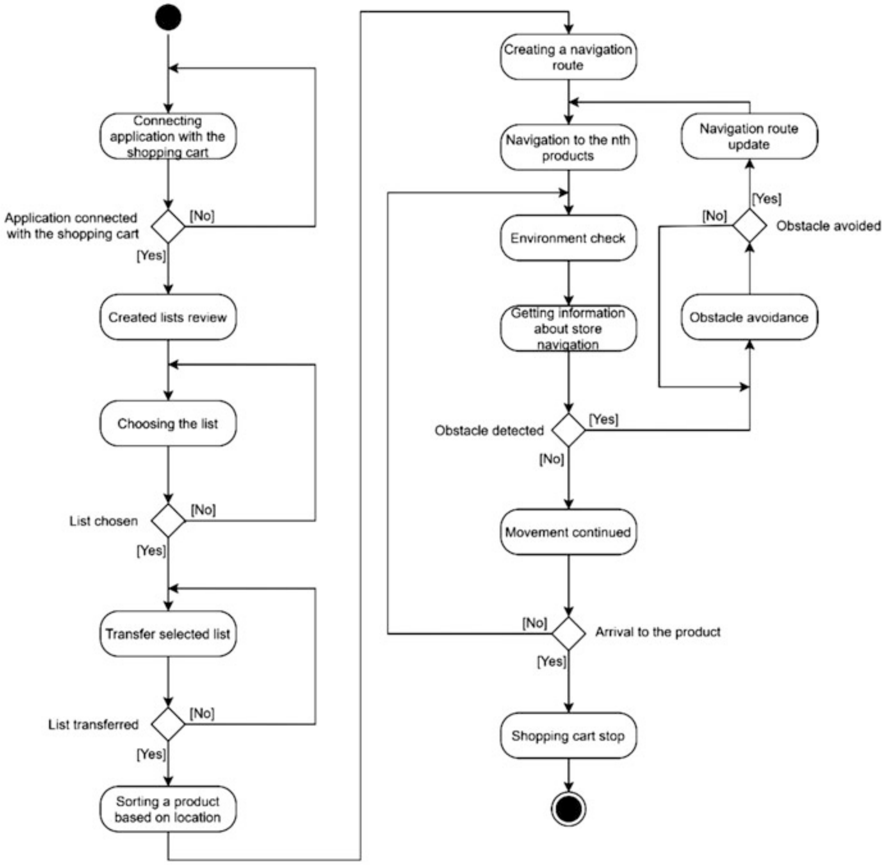

Fig. 14.5 Activity diagram for user navigation through the store

Once the connection between the MD and the shopping cart is completed using the Bluetooth technology wireless connection, the user will select the previously created list of products he wants to use through the application. The created list from the user database will then be transferred to the shopping cart and they will store it in the part of the store database to which they have access. The products on the list stored in the store database will be sorted depending on their location and after sorting the products, the locations of the products on the list will be forwarded to the IPS system for determining the route of movement through the store. When the route creation is complete, the information needed to navigate the cart to a specific product will be passed between the IPS system and the shopping cart. Before the cart starts moving, the sensors built into the cart start the process of checking the environment near the shopping cart to detect obstacles that may appear on the predetermined route. The shopping cart then starts moving along the route provided by the IPS system and through the application they pass the information to the user about his movement through the store. When moving through the store, the user may encounter movable obstacles in the form of other customers and their carts, and immovable obstacles in the form of shelves, product pallets, carts left by other customers, or products that have fallen off the shelf. In order that cart can identify the various obstacles encountered, a camera was built into the front end of the cart. The camera scans the environment and forwards the recording to the microcomputer located in the central processing unit of the cart, which then processes the recording and makes a conclusion about the obstacles type encountered by the user. Once the type of obstacle has been identified, the cart performs the obstacle avoidance procedure and the movement route is updated because there is a possibility that the obstacle directly affected the route that was previously defined.

Call Toward the Employee

If the user is in a situation where he needs the help of another person or when he wants to be further informed about some things in the store, he was given the option of calling the employee. When the user selects the option to call the employee at the info desk, the application starts searching in-store database for the number needed to establish a call, and then the application establishes a VoIP (Voice over Internet Protocol—VoIP) call between users mobile device and mobile device on the info desk.

Product Scanning While Shopping

Inside the store, the user can find two types of products, products already packaged and products in bulk condition, such as fruits and vegetables. Packaged products are marked with RFID tags. Tagging products with RFID tags allows users to scan products more easily, as opposed to using a barcode, because there is no need to lean the product on the tag reader itself as is the case with the barcode. Once the user successfully arrived with his cart to his destination and by destination meaning a product from the list and after detecting and taking the product from the shelf, he puts the product into the cart. In the case of a packaged product marked with an RFID tag, when placing the product in shopping cart RFID tag reader will scan the product and will give a user an audio signal through the application notifying the user of a successful product scan. The information about the scanned product is going to be shown on the user's mobile device screen display and the user is expected to confirm the product entry to avoid the possibility of taking and purchasing the wrong product. After the user confirms the product, the current state of the user's bill is updated, and the updated tab balance is displayed to the user through the application. If the user puts the products in bulk state in the cart a change in weight will be detected using a scale located on the bottom of the cart. While creating a product list, users are expected to define the amount of product they want to buy. When placing a bulk product into the cart, the cart will compare the achieved weight in the cart with the weight on the stored list in the store database. The cart will inform the user through the application about the currently achieved weight of the product. After reaching the weight on the created list, the user will be shown a notification that the desired weight has been reached and he will be required to confirm the entry of the product.

Bill Payment and Completion of Purchase

After the user puts the last product in the cart, the user will receive a notification through the application which they must confirm to complete the purchasing process. After confirmation, a final tab is created, which is then stored in the store database and the user database. The users are then shown the menu where they select the payment method. The user is offered two options, going to the cash register, and paying by cash or credit card, or payment through the application.

When the user reaches the cash register, he is expected to show the employee the QR code on the mobile device. The employee scans the displayed QR code and the user can pay the bill in cash or by using a credit card. Once the payment is made and the employee confirms that the user has paid the bill, the store system that is connected to the cart sends the user an information that the payment has been made and that they can leave the store. The cart then requires the route toward the exit from the IPS system and guides the user toward it. For the user to avoid using the cash register, he is given the option of paying through the application. The condition for using this form of payment is that there is stored information in the application about a credit card that the user wants to use when making a payment. Once the user has selected this payment method, they are expected to select which credit card they will use, if more than one is stored in the application. Once the card is selected, a form for payment is created and automatically filled in with credit card information and the amount on it, and an online transaction is made through the application. After the transaction between the application and the bank is successfully completed, the user will receive a notification about the performed transaction. The application notifies the cart that the transaction has been done and the cart then requires a route to the exit from the IPS systems and guides the user to the exit.

14.5.2 The Functionality of Mobile Application Services

Based on the obtained results of the conducted research with the target user population, the functionalities of the MD application service were defined (information provided to the user of the system). The following basic functionalities of the application are defined: creating an account that includes registration and login, creating a list of products, detecting products on the shelf, locating shopping cart at the entrance, locating carts during shopping, and receiving SOS notifications. In addition to the listed functionalities of the application, additional functionalities

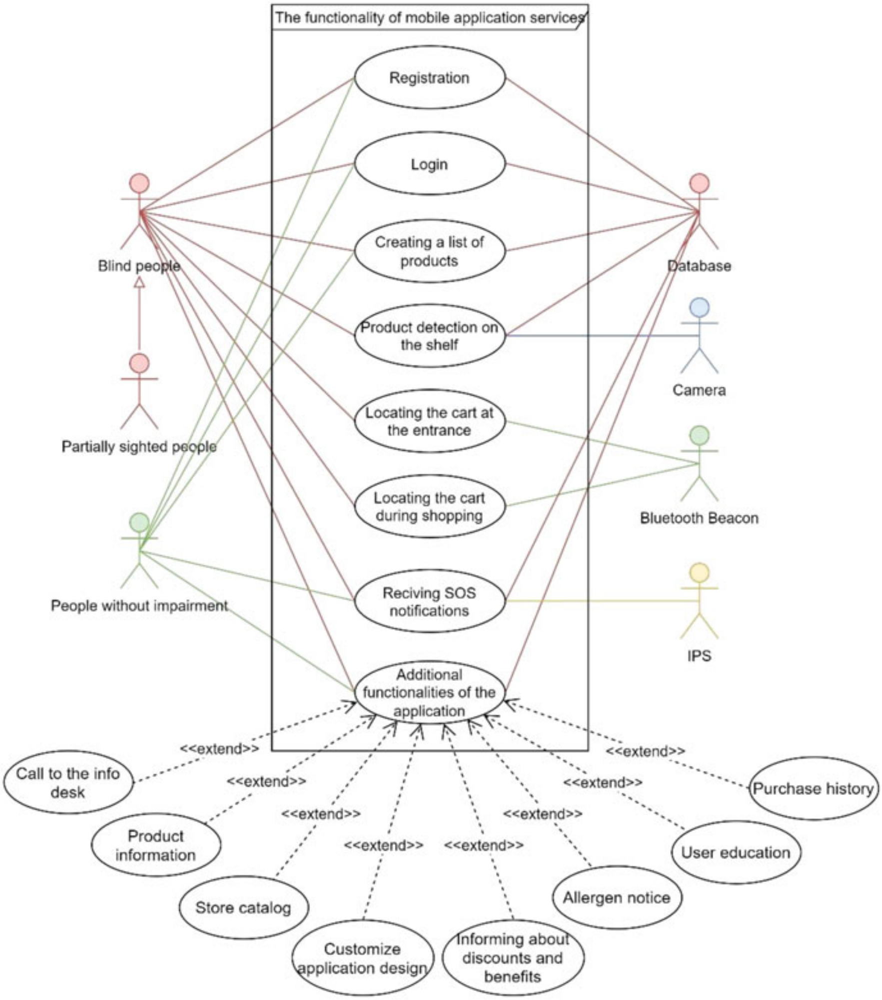

Fig. 14.6 Use-case diagram of mobile application service

can be included: call to the info desk, customization of the application design, product information, information on discounts and benefits, store catalog, allergen notification, user education, and purchase history, as shown in Fig. 14.6.

User Registration

After the installation is completed, the user is expected to create a user account, i.e., registration. When registering, it is necessary to enter personal data such as name, surname, password, and email. In addition to personal data, the user is required to enter their disability status, because on this basis it is possible to adjust certain functionalities of the use of the application itself. Entering disability status will enable blind and partially sighted users to have a talk-back function. Besides the talk-back function, for visually impaired users, the application allows to select the color and font size as well as the background colors to make it easier to use the application.

After entering the type of disability, the user will have the option to choose if he is allergic to any ingredient. If a user indicates that he is allergic to certain ingredients, each time he enters a product on the shopping list that contains an ingredient that is labeled as an allergen, he will receive an information notice stating that the allergenic ingredient is in that product. Except for paying at the cash register, users are also able to pay the products using the application. Payment using the application requires the user to enter information about the cards with which he wants to make a purchase. Data entry is possible during registration or later within the application. The data required for this type of payment: card type, name, surname, card number, card validity, i.e., month and year of card expiration, and CVV/CVC code (card verification value/code). Once these data are stored within the user database, the user will be able to pay via the entered cards.

Creating a List of Products

Using the application, users can create and edit a list of products before going to the store. The user will be shown in all the necessary information about the products, i.e., the ingredients, price, weight, etc., which will help him decide on choosing the type of product. If the user selects a product that contains an allergen, which he defined during registration, he receives a warning. Furthermore, adding a product to the list will automatically calculate the price of all chosen products to get information about the future cost of the purchase.

Product Detection on the Shelf

After the shopping cart has brought the user to a specific location, i.e., place where the product is located, it is necessary to detect the product on the shelf. After the user selects the product detection option, the camera is turned on. Then, the user takes a picture of the products using the camera on the mobile device. The input data in the form of an image from the camera are obtained, which are compared with the data from the list of products, i.e., from the user database, which contains the image of the product itself, so the two images are compared. When the images match, the user receives an audible notification that the correct product has been photographed. After the user has taken the correct product, he selects the option to exit the camera on the application and the camera will turn off.

Locating the Cart at the Entrance

Just before entering the store, the user's task is to turn on the Bluetooth connection option on his MD. The reason for this is that there is a Bluetooth beacon embedded in the shopping cart, a small device that is powered by batteries. The moment the user with his MD is within the radius that the Bluetooth beacon is covering, it will detect the beacon signal and launch the application on the user's MD. Once the application has launched, the user will select the shopping cart locating option after which he will start receiving sound signals that will guide him to the cart.

Locating the Cart During Shopping

Functionality designed to help the user if he moves away from the shopping cart for any reason. When choosing a product from the shelf, there is a possibility of moving the user away from the shopping cart. If the user is too far from the cart, sound signals will be sent to the user to return to them.

Receiving SOS Notification

By sending an SOS notification, the user can be informed about an unexpected or dangerous situation in the store. The user needs to be protected in case of an accident, whether if it is a fire, flood, or some other dangerous situation. Once the store's security system sensors have detected the danger, the app will notify the user of the situation. Once the shopping cart is located, an evacuation route is created from the IPS system. Through the application, the user receives a notification about the danger and the cart safely leads him, according to the defined route, to the nearest exit.

Additional Functionalities of the Application

Their task is to make it easier for the user to use the application, inform the user about the products, and provide them with education. During registration, visually impaired people can customize the design of the application according to their own needs. By selecting the background and text colors, as well as the font size, it is easier for the user to use the application. The application provides the possibility of informing users about current discounts and benefits. At the moment when the product that the user often buys is at a discount, the user receives a pop-up notification on the MD screen via the application. Also, by selecting the option to display the discount and benefits in the main menu of the application, the user is shown those products that are currently at a discount, and their reduced price is displayed. Through the application, users are enabled to collect points with which they can gain additional benefits when making a future purchase, as well as to collect points for participating in prize games, but these possibilities depend on the store itself. By opening the store catalog option from the main menu, the user can view the store catalog. By selecting a specific product, the user can find out details about the product itself, such as the composition of the product, price, weight, etc. In the group of additional functionalities, it is possible to educate users about the use of the service. The user can choose the desired way of education, online through the application or can apply through the application for group education organized in the store. According to the results of the survey and the wishes of the users, it can be held online or live with a group of users. Education is needed to explain to users the process of using the service, thus facilitating their purchase. During the group training, users can ask questions and get additional information about the service. An additional functionality of the application is the purchase history by selecting an option from the main menu. The user is given the opportunity to view the list of completed purchases, which can be sorted according to the desired criteria. By selecting the list, the user can see what was bought and how much money was spent.

14.6 Society 5.0

With the development of AT, new concepts of smart environments and Society 5.0, it is possible to raise the level of quality of life of people with disabilities and people with reduced and difficult communication skills. A sustainable ecosystem is a starting point in the integration of AT and the inclusion of people with disabilities in a smart environment in general (shopping, factory, education, etc.) [13]. It is also important to integrate science, technology, and innovation into the Society 5.0 area from a sustainable ecosystem perspective. In September 2015, the United Nations adopted the 2030 Agenda for Sustainable Development with the Sustainable Development Goals (SDGs) as its core. The goal is to achieve a comprehensive system in which all nations work together in a sustainable world that hopes to achieve economic development and address social issues. In such an environment, greater application of assistive technologies is possible, and greater involvement of people with disabilities in smart environments based on IoT technology. Figure 14.7 shows the concept of Society 5.0 and key technologies with 17 sustainable development goals.

Key IT technologies in Society 5.0 process and possible integration assistive technologies in smart environment are:

- Application program interface (API)
- Machine learning
- IoT
- Big data analytics
- Distributed ledger technology (DLT)
- Smart contracts
- Cloud computing

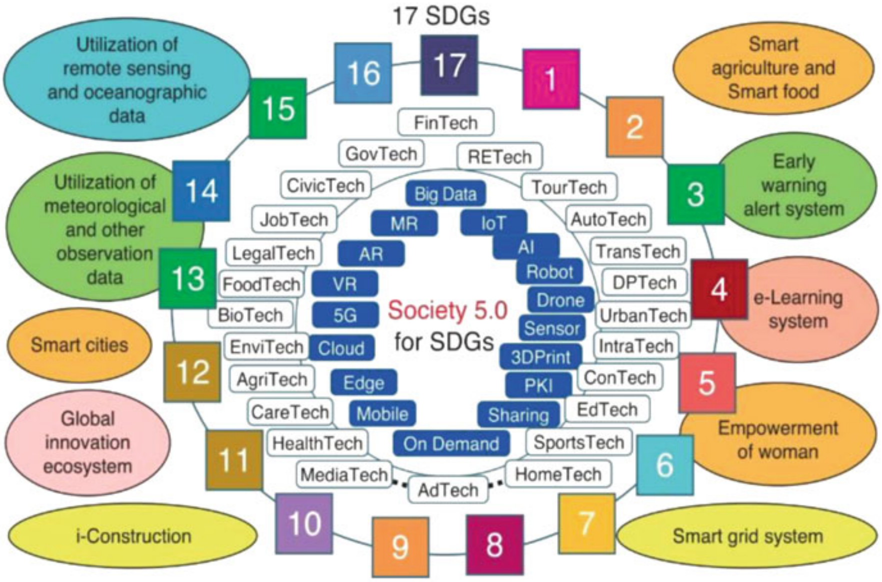

Fig. 14.7 Society 5.0 [14]

- Cryptography
- Biometrics

Quality of Life (QoL) stands as an important aspect in the field of Society 5.0. IC technologies have the task of raising the level of customer satisfaction in smart environments.

14.7 Conclusion

The conducted analysis of user needs defines the basic functionalities of the system of guiding and informing users in smart stores. A guidance system composed of smart cart elements and application services integrated in an MD aim to increase the mobility of blind and partially sighted people. Previous solutions are partial solutions as a form of assistance to blind and partially sighted people, while the presented solution represents the entire IC system as a department of assistive technology. This system architecture can also be implemented through the goals of the Society 5.0 environment as one of the key factors in the integration of blind and partially sighted people into the social context. By applying such solutions, it is possible to increase the degree of mobility and quality of life of each user, regardless of the type of damage.

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Chapter 15
Small Parts Recognition by Convolutional Neural Networks with Implementation to Virtual Reality Devices for Assisted Assembly Tasks

Kamil Židek, Ján Piteľ, Ivan Pavlenko, Peter Lazorík, and Alexander Hošovský

15.1 Introduction to Convolutional Neural Networks and Assisted Assembly Process

The industrial vision system usually works with a combination of the conveyor system and recognized parts are placed on a conveyor belt with the same distance from the camera lens. The recognized part is digitalized from one side. The assisted assembly process has advanced requirements for recognition technology. It is necessary to recognize and identify parts from every side and a different distance from the camera lens. Convolutional neural networks can help solve this complex task without demanding to program. The most problematic part of the convolutional neural network's usability is the input image set preparation. This monotonous task can be simplified by an automatized generation of an image set from 3D virtual models.

The initial research about industrial part recognition by convolutional networks and usability of 3D virtual models was description described in these articles: Recognition of Assembly Parts by Convolutional Neural Networks [1], An Automated Training of Deep Learning Networks by 3D Virtual Models for Object Recognition [2], and some predictions in Predictive model to evaluation quality of the manufacturing process using Matlab tools [3].

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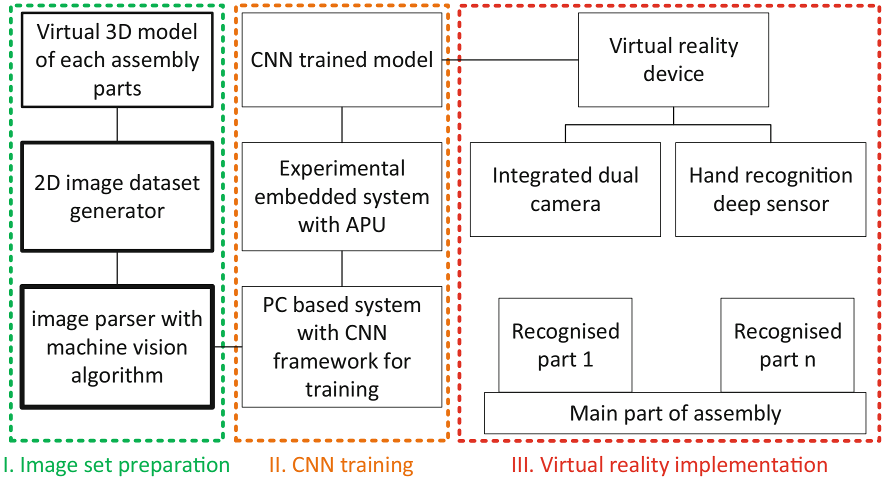

Fig. 15.1 The schematics of industrial parts recognition for assisted assembly by the virtual device

15.2 Main Idea and Proposal Work

The main idea explained in this paper is a combination of classical machine vision algorithms with convolutional neural network training technics for reliable part recognition. The full implementation of methodology with appropriate technics and technologies is explained in the block diagram (see Fig. 15.1).

The scheme presents the process as a flow diagram of technology and technics implementation in three levels:

- preparation of image sets (ROI) from 3D virtual models by standard machine vision algorithms
- experimental training different CNN models and testing by embedded systems with APU
- implementation of the evaluated methodology of recognition with CNN models to virtual devices for assisted assembly tasks.

The main addition or novelty is the preparation of samples from virtual 3D models and image parser technics for the input of tested CNN models.

15.3 Principle Description

The main principle is the extraction of some region of interest in assembly image where it can be positioned parts and ignore flat places as shown in Fig. 15.2.

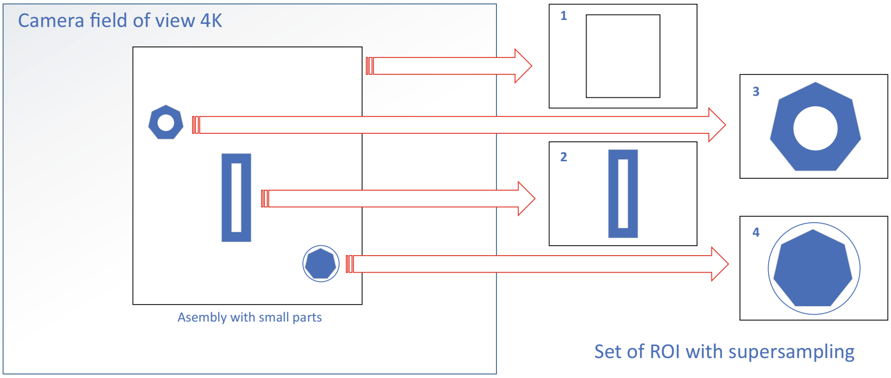

Fig. 15.2 The principle of extraction region of interest (ROI) from assembly image for separate recognition by a convolutional neural network

15.3.1 Theoretical Background

The main limitation of the currently used CNN models is low input resolution; it is not possible to include high-resolution images for example 4K or 8K, because they are automatically downsampled to low resolution. This is the main reason why it is a very problematic recognition of small objects. The human brain solves the same difficult problem with the recognition of a small object or if they are too far from the observer. The next very interesting basic heuristics of the human brain is ignoring from recognition process areas with plain color and focus mainly on places with some patterns. The human brain solves this problem very simply change your position and distance from a recognized object. This approach for the industrial task is not suitable.

It can be defined as two much more effective methods:

- vision system with optical zoom (suitable for recognition of parts for long distances)
- high-resolution images with identification of ROI (region of interest).

The first method is not suitable for the assisted assembly process because the field of view is usually very near to assembly and the optical zoom procedure is a very time-consuming task.

The second method with acquiring high-resolution images for example 4K with parsing image to small ROI is much more effective for industrial part recognition and use in virtual devices for assisted assembly tasks. This method can use high-resolution images with a prerequisite of reliable object detection and minimal delays. It can be recognized as standardized parts with minimal dimensions, for example (screws, nut, washers, holes, threads, etc.), mounted in assembly or before the assembly process. There exist more research papers to solve this problem by comparison of different CNN models or new approaches, which are suitable for this task [4, 5]. Mathematical description and application to recognition bearings errors by neural networks are described in these articles [6, 7]. The article aimed to research the usability of virtual models for training convolutional networks [8–10]. Convolutional networks used for the classification of 3D object research are described in [11], research in the usability of CAD and 3D models in [12]. The research in the usability of augmented reality in robotics is described in [13], other research in the new method of anchoring system [14]. The research area of manufacturing systems with simulation deals with these articles [3, 15, 16].

15.3.2 Experimental Hardware for CNN Model Evaluation

The first platform for testing of introduced approach is an embedded platform with integrated APU and Ubuntu OS Linux distribution from Nvidia Xavier development kit as is shown in Fig. 15.3.

The 4K images are acquired by E-cons dual-camera system with the 13 Mpix CSI module, mounted in the experimental stand with rapid prototyping holders.

The second testing platform is embedded board Raspberry PI4, which doesn't include any APU unit. Additional computing power for CNN is acquired by USB module Intel USB Neural Compute Stick Movidius 2 and is shown in Fig. 15.4.

Assisted assembly can be implemented to virtual devices (VR). HTC Vive Pro provides enough performance for CNN model execution because it uses standard PC with a dedicated graphics card and is shown in Fig. 15.5 [17].

Fig. 15.3 Nvidia Xavier Developer Kit with integrated 13 Mpix (4K) dual CSI camera from e-con system CAM130 CUXVR

Fig. 15.4 Raspberry PI4 with new CSI camera 2 8 Mpix (4K30) and Intel USB Neural Compute Stick 2 (Movidius)

Fig. 15.5 HTC Vive Pro with dual camera and integrated leap motion for hand recognition of trained workers

15.3.3 Software Implementation and Used Libraries

The TensorFlow Frameworks version 1.15 was used for the training CNN model. Nvidia SDK manager provides Tensor RT library for trained CNN model acceleration on NVIDIA Xavier embedded device. Intel offers OpenVINO toolkit for CNN model acceleration for Intel Movidius USB computes stick combined with Raspberry PI 4. Open CV library version 3.4 was used for blob detection. Unity 3D engine was used for transfer CNN models to virtual reality device HTC Vive Pro.

15.3.4 Implementation for External Devices

The trained model must be exported to a suitable format for implementation to real devices. The methodology of transport CNN model trained in TensorFlow to real devices is shown in Fig. 15.6.

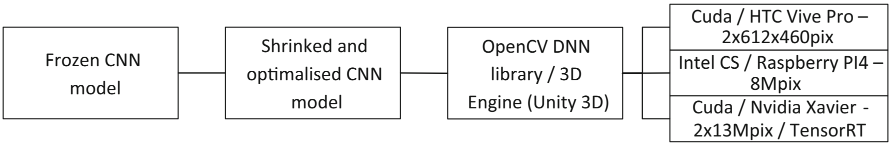

Fig. 15.6 Scheme of CNN model transfer to experimental devices

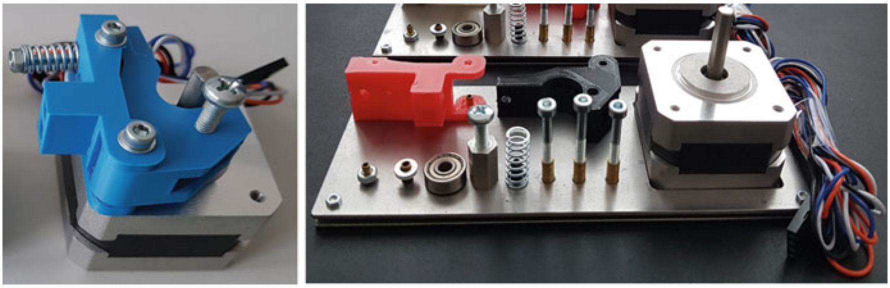

Fig. 15.7 Real assembly (left), all parts positioned in the fixture (right)

Fig. 15.8 The virtual 3D model used for automated generation of the 2D training set of images (left), exploded view for experimental recognition process (right)

15.4 Experiments

The real assembly will be used for evaluation recognition reliability after training the CNN model by the virtual 3D model and is shown in Fig. 15.7.

The 3D virtual model of assembly (left) and exploded view (right) created in Autodesk Inventor 2020 is shown in Fig. 15.8.

Fig. 15.9 Dataset of 2D images generated from 3D virtual models of assembly

The generated 2D images dataset from 3D assembly virtual model: motor, plastic part A and B (top), screws, nut, washer, spring, bearing (bottom) are shown in Fig. 15.9.

15.4.1 *Used Deep Learning Model*

Two separate CNN models (Faster RCNN Inception V2 SSD trained with COCO dataset) were created. The first set for nonstandard parts (top left/right) and second for smaller standardized parts (bottom left/right). The timelines training process of classification losses (left) and position losses (right) for the first CNN model

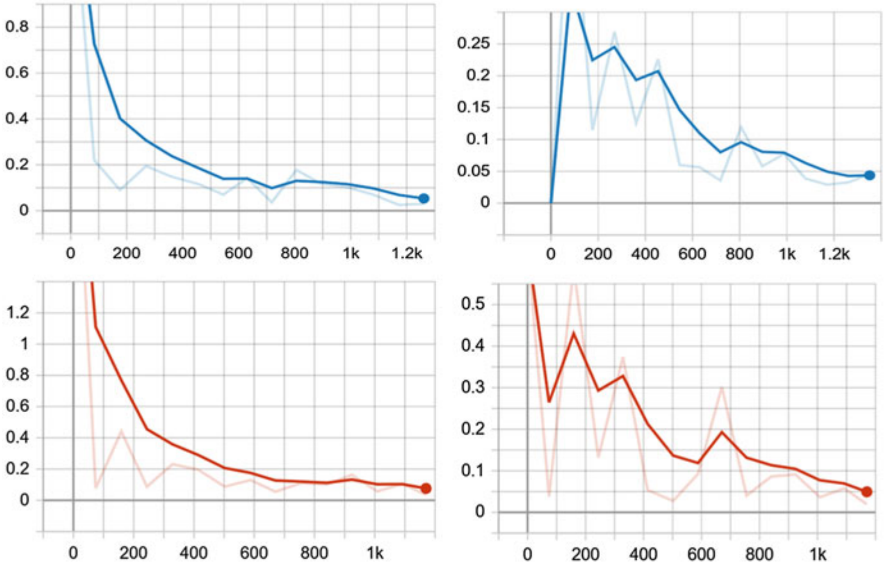

Fig. 15.10 The training process for classification/position loss of bigger parts (top) and classification/position loss of standardized parts (bottom)

(top) and second (bottom) is shown in Fig. 15.10. The teaching loss reaches for nonstandard parts about 0.05 mAP for classification and 0.04 mAP for the position and standardized parts about 0.08 mAP in classification and 0.05 mAP for the position.

15.4.2 Experiment Results

The extraction process of the region of intersecting by standard machine vision algorithms: gradients, contours closing square, and thresholding with ROI is shown in Fig. 15.11.

In the presented image are detected five regions with some pattern and one wrong region. This operation reduces image resolution for DNN input to 30% and increases input resolution for every feature during the detection process. Evaluation of the training process for the virtual model in comparison to real parts is shown in Figs. 15.12 and 15.13.

Table 15.1 gives a summary of all tested CNN model performance in specific recognition tasks. The training time of CNN models was measured for transfer learning (TL).

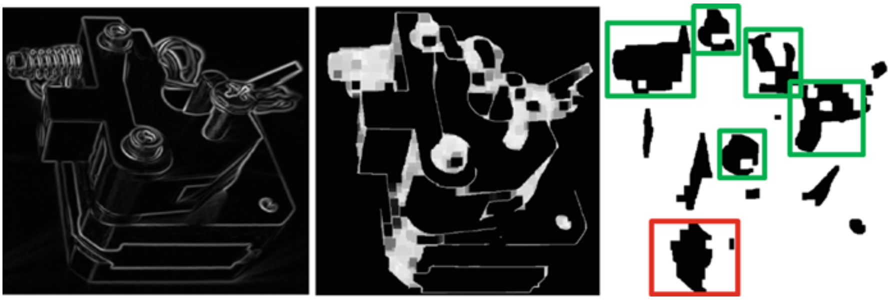

Fig. 15.11 Experiments with extraction of region of interest: gradient (left), contour transformation (middle), final regions (right)

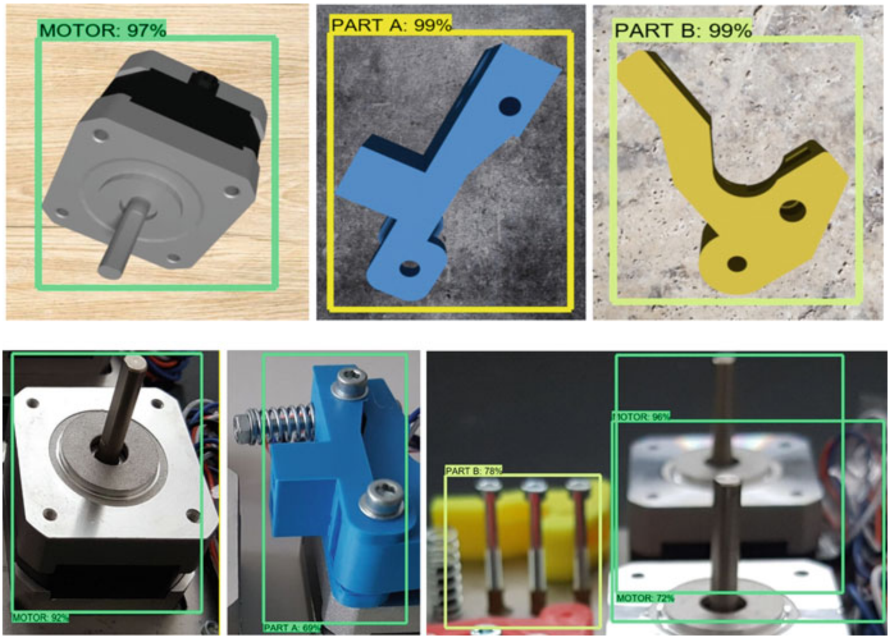

Fig. 15.12 Recognition experiments with CNN model for bigger parts: 3D virtual models (top), real parts in the fixture or mounted in assembly (bottom)

The CNN model was trained with a virtual model without part overlay, but for evaluation, it was used real images with overlays and the recognition precision decrease is about 30%.

Fig. 15.13 Recognition experiments with CNN model for standardized parts: 3D virtual models (top), assembly and real standardized parts classification experiments (bottom)

Table 15.1 Table with recognition results from all tested CNN models

CNN model	Training time (TL) [h]	Minimal recognition precision virtual parts [%]	Minimal recognition precision real parts [%]
Inception v2 SSD for bigger parts	1.3	97	69
Inception v2 SSD for standardized parts	1.5	96	73

15.5 Conclusion

The article presents a new approach to recognize small parts for assisted assembly tasks by a combination of standard machine vision algorithms with deep learning and CNN models. For the experiment we trained two CNN models: the first for bigger parts and second for small standardized parts with single-shot detection. The main reason for the creation of two different models is the reusability of the trained CNN model for a standardized part, which can be used for other assemblies. The first convolutional model acquires precision with real parts classification minimum of 69%. The second CNN model acquired bad recognition in the full image, but significantly better precision in classification after extraction of the region of interest (ROI) minimum of 73%. The main improvement in recognition precision can be the preparation of new photorealistic input to teach samples with some textures instead of simple color material. Texturing can significantly increase recognition precision after the teaching process.

The future works will be the implementation of segmentation from TensorFlow version 2 instead of simple single-shot detection (SSD), which helps detect the exact position of parts and precise orientation in the workspace.

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Chapter 16
Dynamic Measurement of the Surface After Process of Turning with Application of Laser Displacement Sensors

Martin Miškiv-Pavlík and Jozef Jurko

16.1 Introduction

In this time, when industrial production is increasingly changing from manual and physical work to progressive, automated, and highly sophisticated, the application of modern measuring technology is an integral part of such production. The requirements for measuring and reading data are diverse and create constant pressure on the development and application of new types of sensors. One of the many possibilities of using contactless sensors is application in measuring surface deviations from the diameter after the turning process. Using this method, we are able to quickly identify defects on the surface of the workpiece, without the need to send the product for postproduction quality control.

The main thesis of this article was a practical application of the measuring scheme with a noncontact confocal deviation sensor, on round bars C45 after the turning process, and thus to prove a new way of using a confocal sensor in immediate inspection of the workpiece after the machining process.

16.2 Literature Review

Unlike noncontact control, many traditional distance measuring devices, such as micrometers and calipers, touch the surface of the object being measured. In this method, there is a physical contact during which not only the meter but also the measured object is damaged [1].

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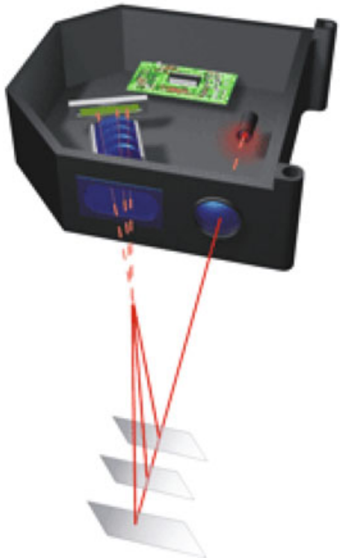

Fig. 16.1 Example of the laser displacement sensor (triangulation sensor) [4]

If the measured object is unfixed or designed to move, the measurement will produce an inherently unstable result, which will not yield consistent results in the next measurement. The current market for sensors is growing dynamically. Choosing the right type of sensor for a specific application is challenging because there are more than a thousand different types of sensors in the countries of the European Union [2, 3] (Fig. 16.1).

16.2.1 Principle of Measurement by Confocal Sensor

Sensor can be defined as a functional unit that implements the sensing of quantities or phenomena on the basis of a defined principle. The sensor, as a basic part of the sensor, forms the interface between external stimuli and internal components for processing and further evaluation of the information obtained during the measurement [5–7].

The essence of this method is that the polychromatic white light from the sensor is projected on the measured surface, through a multi-lens system. The lenses are arranged in a so-called, confocal arrangement, where on impact with the measured object, the radiation is by natural chromatic aberration (deflection of light radiation), divided into monochromatic components (colors) with different wavelengths. The radiation is reflected back to the confocal diaphragm of the sensor, through which only focused radiation, with a specific wavelength, passes to the electro-optical sensor. The amount of light returning to the electro-optical receiver varies significantly depending on the position of the measured object [8–10].

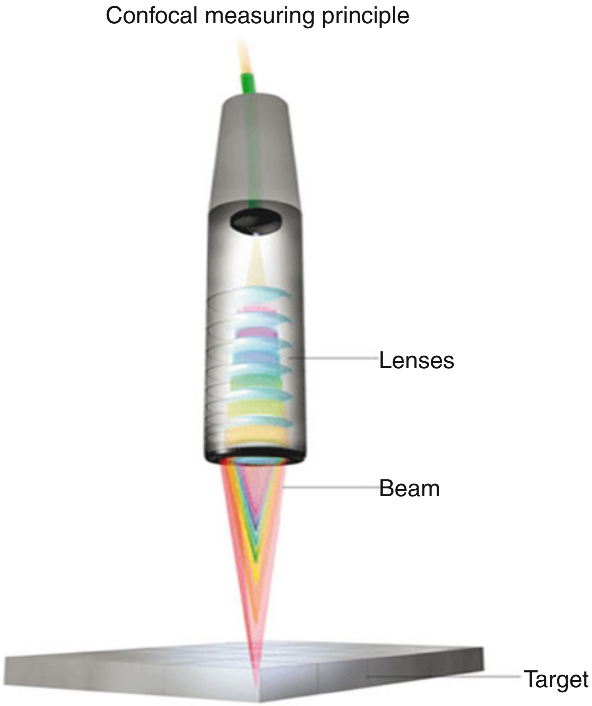

Fig. 16.2 Principle of confocal measuring sensor [13]

This type of sensor can be applied in optimizing, controlling, and diagnosing the productivity and reliability of the production process, based on the surface properties of the products. For these applications, laser scanners are ideal for their high speed, repeatability, and accuracy of up to 1 μm [11, 12] (Fig. 16.2).

16.3 Research Methodology

To be able to use individual measuring sensors, it was necessary to design a wiring diagram of individual components and their connection to the evaluation unit. In Fig. 16.3, we can see the system, which is connected to the evaluation unit, in our case by a laptop with the appropriate software.

Confocal sensor, the measured value from the measuring head with a resolution of up to 1 μm, sends a digital signal to the amplifier, which is connected to the communication module.

By using a confocal sensor is not necessary to install any additional evaluation hardware, such as the PLC control unit for triangulation sensors, because the

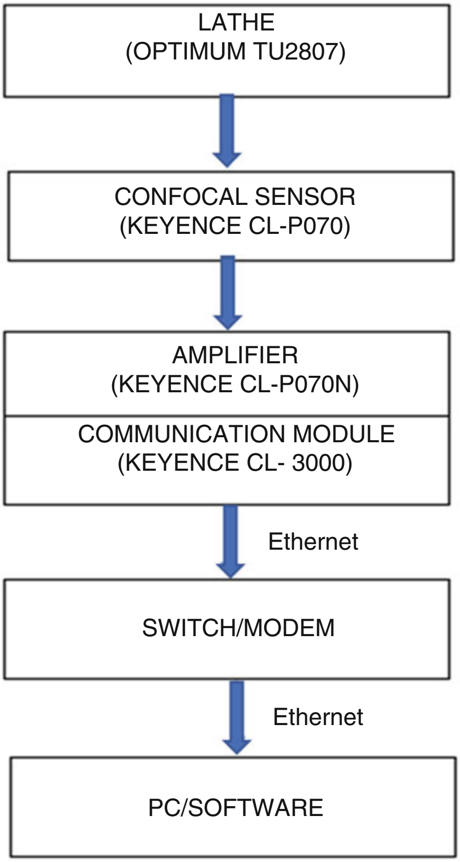

Fig. 16.3 Design of experimental measuring system

measured value from the measuring head is immediately calculated by the PC software from the communication unit in the manufacturer's software.

Subsequently, the data are written to the program memory, which is another advantage over conventional mechanical meters, where the operator must manually write the measured values. As the distance of the sensor from the measured object increases, the measurement inaccuracy also increases, which is one of the disadvantages of these sensors. In addition to the limited measuring distance, the measurement of transparent or glossy surfaces, which can affect the accuracy of the measurement, is also a disadvantage.

16.3.1 Sensor Wiring Diagram

In this section, from Fig. 16.3, we can briefly indicate the connection scheme of the measuring diagram, which consists of the measuring head of the (Keyence CL-

P070) sensor, which was mounted on the lathe holder of the (Optimum TU2807) cutting tool, thus achieving dynamic measurement of the entire machined part. The digitalized data from the sensor head were transferred to the communication module (Keyence CL-3000) by using an amplifier (Keyence CL-P070N), where through Ethernet and the connection of the system with PC software from Keyence (Navigator), was possible to observe microscopic irregularities of the workpiece diameter.

16.4 Results of Experiment

The main object of this experiment was to investigate the possibility of using a noncontact displacement and distance sensor to measure microscopic irregularities in the form of the difference in diameter deviation of three machined round bars with the same machining conditions but with different diameters.

The cutting conditions in the process were feed $f = 0.2$ mm, cutting depth ap = 0.2 mm, and cutting speed vc = 60 m/min. We mounted a confocal sensor on the lathe frame by means of an extruded holder, which was connected to a computer and evaluation software for recording the measured data by means of the constructed measuring scheme in Fig. 16.3.

We set the sensor to a horizontal position so that it is flush with the axis of the workpiece and the cutting tool. As a first step, we measured the zero point of the workpiece, from which we then measured the distance difference with the prescribed measurement deviation (±0.15%) in case of optimum distance from workpiece specified by manufacturer (Keyence) as 70 mm (Fig. 16.4).

Since this is a dynamic type of measurement with the movement of the workpiece in the lathe spindle, it was necessary to design the spindle speed on the work table so as to eliminate the oscillation of the sensor, and thus the measurement errors caused.

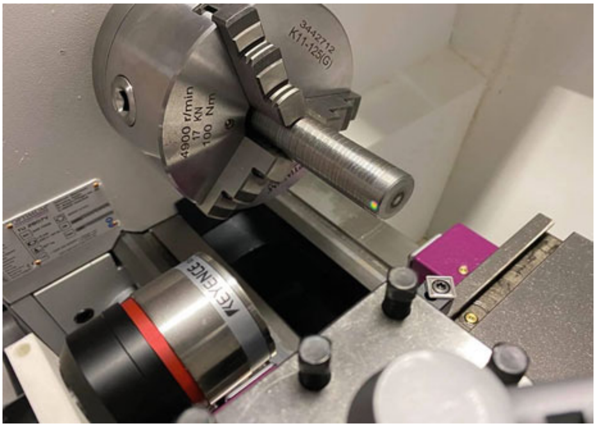

Fig. 16.4 Working zone and position of sensor

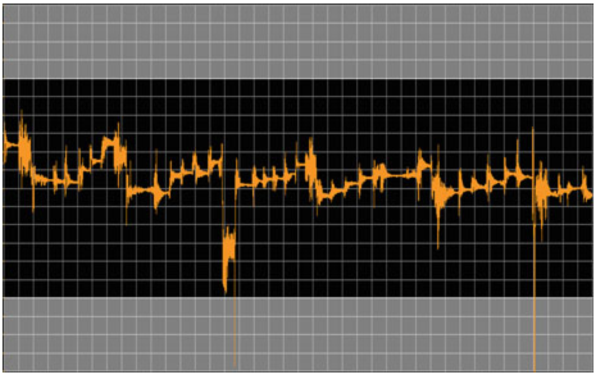

Fig. 16.5 Entire measurement record from software

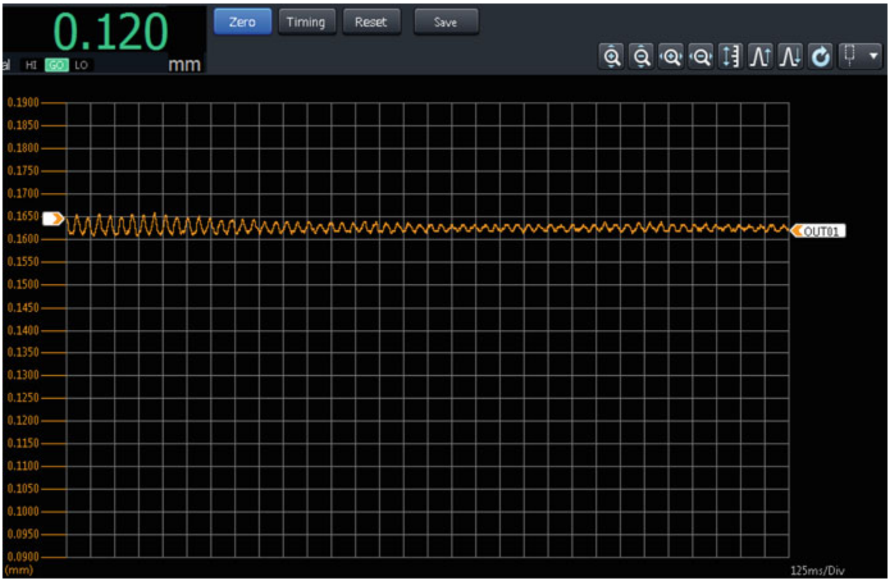

Fig. 16.6 Record of a specific measurement from software

Three measurements alone were performed in the experiment. In the first phase, we set the lathe spindle to a minimum speed of 150 rpm (Fig. 16.5).

In the second phase, we measured the entire length of the measured round bars using the tool feed, which we selected to 1 mm/s. In parallel with the deviation measurement, we also measured the time (Fig. 16.6).

16.4.1 Sample 1

All measured data were written from the software to a table in excel. All measured values were written from the software to a table in Excel. Subsequently, we created a graph, where we chose the distance on the measured part on the X-axis and the value of the deviation from the diameter on the Y-axis.

As the first sample, we measured a round bar with a diameter of 23 mm and a length of 97 mm. The distance of the sensor from the workpiece was set to 70 mm, so that we achieve the best possible accuracy (Fig. 16.7).

After first look on the sample, errors are immediately visible after machining on the workpiece surface. By using a confocal sensor, we measure the entire surface of the workpiece and see how much deviation from the diameter occurred. The feed on the lathe was set to 1 mm for faster conversion. The lathe spindle was rotated 150 times per minute. The sensor was set at 1000 measurements per second with 1 μm accuracy.

All measured data, which in this sample represented 96,670 measured values, were transferred into the excel program, and then a table was compiled with average values for 10 mm sections along the entire length of the workpiece.

During workpiece movement, the deviation about 0.002 mm was achieved due to the quality of the machined surface. The measuring device identifies only deviation from zero position, for real dimension, its value has to be calculated by equation:

$$D = x + d \pm e, \tag{16.1}$$

where

D—the calculated real dimension
x—the required drawing dimension value
d—the measured value of deviation
e—error of the sensor

An example of the real dimension calculation:

– the required value: 23 mm

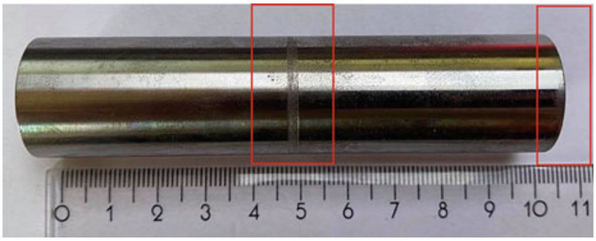

Fig. 16.7 Photo of a machined round bar (sample 1)

Table 16.1 Example table of measured values on individual sections (sample 1)

Distance (mm)	Arithmetic average of the measured deviation ± measurement error (mm)
0	0
1–10	0.004
11–20	0.01
21–30	−0.004
31–40	−0.01
41–50	−0.025
51–60	−0.002
61–70	−0.002
71–80	−0.008
81–90	−0.014
91–97	−0.037

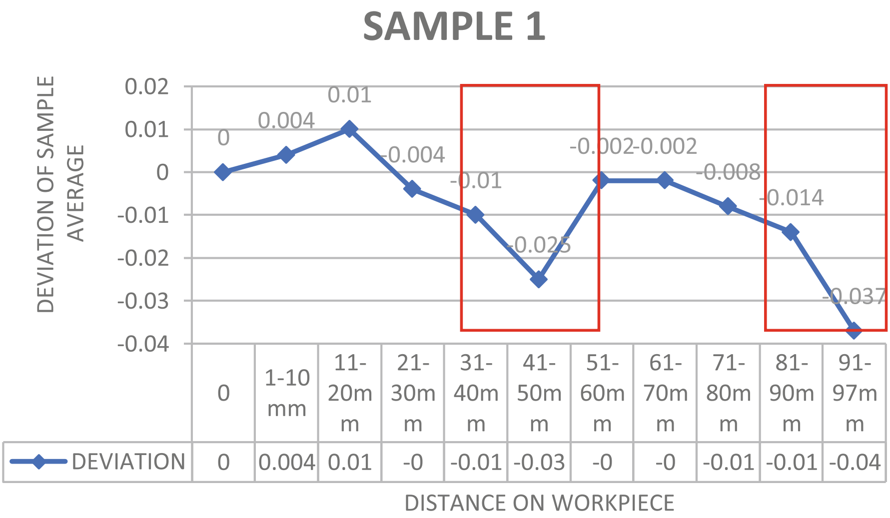

Fig. 16.8 Graph from measured values with marked errors (sample 1)

– the measured value of deviation: 0.006 mm
– sensor error: 0.002 mm

$$D = 23.006 \pm 0.002 \text{ mm}.$$

From the measured data in Table 16.1, it was confirmed that there are errors on the surface of the workpiece in the section between 41–50 and 91–97 mm (Fig. 16.8).

16.4.2 Sample 2

As with sample 1, the same machining and measurement conditions were determined for this workpiece (Fig. 16.9).

The dimensions of this sample were 23 mm in diameter and 94 mm in length. A total of 94,117 measurements were taken in a total time of 1 min and 34 s (Fig. 16.10).

In sample 2, multiple small errors were found on sections 21–30, 51–60, and 91–97 mm, with higher values of deviations, which are more than in sample 1.

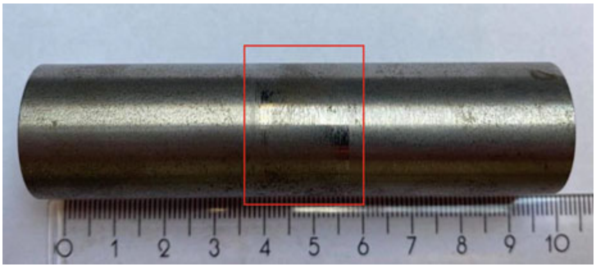

Fig. 16.9 Photo of a machined round bar (sample 2)

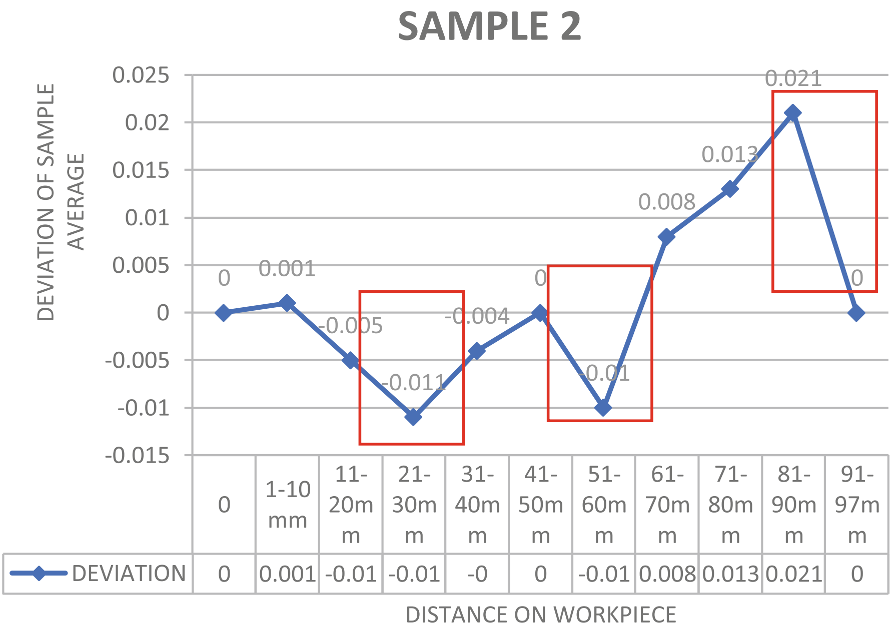

Fig. 16.10 Graph from measured values with marked errors (sample 2)

16.4.3 Sample 3

A round bar with a radius of 23 mm and a length of 100 mm was chosen as the last sample (Fig. 16.11).

On this sample, a total of 100,829 measurements were taken in a total time of 1 min and 40 s.

In Fig. 16.12, you can see only minimal errors on the workpiece failure, from the middle the surface has a small inclination tendency, but the size of the deviation is not higher than 0.007 mm the highest error is located in section 81–90 mm.

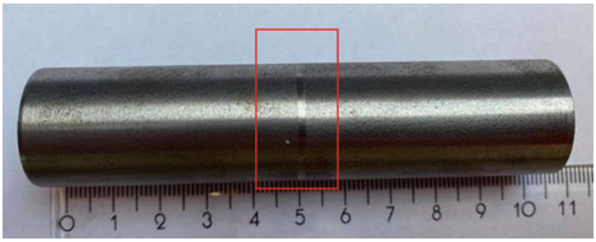

Fig. 16.11 Photo of a machined round bar (sample 3)

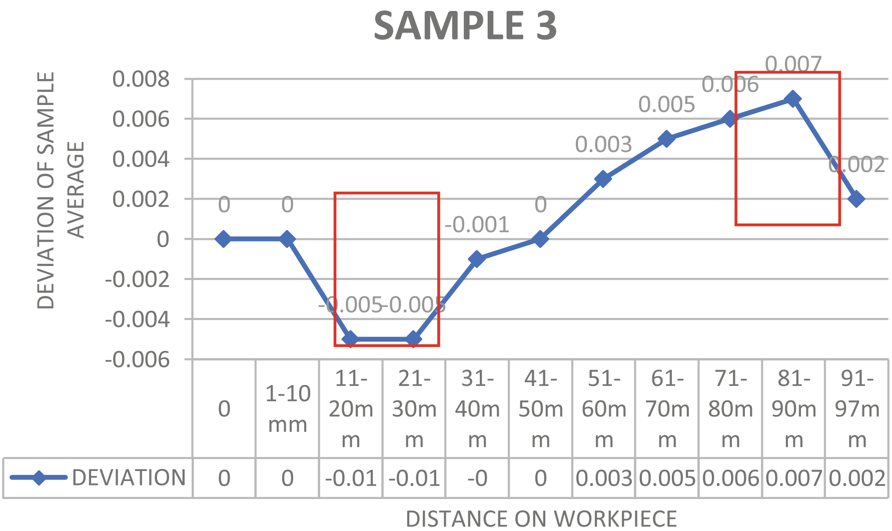

Fig. 16.12 Graph from measured values with marked errors (sample 3)

16.5 Discussion

In the article, there was presented an experimental measurement system based on the noncontact confocal sensor for non-CNC Lathe production machine. When analyzing the graphs, it can be seen that the total average deviation of the workpiece diameter distance ranges from 0.024 to -0.04 mm. By using these differences, we can determine the surface uniformity of the machined material by identifying incorrectly machined workpieces in production. However, these confocal sensors also have their limitations, the measuring zone of these sensors is from 60 to 130 mm, while the optimal zone is 70 mm, after exceeding this range, the sensors are not able to measure. Another area of research at the Faculty of Manufacturing Technologies in Prešov is the application of these sensors in the manufacturing companies and thus replaces the quality control after machining noncontact sensors represent one of the best technologies in the field of optical distance and position measurement. The disadvantage for small and medium automated companies is the higher purchase price of the device, compared to more common diffuse, reflective or single-channel optical sensors, but for companies with mass production and a high degree of automation of the production process, where it is necessary to achieve very high measurement accuracy, but these sensors are a necessity.

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Chapter 17
Design and Evaluation of Production of a Robotic Angle Arm for Collaborative Robot Using the WorkNC CAM Application

Peter Michalik, Michal Hatala, Jozef Dobransky, Jozef Macej, Michal Petrus, Peter Tirpak, and Ladislav Novotny

17.1 Introduction

Collaborative robots play an important role in increasing flexibility, especially in production processes that produce a number of small products in short cycles. One can quickly adapt to changes, and the robot has great endurance to perform the same tasks with high precision around it. This combination makes it possible to automate the production of many types of products on the same production line. In 2015, ABB introduced the YuMi robot—the world's first truly collaborative robot (Fig. 17.1). Since its launch, YuMi has changed the rules of the game and ushered in a new era of safe collaboration between people and robots side by side without any barriers. YuMi means that "you" and "me" will together discover new endless possibilities for automation. The innovative double-arm robot, which can cooperate with humans without barriers, brings new functionalities to automation. YuMi was designed to start a new era in the industry, for example in the assembly of small parts, where humans and robots work together on the same tasks. ABB adds a new member to the YuMi family: the 7-axis YuMi robot, the smallest and most agile collaborative robot ever, making it very easy to integrate into the production process.

The new 7-axis robot also opens up space for new possibilities—for example, single-arm and double-arm YuMi can work together, while three or more other YuMi arms would speed up cycle time. The entire range of YuMi robots is designed to be as easy to set up as possible and as intuitive to program as possible [1]. This means that even workers without special training or previous experience can use

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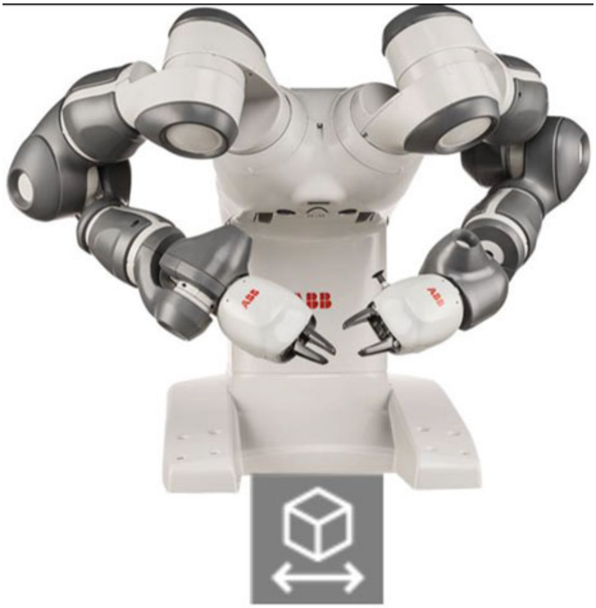


Fig. 17.1 The world's first collaborative robot made by ABB under the name YuMi [1]

robots successfully and efficiently. Collaborative robots can operate various CNC machine tools [2, 3]. In reality, their use is much greater [4, 5] this method can be used for mass production [6]. The industry may encounter the handling of wooden components, plastics. It can also be a matter of handling the materials transported by the hose conveyors [7–9]. Kruthika et al. designed and constructed a robotic arm for a special service of people control by Arduino MEGA2560 I/O board [10]. Faravar designed multipurpose robotic arm using servo motors [11]. Reddy designed a robotic arm with three degrees of freedom with a pneumatically driven gripper [12]. Singh et al. designed a welding robotic mechanism with AC and DC drive [13].

17.2 3D and Table Drawing of Angle Arm

The angular arm Fig. 17.2 contains outer angular planar and rotate surfaces.

The material of the angular robotic arm is duralumin Al4.5MgMn. It provides rotational movement from the gearbox, which is located in a fixed base to the other arms of the collaborative robot. It also serves as a supporting element for other robotic nodes. When manufacturing a diameter of 47 H7 mm, a qualita shape of 0.05 mm must be observed. When manufacturing an outer cylindrical surface with a diameter of 50 f7, a tolerance of ±0.04 mm must be observed. The required surface roughness for an outer rotate surface with a diameter of 50 f7 is $R_a = 1.6$ μm and $R_z = 11.2$ μm.

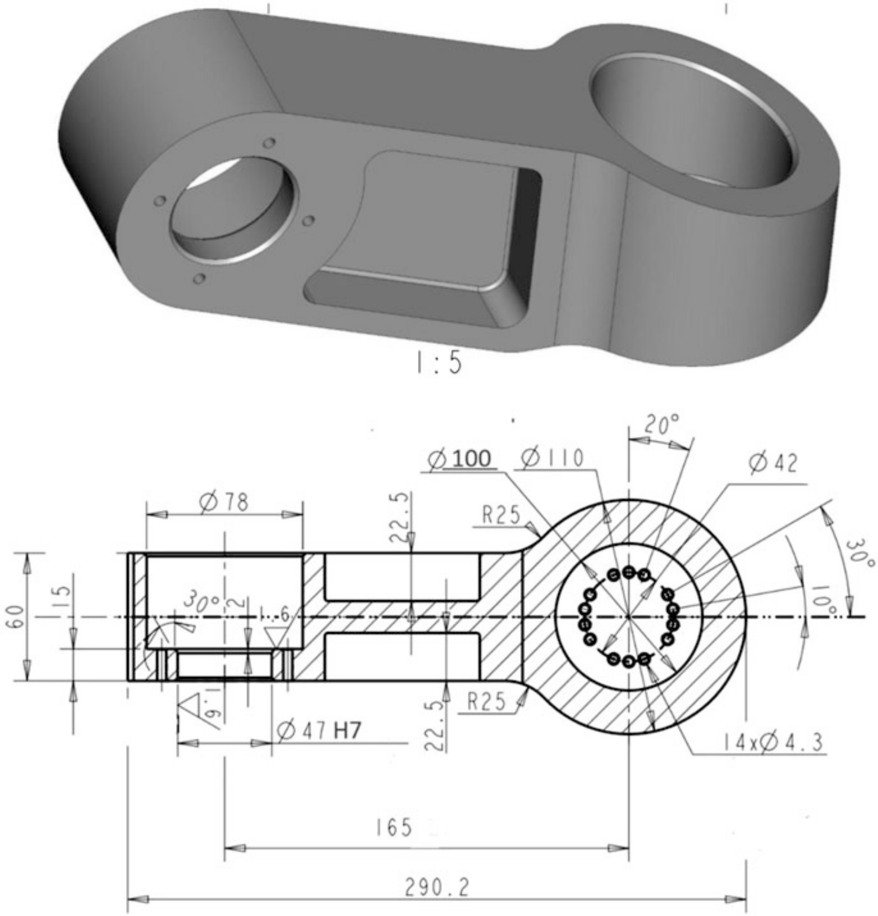


Fig. 17.2 3D and table drawing of angle arms

17.3 Creation of CAM Program

Application WorkNC made a 3D model of the angle arm and subsequently generate a table drawing. The 3D angle arm generated a CNC program for the FANUC control system. Application WorkNC is state-of-the-art automatic CNC software for surface or solid models in molds, dies, and tooling companies for 2- to 5-axis CNC programming. WorkNC is one of the best complementary CAM application that enhances all design and manufacturing systems by providing reliable, efficient, and programmable cutter paths, leading to unmatched productivity and safety. Coordinate system in the middle of the angle arm was selected (Fig. 17.3).

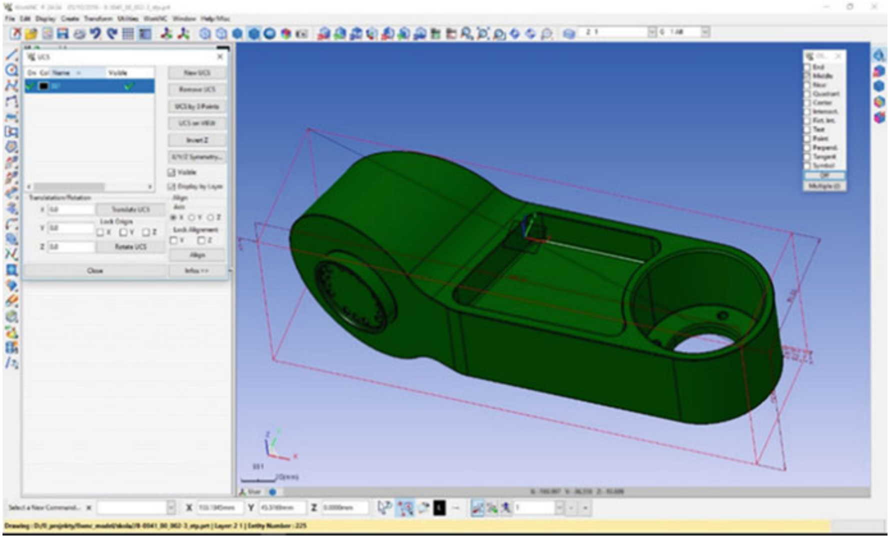


Fig. 17.3 Selection of the zero point on the stock

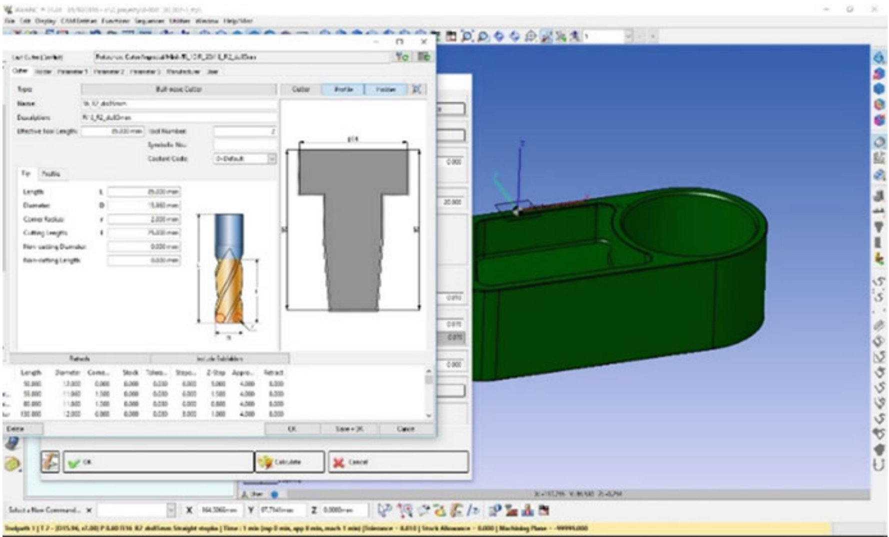


Fig. 17.4 Choice of milling tool and milling conditions

The choice of the tool follows face-milling cutter. Adjustment of its feed rate, feed 1000 mm min^{-1}, and speed value 4850 rpm, required for machining external planar and cylindrical surfaces (Fig. 17.4).

Machining of the internal milling face relief (Fig. 17.5) and of the inner rotate surface to a rate of 78 mm was performed (Fig. 17.6).

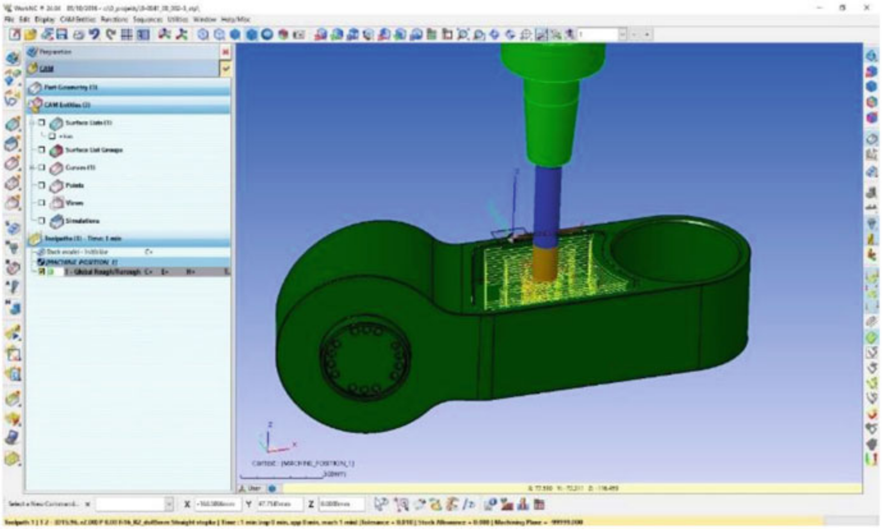


Fig. 17.5 Milling of the alignment of the side of the angular robotic arm

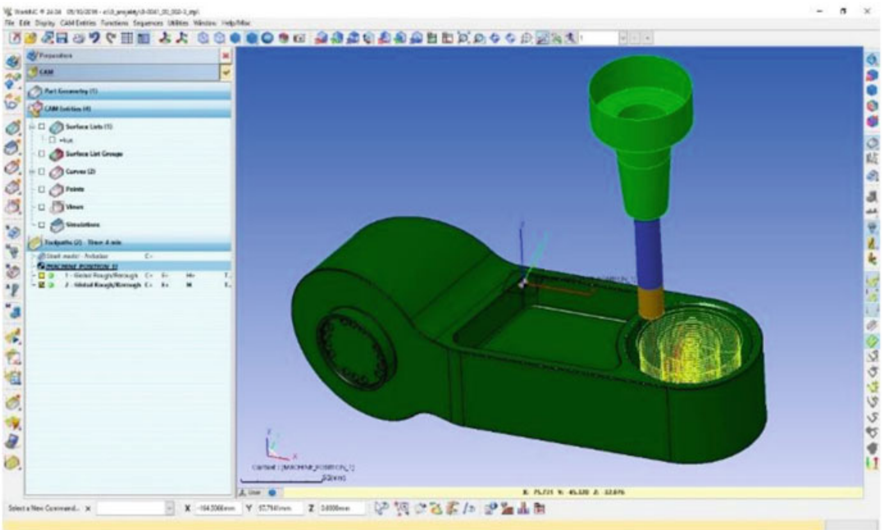


Fig. 17.6 Simulation of machining with a diameter of 78 mm on an angular robotic arm

Another step of machining is rotation surface of 100 mm to a rate of 46 mm (Fig. 17.7), which will be produced after turning the semifinished product.

Operation drilling 14 holes with a rate of $D = 4.3$ mm and four holes D of 5.5 mm and define a feed of 350 mm min^{-1} and a drill speed of 2200 rpm. When

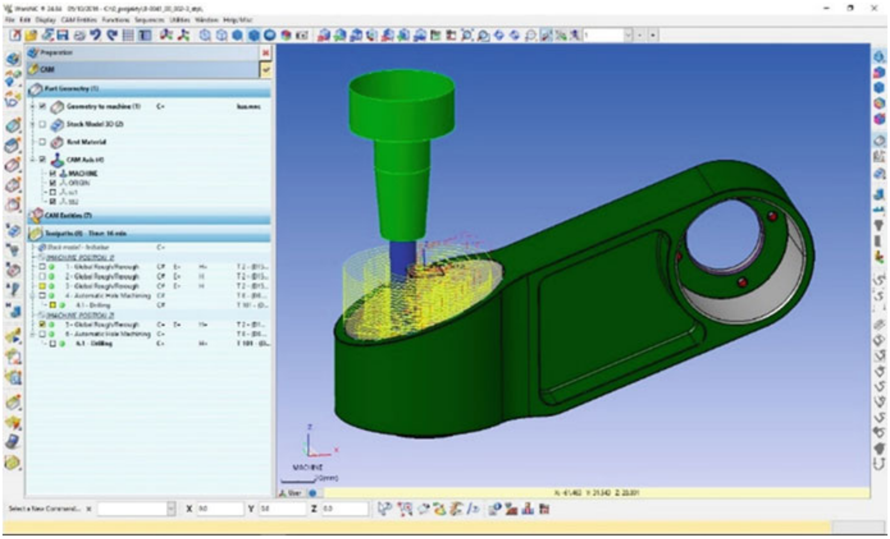


Fig. 17.7 Simulation of production of a rotate surface of 100 mm to a rate of 46 mm

Fig. 17.8 Overview production diameter D50 f7 of the angle arm on the Pinnacle VMC 650 S CNC machining center

machining the angle arm on the Pinnacle VMC 650S (Fig. 17.8). CNC machining will be adapted tools and also to rigidity angle arm.

17.4 Assessment of the Accuracy of the Angle Arm

Measurement of surface roughness on a produced diameter of 50 f7 mm with accuracy of ±0.04 mm was performed on a Mitutoyo SJ 400 device. The finished robotic flange was fixed in a manual vise with flat jaws (Fig. 17.9) with marked measuring points for R_a and R_z.

A Thome 3D measuring instrument Fig. 17.10 was used to evaluate the quality of a rotate surface with a diameter of 47 H7 mm. The angle arm was fixed using a vice with jaw surfaces.

After the surface treatment by anodizing, the assembly with the base and the assembly of another actuator followed (Fig. 17.11).

The course of the measured values of roughness R_a and R_z is shown in Fig. 17.12.

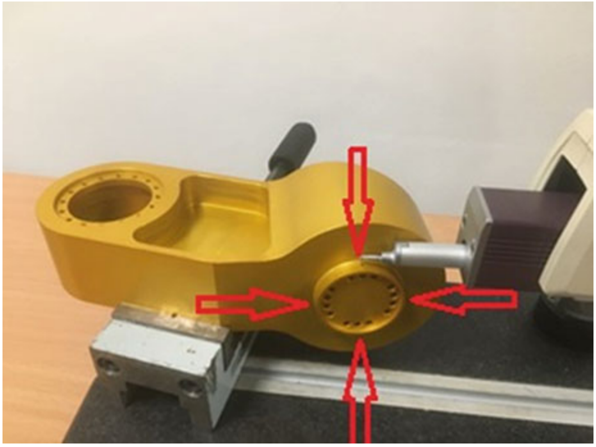


Fig. 17.9 Roughness R_a, R_z measurement on the diameter D50 f7 of the robotic angle arm on the Mitutoyo SJ 400 measuring device with marked measuring points

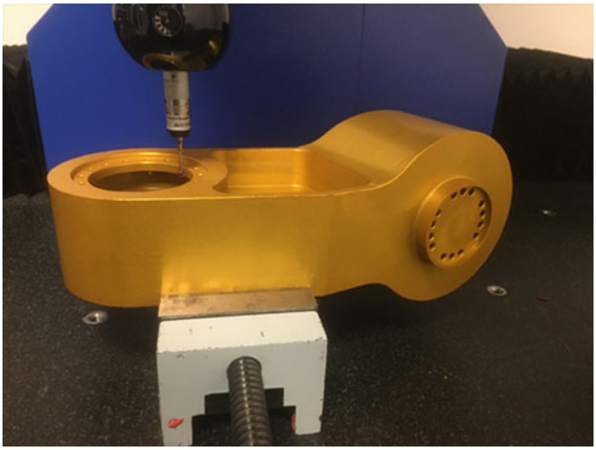
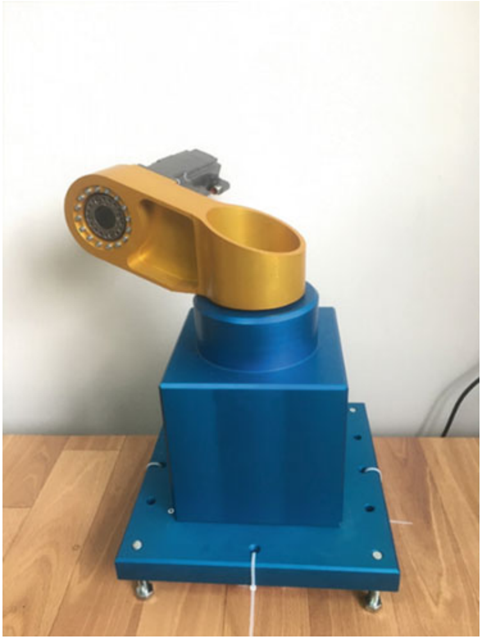


Fig. 17.10 Measurement of the roundness of a robotic angle arm with a diameter of 47 H7 on a Thome device

Fig. 17.11 Assembled robot assembly base and angled arm



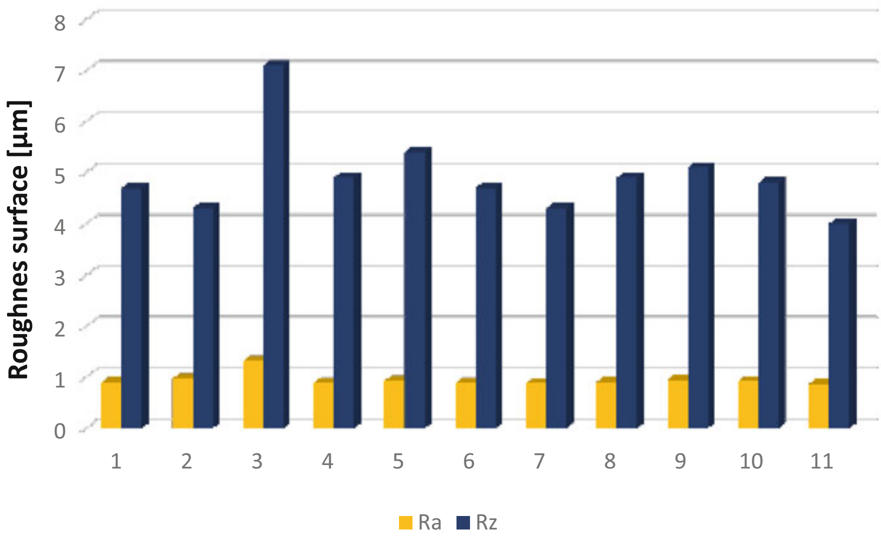


Fig. 17.12 Display of roughness values R_aR_z on average 50 f7

17.5 Conclusion

The safety of the collaborative robot is built directly into itself, so fencing becomes a thing of the past. ABB's growing YuMi family of robots is part of new and exciting collaborative automation solutions that help humans and robots work together safely. At present, such robot constructions are used on power lines with lower component weights, i.e., up to 10 kg. The WorkNC application was selected to generate the NC program. Its inner core of the processor—parasolid is designed for machining shaped surfaces for molds and complex rounded surfaces, which cannot be programmed using manual or workshop programming. Like several CAM applications, WorkNC allows machining simulation, collision indication, etc. The production of a robotic angle arm for a collaborative robot was carried out in the FVT school workshop at the Pinnacle VMC 650 S milling machining center.

The following rates have been achieved in the production of the robotic angle arm. The mean arithmetic value of roughness for the diameter 50 f7 was measured $R_a = 0.95$ µm and $R_z = 4.91$ µm. The roundness deviation for the 47 H7 diameter was measured to be 31.3 µm. By evaluating the accuracy of the angle arm, it was found that no problems would occur during assembly with the counterpart.

Acknowledgments This work is a part of research project VEGA 1/0045/18.

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Chapter 18
Use Cases for C-ITS Testing of Autonomous Vehicles

Michal Jerabek and Jiri Broz

18.1 Introduction

Vehicle-to-vehicle communication (V2V) allows to share information about vehicle traffic (position, speed, direction of travel, braking, etc.), thanks to which potential hazards can be identified and responded to in a timely manner. V2V communication enables safe driving and, for example, avoiding traffic congestion on roads. In addition to V2V communication, vehicles are also able to communicate with transport infrastructure, such as traffic lights, via vehicle-infrastructure communication (V2I). Other functions, such as toll and parking fees, can also be communicated via V2I [1].

For V2X communication, a 5 ms transmission request is specified for a 1600 bytes message with a guaranteed delivery probability of 99.999%, with traffic controlled by events or periodically sent messages with a typical time interval of 100 ms. And in highway scenarios, communication at speeds of up to 500 km/h is envisaged [2].

In the case of autonomous vehicles, a distinction can be made between "immediate" and "remote" surroundings for communication. The immediate surroundings include vehicle–vehicle and vehicle–infrastructure communication (generally V2X), the remote surroundings include communication with information systems such as The National Traffic Information Center (in the Czech Republic NDIC), BackOffice or a cloud connection in general, where, e.g., parents could supervise the movement of their children in an autonomous vehicle.

While a mobile communication network is a clear choice for remote communication, two "competing" solutions dominate in near communication—a telecom-

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munications solution based on building a network using RSUs (ITS-G5 for Europe, DSRC for America) and expanding the possibilities base stations of a mobile communication network with direct communication between terminal devices (LTE-V = LTE-Vehicle).

The choice of a suitable transmission technology is confronted with a number of requirements for system parameters, which include in particular latency, security, availability, reliability, integrity, coverage, permeability of the environment in different circumstances, etc.

Intelligent Transport Systems (ITS) enable traffic management. The individual service combinations must act as additional traffic management tools for the implementation of local transport policies. Effective traffic management, enabled by ITS, is a powerful tool for creating the modal shift on which most growing cities now depend [3]. Cooperative Intelligent Transport Systems (C-ITS) enables mutual communication between ITS while V2V and V2I are important elements.

Closely related to communication, whether V2V or V2I (I2V), is the issue of security. If the vehicle is to respond to information from another vehicle or infrastructure, it is of the utmost importance that the identity of the counterparty and at the same time the originality of the message is guaranteed. Testing and description of communication are given in the documents [4–8].

In the following part, several use cases are listed. The list contains both use cases for V2V and V2I communication. Each of the use case contains the general information about the use case and some of the conditions for testing too.

18.2 Use Cases for Testing

The following division of use cases is by criterium whether the source of information is the vehicle or the infrastructure, with a separate group of VRU—focused use cases (Vulnerable Road Users—pedestrians, cyclists, etc.).

18.2.1 Use Cases with Information from Vehicle

Road works warning—this use case is relevant for the V2V communication as well as V2I and I2V. The use case can be split into several parts such as planned long-term static road works that can be generated in the back offices of the road operator as well as dynamic short-term road works that should be generated in the operating vehicle. The main objective is to warn drivers in advance before lane closure or other unusual situation on the road [9].

Weather condition warning—this use case is related to environmental conditions on the road. The driver should get information about unexpected conditions ahead. This use case can be triggered on the infrastructure side (camera, weather stations) as well as by the other vehicle on the road. The source message can be generated based on the turned windshield wipers on [10].

Stationary vehicle—the vehicle detects that it has stopped for an undefined amount of time/has broken down and broadcasts an alert message to other vehicles. The objective of this use case is to increase the awareness of drivers about stationary vehicles to make him adapt his speed and trajectory to the situation. The other drivers around are able to avoid an accident and this use case helps to improve the safety on the roads [10].

Slow vehicle—the vehicle detects that it goes slowly than other road users and broadcasts an alert message to other vehicles. The objective of this use case is to increase the awareness of drivers about slow-moving vehicles to make him adapt his speed and trajectory to the situation. The other drivers around are able to avoid an accident and this use case helps to improve the safety on the roads [10].

Hazardous location notification—a vehicle detects that it is slipping, danger situation such as an animal, people, or unexpected obstacle on the road and broadcasts an alert message to other vehicles. The objective of this use case is to increase the awareness of drivers about dangerous sections ahead to make him adapt his speed and trajectory to the situation. The alert needs to be early enough for the driver to adapt his speed without stress, but not too early so that the driver does not forget about the alert [9].

Traffic condition warning—sudden changes in traffic conditions downstream of the current position and in the driving direction of the vehicle may have an impact on both traffic safety and efficiency. The objective of the use case is to provide timely in-car driving assistance information on traffic conditions downstream of the current position and in the driving direction of the vehicle. The vehicle driver receives timely an awareness message on the in-vehicle display [11].

Lane change, merge, and overtaking assistance—the main objective of this use case is to provide collision risk warning for lateral manoeuvers. The primary expected impact is the reduction of the risk of lateral collision and thereby improves traffic safety. The secondary expected impact is to smoothen lateral manoeuvers and reduce any negative impact on traffic flow [11].

Electronic emergency brake lighting—a vehicle automatically detects an emergency brake and broadcasts an alert message to other vehicles. An objective of the use case is to provide relevant and fast information about the braking vehicle to other road users, thus leads to the safety and traffic efficiency improvements [9].

Emergency vehicle approaching—the main objective of the use case is to provide information about the emergency vehicle. The emergency vehicle warns the other road users by the message, which can be triggered by the siren or light bar. Awareness about the unclear situation can be improved. The road users can adapt their behavior and clear the road properly, thus leads to the faster passing of the intersection or other road segment by the emergency vehicle [9].

Public transport safety—the use case related to the public transport safety has to improve the safety in the cities. The main objective of the use case is to provide information about the dangerous crossing by the public transport vehicles as well as information about the bus that is leaving the bus stop. In the future, the solution that provides information to warn before the left turning vehicle can be applied [10].

18.2.2 Use Cases with Information from Infrastructure

Wrong-way driving—the service is to warn the driver that he could stumble upon a vehicle that is driving in the wrong way. The aim is not to alert the wrong-way driver that he is on the wrong direction. The objective is to encourage the driver to adapt his speed and his behavior, in case of a wrong-way driving around [9].

Public transport preference—traffic lights interrupt traffic flow and therefore cause delay and emissions. For emergency, safety, environmental, traffic flow efficiency, and business reasons, it may be advantageous to give priority at traffic lights to specific classes of road users [10].

In-vehicle information—the road user receives (not only) speed limit notifications as he drives. The message subject is the dynamic speed limit given by the road manager, which is always mandatory. The road user can receive any other traffic information in the vehicle from traffic infrastructure [9, 10].

Intersection signal violation—the service is to inform drivers approaching an equipped intersection that a vehicle is probably going to make a red light or stop violation. Expected benefits are to reduce the number and severity of collisions at signalized intersections [9, 10].

Probe vehicle data—the service is the automatic collection of road traffic data from the vehicle to the road manager. This data can be used for real-time traffic information and management, but also to build statistical information [10].

Railway level crossing—the level crossing warning message is transmitted via C-ITS messages within this service. The message describes the necessary crossing parameters and provides the approaching vehicle with information about the crossing parameters it is approaching and its current status. It is also possible to inform the driver about the status of the traffic lights at the level crossing [10].

Green light optimal speed advisory—the service is to give drivers advices permitting them to optimize their approach to a traffic light (maintain actual speed, slow down, adopt a specific speed, time to green when it is permitted by legislation) [9].

Intersection collision risk warning—ICRW application is considered as a primary road safety application. Primary road safety applications are ITS applications that target at reducing the risk of collision and thus improving the road safety. An ICRW application provides intersection collision risk warning to drivers. The warning indicates the risk of potential intersection collision risk that requires an immediate action of the driver [5].

18.2.3 Use Cases of VRU

VRU to VRU Direct Cooperation

VRU's device embedding at least one ITS-Station (ITS-S) and potentially other types of applications [12].

Sharing pavement between pedestrians and cyclists—this is typically a VRU to VRU cooperation. Each VRU is equipped with an ITS-S complying with VRU standards. The VRUs are exchanging constantly standard messages enabling the detection of a risk of collision between them. When relevant, an action (in this case, an alert) can be triggered to avoid the collision [12].

Pedestrian crossing a road with an e-scooter approaching—in this use case, one (or several) equipped VRU(s) able to receive and transmit V2X messages, i.e., in VRU-St configuration, is (are) positioned at a crossroad while an electric scooter is approaching. The e-scooter is equipped with a VRU device as well. One of the VRU ITS-S has sufficient processing capabilities to perform a risk assessment [12].

VRU to Vehicle Direct Cooperation

VRU's device embedding at least one ITS-S and the vehicle is also equipped with an ITS-S [12].

Active roadwork—by active roadwork it is meant that human workers are present and active on the roadwork zone. The VRUs to vehicles cooperation can be achieved by VRUs using a device including an ITS-S complying with VRU standards. In such case, the devices' ITS-S are continuously broadcasting VRU standard messages providing dynamic data elements related to their positions and movements. Vehicles are also equipped with an ITS-S complying with VRU standards and so are capable of receiving VRU standard messages and then of detecting and avoiding collision with active workers [12].

VRU crossing a road—in this use case, one (or several) equipped VRU(s) able to receive and transmit V2X messages, i.e., in VRU-St configuration, are crossing a road. In the normal flow, the VRU is (are) positioned at a crossroad. The VRU standard messages are received by other vehicle ITS-S stations. In case of potential risk, the V-ITS-S broadcasts a warning message, which is received by the VRU-St [12].

Rider is ejected from his motorbike—a person riding a motorbike falls on a slippery road and is ejected at a certain distance from the motorbike. Approaching vehicles equipped with a V-ITS-S need to avoid running on the rider and crash the motorbike instead if the TTC is too short to brake efficiently. This use case assumes that a technical mechanism is available to pair the VRU device of the rider with the VRU device on-board of the motorbike when they are sufficiently close to each other. Such a mechanism may use existing protocols such as Bluetooth for example [12].

Emergency electronic brake light—the Emergency Electronic Brake Light (EEBL) application enables a vehicle to broadcast its own emergency braking situation to the surrounding vehicles, including those that have their LOS obstructed by other vehicles or bad weather such as fog or rain. In case there are multiple vehicles driving behind each other, and the first vehicle would have to perform an emergency braking, this application eliminates the delay in reaction time by subsequent vehicles: Each driver/rider is informed immediately, and collision danger could be avoided [12].

Motorcycle approach indication/motorcycle approach warning—Motorcycle Approach Indication (MAI) is an application that informs a vehicle driver that an approaching motorcycle is nearby, even if the driver cannot see the motorcycle. If, based on dynamics information from both vehicles, a possible crossing with the motorcycle is detected or the relative distance between the two vehicles decreases below a given margin, an information is issued to the vehicle driver. The Motorcycle Approach Warning (MAW) application warns a vehicle driver who has a potential risk to collide with a motorcycle. This goes beyond the general notice that a motorcycle is approaching such that the MAI application provides. The MAW application is more sophisticated, because it also calculates the risk of collisions and only provides warnings to the vehicle driver if a collision is likely to occur [12].

V2V Direct Cooperation

The vehicle (with ITS-S complying with the VRU standards) detecting a hidden VRU (may be without equipping) and signaling it to other vehicles [12].

Signaling VRU hidden by an obstacle—some vehicles are equipped with a front sensor (e.g., a camera) and a perception function capable of analyzing collected video and detecting VRU. When a sensor-equipped vehicle is detecting a VRU starting to cross a road, it broadcasts a standard message (e.g., DENM or CPM) signaling to other vehicles being in the C-ITS network that a hidden VRU is crossing. Receiving vehicles will act according to their relative speed and distance to the VRU [12].

I2V Direct Cooperation

A Road Side Equipment (RSE) (with ITS-S complying with the VRU standards) detecting a hidden VRU (may be without equipping) and signaling it to approaching vehicles (with ITS-S complying with the VRU standards) [12].

Signaled few VRUs in a protected area—VRUs are evolving in a protected area (e.g., pedestrian zone, roadwork, police control, etc.). The arrival of vehicles with an excessive speed is detected by means of a static or mobile Road Side Equipment (RSE) via its own sensors (i.e. camera). This RSE may signal the arrival of a vehicle in an excessive speed relatively to its short distance to the protected area. The RSE may also broadcast standard messages to the approaching vehicle(s) signaling the protected area. Optionally, the RSE may trigger an emergency braking at the level of a vehicle presenting a risk of collision with VRUs in the protected area [12].

Non-equipped VRUs crossing a road—VRUs are non-equipped children crossing a road after leaving/boarding their scholar bus waiting for them at the bus station. Before crossing, they can be hidden by the bus itself. Vehicles intending to overtake the bus cannot perceive the hidden VRUs. A Road Side Equipment (RSE) senses the presence of one or several VRUs ready to cross the road and signals this risk to the vehicle (DENM or CPM) or provides them with manoeuver instruction to overtake the bus when a risk of collision with a VRU does not exist anymore [12].

VRUs crossing at a zebra protected by a traffic light—at a crossroad, traffic lights are regulating the traffic and equipped with ITS-S. A traffic light detects the approach of a priority vehicle (e.g., a public transport) via its broadcasted CAMs. Before changing its phase from red to green, the traffic light verifies with an appropriate sensor that no VRU is engaged on the zebra crossing area. If it is the case, the traffic light phase can be changed, if not, the traffic light is waiting that all engaged VRUs have finished crossing before changing the traffic light phase [12].

Scooter/bicyclist safety with turning vehicle—in this use case a typical critical situation is considered, where a vehicle turns right and oversees an approaching scooter or bicyclist, which intended to go straight. A similar situation is considered with a vehicle approaching from the opposite direction and wants to turn left. The driver oversees the scooter or bicyclists and a collision of both road users is possible [12].

Equipped VRU Via a Third-Party Centre

A control center or cloud server monitoring the movement of VRUs. The VRUs may be equipped with an ITS-S detecting risks of collisions with monitored vehicles (with ITS-S complying with VRU standards) and then acting to avoid collision [12].

Network-assisted vulnerable pedestrian protection—this use case is focused on situations where a VRU is moving close to the street or crossing the street. Thanks to exchange of positioning via a global navigation satellite system (GNSS), radio-based positioning, and local sensor/camera information between users and the network via wireless communications, the network-assisted VRU protection system will determine the road user position. All this information is processed for multiple road users for alert generation to vehicle drivers or AD vehicles. Complementing GNSS and in-vehicle equipment with radio-based positioning is crucial in situations where GNSS reception is highly inaccurate or even impossible (tunnel, parking garage) and where in-vehicle equipment becomes unreliable because of non-line-of-sight (NLOS) between vehicle and VRU or bad weather conditions. Goal: To detect the presence of vulnerable road users in proximity of a vehicle with the help of the network and deliver such information to the vehicle and the VRU to avoid the potential collision with the help of accurate positioning technology [12].

Detection of an animal or pedestrian on a highway—highways are now equipped with cameras at strategic locations, which monitor the road traffic as well as events that may happen on the highway and put vehicles at risk. Such event can be the detection of the presence of a pedestrian, or even an animal on the side of the road, likely to enter the driving lanes. These cameras are monitored in a control center, where the decision is made to trigger an alert to passing-by vehicles in a certain area, covered by a cluster of roadside units [12].

Equipped VRU Via a Third-Party RSE

An RSE (with ITS-S complying with VRU standards) monitoring the movement of VRUs equipped with an ITS-S complying with VRU standards, detecting risks of collisions with monitored vehicles, and then acting to avoid collision. RSE and vehicles need to be equipped [12].

Signaled many VRUs in a protected area—in an urban environment, many times VRUs are moving in protected VRU areas and sometimes crossing roads at unprotected points according to their points of interest. If many VRUs are equipped with a portable device including an ITS-S, this may create a local ad hoc network congestion problem. This can be limited if this issue is considered during the design of the overall system. Several possible approaches need to be further explored in the next parts of this standard [12].

Intelligent traffic lights for all (P2I2V)—this P2I2V cooperation is achieved by each VRU using a portable device including an ITS-S complying with VRU standards. In such case, the portable devices' ITS-S are continuously broadcasting standard messages providing dynamic data elements related to their positions and movements. Infrastructure (traffic lights in this case) and vehicles are also equipped with an ITS-S complying to VRU standards and so are capable of transmitting and receiving VRU standard messages and then detecting and notifying the traffic light change setting adjustment [12].

18.3 Conclusion

The above list of use cases is not exhaustive, but represents a comprehensive list of major situations in which dangerous situations may occur that endanger the lives of all road users.

Currently, the driver is informed about a dangerous situation through a warning message, and its transmission to the driver (visually, acoustically, by touch, etc.) must not in itself cause another dangerous situation, e.g., due to the driver's loss of attention. With the progress of the level of vehicle autonomy and communication security (concerning the guarantee of the originality of the message and the identity of the counterparty), vehicles will respond to the received messages themselves in an effort to avoid a dangerous situation or at least mitigate its consequences.

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Chapter 19
Development of Optical Networking for 5G Smart Infrastructures

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19.1 Introduction

The global information infrastructure relies on optical fiber communications and the question for the future is how strongly these communications will penetrate and complement other forms of communication. Optical technologies will play a significant role in the development of the smart city concept. Diverse communication services such as residential, enterprise, and mobile services are supported by optical networking. The same has been imposed to stronger requirements of 5G wireless networks such as high bandwidth, high availability, low latency, and spectrum slicing to optimize resource utilization.

The growth of urbanization and population brings challenges in city functioning. To meet the needs of urban population and to improve the quality of life, emerging technologies trigger the transformation of a city into a smart city. The definition of a smart city in the literature has not been standardized due to broad viewpoints. Cities have different levels of development and areas of interest, so the criteria that cities should meet to become smart are also different. The common in each of smart city applications is the low latency and efficient resource utilization, to provide real-time responses. According to the definition approved by ITU (International Telecommunication Union) focus group on smart sustainable cities (working group 1), a smart sustainable city is an innovative city that uses information and

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communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations concerning economic, social, and environmental aspects [1]. A review of trends, architectures, challenges, and real-world implementations of smart cities is presented in [2]. Collecting and storing a huge amount of smart device data require reliable, high capacity transport network infrastructure. The role of optical technologies to develop such infrastructure has been analyzed in [3]. Currently available optical technologies will not be capable to cope with ongoing and future demands. That is why migration to 5G or flexible concept is the subject of extensive research in the past few years.

The goal of the paper is to address the following research questions (RQ) in the area of optical networking for smart infrastructures:

RQ 1. What are the 5G requirements for optical networking?
RQ 2. What are the available and emerging optical technologies for 5G transport?
RQ 3. What is the role of flexibility in 5G transport?
RQ 4. What are the research challenges on EON deployment in 5G transport networks?

To answer the research questions, the rest of the paper is structured as follows. Section 19.2 presents the smart city architecture. Section 19.3 gives answers to the defined questions. Concluding remarks are given in Sect. 19.4.

19.2 Smart City Layered Architecture

An application of the Internet of Things (IoT) is usually related to the smart city concept. Fundamental characteristics of a smart city are presented in [2, 4]. The study conducted by Berrone et al. [5] evaluated 181 cities in more than 80 countries to determine the smartest cities around the world. City indicators related to economy, transportation, urban planning, governance, etc. are used for evaluation. In order to connect a huge number of smart city objects, connectivity plays a major role. Regarding the IoT, things are objects of the physical world or the information world. Physical things are capable of being sensed, actuated, and connected while virtual things are capable of being stored, processed, and accessed [6].

The functioning of a smart city is based on the architecture composed of four key layers [6]: application layer, service support and application support layer, network layer, and device layer (as shown in Fig. 19.1). The realization of such architecture is partly possible with existing networks while the evolving or next-generation networks are a promising and unavoidable future solution. It could be seen from Fig. 19.1 that optical technologies are represented at the network and sensing layers.

The sensing layer consists of a huge number of devices and sensors that collect the data and parameters. The city has a higher level of smartness if the coverage of sensor networks is higher.

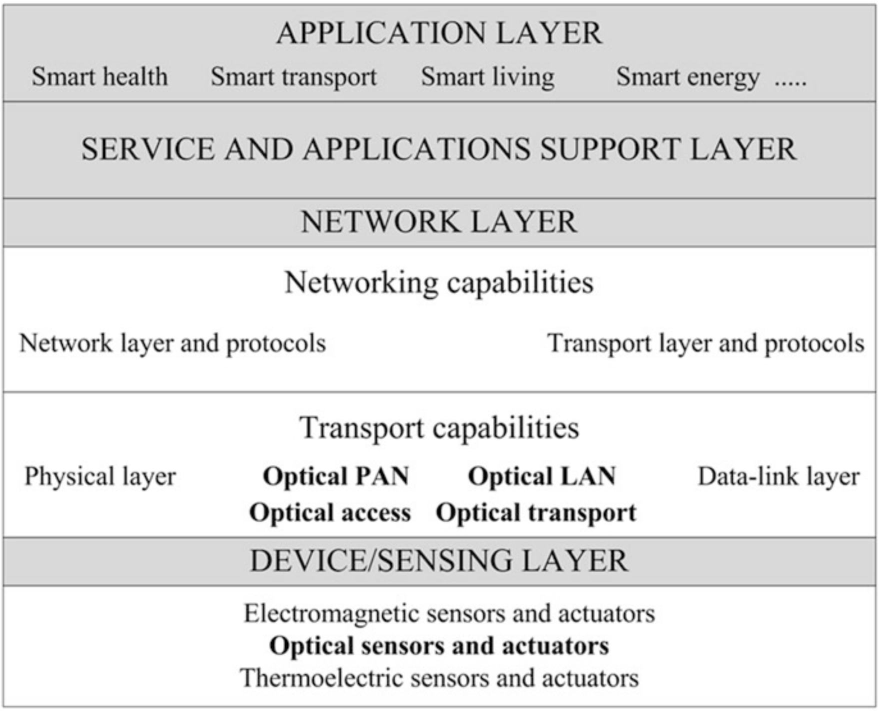

Fig. 19.1 Smart city layered architecture. (Adapted from [6])

The network layer consists of networking and transport capabilities. Networking capabilities provide control functions of network connectivity while transport capabilities provide connectivity for the transport of IoT services, carrying the data to the upper layer.

The service and application support layer performs data organizing, analyzing, filtering, storing, and decision-making tasks. The efficiency of this layer is extremely important for a smart city and that is why many techniques are used to enhance data processing such as the Kalman filtering technique [7].

The application layer consists of IoT applications such as smart transportation, smart energy, smart healthcare, smart governance, smart energy, etc. and it directly interacts with citizens.

19.3 Data Synthesis

In this section, the following research questions will be answered.

19.3.1 What Are the 5G Requirements on Optical Networking?

IoT applications set high requirements to the network infrastructures. These requirements are mostly related to low latency, bandwidth, and energy consumption. The main features of the 5G communication services will include ultra-high system capacity, ultralow latency, ultrahigh security, massive device connectivity, ultralow-energy consumption, and extremely high quality of experience (QoE) [8–10].

5G requirements are given as follows:

- The growth of traffic volume—compared to 4G wireless networks, traffic volume is expected to be higher since the number of connected devices will be more than 100 times higher and therefore a huge amount of data is expected to be concentrated.
- End-user data rates —5G networks are expected to support end-user data rates up to 10 Gb/s that is 10–100 times higher than in 4G [11].
- Low energy consumption—the increase in traffic volume increases energy consumption too. When analyzing the energy issue, all elements must be considered such as sensing elements, devices for data transmission, and networking as well as devices related to data storage and process.
- Low latency—latency is highly critical in some applications such as transportation, health care, virtual reality, education, etc. Based on the application latency, services in 5G networks require an E2E (end-to-end) delay of a few milliseconds and for time-critical applications less than 1 ms [11, 12].
- High spectral efficiency—efficient use of frequency spectrum is expected to be an imperative task in 5G networks and at least three times higher than in 4G networks.
- Low costs—5G systems require low-cost equipment that will deliver the traffic with the same or lower energy than 4G.

19.3.2 What Are the Available and Emerging Optical Technologies for 5G Transport?

The development of machine-to-machine communication, a higher number of connected devices, and smart infrastructures are the main drivers for the progress in optical transmission technologies. The transport network in 4G/LTE (Long-Term Evolution) radio access network (RAN) consists of two parts: fronthaul and backhaul. Mobile fronthaul connects baseband units (BBUs) with remote radio units (RRUs) while mobile backhaul connects BBUs with the core network. Migration to 5G leads to cloud-based RAN (C-RAN) architecture that imposes stronger requirements on the transport network. C-RAN differs from traditional distributed RAN (D-RAN) in the architecture concept. BBUs in the C-RAN are moved away from the cell sites and centralized at the central office [13]. In order to support mobile fronthaul and backhaul and the cloud infrastructures as well as high data rates in both downstream and upstream directions, optical technologies will play an essential role. Depending on the operator's goals a suitable optical technology will be chosen to meet the high bandwidth demands. Two of them are usually considered: Point-to-point (PtP) fiber access and point-to-multipoint (PON, Passive Optical Network).

PtP technology supports bidirectional transmission with one or two fibers for distances generally shorter than 20 km [14]. Latency is limited by transmission distance and it requires a huge amount of fiber resources and a system power. Such technology might unable to meet the bandwidth traffic requirements by the 5G beyond networks.

Better use of fiber infrastructures could be achieved with PON technology with the advantages of fiber sharing, low cost, high bandwidth, and split ratios up to 1:256. The main elements of a typical PON are optical line terminal (OLT) at the central office, an optical distribution network (ODN) with passive power or wavelength splitters, and optical network units (ONUs) at subscribers' locations. The standardization of several generations of PON technologies in ITU-T and IEEE is shown in Fig. 19.2.

It could be seen that operators were able to deploy a number of PON technologies. Current GPON (Gigabit PON) and 10 Gb/s PON technology can serve the residential market in the near future. Innovative PON generations, such as 10-Gb symmetric PON (XGS-PON) and the second standard of NG-PON (NG-PON2) are following the growing demands and became the target of various providers. PON technologies could be divided into WDM-PON (Wavelength Division Multiplexing) and TDM-PON (Time Division Multiplexing) depending on the techniques employed to enhance capacity and fiber efficiency. Further development of 5G networks where latency and bandwidth are essentially considered will be supported

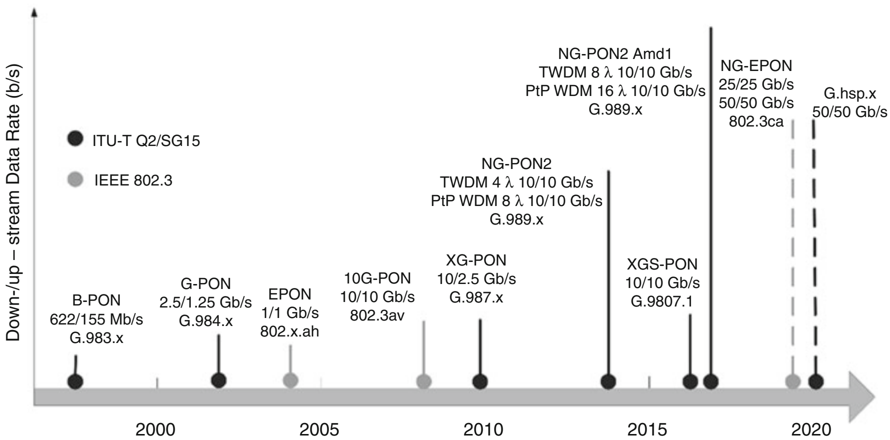

Fig. 19.2 PON technologies developments. (Adapted from [14])

with one of the emerging PON technologies: high-speed PON, low-latency TDM-PON, and WDM-PON [14].

High-speed PON is possible by joining (aggregating) the wavelengths or increasing the data rate per wavelength. For example, NG-PON2 will be able to provide 80 Gb/s bandwidth by aggregating eight 10 Gb/s wavelengths via TWDM or potentially 160 Gb/s more with sixteen 10 Gb/s wavelengths [15]. The IEEE 802.3ca task force has been working on the development of 25G/50G/100G EPON standards. Higher data rate per wavelength will be possible with advanced modulation formats such as duobinary, 4-level pulse-amplitude modulation (PAM4), and discrete multitone (DMT) together with advanced digital signal processing (DSP) equalization [16, 17].

TDM-PON, such as GPON (Gigabit PON) and EPON (Ethernet PON), has been widely deployed because of its cost advantage. The main efforts on emerging TDM-PON are focused on latency reduction. The standard TDM-PON with dynamic bandwidth allocation (DBA) has greater latency. Time taken to process the DBA in the OLT or the grant processing time increases the latency. Since the DBA method directly affects processing time it is important to avoid the complex methods. For this purpose, a low latency DBA method to reduce the DBA cycle or latency as well as to improve bandwidth efficiency has been proposed in [18] where DBA cycle length depends on traffic load.

For WDM-PON, each ONU is assigned a specific wavelength. The wavelengths can be selected in the ODN with passive wavelength splitters or in the ONU with wavelength filters. The technology enables multiple wavelength transmission through the shared optical fiber infrastructure providing in such a way high capacity, fiber savings, and simple network management. These features make the technology suitable for 5G fronthaul. In order to fulfill 5G deployment demands, each wavelength is required 25 Gb/s and above. For this purpose, colorless ONUs using tunable transponders technology will be applied with different lasers locked to a specific wavelength in each ONU. Therefore, tunable transponders and wavelength tuning range are under research investigation. It should be mentioned that the advantages of both WDM-PON and TDM-PON can be effectively exploited through joint application and the result is hybrid TWDM-PON architecture.

19.3.3 What Is the Role of Flexibility in 5G Transport Networks?

The first step toward 5G emerging optical infrastructure is to replace fixed grid with flexible grid technology. The problem of bandwidth scarcity implies migration from fixed DWDM (Dense Wavelength Division Multiplexing) grid to flexible EON (Elastic Optical Network) grid. Fixed grid means equal channel spacing and the whole spectrum allocation to demand, without considering its size. That is why part of a spectrum has been always wasted. Flexibility is the ability of a system to

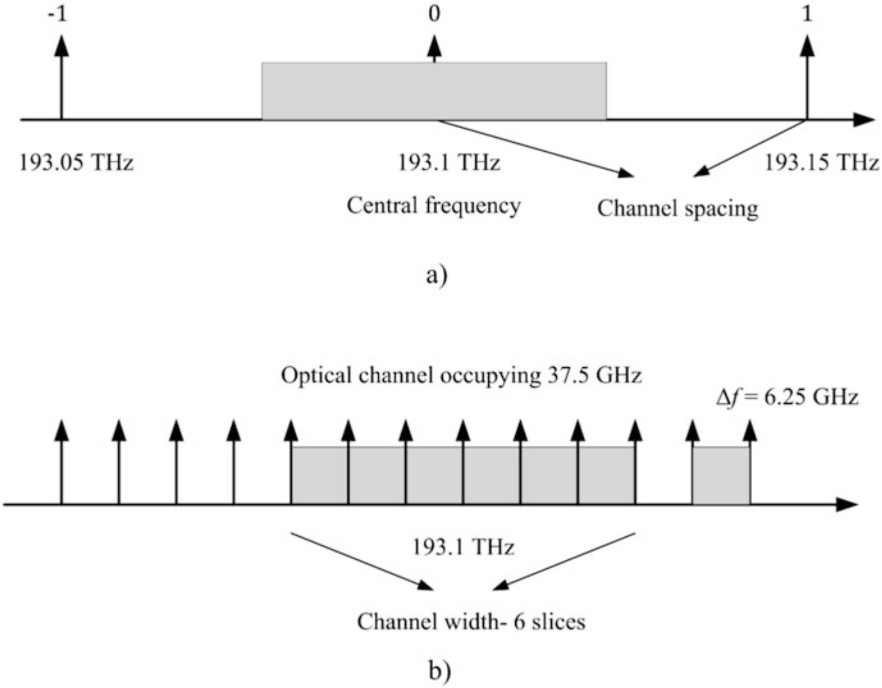

Fig. 19.3 Spectrum allocation: (**a**) fix grid and (**b**) flexible grid [20]

adapt to changes related to traffic or network conditions [19]. A flexible grid means that some parameters, such as channel spacing, or modulation scheme become adaptable. There is no spectrum wastage because the spectrum allocation considers the size of demand. According to ITU recommendation G.694.1 [20] the traditional DWDM fixed grid of 50 and 100 GHz has been replaced with a flexible grid of 25, 12.5, or 6.25 GHz. Spectrum savings of 37.5 GHz used instead of 50 GHz are shown in Fig. 19.3. Figure 19.3b shows much finer spectrum granularity than a fixed ITU-T grid (Fig. 19.3a). The whole spectrum is discretized into units called slots or slices. In this way, elastic optical paths are formed using just enough spectrum. So, the role of flexibility is more efficient spectrum utilization and spectral efficiency improving to cope with growing traffic demands. Such a network is called a flexible or elastic network.

Elastic optical networking is possible with hardware elements such as sliceable bandwidth variable transponders (SBVT) capable of adapting to the central frequency and the modulation format of the incoming signal, and flex-grid reconfigurable optical add-drop multiplexers (FG-ROADM) used for switching along the path. SBVT can form elastic optical paths (superchannels) that consist of several groomed subcarriers and optical paths with different spectral widths. Such elasticity of fine granular spectrum channels and flexibility of SBVTs allows that the right amount of spectrum and transponder resources is allocated to a small traffic demand [21].

19.3.4 What Are the Research Challenges on EON Deployment in 5G Transport Networks?

High capacity and a huge number of connections in a 5G network are driving a network provider for network dimensioning leading to higher Capex and Opex. It does not mean that customers are willing to pay proportionally. In order to be sustainable in such a competitive environment, a network operator should look for opportunities that minimize infrastructure costs and energy consumption. Before the realization of EON-based 5G transport network, some research challenges should be addressed.

Dynamic lightpath establishing in the C-RAN deployment with BBU pools requires optimization of routing, spectrum, and modulation-level selection while satisfying latency and minimizing Capex/Opex as well as energy consumption. Routing and spectrum assignments have to fulfill the spectrum contiguity and continuity constraints while latency depends on the level of functional splits between RRU and BBU.

The second challenge is how to predict traffic dynamicity [21]. Since mobile traffic demands have complex and uncertain nature, machine learning techniques could be applied to capture some parameters such as location, time of the day, etc. The predicted demands allow EON to allocate just enough spectrum and transponders resources. Therefore, predictive models are under investigation.

The consequence of satisfying routing and spectrum allocation constraints is spectrum fragmentation. 5G implies a very dynamic traffic environment where traffic demands range from very low to high bandwidth. If there is not enough available spectrum when a new demand arrives, it is blocked. To overcome the resource fragmentation problem, proactive and reactive approaches are considered [22].

Survivability techniques are another challenge in EON deployment in 5G transport. Failure in an optical fiber or sliceable transponder can have a huge effect on the end user and loss of data. Survivability techniques are related to protection and restoration schemes [22]. In the concept of 5G networks, QoS requirements are also considered and different levels of protection are applied. For example, traffic demands with higher reliability select the lightpath with reliable links and devices, while the rest of the traffic selects the best effort lightpaths.

Energy issue is also important in 5G environment because the dense deployment of technologies will increase the energy consumption. The energy consumption could be reduced with O/E/O (Optical/Electrical/Optical) conversion eliminations at transit nodes and using sliceable transponders instead of several transponders. Another approach is to put some EON devices or small cells/antennas into sleep mode when traffic is below a certain threshold [21].

At the last, design of the advanced control plane to support emerging EON and 5G is required. This will imply SDN (Software Defined Networking) principles to be employed. The control plane will enable data transmission across different domains.

19.4 Conclusion

Considering the importance and growing usage of the applications in smart cities, this paper provides an overview of the optical technologies suitable to meet the 5G demands. 5G is designed to support new applications, services, and industries and the operators' task is to select the best 5G transport deployment model and migration strategy. To meet the optical communication demands imposed by 5G wireless, such as high capacity, low latency, low cost, and power per bit; optical access networks need to be improved and enhanced. The improvement considers primarily bandwidth and latency. The mentioned issues may not be supported with existing optical technologies with a fixed grid. 5G C-RAN deployment alternatives will be supported with a flexible grid in order to utilize spectrum more efficiently and provide reliable connections to a huge number of devices.

In summary, PON innovations are targeting to single wavelength data rate at 25 and 50 Gb/s. To achieve such goals, new modulation formats are investigated, reducing latency in TDM-PON as well as tunable transponders technology in WDM-PON.

Our further research could be focused on analyzing the development and implementation of information and communication infrastructure supported by optical technologies for intelligent real-time traffic management in smart cities and next-generation highway networks.

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Chapter 20
Enhancing the Aircraft Maintenance Management Process for Increasing Safety

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20.1 Introduction

Safety and reliability in aircraft systems and performance are the main concern of rising importance, especially due to the sophisticated and modern maintenance and inspection technologies. Reliability comes through improving the quality or quality level of the components or products [1].

The main goals of aircraft maintenance and inspection technologies have been to efficiently correct defects and avert failures. NDT is the most useful technology for evaluating the soundness and acceptability of an actual component without spoiling its functional properties of it. Nondestructive testing is exactly what its name indicates for an instance, a procedure of testing without destroying. NDT is an analysis of an object or material in a way that will not spoil its future functionality. NDT is the use of technology for examining the materials according to known standards. Nondestructive testing does not in any way damage the serviceability of the part or any component which is being inspected; therefore, these can be applied, if desired, on all kinds of the units produced. Consequently, greater reliability in the production and the maintenance can be achieved. There are a number of NDT methods applicable to the maintenance of the aircraft. In this project work, my major concerns are on the maintenance techniques and/or NDT techniques that are applicable for Aircraft wheel overhaul and the factors affecting the sensitivity of the

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crack detection and the solutions. During the operation of the aircraft, wheels are subject to vast stress and heat during takeoff and landing, which generated some irregularities on its surface. The aircraft wheels are made from a single piece of the materials such as aluminum, steel, magnesium, and so on by the casting process, so we should have to focus on surface discontinuities on aircraft wheels. It is not necessary to focus on volumetric inspection, integrity, or any welded part inspection. As the aircraft wheels are made by the casting process and there is not a weld on them, which means we assume them as a single piece. Thus, we should focus on surface flaws only [1, 14].

The techniques that are applicable for surface discontinuities on aircraft wheels are shown as below:

- Liquid penetrant inspection.
- Magnetic particle inspection.
- Eddy current inspection.

20.2 Aircraft Maintenance

Aircraft maintenance is the overhaul, repair, inspection, or modification of an aircraft or aircraft component [2]. It is the process of ensuring that a system regularly performs its deliberate function at its designed-in level of safety and reliability.

Aircraft maintenance is purposive to be keeping the aircraft in a state which will or has enabled a certificate of release to service to be issued. Maintenance may incorporate such tasks as ensuring concurrence with airworthiness prescriptions or service reports. The maintenance of aircraft is highly synchronized, in order to ensure precise and safe functioning during flight. National regulations are synchronized under international standards, maintained by bodies such as the International Civil Aviation Organization (ICAO). The maintenance tasks, personnel, and inspections are all firmly regulated and staff must be licensed for the tasks they accomplish. NDT is defined as the part of scheduled or unscheduled maintenance [15]. In addition, it is similar to the line maintenance and some similarities have been seen in-shop maintenance, line maintenance should be understood as "any maintenance that is carried out before the flight to ensure that the aircraft is fit for the intended flight" [3]. This would typically include preflight checks, daily checks, failure rectification as well as minor, scheduled maintenance tasks as follows. The shop maintenance covers maintenance on components when removed from aircraft, e.g., engines, APU, wheels, brakes. Sometimes, this is carried out within the same organization as the heavy maintenance, but sometimes special companies carry out this work separately.

Experience has indicated that mishaps are regularly gone before by security-related episodes and insufficiencies along these lines uncovering the presence of well-being perils. In this manner, security information is a significant asset for the location of potential well-being perils. Likewise, while the capacity to gain

Fig. 20.1 Aircraft maintenance safety reporting

from a mishap is essential, absolutely receptive frameworks have been seen as of constrained use in proceeding to present enhancements. Receptive frameworks ought to be supplemented by proactive frameworks, which utilize different sorts of security information, to make powerful enhancements in avionics safety [10] (see Fig. 20.1).

As a result of the standard preparing to perceive and report risks and to comprehend the frequency and outcomes of perils in the exercises supporting conveyance of administrations, operational workforce is learned about the human, specialized and authoritative elements that decide the well-being of the framework all in all.

Basic aircraft safety ought not to be limited to mishaps and occurrences yet ought to incorporate announcing of dangers and perilous conditions that have not yet caused an episode. For instance, a few associations have set up a system for announcing conditions thought about hazardous or unacceptable by the operational workforce. Such reports are generally submitted under deliberate revealing game plans and inner detailing frameworks.

20.3 Nondestructive Testing

Nondestructive testing plays an important role in the quality control of a product [4]. Nondestructive testing (NDT) is the utilization of noninvasive procedures to decide the uprightness of a material, part or structure, or quantitatively measure a few attributes of an article. It is the trying of materials, for surface or interior blemishes or metallurgical condition, without meddling in any capacity with the

Table 20.1 NDT surface examination techniques and their applications

NDT techniques	Applications	Material that can be inspected	Flaws that can be inspected
Liquid penetrant inspection	Surface-breaking defects in all nonporous materials	Metals (aluminum, copper, steel, titanium, etc.)	Fatigue cracks
			Porosity
			Laps
		Glass	Quench cracks
		Many ceramic materials	Grinding cracks
		Rubber	Seams
		Plastics	Overload and impact fractures
Magnetic particle inspection	Surface and slightly subsurface discontinuities in ferromagnetic materials	Ferromagnetic materials: Iron, nickel, cobalt alloys, precipitation hardening steels	Fatigue cracks
			Splits
		Diamagnetic materials: Copper, silver, and gold	Seams
	It is applicable for smaller components of the aircraft wheel such as screws, nut, bolts, washers, bearings, and so on	Paramagnetic materials: Oxygen, magnesium, lithium, molybdenum	Voids that forms when the metal ruptures
Eddy current inspection	Surface, subsurface defects (depending on conductivity)		Fatigue crack corrosion
	Deepness of the crack		
	Can able to detect without removing paint on aircraft wheel		

respectability of the material or its reasonableness for administration. We can say that nondestructive testing (NDT) is a wide gathering of investigative procedures utilized in the science and innovation industry to assess the properties of a material, part, or framework without causing harm (see Table 20.1). The terms nondestructive examination (NDE), nondestructive inspection (NDI), and nondestructive evaluation (NDE) are likewise normally used to depict these innovations. It is a profoundly significant method that can set aside both cash and time in item assessment, investigating, and research [5, 11].

20.4 Results, Comparisons, and Conclusions from the Experiments

Issue no. 1: The nature of the defects and the factors affecting the sensitivity of the Liquid Penetrant Inspection method (see Table 20.2).

- The sensitivity is defined as the smallest defect that can be detected with a high degree of reliability.
- Hydrophobic surface (see Fig. 20.2).
  - High contact angle "θ."
  - Poor adhesiveness and wet-ability.
  - Low strong surface free vitality.
- Hydrophilic surface (see Fig. 20.2).
  - Low contact angle "θ."
  - Good adhesiveness and wet-ability.
  - High solid surface free energy.

  Solution 2: Choice of the good penetrants.

- Fluorescent penetrant frameworks are touchier than noticeable penetrant frameworks on the grounds that the eye is charmed to the gleam of the fluorescing sign.

Table 20.2 The different factors which affect the sensitivity of the inspection by the LPI method during aircraft wheel maintenance are shown in the table as follows

No.	Higher sensitivity	Lower sensitivity
1	Small round defects	Small linear defects
2	Deeper flaws	Shallow flaws
3	Flaws with a narrow opening at the surface	Wide open flaws at the surface
4	Flaws on smooth surfaces	Flaws on rough surfaces
5	Hydrophilic surface	Hydrophobic surface
6	The developers with good adhesiveness and wettability	The developers with poor adhesiveness and wettability
7	Inspection with removing the paint from the surface	Inspection without removing the paint from the surface

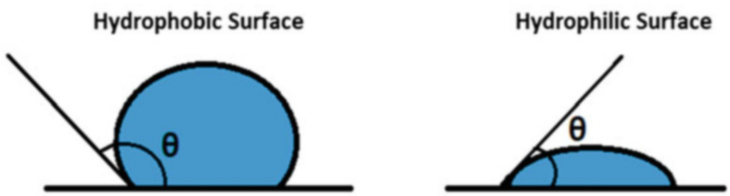

Fig. 20.2 The penetrants with different wetting abilities [6]

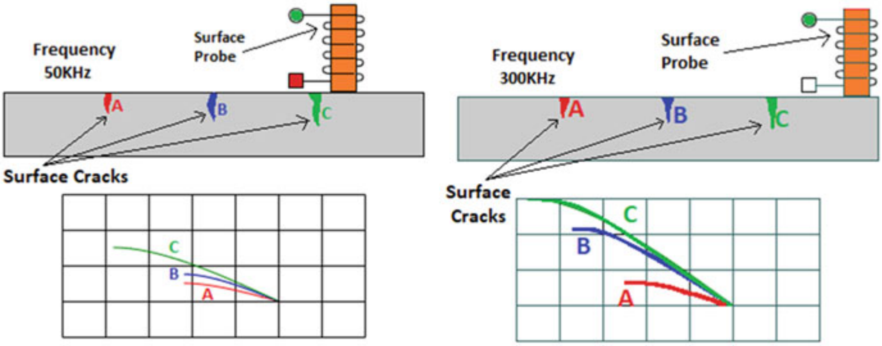

Fig. 20.3 Detection of different types of cracks on aircraft wheel surface with 50 kHz and 300 kHz frequency, respectively [6]

Interestingly, noticeable penetrants don't require an obscured region and bright light.

Solution 3: Choice of the good penetrant removers

- Emulsifiers (Hydrophilic) represent the most noteworthy affectability level and artificially interface with the slick penetrant to make it removable with a water shower. As a quality of the hydrophilic surface of the emulsifies, they are increasingly delicate to the penetrants.

Issue no. 2: The nature of the defects and the factors affecting the sensitivity of the Eddy Current Inspection method (see Fig. 20.3).

- As we discussed above, the higher frequency range of eddy current is familiar with the surface cracks because the eddy current density is much higher at the surface of the test piece. But, eddy current density decreases exponentially with depth so, the higher frequency is no good to examine the subsurface cracks, it needs the lower frequency range.
- The equipment with a single frequency is no essential to solving this problem even it has a higher frequency range or lower.

Solution 1: Multifrequencies equipment.

The best solution for the issue referenced above is to utilize multifrequencies hardware. Moving through different frequencies assists with advancing outcomes or using various tests to get the best goals and entrance required to recognize every single imaginable defect.

Solution 2: PEC (pulsed eddy current) Instrument as a multifrequencies equipment.

The most fundamental advantage of pulsed eddy current is that, when contrasted with single-recurrence eddy current testing, it regularly has a broadband of frequencies, which is profitable for any vortex current based on NDT methods because of the recurrence subordinate skin impact.

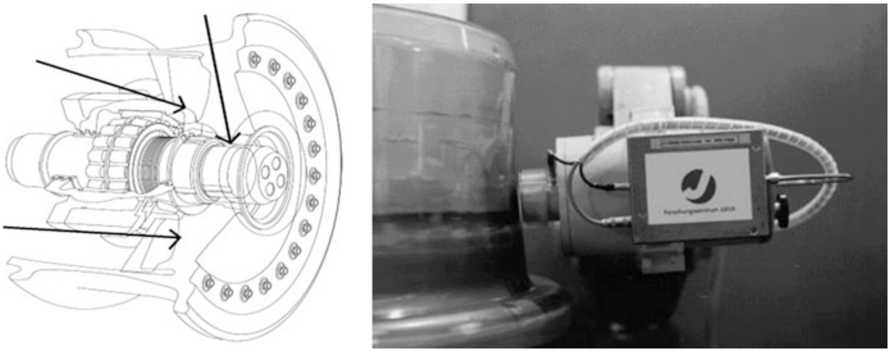

Fig. 20.4 Sketch of an aircraft wheel, with typical crack positions and automated aircraft wheel testing unit, with the SQUID mounted on a robot, during operation respectively [6]

The primary advantage of pulsed eddy current technique over customary swirl current strategy is that it holds a continuum of frequencies. Because of this, it is conceivable to evaluate the electromagnetic reaction to a few unique frequencies can with only a solitary advance [12]. Data from a scope of profundities can be procured at the same time.

Solution 3: Use HTS SQUID gradiometer sensor.

Superconducting quantum interference device (SQUID) is the touchiest attractive field sensor notable these days. SQUID frameworks give high affectability at low excitation frequencies, permitting quantitative evaluation of attractive field maps from the researched structure, permitting the location of more profound imperfections, and high linearity.

Today, the aircraft wheels (see Fig. 20.4) are inspected from the outside with a circumferential scan, measurement, after taking off the tires. Deep flaws are detected with the use of low-frequency eddy current testing probe [13]. However, the sensitivity is limited to large flaws: describe as flaws with 40% wall penetration from the inside and of length twice the wall thickness can be shown reliably. In order to safely detect small hidden defects, the aircraft wheel has to be disassembled and be inspected from the inside. The prototype of the SQUID system for Aircraft wheel testing consists of an automated test stand with the wheel slowly rotating and a robot with the SQUID equipment scanning stepwise along the wheel axis. While the aircraft wheel is turning, the robot moves the cryostat along its outer contour. Thus, a two-dimensional eddy current mapping of the outer surface of the wheel is performed [7].

Issue no. 3: The nature of the defects and the factors affecting on the sensitivity of the magnetic particles inspection method (see Fig. 20.5).

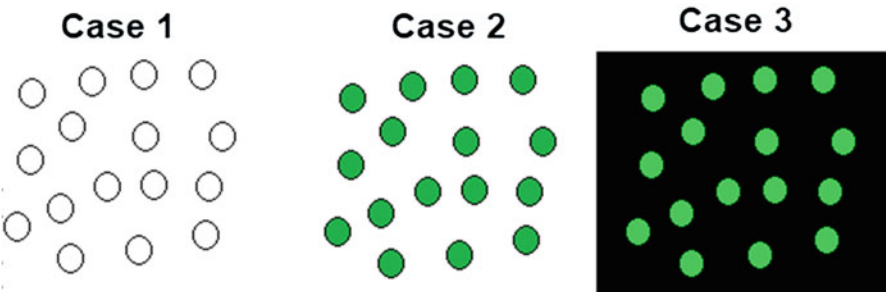

Fig. 20.5 Different magnetic particle cases [6]

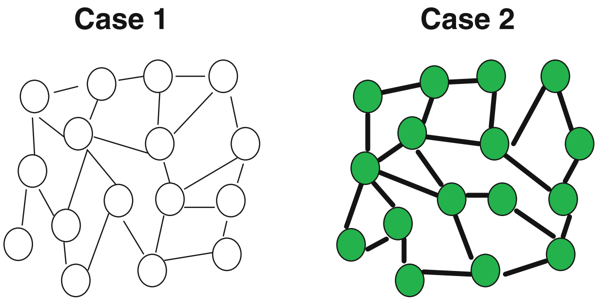

Fig. 20.6 Molecular bonding of different magnetic particles [6]

20.4.1 Discussion and Solutions

The most conclusive in contrast and visibility is achieved by coating the magnetic particles with a fluorescent pigment (typically available in wet method materials only).

The equipment used in wet testing can easily spray a uniform layer of particles over the entire surface of the component being inspected, even if the area is large [8].

The liquid carrier offers mobility to the particles for an extended period, which permits sufficient particles to float to small leakage fields to form a visible indication [6, 9].

- The dry powder is usually more sensitive to subsurface defects. The dry powder method is better for situating defects lying wholly below the surface because of the high permeability and the favorable elongated shape of the dry particles (see Fig. 20.6).
- The wet method is typically best for very fine and shallow defects (Fig. 20.7 and Table 20.3).

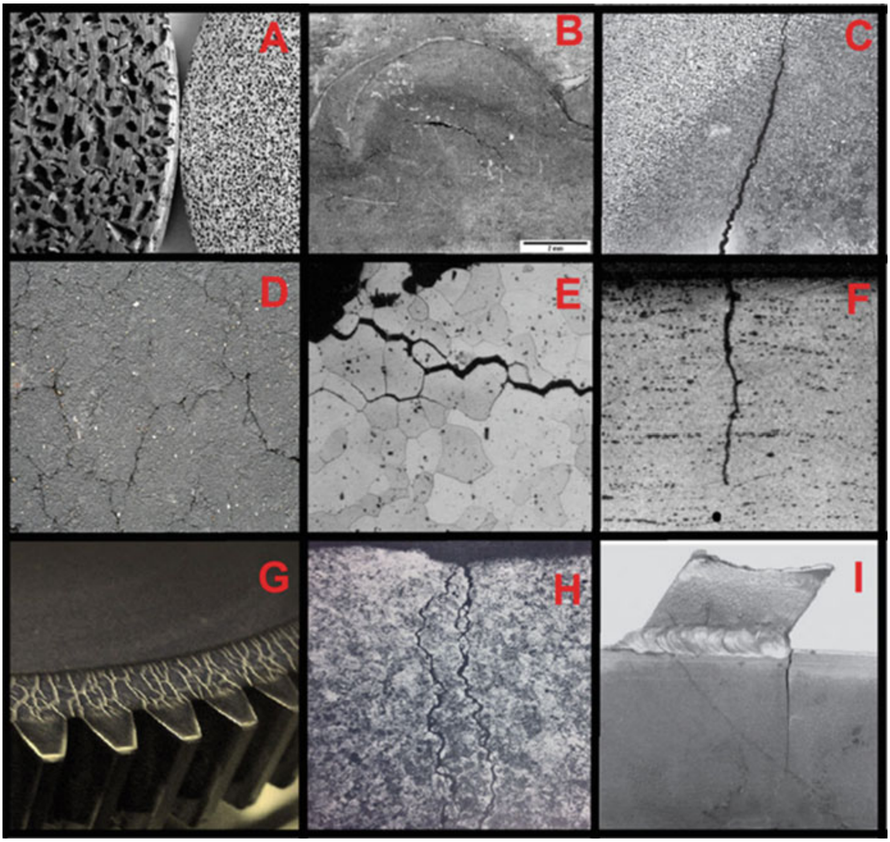

Fig. 20.7 Interpretation of cracks [6]

Table 20.3 Interpretation of cracks and their descriptions

Sr.	Defect	Explanation
A	Porosity	Spherical surface signs
B	Casting cold shut	Dotted lines signs
C	Cracks	Straight continuous surface lines indications
D	Thermal cracks	Interconnecting lines indications
E	Heat treat cracks	Multiple irregular lines signs
F	Fatigue cracks	Continues line in components
G	Grinding cracks	Signs with interconnecting X lines
H	Quench cracks	Continuous interconnecting surface lines
I	Seams	Straight line on edges

20.5 Conclusion

The aerospace industry is driving on the planet for advancement in support methods and demonstrative strategies normally to improve the well-being, dependability, and decrease cost. At the same time, the investigation methods (symptomatic strategies) are additionally being created to screen their uprightness. The surface examination strategies are being created with extraordinary affectability. For example, on account of liquid penetrant inspection procedure, the decision of good designers, penetrants, and remover shows higher permeability and affectability, the model of the SQUID framework for aircraft wheel testing comprises of a mechanized test with higher affectability (eddy current inspection) and the wet attractive molecule testing strategy is progressively touchy for recognition of surface imperfections, for example, weariness splits (magnetic particle testing).

The accompanying sentences delineate the definitive aftereffects of this article. For both surface flaws and subsurface flaws, the eddy current inspection, and magnetic particle inspection are more suitable than liquid penetrant inspection (see Table 20.4). Pulsed eddy current has a broadband of frequencies, which is advantageous for any eddy-current-based NDT techniques due to the frequency-dependent skin effect. The pulsed eddy current method can be done without the requirement of contact with the surface of the material.

Table 20.4 The analysis of considered nondestructive testing methods

Applications	Liquid penetrant inspection	Magnetic particles inspection	Eddy current inspection
Effective on coatings/paints	No	Yes	Yes
Computerized record keeping	No	No	Partial
3D/advanced imaging	No	No	Yes
Time require for particular operation	High	High	Low
User dependence	High	High	High
Cleaning	Yes	Yes	Application specific
Post-inspection analysis	No	No	No
Chemicals/consumables	Yes	Yes	No
Size of the flaw/crack	Not assign	Not assign	Assign
Sensitivity	Higher	Higher	Highest
Suitability for types of cracks detection	Only surface flaws	Both surface and sub-surface flaws	Both surface and sub-surface flaws

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Chapter 21
Architecture of IoT System for Smart Monitoring and Management of Traffic Noise

Dalibor Dobrilović, Vladimir Brtka, Gordana Jotanović, Željko Stojanov, Goran Jauševac, and Milan Malić

21.1 Introduction

Europe-wide activities to reduce environmental noise have a different priority over environmental issues such as air and water pollution, often because such issues are considered to be better addressed at the national or local level. The Republic of Serbia has regulated noise protection measures "Law on Environmental Noise Protection" [1]. In the initial stages, EU noise regulation was based on internal market objectives and in most cases focused on harmonizing the permissible noise values generated by certain devices (motor vehicles, household appliances, etc.). As the information on the impact of noise on human health has become more accessible, there is a need for a higher level of protection for EU citizens.

The problem is produced by traffic noise on city roads because such roads pass through urban settlements, near hospitals, schools, and cultural monuments. The European Union has defined the term "environmental noise" and refers to unwanted and harmful external influences caused by human activity, including noise generated by transport (road, rail, and air) and exposure of the population to noise in cities [2]. International and national directives and legislations have been defined to address environmental noise that has a negative impact on people's health [3]. Monitoring

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of environmental noise by using the Internet of Things within smart cities based on wireless sensor networks has recently gained attention and popularity. The trend is to move from high-accuracy commercial devices to low-cost and ad hoc sensor networks.

According to Marouf et al. [4], effective management of noise requires an understating of its causes, which is mostly limited by traditional monitoring methods that are labor-intensive and are based on expensive equipment. Alías and Alsina-Pagès [5] presented a review of the most relevant wireless acoustic sensor networks (WASN) approaches focused on environmental noise monitoring, with special attention on the nodes' computational capacity and accuracy. The authors classified WASNs based on used sensors on networks based on commercial acoustic measurement devices and network based on customized nodes (usually implemented as ad-hoc networks).

A model of IoT system designed for monitoring the noise in the cities caused by the traffic is presented in this paper. The name of the system is UrbaNoiseMS and it is developed with the idea to be used with the number of sensor stations deployed along the roads in most sensitive parts of urban areas, e.g., in the parts where the low noise levels are required. The sensor collected data are sent to the middleware layer of the system for analytics and for routing the traffic to reduce noise in targeted areas. Because of its usability and high-level applicability, the system uses LoRaWAN, one of the most applied Low-Power Wide Area Network (LP-WAN) technologies. For high scalability, easy maintenance, and expansion, the system architecture is based on micro-services. MQTT protocol is used for intersystem data transfer. To achieve the goal, this model uses the variations of the Dijkstra shortest path algorithm. These algorithm modifications are used to calculate alternative routes for navigating vehicles. The presented system is designed at the level of a prototype, built upon mainly open-source hardware and software components. The core parts of the UrbanNoiseMS system are developed by the authors as well as the integration and configuration of all other components. The presented model of the system and its developed parts are the main contributions of this paper.

This paper is structured as follows. After the introduction, in the second section, a review of related work is given. In the third section, a brief description of LoRa and LoRaWAN technology is given. The system model is presented in accordance with the widely accepted IoT-layered system architecture in the fourth section, where most details are given to the perception, transport, and middleware layer. The modified variants of Dijkstra algorithms used for traffic routing and their evaluation are presented in the fifth section and the sixth section, respectively. Conclusion remarks and future development are presented in the seventh section, together with the explanation of possible usage of the system.

21.2 Related Work

According to [6], high levels of noise in traffic in certain environments (hospitals, schools, kindergartens, urban areas, etc.) may badly affect the lives of people. High traffic noise levels can be an environmental and health problem in urban cities. The European Environment Agency has released a report showing that around 125 million people a day were affected by traffic noise levels above 55 dB, causing 10,000 premature deaths, nervousness, and anxiety in almost 20 million adults, and 8 million a year, had a sleep disorder. More than 900,000 cases of hypertension and 43,000 hospitalized annually have been reported [3]. Noise due to road traffic (cars, buses, trucks, and motorcycles) is the most common source of noise in cities and is the main reason for interfering with human activities. Long-term exposure to high levels of noise has far-reaching negative effects on the welfare and health of people, with measurable economic consequences such as treatment costs, decreased labor activity and productivity, increased mortality, decrease the market value of buildings in excess noise zone [7]. When considering the traffic noise to analyze the noisy feature of the routes and traffic flow frequency, especially in urban environments where there are stop and uninterrupted traffic flows [8].

Segura-Garcia et al. [9] presented experience in using Tmote–Invent (TmI) motes and Raspberry Pi (RPi) platforms for collecting road traffic noise pollution data and measuring the subjective annoyance by using the psychoacoustic metrics given by the Zwicker's model [10]. The proposed model measures nuisance based on the following parameters: loudness, sharpness, roughness, and fluctuation strength. Since the computation of the proposed parameters requires a costly signal processing at these nodes, the authors proposed simplifications to approximate the proposed parameters based on the specific features of road traffic noise. The proposed alternatives TmI and RPi are tested in a traffic-congested area of Valencia City. The experimental results revealed that RPi platforms are a feasible low-cost solution, while TmI has problems due to their limited memory and calibration issues.

Marouf et al. [5] presented the results of a comprehensive program of a low-cost device referred to as an eMote, inexpensive noise systems that use microphones, for pervasive road traffic monitoring. The idea was to design a system with low costs and low-power consumption that operates within a wireless network (ZigBee wireless communication). Up to 100 individual eMotes were deployed in a mesh network, with at least five hopes to reach the gateway device that enable communication with the central server. eMote devices were deployed on lampposts at roadside locations, at approximately 2.5 m above ground level. The system is used for monitoring road traffic noise in two areas in Newcastle upon Tyne (UK). The result suggests that eMote units can be used for improving noise prediction and mapping.

Peckens et al. [11] presented a study aimed at designing a wireless sensing unit (WSU) for long-term monitoring of urban noise. The WSU contains a microcontroller unit that enables onboard computations, a wireless transceiver that uses Zigbee protocol for communication, and an external peripheral board that houses the microphone transducer. The Teensy 3.2 Platform was selected due to its computational capabilities and 34 digital I/O pins and 21 analog input pins that allow interfacing to numerous external peripherals. Each node is capable to communicate with the central node and in a peer-to-peer fashion with other nodes. Raspberry Pi 3 (RPi) single-board computer is used as the centralized node for collecting and storing information from all the other nodes in the network. The system with four units is used for long-term noise monitoring in Holland, Michigan, USA. The results of the implementation indicate that the proposed system is capable of continuous and autonomous data acquisition in the long term, enabling a better understanding of urban noise.

21.3 Low-Power Wide Area Network (LP-WAN) Technologies

LoRa [12] is a radio modulation technology for wireless Low-Power Wide Area (LPWA) networks and physical layer protocol, while LoRaWAN [13] is a network protocol suite using LoRa. LoRa and LoRaWAN belong to the category of non-cellular LPWAN wireless communication network protocols, in contrast to cellular LPWANs such as NB-IoT and LTE-M. LoRa operates in the unlicensed spectrum, where also other noncellular LPWAN technologies such as Sigfox, Ingenu, and several more operate.

LoRa is a proprietary wireless RF technology, designed by Semtech which is one of the driving forces behind the LoRa Alliance where the open LoRaWAN protocol and ecosystem are developed. The LoRa Alliance has hundreds of members since it was founded in 2015. LoRaWAN is developed by the LoRa Alliance and defines a media access control layer protocol, which includes the physical LoRa modulation of Semtech. LoRaWAN is supported by over 70 network operators in more than 100 countries worldwide with IoT deployments. LoRa and LoRAWAN, along with Sigfox, are de facto the main noncellular LPWA ecosystems and solutions. The prognosis is by 2023, that noncellular LPWANs will cede its market share dominance to NB-IoT and LTE-M, as it is expected to cellular LPWANs capture over 55% of LPWA connections [14] by 2023. Despite this prognosis, LoRaWAN will likely keep a significant share of the IoT market in the future.

21.4 Description of the System

This section deals with a detailed description of the system and its main features. The section is structured as follows. After the general architecture of IoT systems, the description of the proposed system is presented layer by layer. Sensing and

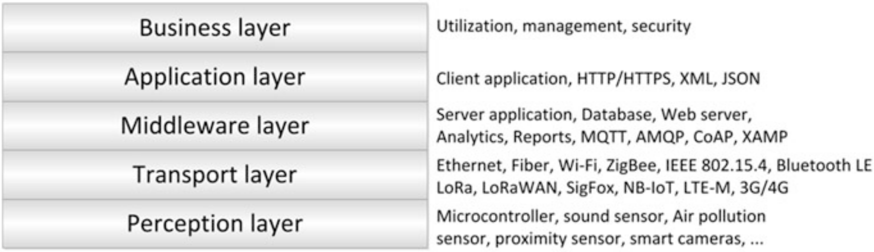

Fig. 21.1 IoT system layered architecture

communication components of the system are described in Sect. 21.4.2 as a part of the perception and transport layer. The deployment of the main components of the system is given in the following section. At the end of Sect. 21.4 (Sect. 21.4.4), the software components or middleware layer is presented as well.

21.4.1 General IoT Architecture

Although at the beginning of IoT, there were different views in its architecture [15, 16, 17], nowadays there is a dominant three- and five-layered approaches. The basic architecture of IoT consists of three layers: perception layer, transport (network) layer, and application layer, although many authors suggest the usage of five-layer architecture [17], adding Middleware and Business layer as well (Fig. 21.1).

The main function of the perception layer, also known as the device layer, is to identify objects and collect information, such as locations, temperatures, humidity, air pollution, etc. The key technologies of this layer are RFID, 2-D bar code, and web cameras for object identification and various types of sensors. For the systems presented in this paper and its prototype, the most important component of sensor nodes is analog sound (loudness) sensor for measuring noise, but the sensor node can be additionally upgraded with magnetic and proximity sensors, and web cameras for traffic intensity monitoring, and other sensors for additional tasks as well.

The second layer is the network layer or transport layer which is the core of IoT. It is responsible for communication and data transfer, addressing each object using a unique address, and secure transmission of information from the perception layer to the application layer and vice versa. All types of transmission medium and communication protocols can be used in this layer. Depending on the situation and the part of the system wired technologies such as Ethernet and wireless technologies can be used. In the core of the system, which is probably situated in data centers and buildings the high-speed Ethernet is more common. In the field, e.g., streets and other open locations in cities, open locations wireless technologies are preferred. Those technologies can be a short and middle range like Wi-Fi, Bluetooth Low Energy, and ZigBee. For the long-range LP-WAN technologies such as LoRa/LoRaWAN, SigFox, NB-IoT, and LTE-M or 3G are part of this layer. In this paper and the presented prototype system, the dominant field technologies are LoRa and Wi-Fi (IEEE 802.11), and backbone of the system is Ethernet and Wi-Fi. A detailed overview of applicable wireless technologies in IoT systems and their comparison is given in [18].

The processing layer, also called the middleware layer, covers data storage, data analyses, and processing of a huge amount of data created by the objects. Thus, it uses a number of different technologies like database software, cloud computing, intelligent processing, and ubiquitous computing. Additionally, but also an important task of this layer is responsible for managing the service implemented by different objects. The middleware layer of the prototype system will be described in detail in the following section.

The application layer integrates collected and processed information and delivers it together with applications to users. This layer is responsible for the global management of the applications implemented by IoT. This layer is not covered with the description of the system and has not been implemented yet in a user-friendly form.

The business layer is responsible for functions such as managing the IoT system and its applications, business model, and services and it provides user's privacy. This layer utilizes data received from the application layer to build business models, graphs, flowcharts, etc. This layer is not implemented in the presented system in this phase and should be discussed as further research and plans.

21.4.2 Perception and Transport Layer Description

For UrbanNoiseMS (Managing System) IoT description the bottom-to-top approach will be used. At the lowest layers perception and transport, the first step is sensor node configuration and deployment. Sensor nodes with the primary function of noise detection and monitoring can be places as roadside units as it is shown in Fig. 21.2 [19]. They are deployed around the city at predefined locations. Defined locations are the most frequently used streets mainly chosen according to the traffic flow frequency and the closeness to the areas where the noise pollution should be controlled, such as hospitals, kindergartens, condo areas, etc. In Fig. 21.2, three types of devices are presented (see the next Chapter).

Device (1) is a data collector (DC). The role of the Data collector node is to collect data from nearby end node stations via Wi-Fi, ZigBee, or similar short-range wireless technology. The second purpose of this node is to send collected and cumulated data to central node LoRaWAN gateway (Fig. 21.3) via LoRa/LoRaWAN or some other Low-Power Wide Area Network Technology (LP-WAN). The data collector can be operative in a standalone configuration without nearby end nodes. This node has the following configuration in the proposed prototype:

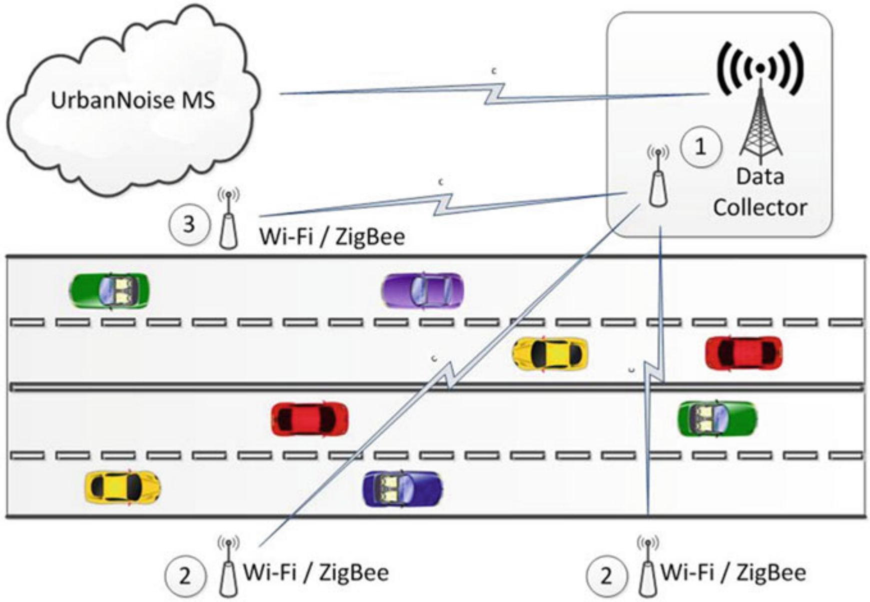

Fig. 21.2 Perception and transport layer description

1. Arduino/Genuino Uno R3 development board.
2. Libelium Multiprotocol Shield.
3. LoRaWAN RN2483/A communication module with 4.5 dBi 868 MHz antenna.
4. Wi-Fi ESP8266 based communication module with PCB antenna configured as an access point.
5. Analog sound sensor with additional sensors as specified for extended functionality.

There are two types of End Devices (ED). Basic Function End Device (BFED) (2) has the purpose of collecting noise data and sending collected data to a Data collector. Its configuration is such as:

1. Arduino/Genuino Uno R3 development board.
2. Wi-Fi ESP8266 based communication module with PCB antenna configured as an access point.
3. Analog sound sensor with additional sensors as specified for extended functionality.

Extended Function End Device (EFED) has additional sensors for extended functionality, e.g., air pollution monitoring sensor, and optionally sensors for monitoring traffic frequency (smart web cameras, proximity sensors, magnetic sensors, etc.). EFED was not considered in this stage of prototype development.

Data Collector device operates with the following data needed for communication: Device ID, Device Name, LoRa Address, parameters needed for connecting to

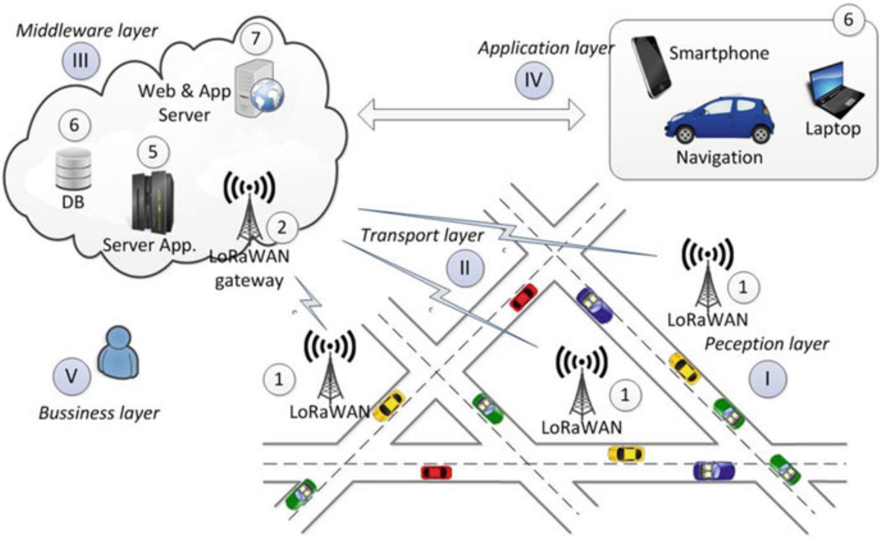

Fig. 21.3 System architecture and deployment

LoRaWAN Gateway, and analog value in dB read from the sound sensor. Both types of End Devices operate only with parameters for connecting to DC and the analog value read from the sensor.

21.4.3 System Architecture and Development

The deployment of the system components is presented in Fig. 21.3. LoRaWAN Data collectors (DC) and End devices (EFED and BFED) are placed near the busiest streets (1) as will be explained in the next section. For the connection to the LoRaWAN gateway (2) they use LoRa/LoRaWAN wireless technology. The LoRa is tested in the city of Zrenjanin and showed that it enables maximum connectivity from 3 to 5 km with stable connections [20]. Achieved distances are more than good for the given scenario.

LoRa Gateway or LoRa GTW (2) device is the RAKwireless model RAK7243. It is based on a Semtech SX1301 chip. One of the main features of this device is the possibility of multichannel sensing to communicate with multiple Data collector nodes. This device is composed as follows:

1. Raspberry Pi 3 single-board computer.
2. RAK2245 Pi Hat.
3. SX1301 communication module.
4. Ublox MAX-7Q GPS module.

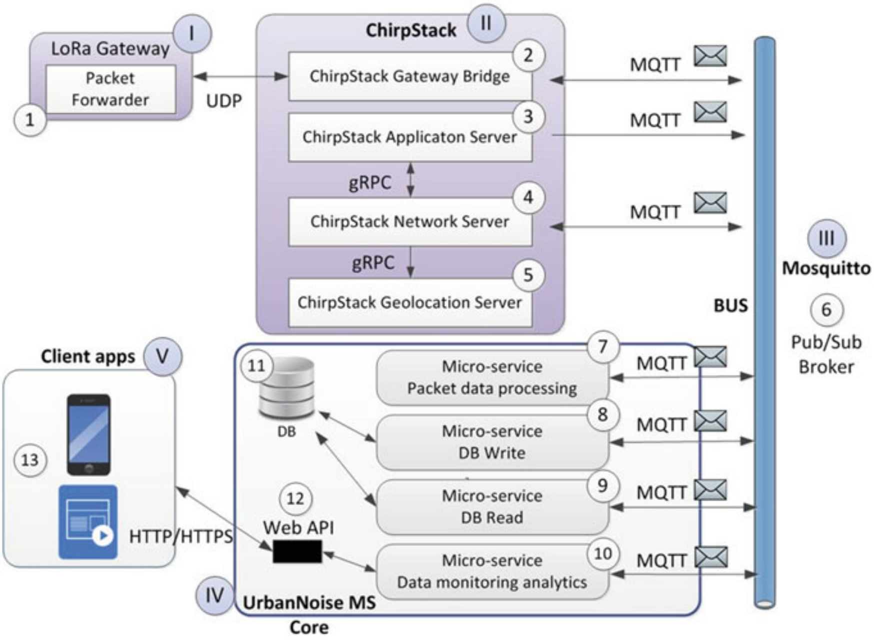

Fig. 21.4 Software architecture

Further, in the UrbanNoiseMS Middleware layer, all packets received by LoRa GTW (1) are forwarded to the server (5) for further processing and analyses and stored in the database (6). Processed data are accessible for the various types of uses and devices via Web API server (7).

21.4.4 Software Architecture

Software architecture is given in Fig. 21.4. This complex structure of software architecture (Fig. 21.4) has the following components:

1. Packet Forwarder.
2. ChirpStack suite.
    (a) GTW Bridge.
    (b) Network Server.
    (c) Application Server.
    (d) Geolocation Server.
3. Mosquitto MQTT Broker.
4. UrbanNoiseMS Core with micro-services for:

   (a) Processing and analyses of data.
   (b) Storage in NoSQL database and reading data.
   (c) Monitoring.

5. Client applications for data access and visualization.

This system uses four third-party software components. Those components are Semtech UDP Packet Forwarder [21], ChirpStack [22], Eclipse Mosquitto [23], and MongoDB [24] NoSQL database. Packet Forwarder is generally used by LoRa gateways with Semtech chip for connection to servers with Semtech UDP protocol. The ChirpStack is an open-source LoRaWAN Network Server stack that provides open-source components for LoRaWAN networks. Its modular architecture makes it possible to integrate within existing infrastructures. All components of the suite are licensed under the MIT license and can be used for commercial purposes. It allows implementation and setup up of a fully scalable, secure stack via MQTT and TLS. Eclipse Mosquitto is an open-source (EPL/EDL licensed) message broker that implements the MQTT protocol versions 5.0, 3.1.1, and 3.1. This is lightweight and is a suitable solution built for usage on all devices from low-power single-board computers to full servers.

A LoRa packet forwarder forwards RF packets received by the LoRa GTW to ChirpStack Gateway Bridge (2) with UDP protocol. ChirpStack GTW Bridge (2) is service for conversion LoRa Packet Forwarder protocol packets in general data format (JSON and Protobuf) to adapt them to the rest of the system. ChirpStack GTW Bridge forwards those packets to MQTT Broker. ChirpStack Network Server component (4) is a service that has tasks to remove duplicated LoRaWAN frames from ChirpStackLoRa GTW and to deal with authentication, LoRaWAN MAC-layer commands, communication with ChirpStack Application server (3), and scheduling of received downlink frames. Communication of ChirpStack Network server (4) communicates with the ChirpStack Application server (3) and ChirpStackGeolocation server (5) with the gRPC system. gRPC (gRPC Remote Procedure Calls) is an open-source remote procedure call (RPC) system developed by Google in 2015. It uses HTTP/2 for transport, Protocol Buffers as the interface description language, and provides authentication, bidirectional streaming, and flow control, etc. It generates cross-platform client and server bindings and it is developed for connecting services in micro-services style architecture and connects mobile devices, browser clients to backend services. ChirpStackGeolocation server (5) is used for positioning of LoRa gateway device with an integrated GPS module.

Application Server (3) is responsible for inventory all received data and handling of join requests and encryption of packet payloads. It offers integration with MQTT and Mosquitto broker. On the other hand, micro-services also uses MQTT protocol (6) as Event Bus and for internal communication. Internal communication of the system is based on MQTT protocol. MQTT is a machine-to-machine (M2M) "Internet of Things" connectivity protocol designed as an extremely lightweight publish/subscribe messaging transport. Its usage is targeted for connections with remote locations where a small code is required and where the network bandwidth saving is important. It can be used in a variety of scenarios, e.g., in sensors communicating to a broker via satellite link over occasional dial-up connections, mobile applications, and in a broad range of home automation and small device scenarios. It supports low power usage and minimized data packets.

Micro-service for packet data processing (7) is subscribed to the same message queue where the Application server publishes new messages containing metadata and payload of LoRa packets. Communication with the Application server goes in both directions with the MQTT protocol. Besides subscribing to messages in message queue published by Application Server, it publishes own generated messages. Micro-service for DB writing (8) has to the role of storing data to MongoDB and micro-service for DB reading (9) has a role to retrieve data from DB and to publish it on the message queue. The database is the NoSQLMongoDB system (11). This database is chosen to make the system capable of efficient handling of a large number of messages.

Finally, the system provides data visualization to client applications (13) designed for various types of users and devices. Data requests are directed to Web API (12) and Web API component further contacts micro-service (10) for data monitoring analytics. After receiving the request for a particular information micro-service (10) creates a new message on MQTT with a request for retrieving the data from the NoSQL database. After retrieving the data from the database it is sent back to micro-service 10 via MQTT. Further processing is done with micro-service (10) before the information is returned to client applications (13). One of the main functionalities of this system, management of traffic noise, is performed in micro-service (10) for data monitoring analytics. The traffic noise management system will be presented in the following section.

21.5 UrbanNoiseMS and Traffic Routing

In this section, the traffic managing method is presented. The data collected with UrbanNoiseMS are used for the routing of the traffic or at least a recommendation for the routing. The basis for the traffic routing is the Dijkstra shortest path algorithm. The city of Zrenjanin is mapped as a simplified graph with 37 nodes and 60 links between nodes. The links between nodes have two types of cost needed for recalculation of the path for vehicles. The one cost is based on distance in meters between nodes, and the other is based on the time needed to travel between nodes. Those two costs with the use of the shortest path of algorithm provide the calculation of the shortest (in kilometers) and quickest (in minutes) routes. The map of the city of Zrenjanin and the matching graph is presented in Fig. 21.5a and a smaller portion of the graph is presented in Fig. 21.5b. To build the model and its evaluation, and only partial graph of Zrenjanin, with a reduced number of nodes and links (streets), is made. The streets included in this simplified form of a graph are the most frequently used streets in Zrenjanin. For the real system implementation, the extended full graph of Zrenjanin streets should be made.

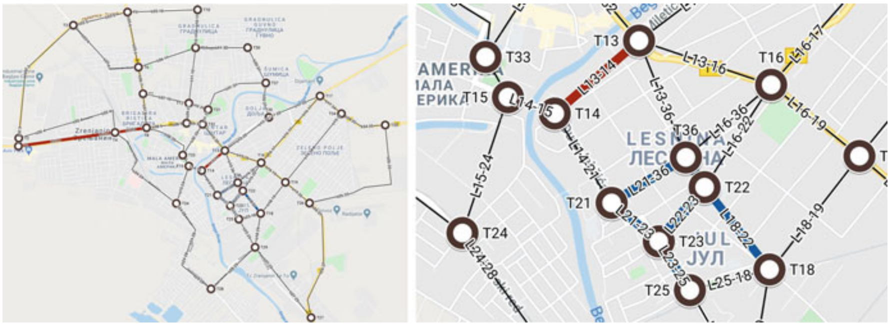

Fig. 21.5 (**a**) Map of city of Zrenjanin and matching graph and (**b**) smaller portion of graph with street to monitor (maps are created with Google maps [25])

Table 21.1 Comparison of total distance drove by vehicles in four scenarios

	Shortest path	Quickest path	Fixed modification	Variable modification
m (AVG)	2.86494	3.11756	3.23401	3.14751
Increase percent		8.81%	12.88%	9.86%

The evaluation of the model is made with the following methodology. The streets chosen for monitoring and traffic management are streets with sensitive facilities such as hospitals, kindergartens, and large residential areas where expected noise levels are low. The nine streets are chosen for monitoring: 1–4, 4–8, 13–14, 21–23, 21–36, 22–23, 22–36, 23–25, and 18–22. These streets are picked for the sensor nodes deployment as it is described in the previous section. The simulation tool for evaluating the model is developed in Octave. The four scenarios are tested: shortest path algorithm (in meters), quickest path algorithm (in minutes), fixed path cost modification, and variable path cost modification with uniform distribution of path cost change. The fixed path cost modification and variable path cost modification are proposed by the authors as a modification of the Dijkstra algorithm. The fixed path cost modification increases all destination path costs on sensitive roads by 20% all the time. The variable path cost modification takes into account three levels of noise on sensitive roads (LOW, MEDIUM, HIGH). When the noise level is LOW, the path cost of sensitive roads is not modified. When the level is MEDIUM path cost is increased 10%, and when it is HIGH path cost is increased 20%. In the simulation of the modified path cost, it is assumed that one-third of the time the noise level is LOW, one-third it is MEDIUM, and one-third it is HIGH. The simulation is set to 50,000 vehicle runs from the randomly defined start and end node.

The results of the simulation are presented in Tables 21.1 and 21.2. Table 21.1 shows that the proposed algorithm (variable path cost modification) optimizes the routes with no significant increase of total distance passed (only 9.86%), that is almost the same as quickest path algorithm. This means that algorithm optimizes routes, with no increase in noise pollution caused by additional traffic as it is the case with a fixed modification cost method.

Table 21.2 Comparison of route segment load (number of vehicle passes) with four algorithms

Route/street	Shortest path	Quickest path	Fixed modification	Variable modification
1–4	4701	3710	1972	2839
4–8	6592	5238	3658	4093
13–14	3956	8599	0	1494
21–23	3392	4929	1016	1040
21–36	1112	69	937	1093
22–23	2038	1291	1045	1045
22–36	8418	1266	0	0
23–25	4128	4110	759	783
18–22	5574	171	0	371

Similarly, Table 21.2 shows that the Variable path cost modification algorithm decreases the load of critical routes comparing to the shortest and quickest paths algorithm, but without completely stopping the traffic in some routes (13–14 and 18–22) as it is in the case of fixed cost modification algorithm

21.6 Dealing with Traffic Noise

A special problem is the routing of traffic in the case of traffic noise. In that case, depending on the time of day, it is necessary to reroute traffic to avoid an excessive level of traffic noise. The routing process is dynamic and is done by changing the cost of certain sections of the route. This change is done by associating a time-dependent function with certain sections, but the algorithm itself remains the same. Unlike the approach described in [26], fuzzy numbers are not used, and the triangular membership function associated with the busiest sections plays the role of a weighting factor. This means that in addition to the length of the route segment (distance) and the time required to cross the segment, noise level data are also used. Bearing in mind that several criteria that affect the cost are used (distance, time, time of day, and noise); the method of vector technique normalization [27] was applied.

Three main transit routes through Zrenjanin were considered, which connect three cities: Novi Sad, Belgrade, and Vrsac (i.e., the border with Romania and the city of Timisoara). The experiment was conducted in Python (Google Colaboratory Note-book). For each hour during the day, transit routes, and their change were monitored. Table 21.3 presents rerouting the Novi Sad–Belgrade via the Zrenjanin route (T1 to T27), during the day.

All four routes take into account segments with requirements for reduced noise levels, i.e., such segments are bypassed. Fig. 21.6 shows the load (0–50) of nodes (1–37), i.e., intersections for all three main routes during a day.

Without the rerouting, the number of nodes that are maximally loaded is 10 (Fig. 21.6a), while rerouting reduces that number to 5 (Fig. 21.6b).

Table 21.3 Novi Sad–Belgrade via Zrenjanin rerouting

Time of day	Route
22 h–08 h	1-4-8-9-32-13-36-22-18-29-27
08 h–09 h	1-2-4-8-9-32-13-36-22-18-29-27
09 h–11 h, 20 h–22 h	1-2-4-24-15-14-21-23–25-18-29-27
11 h–20 h	1-2-4-24-28-29-27

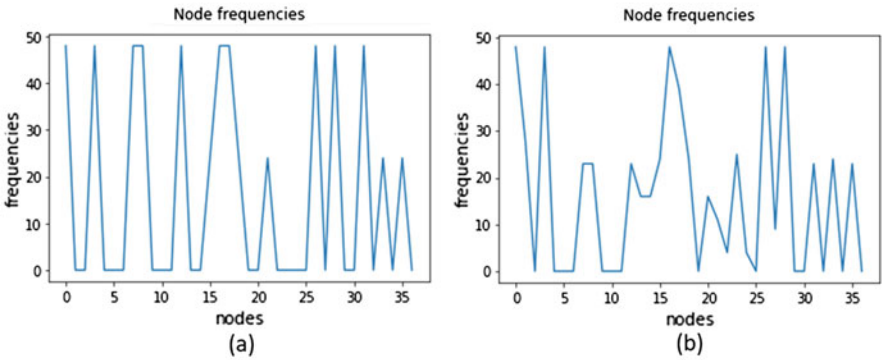

Fig. 21.6 Node loads (**a**) without rerouting (**b**) with rerouting

21.7 Conclusion

Although the primary contribution of the work is a model of the system architecture for noise monitoring and traffic routing in an urban area, as part of a smart city, the shortest path Dijkstra algorithm that would be used by such architecture was considered. The approach of implementation of proposed IoT model architecture is given layer by layer, starting from sensing nodes (perception layer) and wireless connectivity for data transfer (transport layer). The data processing within the system (middleware layer) is presented as a complex system made of interconnected components. Those components are in large part built upon the micro-services to offer easy maintenance, scalability, and system changes. The modified variants of the Dijkstra shortest path algorithm are developed for the routing of the city traffic to manage the level of road noise insensitive part of urban areas. The evaluation of the proposed routing modifications is shown in the example of the city of Zrenjanin, Serbia. The results of the experiments that include the length of the route segment, the time required to cross the segment, noise, and time of day, show that traffic congestion can be avoided, as well as route segments that pass through parts of the city where reduced noise levels are required.

Some layers of the IoT system, such as the application layer and business layer, are not covered with this paper and should be included in the future work. Future work should include a detailed possible description of the application layer. This further research can cover the definition of the model of applications designed for the end system users. These applications can range from navigation software, designed for vehicles onboard computers, navigations gadgets, and smart devices, to interactive road signs, route displays, etc. Before the application model, the end-user profiles should be defined. Similarly is with the business layer, where the description can cover the applications and data analytics results which can be used by the cities authorities to optimize city transport or by specific companies, such as taxi or merchandiser companies to manage their fleets and optimize their routes to preserve the more comfortable environment for all. Same as in the previous case, before the business applications, the business model user profiles should be defined as well. All these issues can be covered in much more detail in future works. Traffic noise greatly affects the human quality of life that stay near roads for a long time or temporarily. Continuous monitoring of noise competent state authorities (inspection services, police, etc.) can react quickly to mitigate the disadvantage to the quality of life in urban areas.

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Chapter 22
The Benefits of Open Data in Urban Traffic Network

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22.1 Introduction

In the last decade, the demand for big data collected by public services and used by third parties has significantly increased. Big data is data on a scale or of a complexity that makes it challenging to use [1]. Key characteristics of "big data" are high volume (1 GB–1 mil GB), great variety (data sets that are sometimes inaccurate and unreliable), and time variability [2]. The transport sector has always collected and analyzed large quantities of data, such as data from timetables, traffic news, and air schedules [3]. However, using that data as the third party for providing transport services of added value such as routing vehicles or intermodal rout guiding within public transport services was often expensive and unprofitable. To expand the usage and re-usage of big data, the first requirement is that this kind of data is open for use. Opening nonpersonal data in the public sector are seen to improve public services, increase the accountability of government, and generate economic benefit through the reuse of public data to develop new products [4, 5]. Among mentioned, the Public Sector Information Directive (PSI) [6] is one of the reasons why country members of the EU are introducing "open by default" principles in their databases. "Open by default means that, when creating a new governmental data set, publishing it under an open license becomes the default process" [7].

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In this paper, we analyzed the amount and type of open data provided by the government services that can be used for the development of applications for optimizing urban traffic network. It is conceived as an overview of so far the progress of unlocking traffic data in Croatia, with emphasis on potential benefits on urban traffic network based on experience from the world.

22.2 Related Work

The authors [8] have presented research results on the open data project conducted in Ames, Iowa. The main goal of the project was to establish the open traffic data service, which will allow vendors and agencies to provide near real-time, proactive alerts to commercial drivers regarding traffic conditions along their routes. Authors stated that with enabled access to relevant traffic data and value-added data feeds, multiple benefits for external and internal users are achieved.

The qualitative research approach consisted of in-depth interviews with six market players and 27 governmental data owners in Flanders, a region in Belgium, which was presented by the authors [7]. The main goal of the research was the assessment of the needs for the reuse of data among commercial multimodal route planners. Besides confirming the moderate needs for reuse of data, the research resulted in identifying three possible constraints in the process of data reusing. It is stated that not every data set will or can be reused as there is a cost for adoption, all data need to be high in quality, and metadata (data about data) needs to be obtained for the data to be reused.

According to authors [9, 10], analysis of public transport data can help to understand transport users' journey patterns across the transport network, in terms of where users travel, what mode they choose, how frequently they travel, and how reliable their journeys are. Moreover, results presented by authors [11], show that data on public transport users can inform transport agencies and operators how people of different demographic groups use a service and with that provide a better insight in customer's needs.

Paper presented by authors [12] included a demo version of Linked Open Data used for intermodal route planning. Throughout an affordable publishing method called Linked Connections, data on transit stops, and time of departure are merged, providing the execution of the route planning algorithm. In this paper route planning algorithm is a basic Connection Scan Algorithm—CSA [13] that solves the earliest arrival problem by organizing connections (transit stops) as one single array, which then scans to compute journeys to all stops of the network.

According to [14], a part of the UK government's strategy to improve transparency and encourage economic growth is "opening up" data in transport by making it more widely available and linking it with data from other sectors. Moreover, the UK government has established a Transport Systems Catapult, overseen by the Technology Strategy Board (TSB), which has specific objectives to encourage the analysis of big data.

The same principle had Austroads, the peak organization of Australasian road transport and traffic agencies. In the report presented by the authors [15], it is stated that Governments can assist industry, researchers, and the public to develop innovative solutions to transport problems by providing open access to transport data. Two goals of the research were to identify key issues in the usage of open data by connected automated vehicles (CAV) and to provide a recommendation for next steps in the usage of that kind of data.

From related work, it can be said that usage and re-usage of open data can provide many benefits. By connecting open data, intermodal trips can be generated. Moreover, analyzed data on time and distance on the passenger's trip can help in providing better public service. Opening data by default can create added value through third parties that are developing applications for traffic optimizations and thus increase its usage.

Stated benefits influence traffic congestion reduction and overall optimization of the urban and suburban traffic network. However, to ensure the use of open data, the decision must come from the government and be legally constituted through the decision legislation.

22.3 Open Data and Big Data in the Republic of Croatia

Open data in the Republic of Croatia is summarized on the central state portal called the Open Data Portal of the Republic of Croatia [16]. The organization for the collection of statistical data in the Republic of Croatia is the Croatian Bureau of Statistics [17]. For many years, the Croatian Bureau of Statistics collects transport statistics that include data used for the strategic traffic development of the country, such as monitoring the border and border traffic of people and goods in the road, rail, water, and maritime transport. The collected statistics are used by competent services to develop a strategy for expanding transport infrastructure. Additionally, to enhance strategic development in terms of investment in new infrastructure, data on the amount and type of traffic can help policymakers to maintain existing infrastructure.

Open data in urban environments is used to expand intermodality as the future of passenger transport. Passenger transport can set several requirements on the system that need to be met to bring the passenger within the given limits from the starting point to the destination. Providing alternatives such as shorter travel time, route selection, or mode of transport makes the transport system more attractive to use, which results in better system utilization. For such alternatives to be possible, it is necessary to consolidate a large set of data on the transport of passengers and their needs, but also the capacity and utilization of transport infrastructure and the superstructure by which the mentioned transport processes are performed. Data aggregation is possible through the development of platforms that enable the connection of open data and the use of big data technologies. The need for such technologies has grown exponentially in recent years, which has led decision-makers to encourage openness and availability of data through legal frameworks. Increasing the quality of legal frameworks such as open by default policies or increasing the degree of openness of data increases both the usability and usefulness of open data.

22.3.1 Legal and Legislative Aspect

Although earlier and valid strategic documents such as the Croatian Strategy for the Development of Public Administration for the period from 2015 to 2020 [18], e-Croatia 2020 Strategy [19], Open Government Partnership Action Plan [20], Anti-Corruption Strategy 2015–2020 [21] included measures and activities dedicated to creating conditions for opening data and opening individual data sets, until 2018 the Republic of Croatia was the only EU Member-State that did not adopt full access to open data through a unified policy at the national level. The lack of such a document has resulted in insufficiently focused development of open data, insufficiently developed an awareness of public authorities about the need and ways of opening data, with the possibility of consequently lagging regarding other European countries.

Recognizing this problem, but also the importance of data available to public sector bodies and the potential of open data, the Government of the Republic of Croatia adopted the Open Data Policy in July 2018, a document whose purpose is to build and permanently develop an environment conducive to creating new social and economic value using public sector data [22]. The basic principles of open data are contained in the Open Data Charter [23] adopted by the G8 in June 2013, which was later acceded to by many other countries, as well as the European Union, and was basically taken over by the Croatian Open Data Policy. These principles are:

- Open by default—Given that the use of data requires that public sector data are available and easily accessible, the policy stipulates that open data is generally made public and in accordance with set standards, taking into account the fact that in exceptional cases for justified reasons, certain data cannot be published. Also, policy measures will encourage the publication of all state data on the Open Data Portal.
- Timeliness and completeness—Open data policy measures will encourage the publication of as many data sets as possible and ensure that published data are timely, comprehensive, and accurate. Also, for users to have the best possible insight into the content of the data, data sets should be described in metadata, written in clear, and simple language. Finally, the policy will ensure the up-to-datedness of published data sets and enable feedback on the content of published data sets through the Open Data Portal and other appropriate mechanisms. To increase the value of open data, policy measures will support the publication of data without restrictions or fees for the reuse of information, for noncommercial or commercial purposes. Also, special attention will be paid to ensuring the

publication of data in machine-readable formats, as well as the publication of data through the application program interface (API), where appropriate, to ensure easy access to updated data.

- Accessibility and usability—Policy measures will seek to make data available to the widest range of users in the widest range of purposes in appropriate (open) formats to ensure that files can be easily retrieved, downloaded, indexed, and searched using all common applications. Where free access cannot be offered, benefits will be promoted and free access to data will be encouraged.
- Comparability and interoperability—Policy measures will ensure the sharing of experiences and exchange of open data at the national level, encourage cooperation of public sector bodies with civil society organizations and citizens, and enable the interested public to provide feedback on the most important data they want to be made public.

In the Republic of Croatia, the reuse of information and the opening of data for use for commercial and noncommercial purposes has been an obligation of public authorities since March 2013, when the Right to Access Information Act (OG 25/13) entered into force. The Act was amended in 2015 by transposing the amendments to the 2013 PSI Directive [6], which significantly expanded the obligation to publish open data as well as provide reuse information on request.

In accordance with the requirements of the PSI Directive, the Act prescribes the publication of data sets in machine-readable and open form, in accordance with the open standard, establishes the obligation to publish lists of databases and data sets, provides for the establishment of the Open Data Portal, costs for users, established possibilities of restricting use, as well as the basis for prescribing conditions and costs and granting exclusive rights, a regulated procedure for exercising reuse on request and protection of rights and supervision over the implementation of the Act by an independent body [22].

22.3.2 Open Data

The Croatian Bureau of Statistics [17] is an organization that conducts statistics at the state level. Data in the field of transport contain data on rail transport, road infrastructure, road transport of passengers and goods, border traffic, urban and suburban transport, pipeline transport, maritime and coastal transport, traffic at airports and seaports, drivers, registered vehicles, and road accidents. Although statistics are kept extensively at the state level and data are open and available for the period of last 10 years, the level of data openness (at least transport data) is low. All available and open data are published under the Creative Commons Attribution [24] license, and the openness of the data is level 2, which would correspond to structured data in a closed format (.xls, .xlsx). For easier comparison, the levels of data openness according to the degree of openness are shown in Fig. 22.1.

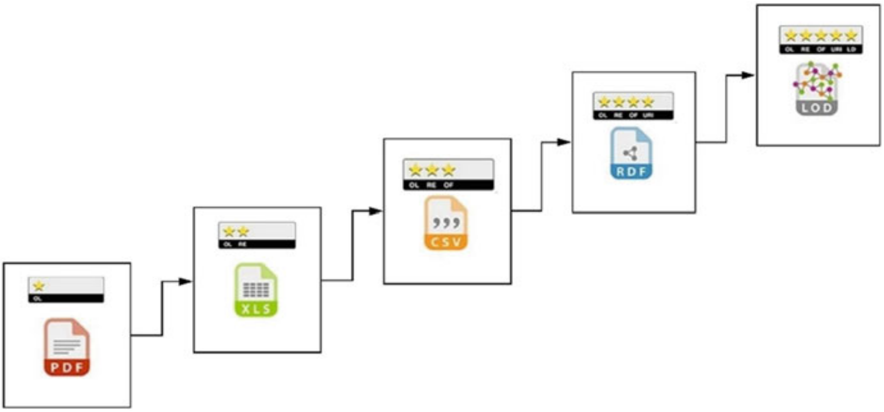

Fig. 22.1 The 5-Star Open data Model [25]

Data available on the Open Data Portal are not linked to other data, nor are detailed with metadata (hour, day, location of data). Open data regarding the traffic on urban roads are collected at the state level and are divided into the following groups

- Transport equipment in road urban and suburban transport
- Kilometers traveled, and passengers carried in road urban and suburban transport
- Vehicle fleet and lines in road urban and suburban transport
- Employees in road urban and suburban transport

The layout of the open data is shown in the original form in Table 22.1

Due to low openness, low detail of data (data available only in summarized form), and their up-to-datedness (data published on an annual or quarterly basis), the usability of data for the improvement of transport processes of passenger or goods at a level lower than the strategic almost nonexciting.

For the development of the systems that use real-time data, it is necessary to use sources that are connected and have updated, usable, and accessible metadata. In the field of transport in the Republic of Croatia, there is an insignificant number of projects aimed at expanding the usability of open data in traffic and transport.

To boost the supply and use of open government data in Croatia and beyond, the EU launched the H2020 project "Twinning Open Data Operational" (TODO). With the support of key organizations in the Croatian open data ecosystem and esteemed national and international experts, TODO will enhance the research capacity and research excellence in open data research of University of Zagreb (UNIZG) and its staff through the partnership with two leading universities in the open data domain, University of the Aegean (UAEGEAN) and Delft University of Technology (TUDELFT).

Through activities directed at training, knowledge exchange, collaboration, outreach, and long-term sustainability, TODO will develop and implement an inter-

Table 22.1 The open data presentation from Croatian Bureau of Statistics

Croatian Bureau of Statistics		2010	2011	2012	2013	2014	2015	2016	2017	2018
Trams										
Lead cars	No.	325	317	313	306	306	303	303	303	295
Pass. places	No.	51,653	50,667	50,339	49,615	49,615	49,306	49,306	49,306	48,479
Trailers	No.	82	77	70	63	63	58	58	58	51
Pass. places	No.	9253	8683	7900	7117	7117	6547	6547	6547	5759
Buses										
	No.	1240	1196	1196	1202	1180	1191	1247	1262	1264
Pass. places	No.	119,269	114,669	114,716	113,104	108,530	108,418	112,973	113,347	112,495
Lines										
Trams	No.	21	21	21	21	21	21	21	21	21
Length	Km	232	232	232	232	232	232	232	232	228
Bus	No.	505	518	479	488	484	481	504	507	514
Length	Km	9282	9525	8281	8307	8129	7956	8718	8881	9822

disciplinary multi-domain open data research approach to increase the maturity of the concept and impact of the open data ecosystem in Croatia and beyond. Through research, TODO will explore the gaps between supply and demand for open data and build an understanding of an open data ecosystem in Croatia. Participation in existing international networks, together with the newly built scientific excellence and innovation capacity and increased mobility of UNIZG staff, will stimulate success in attracting research and education funding and the establishment of a sustainable academic open data research ecosystem in the UNIZG [26].

22.3.3 Big Data

Big data technologies represent great opportunities because they help develop new creative products and services, such as mobile apps or business intelligence products. Such technologies can boost job growth and development, but also improve the quality of life of Europeans. Big data technologies are used to collect, process, and analyze large amounts of data. Data are diverse, structured, and unstructured, generated, and arrives at high speed and different intervals (often in real-time), making them very complex to analyze. The collected data can come from various devices or systems. Some of them are smartphones, smart bracelets or watches, smart refrigerators, ATMs, GPS systems, etc.

In recent years, the amount of data created, stored, and processed has grown exponentially. In the EU, the analysis of big data in 2018 was done by 12% of

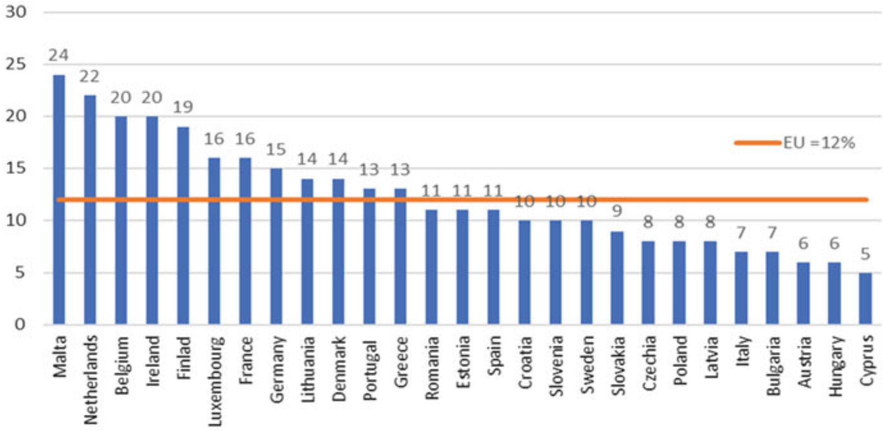

Chart 22.1 Use of big data analysis by enterprises in the EU Member-States, 2018 (% of enterprises) [28]

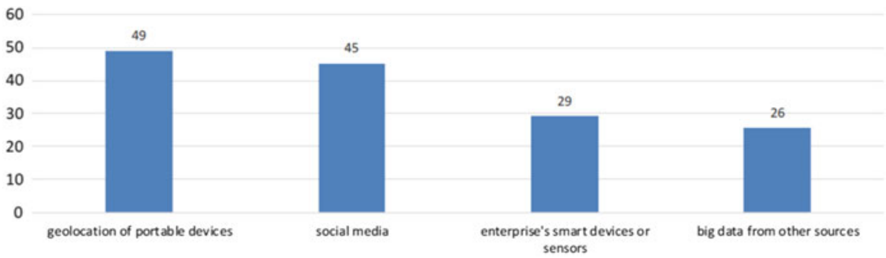

Chart 22.2 Use of big data analysis in the EU by data source, 2018 (% of enterprises analyzing big data) [28]

companies with at least ten employees. Big data analyzes were mostly performed by large companies (33%) or medium-sized companies (19%), with 8% of the analyses performed by employees in companies, while 5% of companies hired an external company as an associate in big data collection [27, 28]. Chart 22.1 shows the ranking of the Republic of Croatia in the use of Big Data in correlation to other EU member-states and the EU average.

According to Eurostat statistics [28] in Republic of Croatia, nearly 10% of companies used the big data analysis, which is below the average of the EU (12%). Chart 22.2 shows the percentage of the big data collected sorted by the data source.

Based on data provided in Chart 22.2. It can be concluded that almost half of the companies (49%) that apply big data analytics analyze geolocation data collected via mobile devices. This is followed by an analysis of data collected through social networks (45%), and less than one-third of companies analyzed data collected with their own smart devices or sensors (29%). Data from other sources are analyzed by 26% of companies [28].

Although the use of big data technology in the country is below the EU average, the Republic of Croatia often and actively participates in projects implemented among EU members. Some of them were launched to maintain ecosystems such as AFTERLIFE, a project that develops technologies that filter and convert wastewater from the food and beverage industry into bioplastics and food additives, while others focus on medical developments such as EUTHYROID, a project that has enabled the establishment of an infrastructure for data collection and analysis to monitor iodine deficiency across Europe [29].

To our knowledge, there are currently no European projects in the Republic of Croatia (except TODO) that could or will significantly affect the development of big data technologies and applications based on such technologies and are related to transport and traffic processes. As already mentioned, the use of big data is considered the future of the development of traffic processes. Therefore, it is necessary to enable the greatest possible usability and transparency (accuracy and up-to-datedness of data) that can contribute to the development of transportation systems.

22.4 The Benefits of Using Open Data and Big Data in Traffic

The European Union considers open data to be an important resource for the development of a digital European society and market, contributing to the creation of competitive advantages for innovation, job development, and the improvement of services for citizens and the economy. According to EU estimates expressed in the document Creating Value Through Open Data [30], the Open data market in 2020 is at least 75.7 billion euros and will potentially open the possibility of new employment for 25,000 people. For the Republic of Croatia, the EU estimates the creation of around 1000 new jobs by the end of 2020, and the market value is estimated at 186 million € [22].

The advantages of using big data technologies have been recognized at the EU level, which has launched several projects related to the use of open data and big data technologies in transport. Although examples of the use of big data technologies in the field of transport in the world are limited and most approaches still use traditional data sources such as inductive loops, travel surveys, etc. according to [31] it is possible to single out applications of big data technologies in transport presented in three main categories:

- Urban planning
- Transportation operation
- Traffic safety.

Categories are analyzed separately, but their symbiosis, i.e., the use of different data clusters can create a system that uses big data technologies in order to speed up the transport of passengers and goods, while considering the cost and safety of the transportation process.

22.4.1 Urban Planning

The use of big data technologies for urban planning is possible through the analysis of travel demand and the prediction of movement patterns using location data from mobile phones or call details records.

The authors [32] in their research showed that the estimated origin–destination flows derived from the aggregation of the trips from millions of individual mobile phone users in the Boston Metropolitan area correlate well with the US Census estimations. Moreover, compared to traditional census survey data, presented estimations allow capturing weekday and weekend patterns as well as seasonal variations. These features could make methods for origin–destination flow estimation based on opportunistically collected mobile phone location data a critical component for transportation management and emergency response.

A similar study was conducted by the authors [33] using mobile phone call detail records (CDR) and limited traffic counts methodology to develop OD matrices. CDR, which consists of time-stamped tower locations with caller IDs, are analyzed first and trips occurring within certain time windows are used to generate tower-to-tower transient OD matrices for different time periods. An optimization-based approach, in conjunction with a microscopic traffic simulation platform, is used to determine the scaling factors that result in best matches with the observed traffic counts. The methodology is demonstrated using CDR from 2.87 million users of Dhaka, Bangladesh, over a month, and traffic counts from 13 key locations over 3 days of that month.

Based on the methodologies used from the examples shown, it is possible to plan a transport network, predict the time spent in the network, or design a route selection model for cyclists. Transport network planning using the mentioned methodologies is explained on the example of research [34] where the authors presented the possibility of designing a transport network with deriving frequent patterns of movements from anonymized mobile phone location data and merging them to generate candidate route designs. Additional routines for optimal route selection and service frequency settings are then employed to select a network configuration made up of routes that maximize systemwide traveler utility. Using data from half a million mobile phone users in Abidjan from the telco operator Orange provide resource-neutral system improvement of 27% in terms of end-user journey times is demonstrated.

Prediction of time spent in the network is shown in the study [35] where the authors show a methodology based on data collected from taxicabs in New York City. Taxicabs equipped with global positioning system (GPS) devices provide the locations of origins and destinations, travel times, fares, and other information on taxi trips. The new model infers the possible paths for each trip and then estimates the link travel times by minimizing the error between the expected path travel times and the observed path travel times. The model was evaluated using a test network from Midtown Manhattan. Results indicate that the proposed method can efficiently estimate hourly average link travel times.

The design of the cyclist route selection model is presented in the research [36]. Based on a detailed GPS-data analysis for the bike-sharing system, mobility patterns of the usage were identified. Depending on different factors like weather conditions, time of the day, and holidays/weekends, a demand model was created to obtain an optimal distribution of bikes within the operating area. At the end of this paper, an application of an operator-based relocation strategy is given. With partial relocation of the fleet, it is ensured that the demand for bikes is optimally satisfied regarding time and space.

From the presented examples, it is possible to conclude that the use of open data and big data can greatly contribute to the optimization of traffic processes. Predicting network time for a large fleet of vehicles, allocating superstructural resources based on estimated use by location or time, and designing transportation networks that minimize travel times, travel predictions, and OD matrices reduce operating costs and potentially increase the utilization of existing infrastructure and superstructure.

22.4.2 Transportation Operation

Transport-related services based on the use of big data technologies are focused on providing decision support services in traffic processes or are support for Advanced Traveler Information Systems (ATIS). The most well-known researchers in this area are focused on travel time prediction, traffic incident and anomaly detection, anticipatory vehicle routing, and predicting bus bunching in the network using smart card data [31].

An example of travel time prediction based on big data technologies is presented in a study [37], where the authors developed a particle filter approach for real-time short- to medium-term travel time prediction using real-time and historical data. A 95-mile freeway stretch from Richmond to Virginia Beach along I-64 and I-264 is used to test the proposed algorithm. The confidence boundaries of the predicted travel times demonstrate that the proposed approach provides good accuracy in predicting travel time reliability. Lastly, fast computation time and online processing ensure the method can be used in real-time applications.

Recognizing incidents and detecting traffic anomalies can greatly help in transportation operations. The authors [38] presented research related to incident detection using an analysis of published data on social media. A comprehensive approach has been developed to extract and analyze real-time traffic-related twitter data for incident management purposes. The developed approach was implemented at the District of Columbia Department of Transportation for incident management. Data validation has been conducted against the real-world incident database. The preliminary results of the analysis have shown that social media data are promising for early incident detection and can be used as a supplemental source for incident data collection.

Advanced vehicle guidance systems use real-time traffic information to route traffic and to avoid congestion. Unfortunately, these systems can only react upon the presence of traffic jams and not to prevent the creation of unnecessary congestion. Authors [39], in their research, presented the anticipatory vehicle routing approach that allows directing vehicle routing by accounting for traffic forecast information. It is based on delegate multiagent systems, i.e., an environment-centric coordination mechanism that is, in part, inspired by ant behavior. Antlike agents explore the environment on behalf of vehicles and detect a congestion forecast, allowing vehicles to reroute. The approach is evaluated in a simulation of a real-world traffic environment, and results indicate a considerable performance gain compared with the most advanced strategy under test, i.e., a traffic–message–channel-based routing strategy.

The public transport timetable from a theoretical point of view often does not correspond to one in reality. The main reason for the frequent delays of tram or bus lines is increased congestion and the inability to maintain the required travel speed, especially in road segments where public transport corridors are not separated from private transport. Such situations often lead to the grouping of public transport vehicles, which creates vehicle redundancy and lowers PT efficiency. To address the problem of vehicle redundancy, authors [40] in their research presented a predictive framework to capture the stop-level headway irregularity based on transit smart card data. Historical headway, passenger demands, and travel time are utilized to model the headway fluctuation at the following stops. An empirical experiment with two bus routes in Beijing is conducted to demonstrate the effectiveness of the proposed approach. The predictive method can successfully identify more than 95% of bus bunching occurrences in comparison with other well-established prediction algorithms. Moreover, the detection accuracy does not significantly deteriorate as the prediction lead time increases. Instead of regularizing the headways at all costs by adopting certain correction actions, the proposed framework can provide timely and accurate information for potential bus bunching prevention and inform passengers when the next bus will arrive. This feature could greatly increase transit ridership and reduce operating costs for transit authorities.

In addition to the mentioned research, the use of open data and big data technologies is possible for developing a dynamic congestion charging system that can be used to determine the price classes of congestion charging depending on the traffic load of the toll zone. Also, the same technologies can be used to develop a demand-responsive parking pricing system that could inform drivers about the availability of parking spaces near the destination and thus reduce the generation of traffic caused by searching for available parking spaces.

22.4.3 Traffic Safety

Traffic safety is one of the important segments, which is considered when designing all traffic processes. Technological evolution and advances in vehicle sensors have also increased the level of safety provided to the driver. Research related to the use of big data technology in the field of traffic safety is addressed to exploring the critical situations arising from the design of infrastructure, understanding behaviors of drivers, and developing models for traffic sign detection or crash prediction based on real-time data mining.

Exploring the critical situations arising from the design of the infrastructure can be used for assessing road safety, behavioral studies, and traffic flow model validation. Researchers [41] in their paper presented a practical framework for the implementation of an automated, high-resolution, video-based traffic-analysis system. The system collects large amounts of microscopic traffic flow data from ordinary traffic using CCTV and consumer-grade video cameras and provides the tools for conducting basic traffic flow analysis as well as more advanced, proactive safety and behavior studies. In addition to providing a rich set of behavioral data about time-to-collision and gap times at nearly 40 roundabout weaving zones, some data validation is performed using the standard measure of tracking accuracy with results in the 85–95% range.

Driving styles can be broadly characterized as calm or volatile, with significant implications for traffic safety, energy consumption, and emissions [42]. Understanding the behaviors of drivers can contribute to increasing traffic safety, decreasing energy consumption, and exhaust emissions. Authors [42], in their research, investigated how to quantify the extent of calm or volatile driving and explore the correlations between these two types of drivers. A fundamental understanding of instantaneous driving behavior is developed by categorizing vehicular jerk reversals (acceleration followed by deceleration), jerk enhancements (increasing accelerations or decelerations), and jerk mitigations (decreasing accelerations or decelerations). Volatility in driving decisions, captured by jerky movements, is quantified using data collected in Atlanta, GA, during 2011. The database contains 51,370 trips and their associated second-by-second speed data, totaling 36 million seconds. Rigorous statistical models explore correlates of volatility that include socioeconomic variables, travel context variables, and vehicle types. The study contributes by proposing a framework that is based on defining instantaneous driving decisions in a quantifiable way using big data generated by in-vehicle GPS devices and behavioral surveys.

Driving behavior models can be developed using real-time data mining technologies. Authors [43] in their research presented an improved framework for real-time crash prediction models. The model has been constructed using high-resolution detector data collected from Shibuya 3 and Shinjuku 4 Expressways under the jurisdiction of Tokyo Metropolitan Expressway Company Limited, Japan. It has been specifically built for the basic freeway segments, and it predicts the chance of formation of a hazardous traffic condition within the next 4–9 min for a 250-m-long road section. The performance evaluation results reflect that at an average threshold value, the model can successfully classify 66% of the future crashes with a false alarm rate of less than 20%. The data used to evaluate the model are provided by Tokyo Metropolitan Expressway, and it contain detector data (data of speed, vehicle count, occupancy, and number of heavy vehicles per lane for every 8 ms round the clock for 24 ha day, 365 days a year) and corresponding crash data.

22.5 The Benefits of Using Open Data and Big Data in Traffic

Until June 2018, the Republic of Croatia was the only EU Member-State that did not adopt full access to open data through a unified policy at the national level. Open data in the Republic of Croatia are summarized on the central state portal called the Open Data Portal of the Republic of Croatia. Data in the field of transport contain data on rail transport, road infrastructure, road transport of passengers and goods, border traffic, urban and suburban transport, pipeline transport, maritime and coastal transport, traffic at airports and seaports, drivers, registered vehicles, and road accidents. Statistics are kept extensively at the state level, and data are open and available for the period of the last 10 years, but the level of data openness is low. All available and open data are published under the Creative Commons Attribution license, and the openness of the data is at level 2. Due to low openness, low detail of data (data available only in summarized form) and their up-to-datedness (data published on an annual or quarterly basis), the usability of data for the improvement of transport processes of passenger or goods at a level lower than the strategic is almost nonexciting. When developing systems that use real-time data, it is necessary to use sources that are connected and have updated, usable, and accessible metadata.

In the Republic of Croatia, nearly 10% of companies used the big data analysis, which is below the average of the EU (12%). For the Republic of Croatia, the EU estimates the creation of around 1000 new jobs by the end of 2020 related to open data and big data technologies, and the market value of 186 million €. The advantages of using big data technologies have been recognized at the EU level, which has launched several projects related to the use of open data and big data technologies in transport. On the examples of the use of big data technologies in the field of transport in the world, urban planning, transportation operation, and traffic safety can be singled out as three main categories.

Based on the methodologies used from the examples shown, it is possible to plan a transport network, predict the time spent in the network, or design a route selection model for a specific mode of transport. Transport-related services based on the use of big data technologies are focused on providing decision support services in traffic processes or are support for Advanced Traveler Information Systems (ATIS). The benefits in this field can be found through travel time prediction, traffic incident and anomaly detection, anticipatory vehicle routing, and detection of PT vehicle bunching.

Research related to the use of big data technology in the field of traffic safety is addressed to exploring the critical situations arising from the design of infrastructure, understanding behaviors of drivers, and developing models for traffic sign detection or crash prediction based on real-time data mining.

As presented in this paper, it can be concluded that the Republic of Croatia still lags in the usage of open data and big data technologies. One of the main reasons is the low level of openness of available data collected on the state level. To encourage the expansion of usage of open data and big data technologies, decision-makers need to provide more open data that is connected, usable, free of charge, and describe in detail with metadata.

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Chapter 23
Case Study in Logistics: Purchase Planning of Goods for Large Retail Chains, Taking into Account Sale Marketing Campaigns

Martin Straka, Peter Kacmary, Andrea Rosova, Olga Vegsoova, and Marian Sofranko

23.1 Introduction

The buying public relatively often encounters a shortage of some goods from the entire range of sales in a large retail chain [1]. Especially, it is the case of items with a temporarily reduced sale price for the purpose of a marketing campaign. In addition, these items are included in campaigns just when their demand is already increased by a certain seasonal event. This article brings the solution to prevent such risks of lack of selected goods and thus to ensure the satisfaction of customers who choose to enter these retail chains only for the purpose of purchasing promoted goods [2–4].

A number of articles have already been written about similar issues. One of the latest researches by the authors Silva, Villa, Cabrera [5] deals with similar forecasting problems by using classical (Holt and Holt-Winters method) but also more sophisticated methods such as ARIMA or artificial neural network. The results show that the artificial neural network obtained a better performance achieving the lowest mean square error. Further work from the authors Adithya Ganesan et al. [6] provides research in the field of forecasting food sales to prevent the disposal of uneaten food after the expiration date [7]. Using the method of the artificial neural network, a model was created that performs better than the traditional time-series models and also performs better than the currently existing model in a retail change company by a factor of 7.7%. This improved performance also leads to a saving of 170 units of food every day [6]. Another article from the author Tsoumakas

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[8] has an orientation toward artificial intelligence. Their article reviews existing machine learning approaches for food sales prediction. It discusses important design decisions of a data analyst working on food sales prediction, such as the temporal granularity of sales data, the input variables to use for predicting sales, and the presentation of the sales output variable [9, 10].

Despite the high popularity of the artificial neural network and sophisticated techniques, simulation included [11–15], this article provides acceptable solution to a relatively complex problem with a simple technique [16].

ABC Stores (the real name of the company is intentionally changed for publishing purposes) is the largest retail chain in the United Kingdom and currently operates more than 830 stores worldwide and employs around 500,000 people. ABC Stores is one of the most developed retail chain in the Slovak Republic. It has been operating since 1996 and currently operates a network of 150 shops stores in Slovakia.

Since 2005, the company has been providing customer service through a modern distribution center in Beckov, a textile warehouse in Senec, which is not only for Slovakia, but for all ABC stores in Central Europe, i.e., Hungary, Poland, and the Czech Republic. ABC Stores has more than 9900 employees and is one of the largest employers in Slovakia. The main goal of the company is to provide the customer with the best and become a business for everyone. The company's vision is based mainly on the high quality of goods, low prices, and continuous improvement of customer service. The retail chain places emphasis on a great importance to the promotion of domestic products. The basic idea is to provide the customer with the best and become a business for everyone.

Maybe for all of the properties mentioned above, this large trade company did not refuse cooperation in the development of the forecasting model and offered important sales data with which it was possible to specify the model. This retail chain is mainly engaged in the sale of food, so the selected items are fast-moving goods, with a short expiration date and are often, mostly irregularly, mentioned in advertising leaflets that the company publishes every week as a certain advertising campaign.

The following food items were selected for the forecast: dairy products—milk, yoghurt, Eidam sliced cheese, Eidam cheese, butter; fruits—apples, bananas; vegetables—potatoes; sweets—milk chocolate; eggs. Not all items are presented here, because of the article range. But the final results will be posted in the discussion. The main aim in selection of these food items was to select those items that showed fluctuations in sales due to changes in prices of goods (intentionally reduced for those, which were published in the leaflets as part of the marketing campaign).

23.2 Methodology

The main principle of the operation of the forecasting model is a different approach to the analysis of sales of a given product item—firstly at the time of normal sales (the product is not listed in the advertising leaflet) and, secondly, sales during the advertising campaign (the product is listed in the advertising leaflet). So the forecast from a single time series of sales will have double results.

The following three methods were chosen for forecasting—exponential smoothing, Holt's method, and linear regression, because the company insisted on using simple methods that can be quickly implemented in their planning system. Thus, the uniqueness of the forecasting model is not in the use of sophisticated methods but in the use of a different approach in the analysis of time series of food items.

1. Linear regression, formula (23.1). It is often used in forecasting to evaluate time series of trend dependencies, but also in uncertain situations, to determine the overall linear trend. In many cases, it is sufficient and even more reliable than nonlinear regression, because the shape of the trend curves in nonlinear models may not correspond to reality [17].

$$F_t = a + b.t \tag{23.1}$$

   where F_t is the forecast for the time t (also known as regression equation),
   a and b are regression coefficients explained below, formula (23.2) and (23.3),
   t is time.

$$a = \frac{\sum Y_t \sum t^2 - \sum t \sum Y_t t}{n \sum t^2 -} \tag{23.2}$$

$$b = \frac{n \sum Y_t t - \sum t \sum Y_t}{n \sum t^2 -} \tag{23.3}$$

   where a and b are regression coefficients,
   Y_t is real value from time series in time t,
   t is time,
   n is total number of values in time series.
2. Exponential smoothing, formula (23.4). The system of exponential smoothing uses the way of evaluating observations or data. The rule is followed that the latest observations or the latest data will usually provide the freshest information for creating an image of the future, so it offers a weighing system that assigns descending weights to older observations or data. Although there are several ways of exponential smoothing, they all have one thing in common—that relatively higher weight is assigned to recent values in forecasts than to older data.

$$F_{t+1} = F_t + (\alpha * (Y_t - F_t)) = \alpha * Y_t + (1 - \alpha) * F_t \tag{23.4}$$

   where F_{t+1} is the forecast for the next period of time (t+1),
   F_t is the previous forecast for the time t,
   Y_t is real value from time series in time t,

α is the smoothing constant $\alpha \in$ <0, 1>. It is basically a representative of weight.

3. Holt's method. It is the linear exponential smoothing that allows to respect the emerging trends in forecasting. The trend component is assumed in each model; therefore, in addition to the normal value of the variable, the current increase caused by the trend is also estimated. Forecasting by Holt's linear exponential smoothing (Holt's method) is already dependent on two smoothing constants α and β (thus applying level and increment smoothing), and consists of the following three formulas (23.5)–(23.7) [17]:

$$L_t = \alpha Y_t + (1 - \alpha) . (L_{t-1} + T_{t-1}) \tag{23.5}$$

$$T_t = \beta (L_t - L_{t-1}) + (1 - \beta) T_{t-1} \tag{23.6}$$

$$F_{t+p} = L_t + pT_t \tag{23.7}$$

where L_t is the estimation of the time series level at time t,
L_{t-1} is the estimation of the time series level at previous time $t-1$,
T_t is the estimation of the time series trend at time t,
T_{t-1} is the estimation of the time series trend at previous time $t-1$,
α and β are the smoothing constants $\alpha \in$ <0, 1>; $\beta \in$ <0, 1>,
$F_{t+\mathrm{p}}$ is the forecast for p periods ahead,
p is number of periods ahead, for which the forecast is calculated.

Original MAPE formula was modified to the form that uses results from all methods to ensure the objectivity of the result to determine the accuracy of the forecast for each item. After this manner, MMAPE (Modified Mean Absolute Percent Error) formula (23.8) was created.

$$\mathrm{MMAPE} = \frac{\left|\frac{E_{\mathrm{ES}}}{Y_n}\right| + \left|\frac{E_{\mathrm{HOLT}}}{Y_n}\right| + \left|\frac{E_{\mathrm{LR}}}{Y_n}\right|}{3} * 100\ [\%] \tag{23.8}$$

where MMAPE is modified mean absolute percentage error.
E_{ES} is forecast error from exponential smoothing ($E_{\mathrm{ES}} = Yn - Fn^{\mathrm{ES}}$),
E_{HOLT} is forecast error from Holt's method ($E_{\mathrm{HOLT}} = Yn - Fn^{\mathrm{HOLT}}$),
E_{LR} is forecast error from linear regression ($E_{\mathrm{HOLT}} = Yn - Fn^{\mathrm{LR}}$),
Y_n is the last known real value from time series (in time n).

Finally, the total error from many forecasts is combined by this way.

23.3 Results

This chapter provides forecasts of selected food items, one is for normal and the other is for a marketing campaign when the price is reduced.

23.3.1 Forecasting of a Butter Future Sale

A butter (250 g package) sale time series was used to forecast its future development. The sale data consist of weekly sales in pieces within the period from September 6, 2017 to February 25, 2018, i.e., a total of 25 records of butter sold (Figs. 23.1 and 23.2).

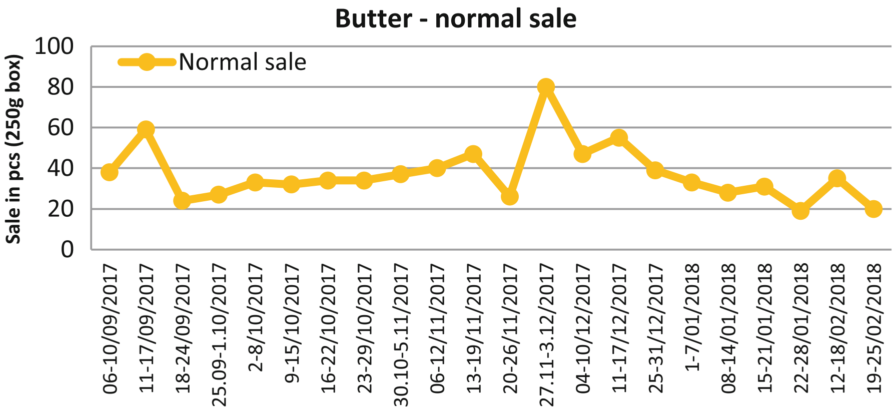

Fig. 23.1 Sale of butter—normal sale

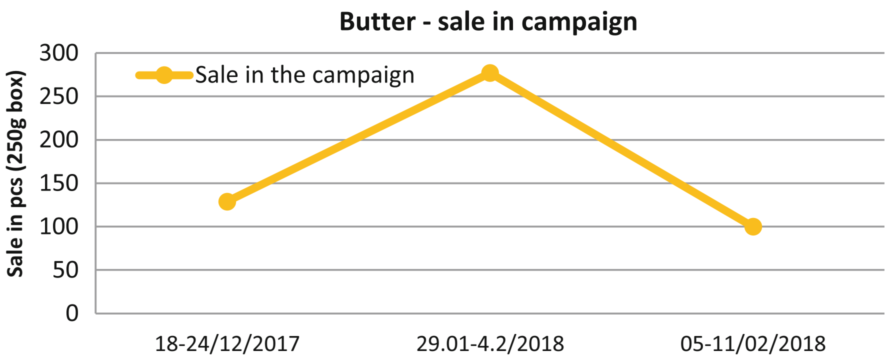

Fig. 23.2 Sale of butter—sale in the campaign

Following these real sales presentations of butter, the forsecasts of these two regimes were made by using forecasting methods mentioned above. The results are in Table 23.1 for normal sale and Table 23.2 for sale in the campaign. Also, the real obtained value (within the forecast period) is mentioned in these tables to compare the forecast accuracy.

As it can be seen from the result tables, in both cases, there was a higher consumption of butter in the week for which the forecast was made. Fluctuations in consumption are very difficult to predict, as this is influenced by a large number of random factors. Therefore, a 20% tolerance was determined, i.e., when ordering goods for the planned advertising campaign, 20% more products will be ordered in order to cover this contingency in consumption and to prevent stocks from being sold out during the campaign period.

23.3.2 Forecasting of a Milk Future Sale

A milk (1 L tetra pack) sale time series was used to forecast its future development. The sale data consist of weekly sales in pieces within the period from September 6, 2017 to February 18, 2018, i.e., a total of 24 records of milk sold (Figs. 23.3 and 23.4).

Table 23.1 Forecast of butter sales at normal prices (in pcs during the forecasted week)

Linear regression	Holt's method	Exponential smoothing	Real value	MMAPE
34	20	26	35	23.8%

Table 23.2 Forecast of butter sales in the campaign prices (in pcs during the forecasted week)

Linear regression	Holt's method	Exponential smoothing	Real value	MMAPE
155	172	152	198	19.3%

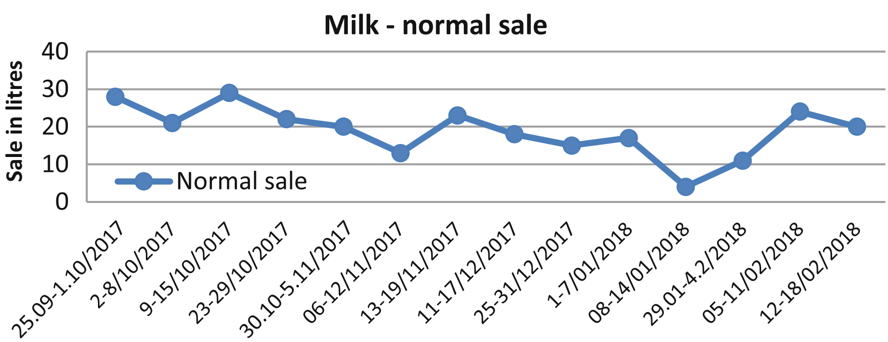

Fig. 23.3 Sale of milk—normal sale

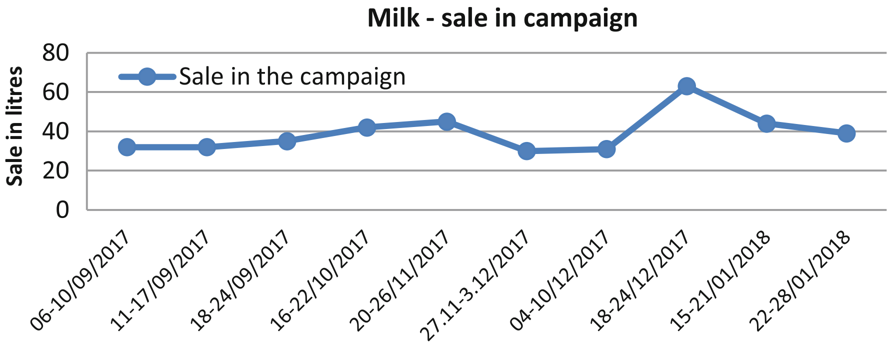

Fig. 23.4 Sale of milk—sale in the campaign

Table 23.3 Forecast of milk sales at normal prices (in l during the forecasted week)

Linear regression	Holt's method	Exponential smoothing	Real value	MMAPE
14	22	19	15	26.7%

Table 23.4 Forecast of milk sales in the campaign prices (in l during the forecasted week)

Linear regression	Holt's method	Exponential smoothing	Real value	MMAPE
30	46	43	45	13.3%

The forecast results are in Table 23.3 for normal sale and Table 23.4 for sale in the campaign. Also, the real obtained value (within the forecast period) is mentioned in these tables to compare the forecast accuracy.

As it can be seen from the result tables above, the forecasts in the case of milk were much more accurate. Very good result is in the case of forecasting for the period in the advertising campaign.

23.3.3 Forecasting of Future Sale of Apples

Time series of apples (red apples free sale in kilograms) sales was used to forecast its future development. The sale data consist of weekly sales in pieces within the period from September 6, 2017 to February 25, 2018, i.e., a total of 24 records of kilograms of apples sold (Figs. 23.5 and 23.6).

The forecast results are in Table 23.5 for normal sale and Table 23.6 for sale in the campaign. Also, the real obtained value (within the forecast period) is mentioned in these tables to compare the forecast accuracy.

However, the real sale was a bit smaller than forecasts for the campaign, the forecasts in case of apples were much more accurate as it can be seen from the result tables above. Another very good result supports this technique of the model.

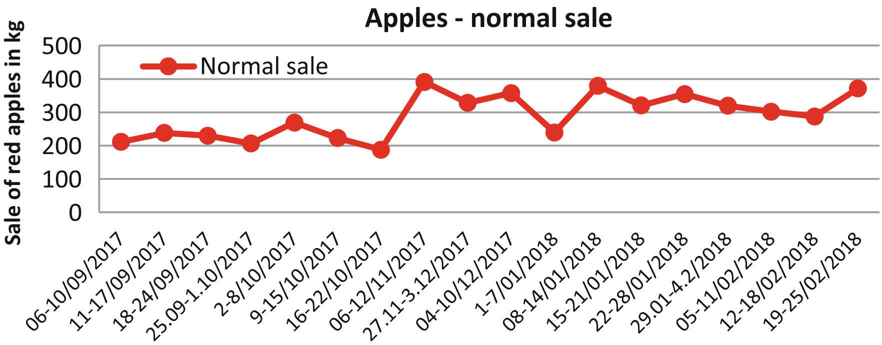

Fig. 23.5 Sale of apples—normal sale

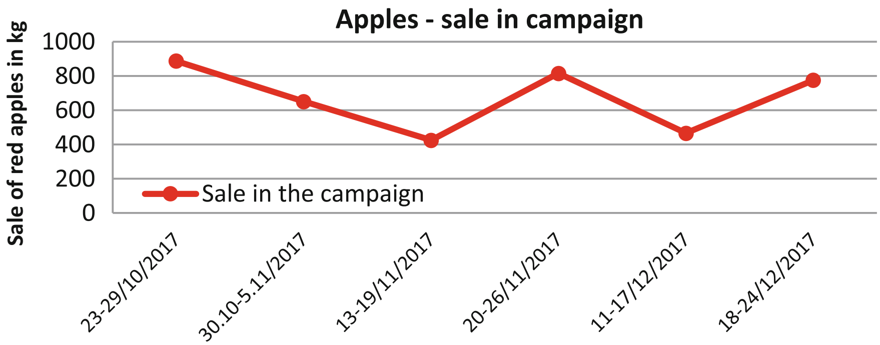

Fig. 23.6 Sale of apples—sale in the campaign

Table 23.5 Forecast of sales of apples sale in the campaign prices (in kilograms during the forecasted week)

Linear regression	Holt's method	Exponential smoothing	Real value	MMAPE
619	631	682	587	9.7%

Table 23.6 Forecast of sales of apples at normal prices (in kilograms during the forecasted week)

Linear regression	Holt's method	Exponential smoothing	Real value	MMAPE
357	334	337	253	35.4%

23.3.4 Forecasting of Future Sale of Milk Chocolate

A milk chocolate (German world-famous brand of 100 g package) sale time series was used to forecast its future development. The sale data consist of weekly sales in pieces within the period from September 6, 2017 to February 25, 2018, i.e., a total of 24 records of milk chocolate sold (Figs. 23.7 and 23.8).

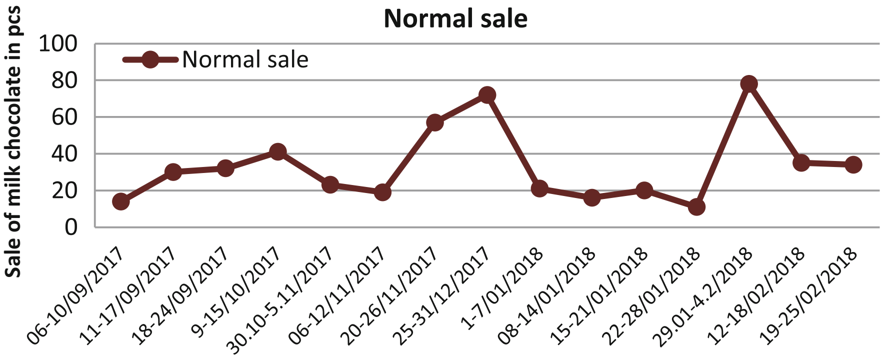

Fig. 23.7 Sale of milk chocolate—normal sale

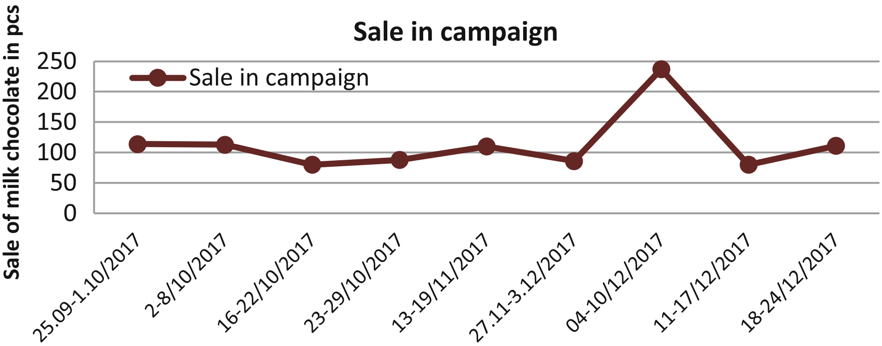

Fig. 23.8 Sale of milk chocolate—sale in the campaign

Table 23.7 Forecast of milk chocolate sales at normal prices (in pcs during the forecasted week)

Linear regression	Holt's method	Exponential smoothing	Real value	MMAPE
40	45	38	33	24.4%

Table 23.8 Forecast of milk chocolate sales in the campaign prices (in pcs during the forecasted week)

Linear regression	Holt's method	Exponential smoothing	Real value	MMAPE
127	125	117	108	13.9%

The forecast results are in Table 23.7 for normal sale and Table 23.8 for sale in the campaign. Also, the real obtained value (within the forecast period) is mentioned in these tables to compare the forecast accuracy.

Similarly, there are other food items that cannot be placed in the article, because the range would exceed the set limit. The overall forecast results for normal prices and campaigns are shown in the following chapter.

Table 23.9 Comparison of the results among the food item forecasts at normal sale

	Real value	Linear regression	Holt's method	Exponential smoothing	MMAPE (%)
Butter (pcs)	35	**34**	20	26	23.8
Milk (l Ltetra pack)	15	**14**	22	19	26.7
Yoghurt (pcs)	11	20	20	**19**	78.8
Eggs (30 pcs box)	125	118	**121**	118	4.8
Milk chocolate (pcs)	33	40	45	**38**	24.4
Cheese (250 g pac.)	79	111	99	**94**	28.3
Sliced cheese (100 g pac.)	23	**22**	31	26	17.4
Apples (kg)	253	357	**334**	337	35.4
Potatoes (kg)	190	252	**203**	222	18.77
Bananas (kg)	1114	**1241**	1261	1537	20.86

23.4 Discussion

The following tables compare the results of all selected food items for which we created a forecast. The forecasts that came closest to the actual value are marked in boldface. Table 23.9 is for sales at normal (unchanged) prices and Table 23.10 is for marketing campaigns.

In the case of normal sales at unchanged prices, the most successful method was linear regression. This is probably because normal sales are not as variable as the sales during marketing campaigns. On the other hand, exponential smoothing was the best when selling during campaigns. This fact could be further implemented in the model in the form of combining the results from individual methods into the overall forecast by adding weight to the results of more successful methods.

23.5 Conclusions

The results of forecasts of suggested methods, for the period for which the forecast was calculated, were compared with the actual values by using a modified MAPE (MMAPE). The aim of this study was that the MMAPE did not exceed a 20–25% deviation, especially for the products, which were chosen for a marketing campaign.

Table 23.10 Comparison of the results among the food item forecasts at normal sale

	Real value	Linear regression	Holt's method	Exponential smoothing	MMAPE (%)
Butter (pcs)	198	155	**175**	152	19.3
Milk (l Ltetra pack)	45	30	**46**	43	13.3
Yoghurt (pcs)	37	32	29	**34**	14.4
Eggs (30 pcs box)	194	**225**	239	**225**	18.4
Milk chocolate (pcs)	108	127	**125**	225	13.9
Cheese (250 g pac.)	113	124	127	**119**	9.1
Sliced cheese (100 g pac.)	101	88	82	**96**	12.2
Apples (kg)	587	**619**	631	682	9.7
Potatoes (kg)	774	**738**	704	735	6.2
Bananas (kg)	5560	4685	4825	**5091**	12.5

Problems were in products that are sold in very small quantities. This is shown in sales of a type of yogurt, where the forecasts predicted almost double sales as it actually was. However, with such small amounts, even a relatively small difference (in pieces) results in a large MMAPE deviation.

There is a relatively large amount of goods at a reduced price every week in marketing campaigns. These items are listed in a promotional leaflet and many customers decide, on the basis of these advertising campaigns, where to go for the regular purchase of food at home. Thus, it can be very annoying for them if they cannot buy everything they wanted due to the lack of some goods. From 100 types of campaign items, it was quite common that 15–20 items were sold out before the campaign ended. This was due to the insufficient supply of these types of goods, which resulted from a miscalculation of future consumption [18, 19]. After a test run of this model, this status was reduced to 3–5 items, but these cases were mostly caused by a supplier problem. This improvement is therefore calculated up to 66%.

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Chapter 24
Methods of Increasing Warehouse Capacity in an Enterprise: Case Study

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24.1 Introduction

Warehousing of goods is one of the most important subsystems of the logistics system in a company. It covers the storage of goods of various types and properties for various periods of time. A warehouse is a place where multiple activities are carried out, depending on the warehouse function and position within the logistics system of a company or in its supply system. Several authors have presented the characteristics of warehouse and warehouse systems in their publications, or they deal with issues regarding solutions to specific problems related to the warehousing of goods. The technical literature deals with issues concerning the warehouse design [1, 2], warehouse and rack systems [3], warehouse space [4], warehouse layout [5–7], warehouse manipulation [8], costs, performance [9], etc. An important parameter of a warehouse is the warehouse capacity. The warehouse capacity depends on several parameters, primarily on the properties of goods (products), the storage unit size, the type of the storage facility and the handling (manipulation) technology, the storage method, and the warehouse layout [10]. The warehouse capacity is a parameter that may be expressed in various forms [11]. We distinguish between the warehouse static capacity and the warehouse dynamic capacity. The warehouse static capacity relates to the number of storage places for goods at a standstill that is available for removal and subsequent shipment [12].

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The main purpose of the present article is to propose the method of increasing the current static capacity of a selected warehouse of returnable packaging by using existing racks, installing new racks, and with the current or new handling technology [13].

The automotive industry as the fastest growing industry for individual components handling applies returnable packaging on a regular basis [14]. In connection with plastic pallets and a pallet cover (the lid), returnable packaging (boxes) forms an integrated transport unit. Standardized plastic boxes can be stored on a standard plastic or wooden pallets and be covered with a standardized cover (the lid) in a particular dimension [15]. This will create an integrated pallet unit for transport, handling, and warehousing [16].

24.2 Methodology

The warehouse static capacity (WSC) represents the number of storage units that may be stored in a warehouse at the same time. For the existing warehouses, such capacity is calculated on the basis of the rack system parameters, using a simple formula (24.1) [10]:

$$\mathrm{WSC} = \sum_{i=1}^{m} \left(R_i \cdot N_{\mathrm{RF}_i} \cdot N_{\mathrm{L}_i} \cdot N_{\mathrm{URC}_i} \right) \tag{24.1}$$

where:

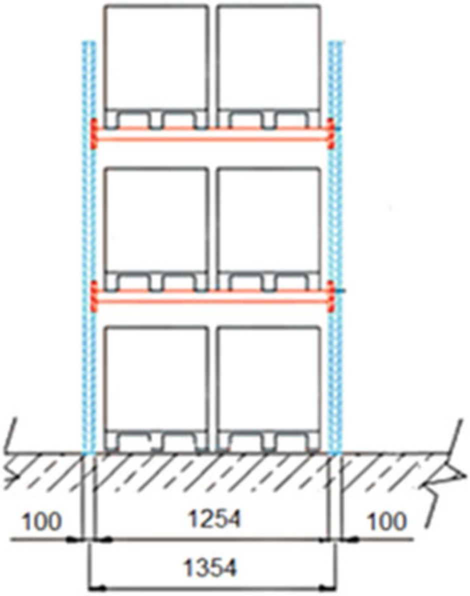
m is the number of rack types (depending on the number of rack fields)
R_i is the number of racks at the given number of rack fields
N_{RF_i} is the number of rack fields, in pieces
$N_{\mathrm{L_i}}$ is the number of levels in the rack field, the number of rack cells, in pieces
N_{URC_i} is the number of storage units (places) in the rack cell, in pieces

The R_i parameter indicates the number of racks in the warehouse. The racks consist of rack fields N_{RF_i} that may comprise several levels. Each level corresponds to a single rack cell. In the rack cell, storage units N_{URC_i} are placed. Their number (storage places) depends on the dimensions of a storage unit and on their number. Figure 24.1 presents an example of a rack field consisting of three levels, and in each rack cell, there are two storage units, including the parameters of the main rack field and the additional rack field.

Another important parameter is also the area of the rack assembly (rack system) A_{R} that is calculated using the formula (24.2) [17].

$$A_{\mathrm{R}} = \sum_{i=1}^{m} \left[R_i \cdot \left(A_{\mathrm{F}} + n \cdot A_{\mathrm{A}} \right) \right] \tag{24.2}$$

Fig. 24.1 Rack field scheme



where:

A_F is the area of the basic rack field in m^2
A_A is the area of the additional rack field in m^2
n is the number of additional rack fields
R_i is the number of racks at the given number of rack fields
m is the number of rack types (depending on the number of rack fields).

In order to achieve the objective defined in the introductory part (increasing the current static capacity), the first step is to calculate the WSC parameter using the formula (24.1), on the basis of the analysis of the current situation—the analysis of the parameters of storage units and the analysis of the parameters of the installed rack system: the rack cell size (number of storage units in one rack cell), number of levels in a rack field, number of rack fields, and arrangement of racks in the warehouse premises [18].

The second step is to determine the conditions under which it is necessary to propose increasing the capacity. The third step is to propose several possibilities on how to increase the existing capacity and produce the underlying calculations.

The last step is to make a decision while considering the selected parameters (e.g., investment costs, execution time, etc.), on which of the provided possibilities is acceptable in the given conditions [19].

24.3 Results

Increasing the warehouse static capacity, hereinafter referred to as capacity, was carried out for an enterprise that plans to increase its production by 25%. This will have an impact on the warehousing process in the company [20]. Increasing the capacity was carried out in the warehouse of returnable packaging. The company uses several types of returnable packaging—plastic boxes, according to customer requirements. A warehouse for returnable packaging is designed to get packages as quickly as possible to the production line [21, 22]. Following activities are carried out in the warehouse:

- Receiving pallets with boxes,
- Control of boxes (number of pieces and type) and registration into the information system,
- Placing the full pallets in the racks,
- The boxes are moved to the production to the respective production lines, as required [23].

24.3.1 Determination of the Current Static Warehouse Capacity

Returnable packaging is plastic boxes KLT, which are placed on plastic pallets (1200 × 800 × 145 mm). In the storage area, there is a rack system with the racks arranged in one row and two rows. The warehouse contains seven racks. Each rack consists of 32 fields. The rack field comprises three levels, i.e., three rack cells. The rack cell is 1254 mm long and 1500 mm high (see Fig. 24.1). The rack depth is 954 mm. In a single rack cell, there are three pallets. The current capacity of the rack system, calculated using the formula (24.1), is 1344 pallets.

The rack system area is 289.4 m^2, which is 30% of the warehouse area (985 m^2). A diagram of the rack arrangement in the warehouse is shown in Fig. 24.3. One insufficiency is looking at the current warehouse layout (see Fig. 24.2): a manipulation aisle with a width of 3512 mm for only one rack.

For analysis of storage directly in the warehouse, it was found that the current capacity is insufficient even for the current state. A 5% overload of the warehouse was found on average [24, 25].

Proposed possibilities of increasing the current capacity. In order to increase the capacity, four options were proposed.

A. Elimination of the widest aisle (Proposal A1 and Proposal A2).
B. Decrease of the current rack cell height, Proposal B.
C. Exchange of handling equipment, Proposal C.

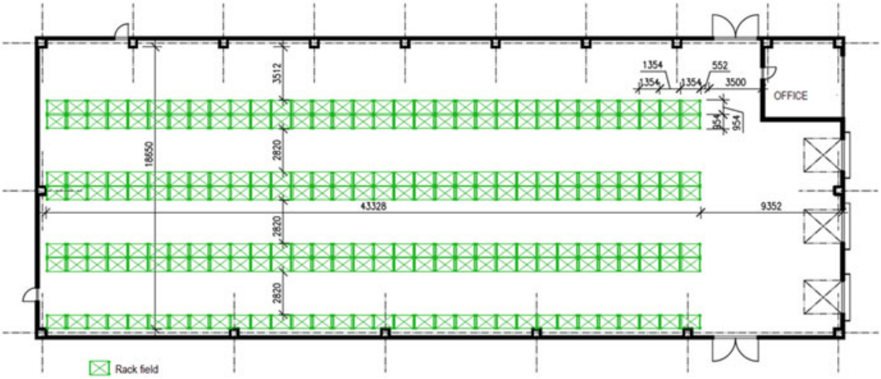


Fig. 24.2 Current warehouse layout

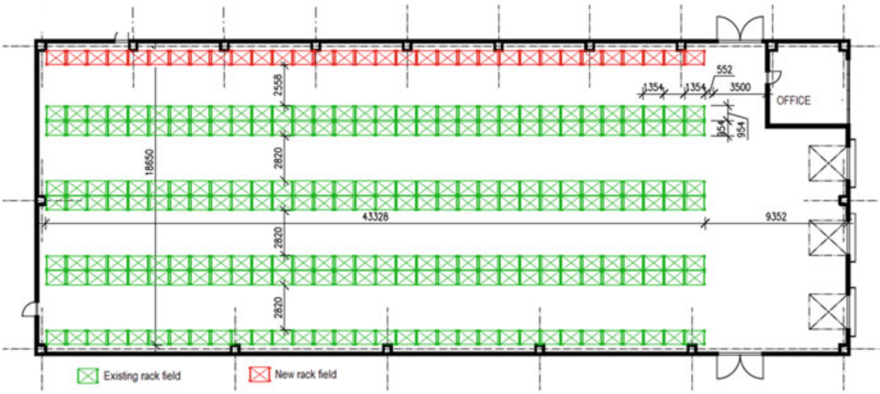


Fig. 24.3 Proposal C—Exchange of handling equipment

A. Elimination of the widest aisle

A1. Figure 24.3 shows the elimination of the widest aisle by rearrangement of the first current double row of racks and installing of new racks. This proposal will increase the capacity of 72 pallet places (5.4%). In this way, only the current overload of the warehouse is covered.

A2. New rack will be placed in the wide aisle area, (see Fig. 24.4). The capacity of the warehouse will increase by 192 pallets (14.3%) and aisle width would be reduced to 2558 mm, by installing a new rack. The disadvantage of this solution is that the new aisle width is not suitable for the currently used forklift. For this proposal, it is necessary to change a forklift. In this way, the current overload of the warehouse is covered, but there is no 25% capacity increase.

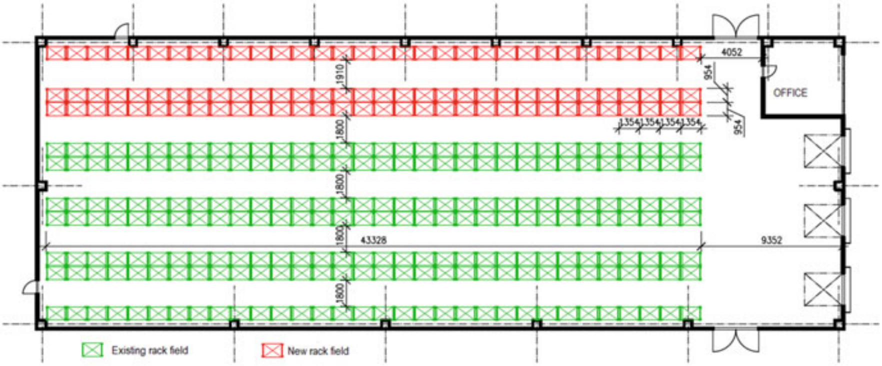


Fig. 24.4 Proposal A1—Elimination of the widest aisle

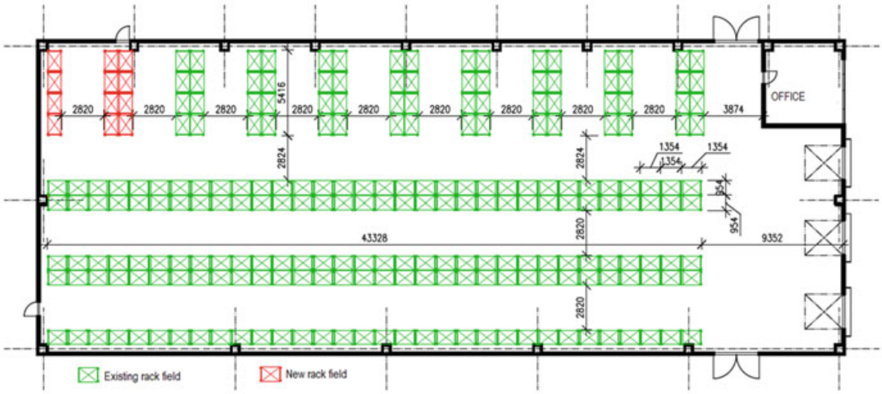


Fig. 24.5 Proposal A2—Elimination of the widest aisle

B. Decrease of the current rack cell height

Decrease of the current rack cell height from 1500 to 1000 mm. The decrease in the height of rack cells can be installed fourth-level rack field. The adjusted rack field would facilitate the storage of eight pallets (originally six pallets). In this particular case, an increase in the capacity represents 448 pallets, a 33% increase. This capacity increase will be sufficient for the planned increase in production.

C. Exchange of handling equipment

The current forklift is exchanged by a three-way electric pallet stacker truck. This type of truck requires less space, narrower aisle when handling pallets. Figure 24.5 shows the warehouse layout after the forklift-type change. In this case, existing racks would be rearranged and three new racks would be installed. This proposal will increase warehouse capacity by 576 pallet places (43%). This capacity increase will be sufficient for the planned increase in production.

Table 24.1 Comparison of the current situation and the proposals

Proposal	Current status	A1	A2	B	C
Parameter					
The number of levels in the rack field	3	3	3	4	3
WSC: number of pallets	1344	1416	1536	1792	1920
WSC increase: number of pallets	0	72	192	448	576
WSC increase: %	0	5.4	14.3	33	43
The rack system area: m^2	289.4	304.9	330.7	289.4	413.4
Use of warehouse area: %	30	31	33.6	30	42
Forklift	Current	New	Current	New	New

24.4 Discussion

The increase of warehouse static capacity will be achieved by proposal B and proposal C, for the planned increase in production. The implementation of both proposals is time-consuming and physically demanding work.

For proposal B, it is necessary to adjust the rack cells to a height of 1000 mm. This proposal requires costs: the costs of purchase of new 448 beams (two beams per rack cell) and the cost of work performed (relocation of existing and new beams).

For proposal C, however, it is necessary to rearrange the existing racks and install new ones. Necessary costs: the cost of purchase and installing new racks, the cost of work performed (relocation of existing racks), and the cost of purchase of a new forklift truck.

The proposal A2 is also interesting; although it does not meet the requirements it has its advantages as well. In a particular, case proposal A2 there may be a first step in increasing warehouse capacity. The second step would be proposal B or C. By combining the proposals, we would have increased the capacity of the following: 704 pallets (combination A2, B), 768 pallets (combination A2, C). This is more than 50% of current capacity. This is more than 50% of current capacity (see Table 24.1).

24.5 Conclusions

The present article deals with the issues regarding increasing the static warehouse capacity. The case study was carried out for the warehouse of returnable packaging in the manufacturing company. The analysis of the existing warehousing and the description of the rack system facilitated the calculation of the static capacity—the number of pallets (in pieces) that may be stored in the installed racks. Based on the analysis, four options for increasing this capacity were proposed. The possibilities to increase capacity were realized by rearranging existing racks and installing new racks. The two proposals were to change the existing forklift truck for a three-way electric pallet stacker truck, necessary. The expected investment cost for the purchase and installation of new racks is EUR 20,000, at the most expensive option (C). The change of the truck can be realized by using the possibility of operational leasing with the possibility of a full service or a long-term lease.

Acknowledgments The submitted work is a part of KEGA Project 006TUKE-4/2019 “Transfer of knowledge from the field of logistics into the preparation of innovative teaching materials for selected study units of the newly accredited study program” “Commercial logistics” and a part of the VEGA Project 1/0515/18, “Decision-making model of the regional raw material policy evaluation process,” a part of the VEGA Project 1/0797/20, “Quantification of the impacts of the environmental burden on the regions of Slovakia on the health and social and economic system of the country,” funded by the Scientific Grant Agency of the Ministry of Education, science, research, and sport of the Slovak Republic and the Slovak Academy of Sciences.

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Chapter 25
The Use of Telematics Systems in Transport and Forwarding Management

Katarzyna Huk and Mateusz Kurowski

25.1 Introduction

Changes in logistics generate the need for flexible adaptation to the conditions in the environment. This applies directly to transport and forwarding. Currently, effective transport management is understood as the one that contributes to various benefits for an organization. The development of transport generates increasing needs for the control of haulage. This problem is affecting not only transport and forwarding companies but also those using their services. There are great development opportunities facing by transport and forwarding sectors, but there are also specific problems arising. Recently, there has been a lack of drivers specializing in truck transport. The current market situation has slowed down this trend, but it will be another real threat in the coming years. The solution to the lack of employees will be IT systems used in transport and forwarding, such as autonomous trucks running on autopilot or without a driver, systems replacing the work of freight forwarders, etc. The other important problem is the increase in demand for transport services among companies that perform sporadic transports and they cannot fully control these freights. This one can be solved by using advanced IT systems for the transport and forwarding industry.

The aim of the article is to analyze telematics systems used in transport and forwarding and to propose improvements in the form of central solutions. The article is literature-empirical and based on the analysis of the publications on the subject and own research.

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25.2 Telematics Systems in Transport and Forwarding the Concept and Application

Transport has been used for centuries. In recent decades, we have observed the growth of its importance in the functioning of not only single enterprises or sectors but also entire economies. According to the research of the American association Council of Logistics Management transport is the leader in the use of the Internet in supply chains, with a share of 56.2% [1]. "Transport is a concept that describes the activities associated with the movement of a company's material resources in supply chains. From the perspective of services, it is an important complementary part to the provision of services" [2]. Transport is meant to support activities aimed at providing the customer with added value [3].

On the one hand, transport is the functional area of each enterprise, on the other hand, the gainful activity of people who specialize in relocating goods. We can then talk about transport services that will be provided by transport and forwarding companies. "Transport services consist of relocating loads in conditions appropriate to its vulnerability in natural transport, technical and economic aspect" [4]. Transport services can be considered in three perspectives: in the narrow sense of transport, in a broader sense as transport enriched by transshipment, completing and consulting activities, which are carried out by freight forwarding [5]. Therefore, transport activities can have many dimensions, and the service itself can be extended depending on the client's needs.

In order to efficiently implement transport services and organize transport within the activities of manufacturing and commercial enterprises, IT systems used in this area play an important role. At the turn of the twentieth and twenty-first centuries, the new term intelligent transport systems (ITS) was presented in literature [6]. ITS constitutes a wide collection of various technologies: telecommunications, IT, automatic, and measuring [7]. It is a collection of tools in which telecommunications and IT technologies as well as telematics play an ultimate role. These systems allow the user to visualize and implement methods and techniques to control and manage transport systems and transport networks, which are formed by the fleet of owned vehicles. Figure 25.1 shows the genesis of intelligent transport systems.

Telematics is one of the elements that allows users to visualize and reflect the real course of transport means and also helps to locate them, plan routes, etc. There is a wide variety of systems that can be classified as ITS and their tasks are different, from transport management, route planning, through controlling the work and time of drivers, fuel consumption, to systems where only transport is only one of the elements. Transport management is also additional module of the APS systems that support the optimization of roads and the order of deliveries and transports [9].

Telematics systems are not a new concept in the area of logistics. "Telematics is a part of telecommunications dealing with issues related to the transmission of messages in the form of a static image (alphanumeric text, graphic characters, photographs and other objects)" [10]. Figure 25.2 presents a diagram of information flow in a typical telematics system.

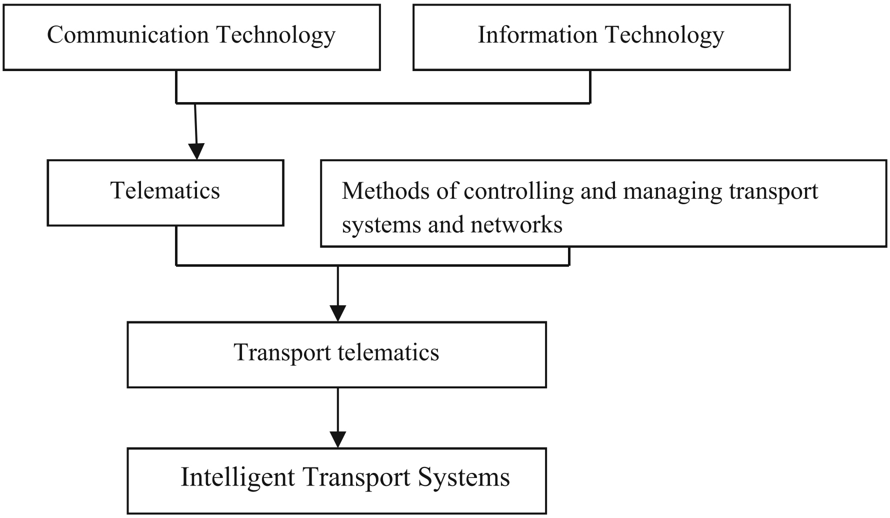

Fig. 25.1 The genesis of intelligent transport systems [8]

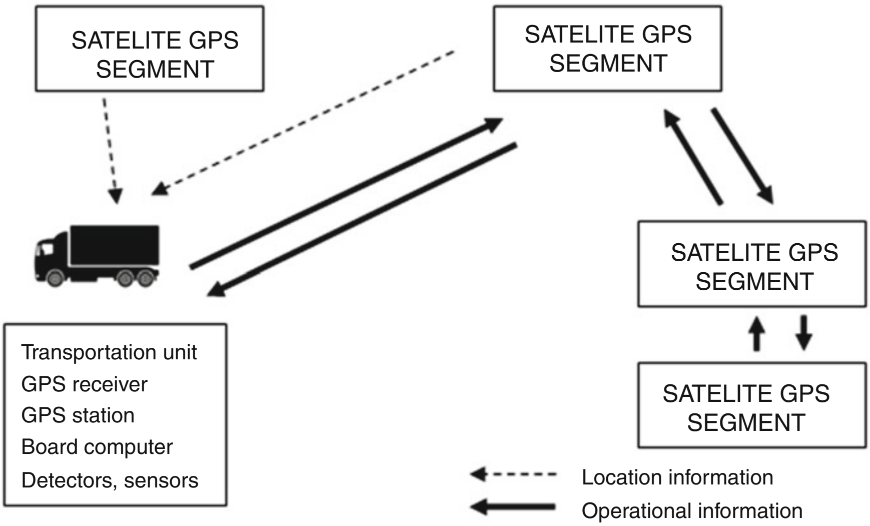

Fig. 25.2 Information flow in typical telematics system [11]

"A telematics system meeting basic location and communication services should have an object's position determination system and information transfer system to the control center. Automatic position determination (without the operator's control) can be done by determining geographical coordinates (GPS) and comparing this position with the map, pinpointing the position of the mobile station (GPS) or by reading the position from transmitters or markers via microwave, infrared or electromagnetic transporters" [12]. Currently, the systems are transmitted via cellular devices or Wi-Fi.

The key element in using these systems is GPS receivers. "GPS—global positioning system" is a satellite system for identifying the location of objects on the globe [10].

It should be noted that under the term telematics systems, we will now distinguish much more systems that can indicate the location of cars. However, the use of the GPS system is still the most popular and the most common in use among this sector. Further evolution of information technologies will undoubtedly affect the development of used transport systems. Intelligent networks will allow for new wireless and wired communication, through intelligent sensors, communication technologies. Thanks to this, we will be able to implement new innovations that also affect the intelligent movement of transport means [13]. Creating new virtual networks, innovations in IT systems solutions, and means of transport will undoubtedly have an impact on the development of systems used in transport and forwarding. This will also be influenced by the growing requirements of consumers who are recipients of transport services.

25.3 Telematics Systems in Transport and Forwarding Companies and in Entities from Other Sectors

The analysis of the use of telematics systems was performed based on surveys conducted on a sample of 200 enterprises. They were carried out in the period of April and May 2020. The survey questionnaire was divided into three parts: a metric, a part for transport/forwarding companies, and a part for non-transport/forwarding companies. The division of the surveyed entities was a deliberate act due to the desire to compare companies in the industry that should use telematics systems with others. The selection of the sample was deliberate due to the adopted criteria. Table 25.1 shows the division of companies by type of activity, size, and direction of activity. The group of "transport companies" in the research covers both transport and forwarding entities.

In the research sample, a significant percentage is manufacturing and commercial enterprises that do not carry out transport and forwarding activities by themselves. Their size was determined on the basis of the number of employees.

Respondents were asked to identify the transport systems used in their organization. The most frequently used systems by transport companies include GPS, freight exchanges, route accounting, work time management, fleet management, fuel accounting. However, among the other companies most commonly used are GPS, ERP, work time management (Fig. 25.3).

The conducted survey also analyzed the type of used GPS systems, what is shown in Fig. 25.4.

Table 25.1 The characteristics of surveyed entities

		Transport companies	Other companies	Total
Size(no. of employees)	Micro (1–9)	8	20	28
	Small (10–49)	24	32	56
	Medium (50–249)	16	48	64
	Large (≥250)	12	40	52
	Total	60	140	200
Routes (range)	Local	4	8	12
	Regional	12	8	20
	Country-wide	0	24	24
	International	36	84	120
	Global	8	16	24
	Total	60	140	200

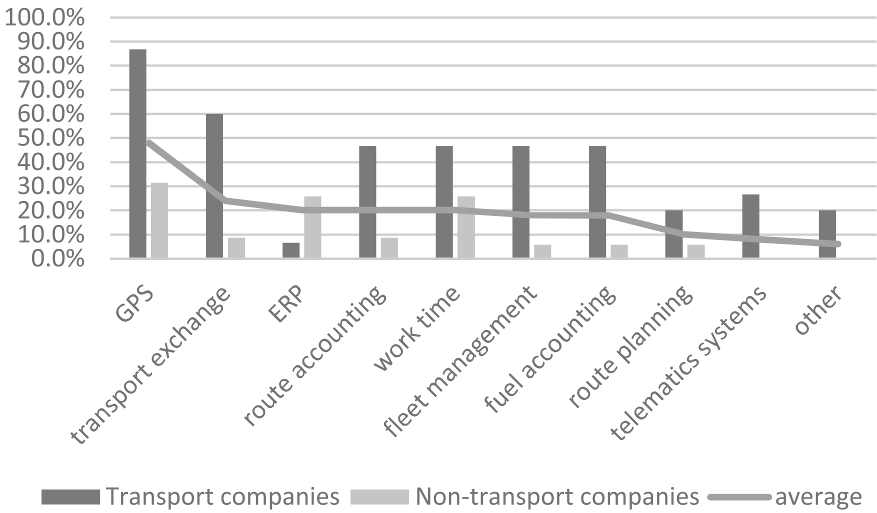

Fig. 25.3 The use of systems supporting transport management

Transport companies to the greatest extent use external or dedicated devices that track GPS systems and can indicate the location of a given vehicle in real time. Currently, all truck manufacturers are installing GPS sensors in their vehicles. Unfortunately, the problem arises when it comes to the possibility of locating all transportation units in one program. Hence, the safer way to control and monitor vehicles is to buy additional software for this purpose only. The inability to identify all cars in real time is indicated by a small percentage of transport companies (5.4%), but in the group of the non-transport companies, this is the case of a half of the entities (Table 25.2).

There is a significant problem on the side of logistics service recipients. Companies can only identify the location of their fleet or vehicles of regular contractors. It

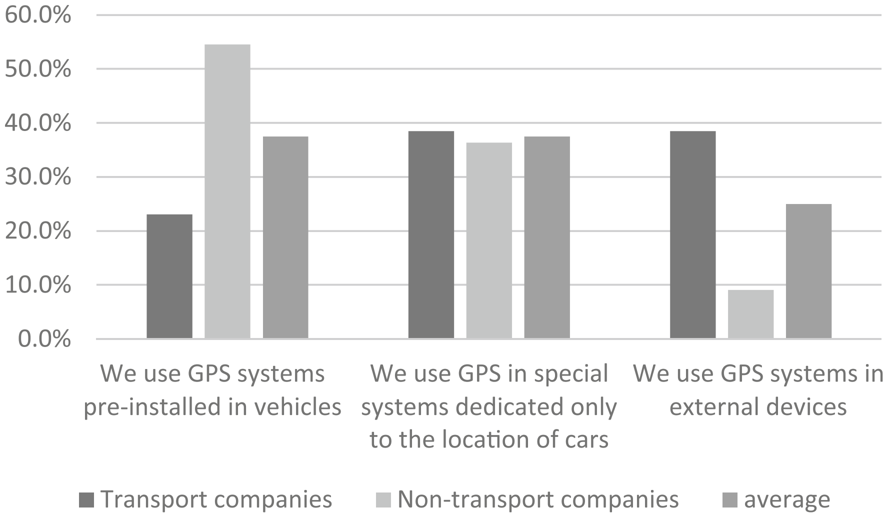

Fig. 25.4 The use of specific GPS systems in companies

Table 25.2 The ability of real-time fleet position identification in one program

	Transport (%)	Non-transport (%)
Own and external fleet	78.9	35.7
Only own fleet	15.8	14.3
No ability	5.4	50

Table 25.3 Improvement needs in the area of transport management

Improvement	Transport companies (%)	Non-transport companies (%)	Average (%)
Implementation of route planning systems	46.7	34.3	38.0
Implementing a program that will track all cars at the same time	26.7	31.5	22.0
Unifying GPS systems in vehicles	20.0	14.3	16.0
Improving settlements with drivers	13.3	25.7	22.0
Implementing telematics system	6.7	0.0	2.0
Training drivers more often	6.7	0.0	2.0

is also possible to identify transportation units through transport exchanges, but in most cases, it requires the use of two systems. Things get more complicated when using several transport exchanges. Recipients of logistics services who use transport services would like to be able to track rented means of transport. This is the matter of necessity and the ability to identify all vehicles in one telematics system. This issue was covered by the research in the area of the possibilities and needs of development of transport systems (Table 25.3).

Route planning appears to be the biggest problem for companies and implementation of this kind of system is their biggest need for improvement. After that, it was pointed out that GPS systems installed in cars should be standardized and real-time transport identification programs should be implemented that will monitor the location of all vehicles without the need to install additional devices on the logistics service provider's side.

In the research concerning the use of telematics systems, an analysis of indicators that reflect the level of the phenomenon under study may be used. To this purpose, two indicators were used: the degree of utilization of transport information systems and the degree of utilization of telematics systems using GPS for transport management.

The indicator of the use of transport information systems was based on the level of systems dedicated for transport and compared with the total number of solutions used for enterprise management:

$$\theta_{\mathrm{TS}} = \frac{T_{\mathrm{TS}} * 100\%}{S_{\mathrm{IT}}} \tag{25.1}$$

where:

θ_{TS}—the degree of the use of information transport systems

T_{TS}—number of information transport systems used

S_{IT}—the number of information systems used to manage the enterprise.

The analysis of the degree of utilization of telematics systems using GPS was based on the analysis of the ratio of telematics systems using GPS for transport management and the general number of information systems dedicated to enterprise management:

$$\theta_{\mathrm{TG}} = \frac{T_{\mathrm{TG}} * 100\%}{T_{\mathrm{TS}}} \tag{25.2}$$

where:

θ_{TG}—the degree of the use of telematics systems using GPS for transport management

T_{TG}—the number of telematics systems used that use GPS to manage transport

T_{TS}—number of information transport systems used.

In order to analyze the studied phenomenon, an index analysis and an average percentage share of the indicated answers in the survey questionnaire (according to the arithmetic average) were carried out (Table 25.4).

The research shows that transport companies make the most use of systems dedicated to this industry (90.5%), including many of them using telematics systems based on GPS (94.7%). It should be noted that among non-transport companies, the percentage of use of this type of software is also high. As much as 90.5% of them indicated that they use systems dedicated for transport, and 39.3% use telematics systems. On average, 40% for transport and 11.7% for non-transport companies, software used in the organization is dedicated to transport. Analyzing

Table 25.4 The analysis of the use of telematics systems based on GPS

	Percentage of companies using systems supporting transport management (%)	Percentage of companies using GPS systems (%)	The use of transport systems (average) in individual companies (%)	The degree of the use of information transport systems (%)	The degree of the use of telematics systems using GPS for transport management (%)
Transport	90.5	94.7	40	47	4
Non-transport	45.9	39.3	11.7	41	12

the indicator of the degree of the use of transport systems in relation to other management programs, it is 47% for transport and 41% for non-transport entities. This result depends on a large number of programs dedicated to transport and comprehensive enterprise management solutions, e.g., ERP systems, which cover various departments of companies (e.g., logistics, production, accounting, human resources, transport). Regarding the degree of utilization of telematics systems, the indicator for transport companies is at the level of 4% and is significantly lower than in non-transport companies (12%). This can be explained by the fact that telematics systems represent a small share of the transport system market. The lower indicator's value is, the stronger it will indicate the use of other systems dedicated for transport and forwarding (average) in individual companies.

It is also important to answer the question what are the factors determining the use of telematics systems. For the needs of the analysis, a probit model was created describing the probability of using a telematics system in an enterprise based on the entities surveyed for the research.

The probit statistical probability model is used when the dependent variable assumes limited values in this case it is two level. In the study, it is assumed that the value of 1 means the use of a telematics system in the company, while 0 means it was not implemented.

The probability of the enterprise using the telematics system was calculated using the formula (25.3) for the probability of occurrence of the event in the probit model [14]:

$$p_i = \text{prob}\left[Y_i = 1|X\right] = \Phi\left(x_i'\beta\right) = \int_{-\infty}^{x_i'\beta} (2\pi)^{-\frac{1}{2}} \exp\left(-\frac{t^2}{2}\right) dt \tag{25.3}$$

where Φ is a distribution function of the normal distribution and $x_i'\beta$ is a linear combination of independent variables:

$$x_i'\beta = \beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k \tag{25.4}$$

Table 25.5 Values for probit model describing the use of telematics system in company

	Coefficient	SD	p value	z statistic	Marginal effect
Const.	−1.97962	0.604258	0.0011***	−3.276	–
Size	0.741365	0.265682	0.0053***	2.790	0.294879
Sector	2.19149	0.631469	0.0005***	3.470	0.665538
Range	0.0194899	0.0330711	0.5556	0.5893	0.00775216
McFadden R^2	0.352565				
Predicted correction	80%				

***Statistical significance level of $\alpha = 0.01$

Model interpretation based on the obtained β coefficients is limited only to the direction of the dependence. In order to estimate its strength as well, one should calculate the marginal effect for changing the value of the x_k variable with the other variables constant according to the formula [14]:

$$\frac{\partial p_i}{\partial x_{ik}} = \varphi\left(x_i'\beta\right)\beta_k \tag{25.5}$$

where φ is the probability density function of a standard normal variable.

In this particular model three independent variables were implemented:

- The size of the company (*size*) classified into four groups based on the number of employees: micro (0), small (1), medium (2), large (3),
- Business sector (*sector*) indicating only two groups of entities transport (plus forwarding) companies (1) and others (0),
- The number of countries where the company provides services or sells products (range).

The probit model was computed using gretl software and the results are presented in Table 25.5.

The model has predicted correction on the level of 80%. The obtained results indicate that the activity in the transport sector increases the chance of using the telematics system in the enterprise by 66.55%. Also, the increase in enterprise size has a positive impact on the use of telematics. The probability increases by 29.49% as the company increases in size by one class. The impact of both described variables turned out to be statistically significant in contrast to the last parameter, which was the company's range. The expansion of operations by one country increases the chance of using telematics by 0.78% while the relationship was not statistically significant.

Therefore, it turned out that the use of telematics systems was not related to the range of activity of the surveyed enterprises. The most important was the fact of carrying out transport as the core activity, and the supporting factor was the size of the company indirectly related to substantial investment opportunities and a greater number of transport operations.

25.4 Transport Monitoring and Control Using Central Control IT Systems

Most companies struggle with the lack of real-time control and tracking of vehicles by using only one telematics system. Each unit is equipped with preinstalled telematics systems, but also uses various types of additional software. The usual software used to control the transport fleet is that which operates through sensors installed inside the vehicles. Transportation units are fitted with GPS-tracking systems and fuel consumption probes at the request of the company owner. Then the GPS sensor and probe synchronize with the software installed on the computer in the office. Thanks to this, the owner is able to locate all his vehicles in real time. The problem with tracking may occur when using external means of transport, e.g., by using a forwarding company, or trusted carriers, recommended or hired through freight exchange. Then it is impossible to control the cars. In addition, the implementation of GPS systems in the entire fleet generates further costs. The use of GPS systems, which are currently installed by every truck manufacturer in their vehicles, seems important. The key solution would be to implement a central telematics system throughout supply chains. Figure 25.5 shows the implementation diagram of such a central telematics system.

Figure 25.6 presents the simplified supply chain with an indication of the services of transport and forwarding companies and information intermediaries, e.g., transport exchanges, freight forwarding. It should be noted that in the case of subsequent resale of transactions on freight exchanges, the company can only act as an intermediary or forwarder, it does not necessarily have to carry out transport. Nevertheless, we deal with such situations in transport sector. The key point of the proposed system would be transferring the location of individual vehicles directly to recipients of logistics services. The first platforms with such solutions are beginning to appear in Poland (e.g., CO^3). Their task will be to indicate the location after identifying the GPS sensor regardless of its type.

The idea of the presented solution is to send location information directly from individual means of transport to the central system. Then information about the location of each vehicle can be known not only by its owner but also by the person renting a vehicle for transport on the freight exchanges, a company using the services of transport and forwarding companies, etc. This is the answer to the problem of real-time location of the vehicles, which is arised from the survey.

25.5 Conclusion

The essence of the modern market is competition. We can observe it in all aspects of organization's activity. It also exists on the transport and forwarding market, as well as on the market of software offered for transportation. Companies are increasingly trying to make the best IT software available to support all logistic

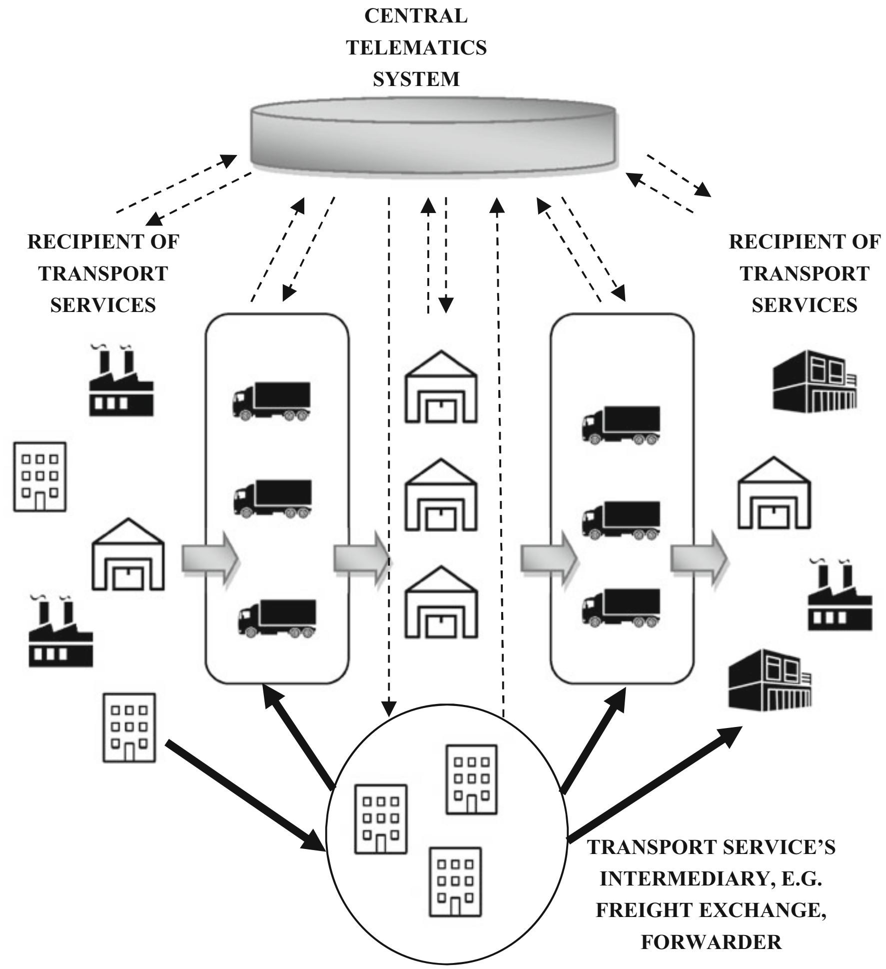

Fig. 25.5 Central control system for information from telematics systems

processes. The fact is that sometimes utility of the system becomes less important than other factors or addition to the basic product. This is the case of transport location using telematics systems based on GPS.

The main problem concerns finding real-time location of all vehicles in one system. There are many programs that support the location finding feature, but they require devices mounted physically inside the transportation unit. Although vehicles are equipped with internal GPS systems, they cannot be located in one program. There are no complex transport management systems which could play the same role as ERP systems for the company's management. On the other side of the service are customers who have rented a particular vehicle to transport their

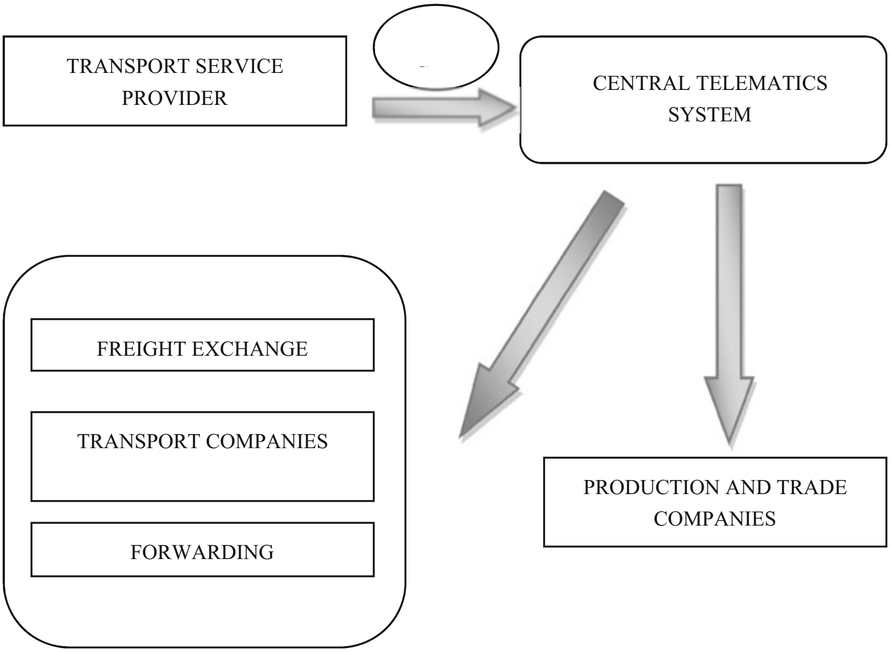

Fig. 25.6 Diagram of central communication of telematics systems using GPS

goods. They also need unrestricted and rapid access to the information about real-time location of their freight. This is another area for development.

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Chapter 26
Mobile Picking Robots: A First Study of the Effects of Human-Robot Interactions in Conventional Order Picking Systems

Dirk Kauke, Florian Sailer, and Johannes Fottner

26.1 Introduction

Order picking systems (OPS) form the centerpiece of all warehouse operations. The rapid growth of e-commerce, in particular in recent decades, has led companies to focus on their OPS processes. Over 80% of all warehouses are still operated manually, and up to 55% of the total costs for warehousing can be assigned to the order picking process [1]. On the other hand, more and more companies are facing increasing staff shortages [2]. A solution was therefore sought that would meet the flexibility requirements of manual picking and keep the scalability of the system. The most promising approach is the use of mobile robots. Like humans, mobile robots can be used flexibly as required and do not represent a rigid solution as in the case of automated storage and retrieval systems. When using mobile robots, a distinction can be made between fixed and movable shelves. In the case of movable shelves, the mobile robot picks up a shelf and transports it to a defined spot where a human does the actual pick. One of the most famous systems is the Amazon Robotic System. In the scientific world, these systems are often called Mobile Robotic Fulfillment System (MRFS). If the shelves are fixed, the mobile robot either picks the goods on its own or assists the human and provides empty picking cases [2]. This paper focuses on the mobile picking robots (MPR), which can actually pick goods.

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Regardless whether it is a classic OPS or a hybrid OPS, these types of systems must be validly planned and designed. An essential distinguishing feature of hybrid OPS is the direct co-existing between humans and robots which must be considered during planning and design.

This paper presents a simulation model that can represent a hybrid OPS. The performance relevant effects of the joint interactions shall be highlighted, and first conclusions on the layout design shall be drawn.

For this purpose, the scientific literature is first consulted in Sect. 26.2. In Sect. 26.3, the structure of the model is presented, and in Sect. 26.4 the results are discussed. The paper concludes with a summary and an outlook on future research.

26.2 Related Literature

Manual picking systems have been scientifically investigated for many years. In the course of time, the different issues have been categorized accordingly, so that a distinction can be made between strategic, tactical, and operational decisions [3]. The degree of automation or the layout is determined within the strategic decision-making process. In the course of the tactical considerations, the warehouse occupancy, among other things, is determined. The operational department decides, e.g., on batching or routing [3]. Reference [3] has examined the research method to analyze the OPS. Simulation has been used the most.

Since this paper investigates the usage of mobile robots within OPS, the literature review should rather focus on papers dealing with this specific topic. First and foremost, the work of Azadeh should be mentioned, who conducted a very extensive literature review on the various uses of mobile robots in OPS [2]. In addition, two works [4, 5] will be highlighted. There, a simulation model for Mobile Robot Fulfillment Centers was developed, which not only examines the general performance but also considers failure-handling strategies. A much older reference is [6], which already investigated the design of Kiva-Robots systems, an example for MFRS in 2008. A further literature review on shelf-moving robots was carried out by [7]. Recent work related to mobile robotics in OPS are [8, 9]. Reference [8] developed a queuing network to minimize the order throughput time. A similar approach was chosen by reference [9]. However, they clearly varied the size of the layout.

In summary, it can be concluded that there is already a large number of scientific papers dealing with different questions in the field of strategic, tactical, and operational design of MFRS. However, at this point, no scientific work can be found that has developed a model for investigating mobile pick robots, which work together with humans. The next chapter therefore serves to present this type of model.

26.3 Model Design

26.3.1 General Design

The model has been designed with the Tecnomatix Plant Simulation software. Plant Simulation is a discrete event simulation tool that is commonly used to investigate material flows and production processes. The layout of the OPS can be divided into following aspects:

A: Number of aisles per block
B: Number of blocks
W_a: Aisle width
L_a: Aisle length
W_s: Shelf width
L_p: Path section length
W_p: Path section width
D: Depot location
W_p: Pre-zone width
S: Number of workstations
C: Back cross-aisle available

Figure 26.1 shows the exemplary structure of a layout. The special feature here is that any number of blocks and storage aisles can be considered, although it is possible to display both common positions of the depot.

Each aisle consists of individual path sections. Each path section operates as a node that can be traveled in both X and Y directions. The time required to cross a path section depends on the speed of the respective participant. If an agent changes direction on a path section, the time needed to cross the section is taken into account as well as the amount of time for turning.

$t_{t,h}$: Turning human
$t_{t,r}$: Turning robot

This has the advantage that storage locations on the same side of the shelf are preferred when orders are allocated, since additional turning operations would be necessary.

26.3.2 Interaction

As robots make use of safety sensors to navigate safely throughout the warehouse environment, modeling the safety areas is therefore crucial for depicting the robot behavior, so that time losses and changes in moving speed as a result of interaction can be taken into consideration. In general, robots have two different safety areas, namely, *the protective zone* and *the warning zone*. If an object is located within

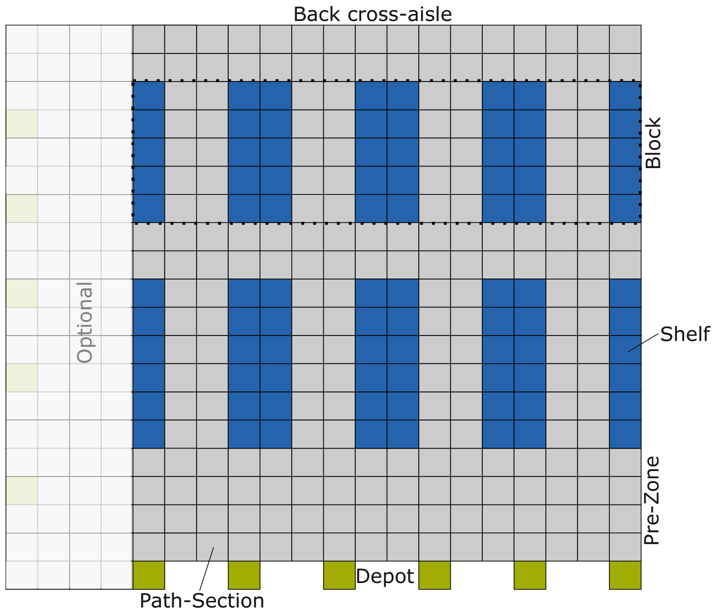

Fig. 26.1 Layout components

the borders of the protective zone, the robot stops its operation immediately. When the object is located within the warning zone, then the robot continues at creep speed until the detected object crosses the borders of the protective zone. Similarly, human order pickers observe their environment and adapt their behavior depending on occurring interactions. Therefore, the same safety concept is also applicable to human order pickers.

The protective zone When a robot or a human worker is located on a specific frame, the adjacent frames represent its protective zone in the simulation model. Therefore, system participants should recognize the objects in the adjacent frames. Depending on the position of the frame in the warehouse model, the number of adjacent elements varies between 2 and 4. The created model monitors the contents of all available successors, and interaction occurs if any of the areas are occupied.

The warning zone Similar to the monitoring of the protective zone, the content of the warning zone needs to be monitored. The warning zone in the created simulation model is defined as the frame, which is located beyond the protective zone in the movement direction of a system participant. The protective zone and the warning zone are illustrated in Fig. 26.2.

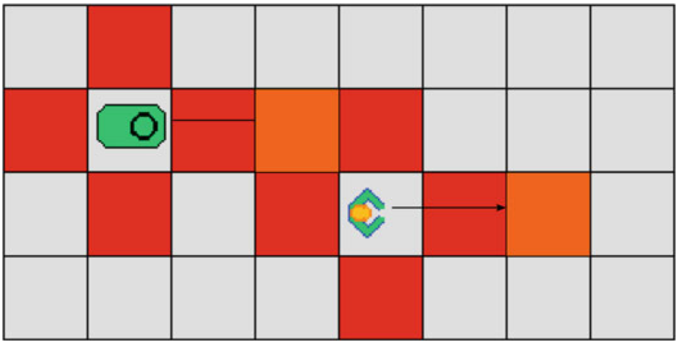

Fig. 26.2 Protective and warning zone

26.3.3 Modeling Humans and Robots

Both the humans (h) and robots (r) are based on the class transporters. Their main differences can be seen in the following variables:

v_h:	Velocity of the human	1.5 m/s
$v_{h,red}$:	Reduced velocity of the human	0.75 m/s
v_r:	Velocity of the robot	1 m/s
$v_{r,red}$:	Reduced velocity of the robot	0.5 m/s
$t_{wait,h,h}$:	Interact.loss betw. h and h	1 s
$t_{wait,h,r}$:	Interact.loss betw. h and r	3 s
$t_{wait,r,r}$:	Interaction loss of robot	5 s
Cap_r:	Capacity of a robot	12 units
Cap_h:	Capacity of a human	12 units

26.3.4 Operation and Order Structure

The sequence of the picking process is based on the classic procedure of an order picking system. A new picking order is generated at the start of every picking tour. For this purpose, a heuristic is applied based on the existing orders in the order pool. The aim is to generate a tour that is as short as possible. Once the picking order is completed, it will be handed over to either a human or robot. Currently, specific peculiarities of humans and robots are not taken into account when releasing orders. In the future, it would be conceivable that orders with higher priority could be picked primarily by humans. In addition, when allocating orders and allocating storage space, it must be taken into account which article types the robot can handle.

After the order has been assigned, it will be processed according to the generated tour. With the completed picking order, the participant returns to the depot to hand over the picked items and receive a new order.

26.4 Simulation and Analysis

26.4.1 Objective and Relevant Parameters

The main goal of the simulation study is to find out what influence the interaction between humans and robots has on the overall performance of the OPS. The previous chapter described the design of the model, including all sub-elements. The number of orders (N) processed within 1 day is used as a key figure. Each day (t_{day}) corresponds to two shifts (t_{shift}), each with 8 h of working time reduced by the break and battery charging times of the humans and robots, respectively.

The maximum number of agents ($P_{h,r}$) in the system is limited to 20. The composition is varied with each simulation run. Besides the number of humans and robots in the system, the layout is also varied. A distinction is made between the width of the aisle as well as whether a cross-aisle at the end is available. If a cross-aisle is available, the routing can change between return and traversal depending on the order. A summary of all relevant parameters can be found in Table 26.1.

Table 26.1 Basic parameters in experiments

Variable	Value
A	4
B	1
W_a	4, 6
L_a	24 m
W_s	2 m
L_p	2 m
W_p	2 m
D	South
W_p	8 m
S	8
C	True, false
t_{day}	2 shifts
t_{shift}	8 h
$P_{h,r}$	1, …, 20

26.4.2 Total Throughput in a Homogeneous OPS

During the first step, the performance development of the overall system with a continuous increase in the number of participants in the system should be considered. In this case, the system is homogeneous, i.e., either only humans or only robots is represented in the system. Figure 26.3 illustrates the performance curve among 1 and 20 participants. The highest performance is achieved by a system operated by humans only, with 6-meter-wide aisles. Furthermore, it can be seen that the cross-aisle does not provide any significant added value with regard to system throughput. If you look at the performance curve of the robots within the same system, you can see that it is significantly lower on one hand and, on the other hand, there is no difference at all between return and traversal routing. The lower performance is caused by the fact that the motion sequences of the robot are significantly slower and the time loss due to interactions (waiting, evasion, etc.) is significantly higher.

If one looks at the remaining two pairs of curves, different aspects can be determined. With seven or more participants, both pairs of curves are below the performance of the 6-meter-wide systems. This is mainly because the narrow aisles provide less space for both groups of participants to move without interaction. Consequently, the interactions increase and the performance decreases. It can be seen that the loss of performance of the human compared to the robot is significantly

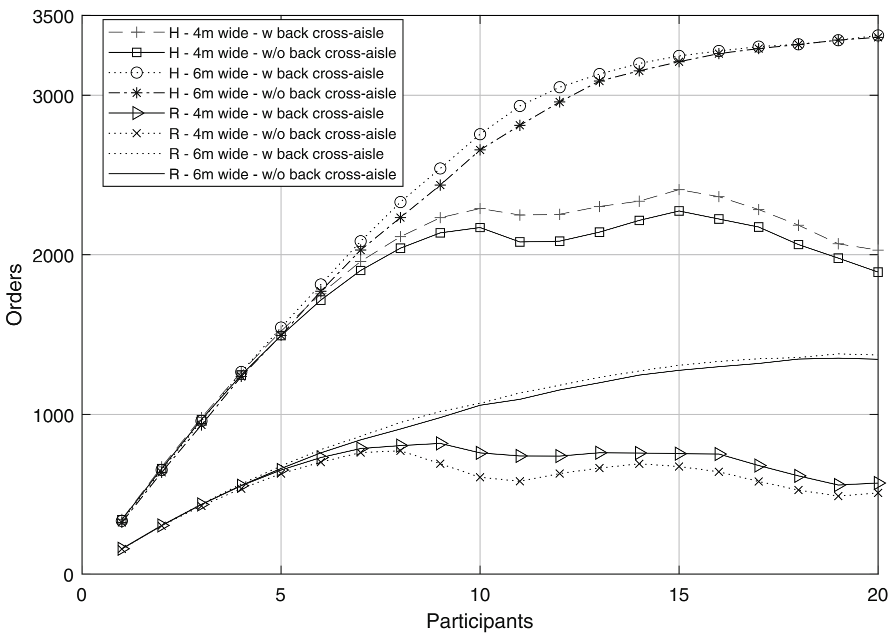

Fig. 26.3 Performance curve for different system configurations

higher. Finally, it becomes apparent that in the 4-meter-wide systems that have between 7 and 20 participants, the performance both increases and decreases. Despite repeated experiments, this can only be explained by the increase in interactions. Since order release is independent of the utilization of individual aisles, a higher number of interactions can therefore occur in individual configurations, although the maximum number of participants has not yet been reached. It can thus be stated that the width of the aisles has a considerable influence on the performance of the overall system.

26.4.3 Average Throughput

In the previous chapter, it became obvious that with an increasing number of participants, the performance can vary. In the following chapter, the question of average performance development will be examined. Figure 26.4 shows the average performance trends of humans and robots in a 6-meter-wide aisle system with a back cross-aisle.

At first, the difference between human and robot performance is noticeable, as shown in Fig. 26.3. Furthermore, it can be seen that the performance curve of the robot is an equable curve, whereas the other graph decreases more rapidly between 10 and 20 humans. However, the average performance is reduced by around 50% in both cases. The average human performance starts at a homogeneous system at about 340 orders and drops to 160 orders within 2 shifts. A single robot, on the other hand, manages almost 150 jobs within 2 shifts. When a total of 20 robots are in operation, the average output per robot in 2 shifts is reduced to about 70 orders.

Figures 26.3 and 26.4 show the course of performance, with an increase in the number of actors of the same type. In other words, how does the human-operated system behave when more people are added. The performance loss shown in the

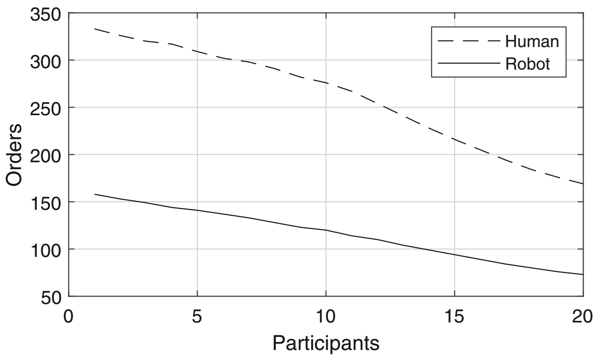

Fig. 26.4 Average performance trends of humans and robots in a 6-meter-wide aisle system within two shifts

figure proves the effectiveness of the warning and protection zone. In the following chapter, the performance development in the hybrid system will be more closely examined.

26.4.4 Performance in Hybrid OPS

There is currently no other simulation model that can determine the performance of a hybrid OPS. Due to the constant increase in different market-ready solutions in this area, a tool for system design is absolutely necessary. One of the primary questions in this type of system designs is the performance and which human-robot combination best achieves this. Figure 26.5 illustrates the performance of the above-defined system.

Figure 26.5 shows the single performance of humans and robots as before. Additionally, all possible combinations of humans and robots and their performances are shown. Assuming a target value of 2000 orders per day, different combinations of humans and robots are possible. In theory, the minimum number of humans and robots would be an optimal solution ($P_{7,1}$). However, a predominant lack of human resources can lead to the fact that a continuous availability of, in this case, seven humans cannot be guaranteed in practice. For this reason, it may be necessary to fall back on other possible combinations. The next variant with a capacity $\geq$ 2000

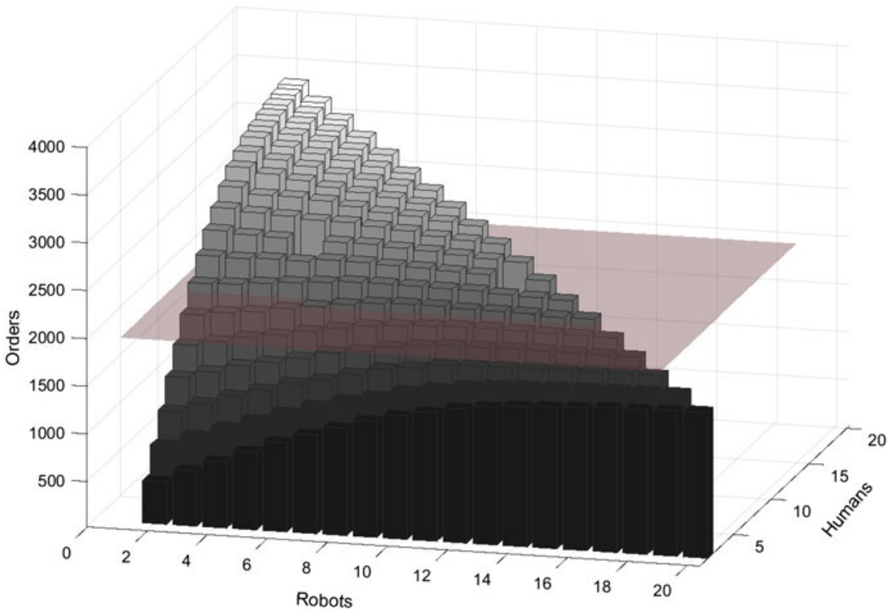

Fig. 26.5 Combination of all possible participants in OPS and their performances

orders would be ($P_{6,5}$). This means that the loss of one human in this system configuration must be compensated by five robots. It becomes clear that the greater the sum of $P_{i,j}$, the greater is the necessary compensation of a human by robots. This shows the high necessity of a perfectly coordinated system, so that possible shortfalls in human resources have to be compensated for by only a few robots. In addition, the system should of course be able to provide a solid base performance through possible strategy adjustments. Zoning is one possible strategy adjustment for increasing the system's basic performance. This is examined in more detail in the following chapter.

26.4.5 Zoning

In this context, zoning means that humans and robots pick in different aisles of the picking system. This means that the orders are assigned to either a human or a robot, depending on the aisle. An interaction can therefore only take place around the depot. Figure 26.6 describes the applied scenario.

In industrial applications, the aim is to ensure that humans and robots can work more freely in their work processes. It should be apparent that people work more efficiently if they work exclusively with humans. The same applies to robots. Due to the significantly faster and less comprehensible movements of humans, it can be assumed that the robot's performance is more often disrupted, which results in a

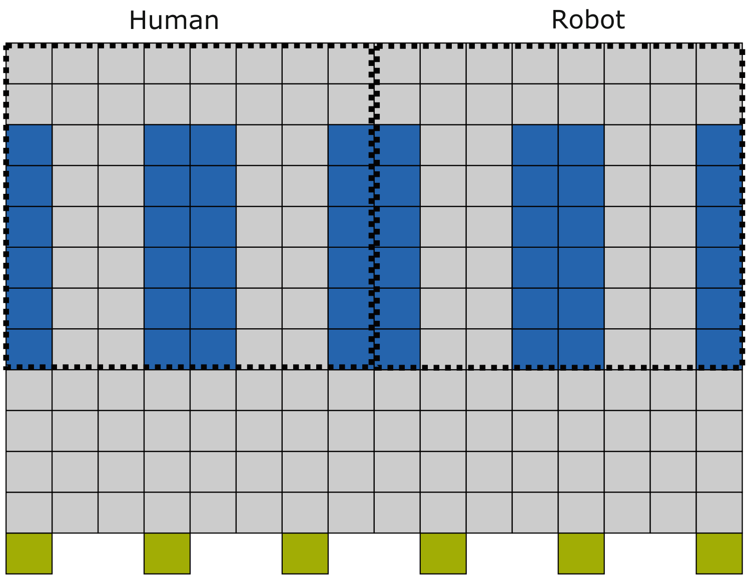

Fig. 26.6 Application of a zoning

decreased overall performance. Therefore, in this chapter, the development of the overall performance is shown. The effects can be found in Table 26.2.

All in all, it can be stated that the performance increases through the use of zoning in the OPS. However, the performance decreases in some constellations. In most cases, however, these are homogeneously aligned systems, which means that the fixed allocation of aisles can have a negative effect because too many agents have to operate in only two aisles, which leads to more interactions. In a balanced system, however, an increase in performance in the middle single-digit range can be detected without exception. This is mainly due to the fact that by working separately, both agents are not confronted by behavior different from their own, which again leads to an increase in efficiency. Since the reference system is a relatively small system with only four aisles, the question arises whether the added value of fixed zoning is more drastic in larger systems. This should be considered more closely in future studies.

In practice, however, such strict zoning poses a number of challenges. In particular, warehouse occupancy and batching can make such an approach difficult. The robot will probably not be able to pick the entire range of articles. This means that the size of the robot zone is directly dependent on the assortment of pickable articles by the robot if a strict separation within the aisles is desired.

On the other hand, turnover frequency and thus batching play a role. There is no question that the robots are less efficient. If the articles in the robot zone are fast-moving items, the robot may not be able to provide the required performance and the warehouse builds up backlogs. Accordingly, fast-moving articles should be kept in the human zone as a precaution, although it is conceivable that the robot is not working at full capacity due to slow-moving articles and, therefore, is not operating economically.

It is difficult to find a generally valid solution for this problem. In individual cases, the reference system with the specific warehouse occupancy and order load must be examined. However, a semi-fixed zoning represents a conceivable alternative. Here, the robot moves exclusively in the assigned aisles. In exceptional cases, however, humans can also pick in the robot zone. The performance development could then be compared with that of fixed zoning (Table 26.2).

26.5 Conclusion and Future Research

The increasing lack of human resources in logistics is leading to an increase in demand for flexibility initiatives in manual OPS. The presented MPRs are one possible approach to meet this demand for flexibility. For the first time ever, this paper has presented an approach in which hybrid OPS can be investigated using a simulation model. Initially, the interaction between humans and robots was the main focus. It became clear that in homogeneous systems, the interactions increase with an expansion of the agents and the performance decreases accordingly. Especially the width of the aisle as well as the presence of a back cross-aisle influences

Table 26.2 Increased performance through zoning

	Human																		
Robot	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	4%	5%	5%	4%	3%	4%	2%	2%	1%	0%	0%	−1%	−1%	−1%	−1%	−3%	−1%	−2%	−10%
2	5%	6%	7%	−8%	2%	6%	4%	5%	4%	3%	3%	1%	0%	−9%	−1%	−1%	−2%	−10%	–
3	5%	6%	7%	7%	7%	8%	6%	5%	5%	3%	1%	0%	0%	0%	−1%	−10%	−15%	–	–
4	4%	6%	7%	8%	9%	8%	7%	6%	18%	−9%	0%	0%	0%	−1%	−1%	−1%	–	–	–
5	2%	6%	6%	9%	8%	8%	6%	4%	4%	1%	0%	−16%	0%	−1%	−2%	–	–	–	–
6	1%	4%	7%	7%	7%	2%	4%	3%	2%	1%	0%	0%	0%	−1%	–	–	–	–	–
7	−1%	3%	5%	7%	6%	5%	4%	3%	2%	1%	0%	0%	0%	–	–	–	–	–	–
8	−1%	3%	3%	5%	5%	3%	3%	2%	1%	1%	0%	0%	–	–	–	–	–	–	–
9	−3%	1%	3%	4%	4%	3%	2%	−3%	−5%	0%	0%	–	–	–	–	–	–	–	–
10	−2%	1%	2%	2%	2%	3%	2%	1%	1%	0%	–	–	–	–	–	–	–	–	–
11	−4%	0%	1%	2%	2%	2%	2%	13%	1%	–	–	–	–	–	–	–	–	–	–
12	−4%	−1%	2%	2%	2%	2%	2%	1%	–	–	–	–	–	–	–	–	–	–	–
13	−4%	−1%	2%	2%	2%	2%	2%	–	–	–	–	–	–	–	–	–	–	–	–
14	−3%	−1%	1%	1%	1%	1%	–	–	–	–	–	–	–	–	–	–	–	–	–
15	−2%	0%	1%	1%	1%	–	–	–	–	–	–	–	–	–	–	–	–	–	–
16	−3%	−1%	0%	0%	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
17	−2%	−1%	0%	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
18	−2%	−1%	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
19	−3%	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

the performance. It was shown that the average performance of both participants decreases equally with an increase in the number of participants.

In the second part of the paper, the hybrid systems were examined more closely. The previous results were again confirmed. However, it also became clear that different constellations are possible if a specific target performance (e.g., 2,000 orders per day) is taken into account. A minimum total number of actors always lead to a high number of humans and only a few robots. Reducing the number of humans by replacing them with robots cannot be achieved at a one-to-one ratio. In the presented application scenario, the performance of one human could only be replaced by five robots. This illustrates the necessity of an optimally coordinated system, possibly even by adapting individual strategies.

One such strategy is to zone the picking system. Two aisles were assigned to robots and two aisles to humans. This means that they also pick in only their two aisles. It became clear that in balanced systems (e.g., $P_{6,5}$), an increase in performance is to be expected. For an industrial application, however, the batching and storage assignment must be considered more closely.

Future research should first consider the influence of zoning for different system sizes. Since the examined system is a rather small-scale system, the effects could be more significant for larger systems. Furthermore, the influence of multiple cross-aisles on human-robot interactions is still unclear. Furthermore, the influence of multiple cross-aisles on human-robot interactions is still unclear, and the presented semi-fixed zoning should be further explored. In conclusion, it can be stated that the use of MPRs will increase in the future and so will the need for suitable planning tools.

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Chapter 27
How Frustrated Are You? User Perception About Different Videoconference Quality Degradations

Marko Matulin, Štefica Mrvelj, and Borna Abramović

27.1 Introduction

For the first time, the COVID-19 virus pandemic has caused a slowdown or complete stalemate across many industries and business sectors in 2020, on a global scale. While many authors are analyzing the social, economic, political, health, and other effects of this pandemic, the focus of this paper is not on the crisis itself and its direct or indirect impacts. The primary goal of our research is to work toward uncovering user quality of experience (QoE) when using videoconferencing applications, regardless of the pandemic. Nevertheless, it is indisputable that the existence of the epidemic and the lockdown measures, which were in power in most countries greatly affected respondents of our survey, i.e., their willingness to participate in such research and thus contributed to the validity of the results presented here.

When browsing through the latest videoconferencing market size reports, such as [1, 2], interesting information can be obtained, which can paint a background image for this paper. Firstly, one should note that since 2010 the amount of telecommuting has more than doubled, and it is expected that within the next decade, around half of the working population will take part in videoconferencing. The shift is already happening in some countries (e.g., 54% of workers in the United States frequently participate in videoconferences). Naturally, one of the most significant incentives for using this technology is potential cost reductions, mainly transportation costs (up to 30% according to [3]), but also reduction of business and operational costs, as well as increased time management efficiency. Currently, the largest share in this market holds the Zoom videoconferencing platform. In December 2019, Zoom recorded ten

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million users per month on average. Due to the crisis, the number rapidly increased to 200 million at the beginning of 2020. It is predicted that by the end of 2020, the market size of this industry will reach 6.4 billion US dollars.

Apart from the Zoom videoconferencing platform, there are dozens of others in the same pool, fighting for their place under the sun; hence it is safe to argue that this is a competing industry with expected high growth in the upcoming years. The increase is even more accelerated due to the unique circumstances imposed by the pandemic. Hence, our motivation to research user experiences and practices when using videoconferencing applications is clear and well-timed. Knowing how a user perceives different quality degradations during the online meetings (e.g., different video and sound artifacts), depending on their meeting role and meeting purpose, their past experiences, etc., can be of crucial importance for quality of service (QoS) and QoE management in IP (Internet Protocol) networks. The knowledge can also be utilized for user QoE modeling and prediction in a specific use case, as it is done in [4, 5] for video streaming service.

The remainder of this paper is structured as follows. In Sect. 27.2, we provide a brief overview of related work. Section 27.3 brings a description of the data collection methods, i.e., a description of the questionnaire used in the survey and how the potential respondents are approached. General statistics about the sample can also be found in this chapter. Obtained results and discussions can be found in Sect. 27.4. There are three main result categories that we discuss: (a) characteristics of a user environment from where the conferences are most often accessed, (b) description of a typical online meeting scenario, and (c) user perception about the meeting quality if specific quality degradations occur. Concluding remarks and outlook of our future research paths can be found in Sect. 27.5.

27.2 Related Work

Before focusing this review of related work on videoconferencing technology, it is beneficial first to devote attention to the QoE concept and its definitions. The birth of the QoE idea came at the beginning of the new millennia when different multimedia applications became widely available to the general public via the Internet. For each type of application, different network requirements were defined. These are called QoS requirements, and they are typically used for network design and management. For instance, the quality of Internet telephony is considered acceptable if the packet latency is maintained below 150 ms. Thus, network operators were given a set of quantifiable targets per specific application type, which should ensure satisfied customers. However, it was discovered that sometimes users are not completely satisfied with the services even if the QoS requirements were met. Something was missing from the equation.

Different authors tried to reveal why the relationship between measurable QoS requirements (i.e., network performances) and user perception is not as straightforward as it was expected to be. It was discovered that many qualitative, subjective factors, which are difficult to measure, significantly affect user opinions about the service. These factors are, for instance, ease of use, service usability, level of entertainment, user expectations, and many others. Hence, a new concept was introduced (QoE) that provided a more holistic approach to service quality analysis.

Today the reference point for learning about QoE and understanding it can be found in [6] from here we provide the following QoE definition: "Quality of Experience is the degree of delight or annoyance of the user of an application or service. It results from the fulfillment of his or her expectations with respect to the utility and/or enjoyment of the application or service in the light of the user's personality and current state." As seen from this definition, the user is the center point of the quality analysis. QoS is still an essential factor for ensuring satisfied users but is not the only one; that was the significant change that was introduced with the QoE concept.

Videoconferencing technology has been in use for over 20 years in many industries and business sectors. A simple Web of Science (WoS) search of the term "videoconference" can reveal various disciplines where this technology has been studied in the past. The treemap of WoS search results, showing the top ten disciplines and the number of published papers per discipline, can be found in Fig. 27.1.

As seen from the figure, a considerable amount of research endeavors have been undertaken in the healthcare and education fields. The focus of those papers is mainly on the application of videoconferencing technology. This is not in the center of our review of related work. We are more concentrated on technical aspects of videoconferencing, i.e., how the service performs in different network conditions and how that performance affects end users and their subjective opinions about the service. Hence, the papers of interest in this review come from more technical disciplines shown in Fig. 27.1.

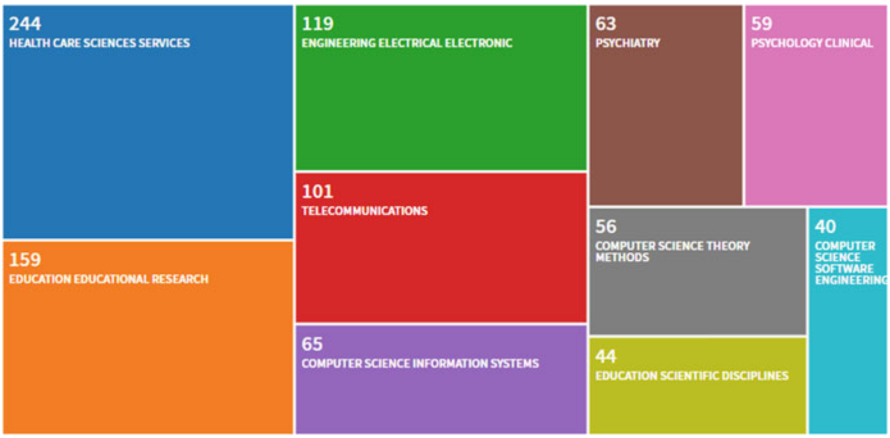

Fig. 27.1 WoS search results for the term "videoconference" visualized with the treemap, indicating the number of published papers per specific field of study

An essential factor for a satisfactory videoconference session, from the end-user point of view, is a successful video transmission with as little video artifacts and transmission interruptions as possible. However, unlike video streaming sessions, when a video is stored and accessed through popular video portals (like YouTube or Netflix, for instance), the video signal during a videoconference session is not stored before playback. It is transmitted live from one meeting participant to a group of peers (multicast transmission) that are located in different network locations, often with limited upload/download capabilities. The limitations, in turn, can affect video transmission quality and, thus, quality of experience for all peers participating in the session. For this reason, a significant amount of work has been published on topics such as video coding techniques for videoconferencing [7, 8], adaptive video streaming methods [7, 9, 10], or multicast video transmission over wireless networks [11, 12], all focusing on the objective aspects of videoconferencing service and its quality.

On the other side of the spectrum of published research exists papers that are focused on subjective aspects of videoconferencing quality, i.e., the analysis of end-user opinions, experiences, and perceptions of the service quality. Our paper falls into this category. However, it is interesting to note that, while user QoE for video streaming is extensively researched area, the research of user QoE concerning videoconferencing is somewhat limited. Given the latest rapid growth of users of this service, it can be expected that researchers will devote more time to investigate QoE for videoconferencing.

In [13], Belmudez discussed audiovisual quality aspects for interactive communication and presented the QoE model for videoconference service. The model operates with objective (quantifiable) parameters such as packet loss rate. Another attempt to bridge a gap between network performances and user QoE for this type of service is made in [14]. They developed different service distortion scenarios (namely, introducing packet loss, packet reordering, and experimenting with different coding bit rates) and evaluated user experience using perceived video quality (PVQ) metric. In [15], an interesting experiment has been conducted to determine how different network conditions affect the ability of four test subjects to collaborate and build a Lego model over a videoconferencing platform. This paper is important from the QoE for the videoconferencing perspective due to the following. The authors have moved away from mere video quality analysis and invested additional efforts into disclosing how the subjects interact with each other and how they reach an understanding in a real-life scenario about the task in hand.

Rao et al. [16] experiment with the QoS–QoE relationship for videoconferencing. Similarly to [14], they developed different network performance distortion scenarios (by introducing jitter, packet loss, uplink throttling, and latency) on the sender side. Then they quantified the perceived video quality on the receiver side. However, the authors did not conduct subjective tests with actual test subjects. Instead, the incoming video signal was stored and then compared to the original video (i.e., full reference method was used). The DMOS (differential mean opinion score) value was then computed as a measure for human judgment of video quality. Though more efficient compared to the actual subjective tests, results obtained from this type of experiment rely on the accuracy of someone else's mapping between QoS and QoE.

In the papers reviewed here, the subjective experiments were conducted after the subjects took part in a videoconferencing session (in real-life or in a laboratory), or they evaluated the quality of one or more specific videoconferencing video streams. Our research differs in that respect. We were not focused on examining the quality of particular session(s) or incoming video stream(s) since we were unable to measure network QoS of our survey respondents during their online meetings nor the audiovisual quality of the incoming videos. Instead, we took advantage of the pandemic. We reached to our respondents (who participated in many videoconferences due to the lockdown measures), asking them to disclose their opinions about the quality of their typical videoconferencing session. We were especially curious about how different meeting roles affect the subjects' perception of quality degradations, which may occur during the sessions. To the best of our knowledge, this is the first attempt of that kind. Moreover, being unable to correlate between user QoS and the perception of quality for a specific session, we shifted the focus away from the *causes* of quality degradations (e.g., packet loss rate, jitter, and latency) on to the *effect*, i.e., user perception about specific degradations.

27.3 Survey Description

During the lockdown, businesses across different industries shifted into in-home office mode. In turn, this caused a massive usage of online meeting tools. As discussed previously, we took advantage of these circumstances and decided to design and conduct a survey aimed at disclosing user experiences and practices when using these online meeting platforms. In this section, we describe the questionnaire used in the study and provide some general statistics about our respondents.

27.3.1 The Questionnaire and the Response Rate

The questionnaire used in the survey was created on the LimeSurvey platform. It contained 31 questions and took around 15 min to complete. The questions were grouped into five categories, as follows.

1. Category name: *First things first*. Description: With this group of questions, we learned if the respondent participated in videoconferences over the past month. If the answer was *Yes,* then we asked how many of them and when his/her last meeting was. If the answer was *No,* the survey ended.

2. Category name: *Tell us something about yourself.* Description: General demographic data were collected with this question category (respondents' gender, age group, the status of their education, and employment).
3. Category name: *We want to know a few things about your environment*. Description: The respondents answered from where they usually connect to the meetings (home or work or both), on which type of device they often connect (desktop computer, laptop, smartphone, or tablet), on which type of network (WiFi, DSL, mobile network, etc.). Here we also asked the respondents to imagine the following scenario: *You are in front of your commonly used device for the meeting(s). The device is connected to the Internet, as you described. You are not currently in a meeting, and you just want to watch, e.g., a YouTube video from your favorite channel.* Then we asked them how long it takes for a video to start, how frequent rebuffering events are, does the video resolution often changes. As discussed earlier, we were unable to measure network QoS of our respondents; hence, the purpose of this question was to indirectly learn about the quality of the respondents' network connection, which they typically use for videoconferencing.
4. Category name: *We will now learn more about your usual online meeting scenario*. Description: We asked respondents to rank their most common meeting purposes (work-related or socializing with friends and family), the most common application used (we provided a list with over 100 different items to choose from), their usual meeting role (leader and presenter, presenter, participant, or guest).
5. Category name: *Tell us your opinions about meeting quality*. Description: The final category contained questions about participants opinions about which parameters are essential for a good quality meeting (sound and image quality, screen sharing, application interface, understanding how the role system works, etc.), which quality degradations are usually appearing when they are on the meeting (different video and sound degradations, meeting disconnections, etc.) and how frustrating it is to them to experience those degradations (evaluated on a five-point scale). The respondents were also asked to assess how frustrating the degradations are if they are in different meeting roles. Lastly, we asked if the degradations have any impact on their level of understanding of the meeting topic.

When we felt necessary, additional explanations were provided alongside questions. For instance, when asked which type of network is most often used for accessing the videoconferences, the respondents were provided with a short explanation of what is WiFi, DSL, mobile network, and other technologies they could select.

The survey lasted for 3 weeks, and it was anonymous. Due to the lockdown measures, we reached the potential respondents via LinkedIn and ResearchGate platforms and using personal contacts with colleagues working in other universities. Moreover, we used mailing lists of different networks we are members of (such as CIVITAS network, Croatian Scientist network, Shift2Rail Community, EURNEX, and others). In total, 751 people took part in the survey. After the exclusion of uncompleted questionnaires, the data analysis was conducted on 574 questionnaires. However, 33 respondents indicated that they have not participated in videoconferences over the past month; hence, the results presented here are based on 541 fully completed questionnaires of respondents who participated in the meetings. Note that we enabled cookies in the LimeSurvey settings, so respondents could complete the survey only once from a specific device (unless they deleted the cookies on the devices and revisited our LimeSurvey website; however, we firmly believe this is an unlikely scenario).

27.3.2 General Information About the Sample

The gender distribution of our respondents (541 questionnaires) is 51.2% females and 48.8% males. The age group distribution is as follows: under 18 (0%), 19–30 (13.86%), 31–40 (28.28%), 41–50 (33.27%), 51–60 (17.93%), 61–70 (5.91%), 71 or older (0.74%). Over 90% of the respondents holds a faculty degree (bachelor's, master's, or doctorate) and works full time or part time.

Figure 27.2 shows the distribution of the online meeting number on which the respondents participated in the past month (looking back from when they were completing the questionnaire).

As seen in Fig. 27.2, our respondents are experienced users of videoconferencing platforms, which is highly beneficial to us and gives us a strong basis for data interpretation from now on. Moreover, close to 38% of respondents had their last online meeting the same day when they were completing the questionnaire, 23.66% had it the day before, 20.15% from 2 to 4 days before, 11.46% from 5 to 7 days

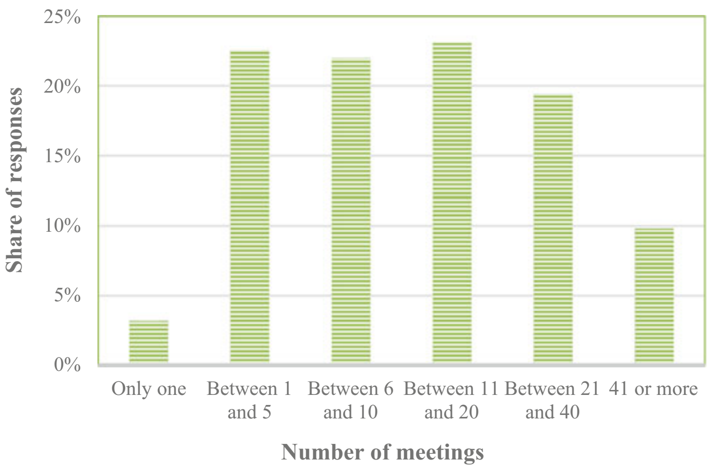

Fig. 27.2 Distribution of the number of meetings in which the respondents participated

before. Hence, over 93% of respondents had their last meeting within 1 week before they participated in the survey. Given the distribution of the number of conferences and the time of their previous meeting, we can strongly argue that the respondents were able to evaluate their experiences with videoconferencing service objectively. Furthermore, given the respondents' gender and age group distribution, as well as their education and employment status, we can argue that the sample is close to the ideal when trying to evaluate the videoconferencing quality since this technology is primarily designed for the business sector.

27.4 Results and Discussion

As announced in the Introduction, we grouped the results of our survey into three main categories. First, characteristics of a user environment were analyzed, focusing on the description of user network conditions. Second, a description of a typical videoconferencing scenario was obtained for each respondent (we learned about, e.g., the most common meeting role of respondents, the most common purpose of the meetings, etc.). Third, respondents' perception about the quality was investigated concerning different degradations which they may have experienced.

27.4.1 Characteristics of a User Environment

The respondents were asked to rank the devices they most frequently use for conferencing. They were able to choose from four different devices: laptop, desktop computer, smartphone, or tablet. The results of their ranking are shown in Fig. 27.3.

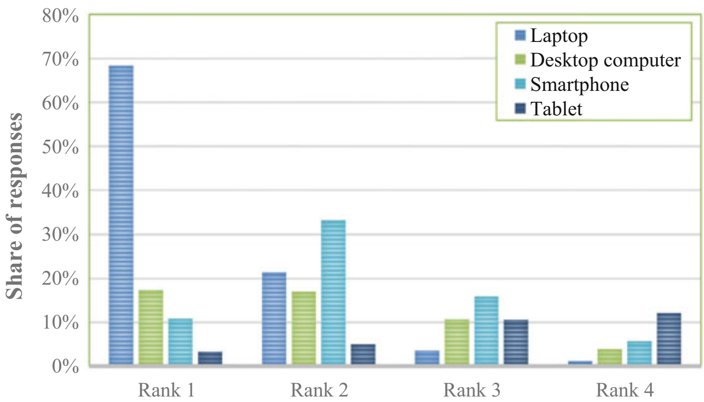

Fig. 27.3 Ranking of devices most frequently used for conferencing

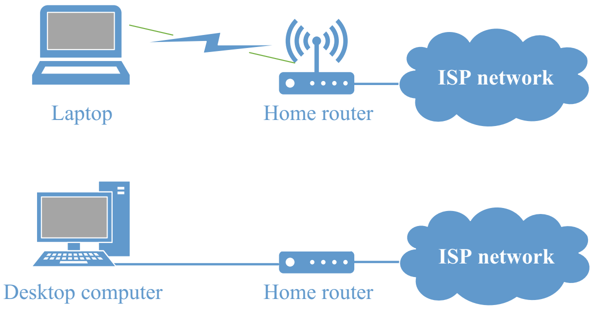

Fig. 27.4 Two most common respondents' network topologies

The figure shows that the respondents' first choice of a device used for videoconferencing, i.e., rank number 1, are laptops (68.39%) and desktop computers (17.38%) which is expected since it is more efficient to use those types of devices for holding presentations, for instance. If we look at which devices were most frequently ranked second, we find a smartphone device (33.27%). These devices were usually connected to a WiFi (66.54%) or DSL network (15.53%). Since over 72% of respondents stated that they are traditionally attending videoconferences from their home, we infer they are using home WiFi or DSL network. Hence, it is safe to say that the respondents' home network topology usually looks as illustrated in Fig. 27.4 (two most frequent cases).

We tried to learn more about the network performances at the location of our respondents by asking them to imagine a hypothetical scenario and answer if provided statements are true or not. The scenario description was: *You are in front of your commonly used device for the meeting(s). The device is connected to the Internet, as you described. You are not currently in a meeting, and you just want to watch, e.g., a YouTube video from your favorite channel.* The results are presented in Fig. 27.5.

The logic behind our proposed scenario is that video streaming service is one of the bandwidth-hungry applications. Hence, if a respondent can watch, e.g., a YouTube video steam without many interruptions, then their network environment is most likely suitable for attending videoconferencing sessions as well. It is worthy of repeating that we were not able to measure network QoS of our respondents nor analyze the audiovisual quality of the incoming stream, so this was an attempt to find out how their network usually performs.

27.4.2 Description of a Typical Videoconferencing Scenario

In this question category, the provided answers disclosed the most common purpose of the videoconferences (Fig. 27.6), applications used for hosting the conferences

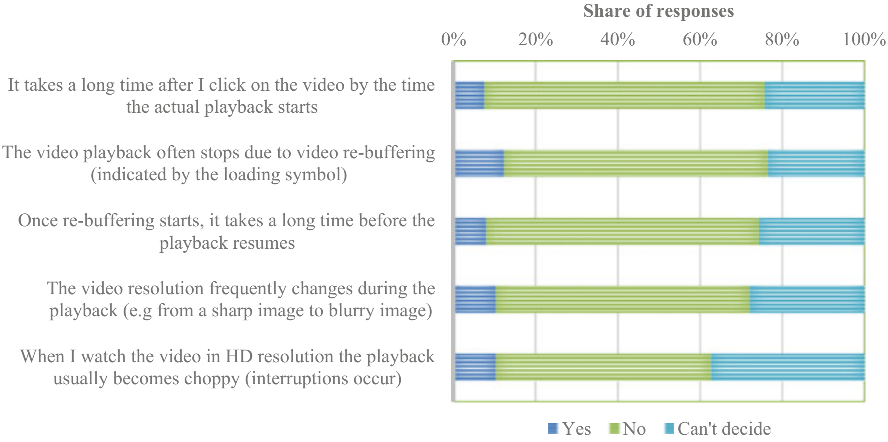

Fig. 27.5 Respondents' opinions about predefined statements describing the imagined scenario

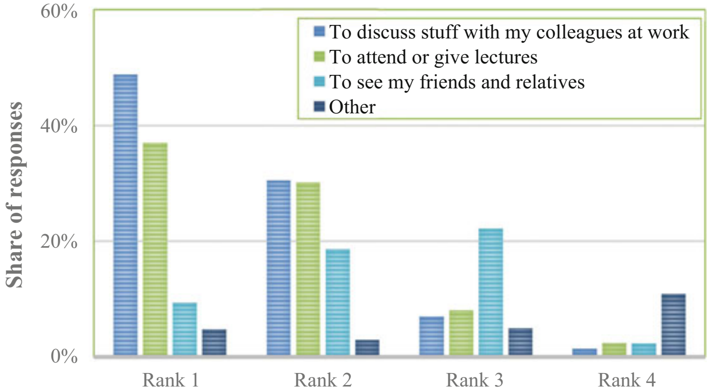

Fig. 27.6 Ranking of the most frequent meeting purposes

(Fig. 27.7), and most frequent respondents' meeting roles (Fig. 27.8). Figure 27.6 shows that the most frequently ranked purpose on the top of the list was either business meetings (48.80%) or school/university-related meetings (36.97%). The trend is the same if we look at which purposes were usually ranked second. *To see my friends and relatives* was the most frequently ranked purpose in the third place (22.18%), yet this purpose was often listed second as well (18.67%).

We already discussed in the Introduction how the Zoom videoconferencing platform is the current market leader in this sector. Hence, it is not unexpected to find that this platform is most frequently ranked as the number one choice between different videoconferencing applications (Fig. 27.7). It can also be seen that Microsoft Teams is one of the most popular applications, perhaps due to the availability of Office365 service to school/university employees and students.

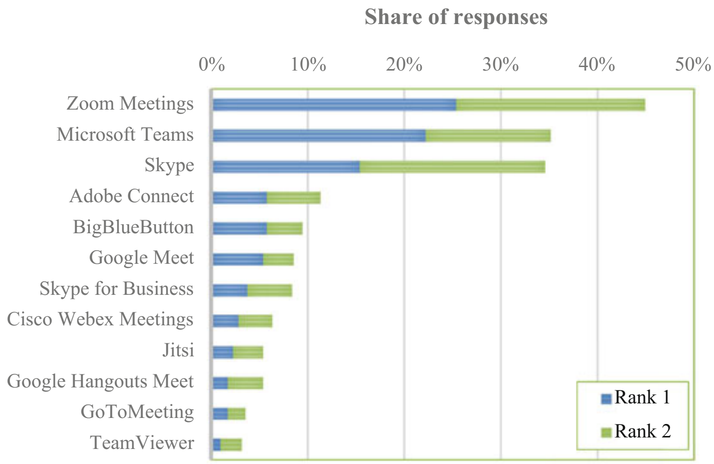

Fig. 27.7 Ranking of the most frequent applications used for the meetings

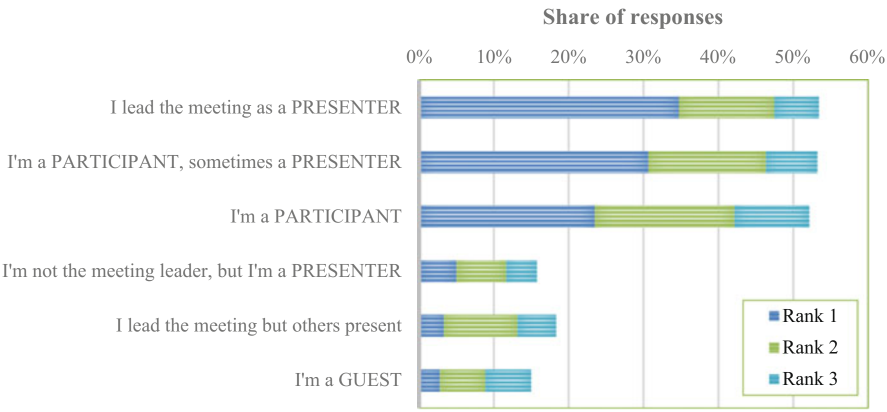

Fig. 27.8 Ranking of the most frequent respondents' roles in the meetings

Moreover, if we include Skype and Skype for Business into this brief discussion, it could be argued that Microsoft, with its' product pallet, is more dominant compared to Zoom in this market. Yet, due to the limited scope of our research and the number of respondents, we cannot claim that. Note that the respondents were provided with the list of over 100 different videoconferencing applications to rank, but, for the sake of clarity, the figure shows only the top twelve applications and only two rank levels.

Different videoconferencing applications have similar role systems implemented. Usually, there is a presenter role (a person who is talking most of the time, often shares a screen to show, e.g., a PowerPoint presentation), a participant (a person who listens but can talk if allowed), and a guest role (a person who can only listen

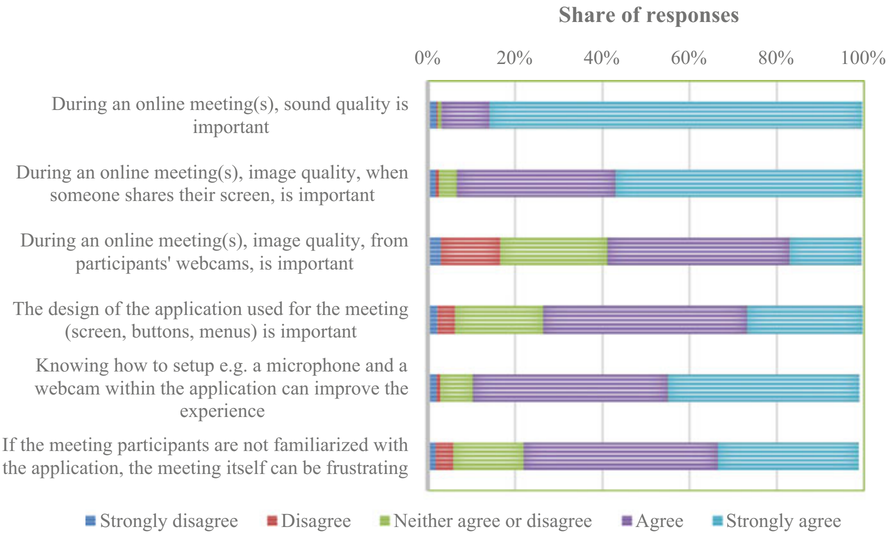

Fig. 27.9 Respondents' opinions about which aspects of an online meeting are essential for its quality

to others). Naturally, one or more persons is managing the meeting, giving roles to other peers. We explained this to the respondents when they were asked to rank the roles they usually take when attending videoconferences. The results of this analysis are depicted in Fig. 27.8 (showing only three top rank levels, for clarity reasons). We see that *a presenter* role is most frequently ranked as number one (34.75%), followed by *a participant, sometimes a presenter* mixed role (listed as number one by 30.68% of respondents). We see that the respondents assumed different roles during their conferences. That made them more experienced, i.e., they were able to evaluate the conferencing quality from different perspectives, which is vital in this research.

27.4.3 User Perception About the Meeting Quality

User perception about the meeting quality was the final question category of our questionnaire used in the survey. Here we first asked the respondents to evaluate how much they agree or disagree with the statements listed in Fig. 27.9. The objective was to discover their opinions about the importance of sound and image quality, but also about the importance of the application design, the attendances' abilities to set up their equipment, or operate with the application used for hosting the conference.

From the figure, we see that majority of respondents (85.40%) *strongly agree* that sound quality is an essential aspect of the meeting. The image quality of a screen-sharing video stream is also considered as important, i.e., 56.56% *strongly agree,*

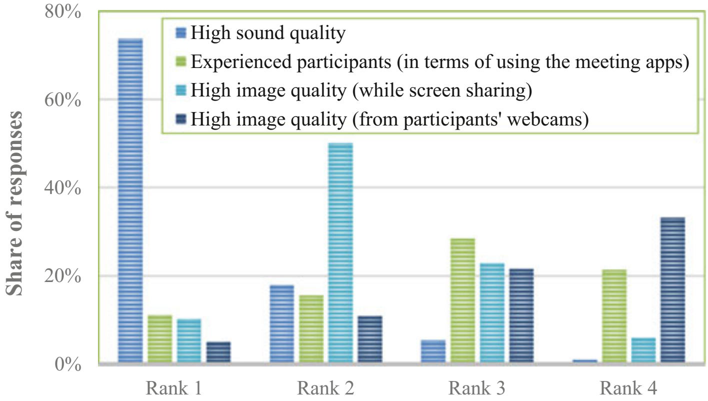

Fig. 27.10 Ranking of different aspects of the meeting by their importance concerning the meeting quality

and 36.41% *agree* that this is the case. On the other side, image from webcam video streams is not evaluated as important as a screen-sharing video stream, which is a logical outcome.

Interestingly, 76.71% of respondents expressed some form of agreement with the last statement shown in the figure. Being a highly interactive type of service, it is not surprising to see how videoconferencing quality depends not only on objective parameters (such as video bitrate, packet loss, etc.). It also depends on user experience, and not just on the experience of a single user, but the experience of all users attending the conference.

We wanted to learn more about the importance of different aspects of the conference, so we ask the respondents to rank them. Ranking results are shown in Fig. 27.10. The sound quality was most frequently ranked at the top of the list (73.75%). The importance of having experienced conference participants was also ranked at the top by 11.09% of respondents. In the second place, the most frequent selection was the image quality (from screen sharing), and it equaled 50.09%. In terms of QoS requirements, this is an important finding. Screen sharing during conferences usually means the video itself does not contain many moving objects and dynamic scenes. Naturally, there are exceptions; however, the screen-sharing option is mainly used for showing presentations to the peers, i.e., a static image (containing text, images, graphs, etc.) is transmitted using multicast transmission to other users. Hence, during data transmission from the sender's side, more attention can be devoted to the audio coding quality as that is more important to a user.

Next, the respondents' evaluated how often specific quality degradations occur during their typical videoconference meetings. The results are presented in the left subplot of Fig. 27.11. We learned earlier that respondents' network environment is suitable for videoconferencing, i.e., in most cases, it can meet QoS requirements (see our previous discussion about the results presented in Fig. 27.5). Hence, it is not surprising to discover that most of the degradations happen *never*, *rarely*,

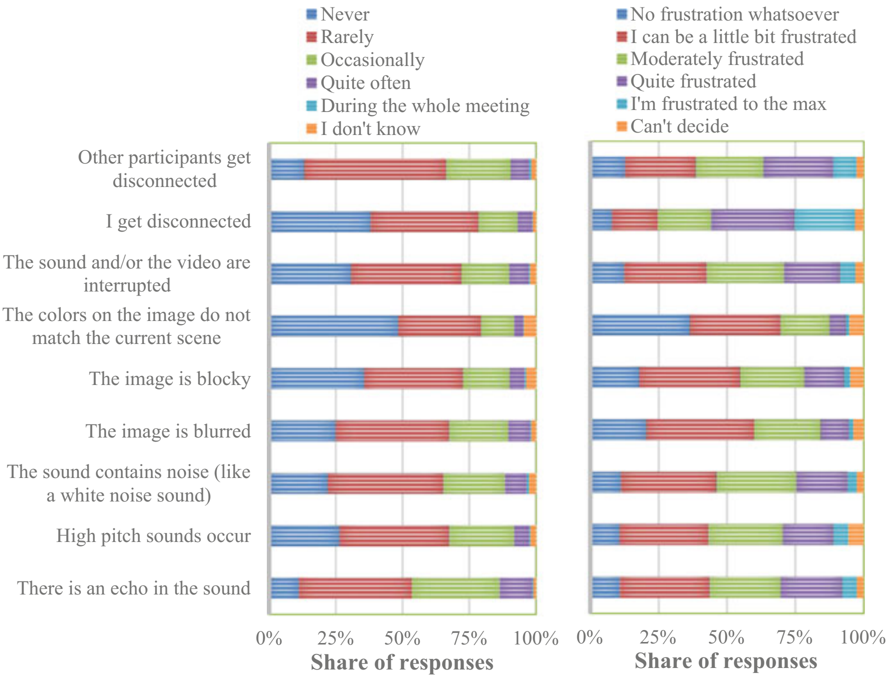

Fig. 27.11 The frequency of quality degradation appearance in a typical videoconference (on the left), causing different levels of respondents' frustration (on the right)

or *occasionally*. Yet, if they occur, we wanted to know how frustrating those occurrences are to our respondents, in general. These results are presented in the right subplot of Fig. 27.11.

The right subplot of the figure shows that the respondents are more adversely affected by those degradations connected with the sound quality (echo in the sound, high pitch sounds, and sound noise). These results correspond with the results commented earlier when we revealed that the respondents think that sound quality is the most critical aspect of a videoconference. However, the highest levels of frustration are caused by the meeting disconnections. Although they rarely happen, when they do, it hurts the experience. For instance, when the respondent gets disconnected from the meeting, 30.50% and 22% reported that they feel *quite frustrated* and *frustrated to the max*, respectively. The percentages are somewhat alleviated when other participants get disconnected, yet, they are still noticeable.

The subjects were asked whether the degradations affect them more if they are speaking or listening during the meeting. In total, 144 respondents (26.62%) stated they are more affected by the degradations if they are listening and 252 (46.58%) if they are speaking. These respondents had an additional question to answer. We asked them to reevaluate their levels of frustration, depending on their specific role. The results are presented in Fig. 27.12. The left subplot shows the reevaluated levels of frustration while listening (note that the analysis is conducted for those

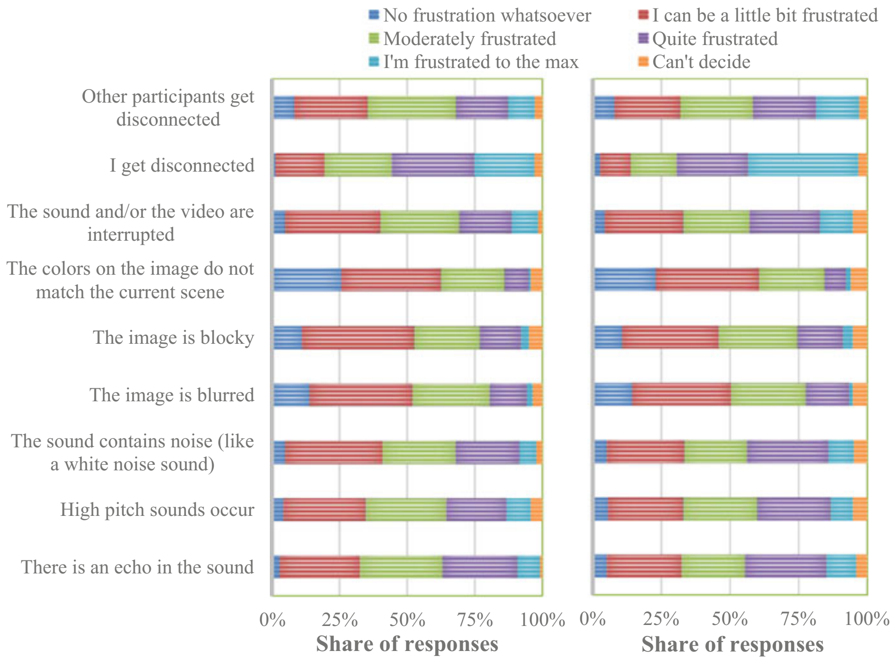

Fig. 27.12 The respondents' level of frustration due to different quality degradations and depending on their role: while listening to others (left subplot) and while speaking (right subplot)

144 respondents), the right subplot shows the same degrees but while speaking (the investigation was conducted for those 252 respondents). Both subplots show considerable changes in the levels of frustrations for nearly all types of degradation. While listening, the difference is more noticeable for those degradations affecting the sound quality. For instance, there is a higher share of *frustrated to the max* responses if echo and high pitch sound occur. Furthermore, over 40% of respondents stated that they feel *frustrated to the max* if they are disconnected while speaking, and 26.19% get *quite frustrated*. It seems that the respondents meeting role affects their perception about the overall service quality in cases when the degradations appear.

Finally, we want to draw attention to the impact of those degradations on the level of understanding of the conference topic. Note that 12.94% of respondents agreed with the statement *Yes, I always get confused about the meeting topic whenever the degradations occur*, while 65.80% agreed with *Yes, I get confused about the meeting topic if the degradations occur for an extended period*. Thus, the users can be affected by the degradations on at least two different levels. First, they may get frustrated with the service provided during the advent of specific quality degradations, and depending on their meeting role. Second, their performance at work/school/university can be downgraded if they cannot follow the meeting topic during the conference due to the degradations.

27.5 Conclusion

With this research, we embarked on a path toward discovering user QoE for videoconferencing services. In the first stage of this journey, we conducted a survey of user opinions and practices about online videoconferences. We collected the information about their network environment, typical conference scenario and their meeting roles, and their opinions about which aspects of the conference are important to them and how they perceive the appearance of different quality degradations. During this process, we reached the following conclusions.

- While conferencing with their colleagues, friends, and family members, the users value more sound over video quality.
- The users can become frustrated if other conference attendances are not familiarized with the application used for hosting the conference. Thus, user QoE depends also on the knowledge of other conference peers.
- In the set of quality degradations which we investigated, meeting disconnections are the most adversely perceived by the respondents.
- User QoE for videoconferencing depends not only on video and sound quality, the application design, and ease of use; it depends on the meeting role of a user. Specifically, users can be additionally agitated if the degradations appear while they are speaking (presenting) during the meeting. This is especially true if meeting disconnections occur.
- Inadequate network QoS and resulting quality degradations can confuse users and affect their level of understanding of the meeting topic. This, in turn, can affect their performance at work/school/university (depending on the type of the conference).

In this paper, only descriptive statistics are provided. Hence, the outlook of our future research includes more sophisticated statistical analyses that may reveal different correlations between, for instance, various user groups and their experiences. We also plan to work on modeling user QoE for videoconferencing service using the results of this research.

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Chapter 28
Dynamic Load of Teeth of Cylindrical Worm Gear

Slavko Pavlenko and Jozef Mascenik

28.1 Introduction

Worm reducers are used in case of drives of a number of modern machinery of diverse technological direction, especially in mechanical engineering, construction industry, road transportation, agriculture, metallurgical engineering, chemical and food industry, consumer industry, etc. Their technical level and load capacity in a high degree determine technical, economical, and operational characteristics of machines the part of which they become after assembling. Thus the need to assure an increase of service life of worm reducers represents a significant and up-to-date task [1].

Modern scientific researches in the field of design proposal and structure of machines move in direction of the development of methods of phenomena analysis. The development is connected with the development of the branches as follows: general mechanics, mathematics, theory of optimization, mechanics of continuum, tribology, theory of stochastic processes, and theory of reliability, experimental methods, and methods of research of particular machines under actual operating conditions. The conditions can be either actual or created artificially or are mathematically modeled, i.e., realized by means of so-called simulation research with the application of modern computer technology.

Dynamics of machines perceived in a modern manner represent dynamics of systems requiring dual approach: on the one hand, it is a detailed research of individual parts of the system and on the other hand, it is a complex analytical research of the entire system.

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Modal analysis is a modern branch of dynamics [2] which for description of oscillatory processes and oscillating behavior of engineering structures and their parts uses the possibility of disintegration of a complex oscillating process into partial, i.e., modal constituent. Each constituent is consequently characterized by modal frequency and by modal shape of oscillation.

28.2 General Principles—Worm Gears

Worm gears are designed to transfer torsional moment between skew shafts mostly at angle of 90°. The worm gear which is located in a solid locked casing represents a worm gearbox (Fig. 28.1). The worm gearbox can consist of a single or several worm gears. Except for worm gears, it may contain other toothed gears as well. The solid casing represents a support for capturing actions of forces from positioning of shafts which carry the segments of worm gear in precise axial directions, protects the gear against impurities, and generates conditions for its effective lubrication [3].

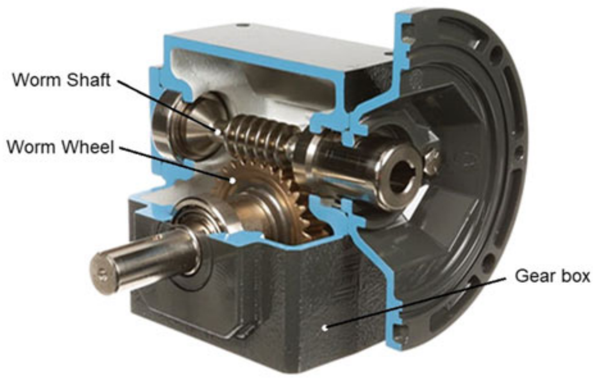
From a structural point of view, the worm gears are produced as independent nodes which are fixed to a joint frame with driving machines or other driven machines or as an integrated structure with a drive or other parts of machines in a single unit. Flange method of fixation can also be observed [4].

Worm gears designed for general utilization are produced with particular parameters in accordance with norms and standards referring to application in diverse machineries even of special determination in case of which specific requirements are imposed upon their operation and working modes [6].

Theoretically, all of these worm gears can have a random angle between axes yet the most broadly utilized are the gears with mutually perpendicular axes.

Continuity of running is reached through good adaptive ability of a pair of segments of worm gear. One of the main advantages of worm gear is possibility of self-locking in case of change of direction of transfer of performance by means of gear which is rather significant in a number of machines, especially in case of

Fig. 28.1 Worm gears [5]



lifting device. Therefore the gears of some of the devices contain self-locking worm gear although its use could be avoided without any losses [7].

28.3 Dynamics of Worm Gears

Despite the fact that worm gears are extensively applied in practice, the professional literature only rarely offers publications related to research of the gears from the point of view of their dynamics. The exception to the rule is the work by V. Klima [8], in which the author presents the necessity of taking into consideration the influence of dynamic effects of teeth meshing in the determination of maximal values of loading forces.

For the case of teeth meshing of cylindrical worm gear system, the more positive influence of dynamic effects during the start of teeth meshing is presented in [8]. In case of spur-toothed wheels, the circumferential speed of both meshing teeth is of the identical value and identical direction in a pitch point. In case of mesh of teething of cylindrical worm gear systems, the relative speed of faces of teeth of worm is at an angle of $90^\circ - \gamma$ (with γ standing for lead angle of worm on pitch cylinder) toward direction of circumferential speed of worm wheel at pitch diameter. Except for the aforementioned, even circumferential speed of worm is several times higher than circumferential speed of worm wheel, and therefore onset of faces of teeth of worm onto wheel teeth is more continuous and lacks negative dynamic effects contrary to spur wheels. The author states that at larger lead angles of worm or in case of higher rotations of worm it is inevitable to take into consideration dynamic effects as well. The author recommends to apply the method of replacement of mesh of cylindrical worm gear system by mesh of a gear rack with worm wheel and to use derived relations for determination of dynamic effects in case of spur gear systems [9].

Out of the foreign authors dealing with dynamics of worm gear A.W. Tuplin and N.L. Vejc must be mentioned. The other of the two elaborated in his publications mainly dynamics of self-locking worm gears [10–12].

As it has already been mentioned, the [13] offers the method of calculation of magnitude of additional dynamic force in case of worm toothing. To determine yielding property of worm gear, Tuplin applies the relation to determine yielding property of teeth of spur-toothed wheels with skew teeth. The author takes into consideration the yielding property as follows:

- From deflection of tooth as of fixed beam
- From deformation of the surface of faces of teeth
- From the shift of teeth with regard to bodies of wheels
- From circumferential stress in a rim

Apart from the aforementioned yielding properties, the author also offers relation for calculation of yielding property occurring as a result of worm flexure due to loading.

Additional dynamic force is given by the following relation:

$$F_{dj} = \frac{A_b e_b}{G_z} + \left(F_j \text{ or } \frac{A_s e_s}{G_z}\text{; lower of the values}\right) \quad (28.1)$$

with

e_b—total of permitted deviations of pitches of adjoining teeth [m]

e_s—periodical error of gear (profile deviation) [m]

G_z—yielding property of worm gear system in direction of the tangent toward pitch circle of worm wheel per unit of length [$\mathrm{m^2N^{-1}}$]

A_b, A_s—diagram values ([14] diag. 10)

F_j—circumferential force of worm wheel per unit of length [$\mathrm{Nm^{-1}}$].

The [11] offers a detailed analysis of the follow-up of self-locking worm gears. The follow-up is characterized as motion with declining kinetic energy and machine halt. From the point of view of direction of transfer, the follow-up of self-locking gear can be divided into two types as follows:

1. The follow-up with transfer direction of torsional moment identical with the one in case of steady running conditions.
2. The follow-up with the change of transfer direction of torsional moment.

A lifting mechanism with self-locking worm gear, which drives the winding drum can serve as an example. Standard mode refers to load lifting and unbraking mode is connected with lowering of a load. In the first case, the worm is a driving element and the worm wheel is the driven one. In the second case, the worm as well as the wheel represents the driving elements. Special emphasis is put on the determination of conditions related to unbraking. The [12] presents conditions under which the unbraking mode occurs. The mode is typical for a sharp increase of accelerations or decelerations which practically results in an instant halt.

In practice, the phenomenon is referred to as wedging of self-locking gear and it is usually accompanied by considerable load causing in some cases damaging. It must be mentioned that conditions of dynamic wedging differ from those of the static one.

28.3.1 Experimental Examination of Mechanical Systems

More obsolete methods of experimental examination of oscillation of toothed gears rested in the monitoring of changes of torsional moments affecting the rotating shafts. Transfer of relatively weak signals from rotating shafts caused difficulties which were solved by means of telemetric transfer, i.e., by fixing a transmitter onto rotating shaft with consequent monitoring of the signal by a static antenna. To prevent disturbing effects in operation the signal modulated with frequency was used for transfer.

Modern methods of experimental examination stem from measuring of response of structures (drives) in their controlled actuation in the selected network of points on the surface. The assessed frequency transfers between the individual pairs of points serve for the determination of modal frequencies and regressive calculation on the basis of measured data is used for the determination of modal shapes of oscillations. The procedures are referred to as experimental identification or modal testing.

To illustrate oscillation shapes the graphical programs are used with animation of the individual oscillation shapes being activated gradually on the screen.

28.3.2 Mathematical and Physical Dynamic Model of Cylindrical Worm

In formation of dynamic model of worm gearbox, it is not possible to take into consideration torsionally isolated gearbox as for instance in [15, 16].

Contrary to spur-toothed gear system, it causes higher gear ratio, lower mean stiffness of toothing, and mainly considerable flexural yielding property of worm shaft. The yielding property which in the highest degree contributes to the overall yielding property of flexibly deforming elements of gear is transformed to torsional stiffness of gear to stiffness in the direction tangential to pitch circle of worm wheel. In case of majority of cylindrical worm gears (UCG160) after reduction and formation of reduced torsional system, it shall be detected that reduced mean stiffness of toothing is lower or correspond by order with torsional stiffness of worm shaft from part of the driving machine k_{tM}. However, the reduced torsional stiffness of shaft of worm wheel k_{tB} from part of the driven machine is mostly at least by a single order lower contrary to the reduced stiffness of toothing.

$$k = \frac{1}{\frac{1}{k_o B} + \frac{1}{k_{\mathrm{oh1}}} + \frac{1}{k_{\mathrm{oh2}}}} \tag{28.2}$$

with k—mean stiffness of toothing [Nm^{-1}]

k_{o}—mean stiffness of toothing of cylindrical worm gear from flexure, from contact deformations and from shift of teeth per unit of width of wheel [Nm^{-1}]

B—width of worm wheel [m]

k_{oh1}—flexural stiffness of worm shaft transformed to stiffness in tangent to pitch circle of worm wheel [Nm^{-1}]

k_{oh2}—flexural stiffness of shaft of worm wheel in tangent to pitch circle of worm wheel and parallelly with the worm axis [Nm^{-1}]

Torsional stiffness according to Fig. 28.2 is considered to be torsional stiffness of worm shaft from part of driving motor k_{tM}.

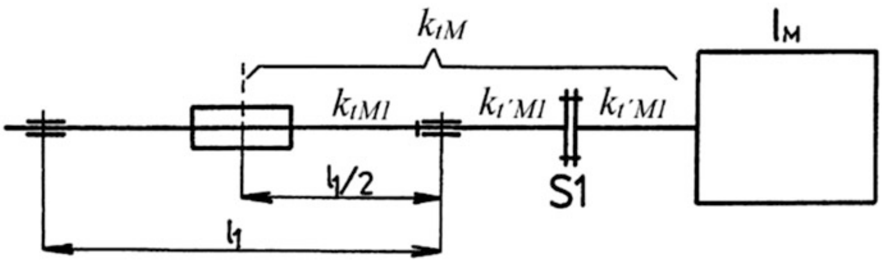
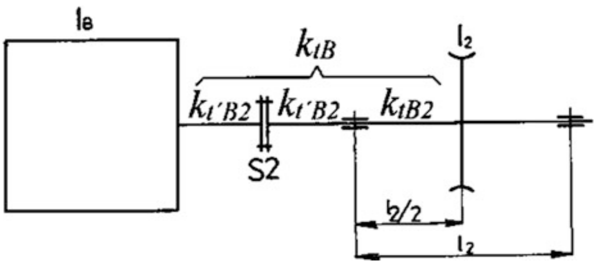


Fig. 28.2 Torsional stiffness of worm shaft

Fig. 28.3 Torsional stiffness of shaft of worm wheel



$$k_{tM} = \frac{1}{\frac{1}{k_{tM1}} + \frac{1}{k_{tM1}}} \tag{28.3}$$

in case of which k_{tM1}—torsional stiffness of worm shaft from the center of bearing distance up to bearing from part of driving motor [Nmrad^{-1}].

$k_{t'M1}$—torsional stiffness of worm shaft from bearing up to clutch S_1 or from clutch to rotor of driving motor I_M [Nmrad^{-1}].

It can be assumed that clutch S_1 is absolutely stiff and torsional stiffness of shaft of driving motor up to its rotors is (in case of certain simplification) equal to stiffness of worm shaft from bearing to clutch S_1.

The same is applicable for torsional stiffness of shaft of worm wheel k_{tB} Fig. 28.3.

$$k_{tB} = \frac{1}{\frac{1}{k_{tB2}} + \frac{2}{k_{t'B2}}} \tag{28.4}$$

in case of which k_{tB2}—torsional stiffness of shaft of worm wheel from the center of bearing distance up to bearing from part of the driven machine [Nmrad^{-1}].

$k_{t'B2}$—torsional stiffness of shaft of worm wheel from bearing to clutch S_2 or from clutch S_2 to I_B [Nmrad^{-1}].

On the basis of analysis of stiffness parameters of cylindrical worm gear the following mutual relations were detected:

1. Due to higher gear ratio, which is typical for worm gear, after reduction per shaft of worm rather low reduced axial moment of inertia of the driven machine is achieved.
2. Reduced mean stiffness of toothing is lower or corresponds by order to torsional stiffness k_{tM}.
3. Reduced mean stiffness of toothing is higher contrary to reduced torsional stiffness $k_{t\mathrm{Bred}}$ or in case of average and larger sizes the difference is expressed in orders.
4. With regard to reduced axial moment of inertia of worm wheel $I_{2\mathrm{red}}$, I_M is higher by orders [17].

To get oriented the values of calculated stiffness for average size of gearbox UCG160 (axial modulus $m_x = 6.3$ mm, $\alpha = 20°$, number of runs $z_1 = 4$, transference number $u = 10$) shall be given

$k_{tM} = 1.124105\ \mathrm{Nmrad}^{-1}$
$k_{t\mathrm{red}} = 3.177104\ \mathrm{Nmrad}^{-1}$
$k_{t\mathrm{Bred}} = 4.379103\ \mathrm{Nmrad}^{-1}$

in case of which $k_{t\mathrm{red}}$—reduced torsional stiffness of toothing [Nmrad^{-1}]

$$K_{t\mathrm{red}} = \frac{K r_{1f}^2}{u^2} \tag{28.5}$$

$$K_{tB\mathrm{red}} = \frac{K_{tB}}{u^2} \tag{28.6}$$

28.3.3 Influence of Geometrical Parameters upon Inherent Frequencies

By means of computing program which uses method of impedance matrix mentioned the inherent frequencies of dynamic model of cylindrical worm drive were calculated as well as of dynamic model with worm drive. Detected was the influence of axial moment of inertia of worm wheel and flexural stiffness of worm shaft upon change of inherent frequency of cylindrical worm drive.

The results are plotted in spatial graph (Fig. 28.4) for the monitored gearbox. The axial moment of inertia as well as flexural stiffness was being changed within the range from 0.6 to 1.4 times with regard to currently produced state. The influence is clear from the given figure.

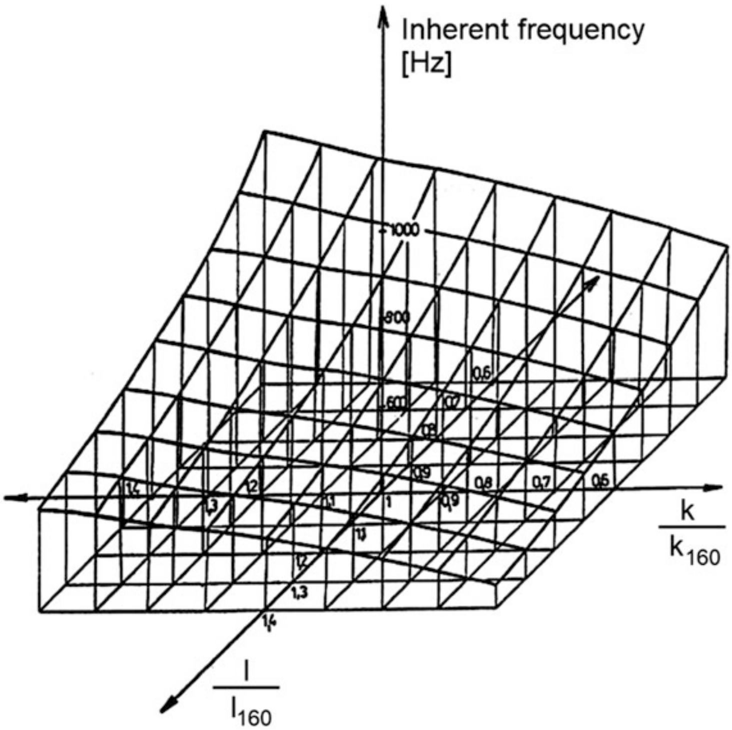


Fig. 28.4 Gearbox UCG160—The axial moment of inertia as well as flexural stiffness depending on the inherent frequency

28.3.4 Dynamic Load of Teeth of Cylindrical Worm Gear

Figure 28.5 shows the development of values $\overline{\eta}_1$ for the UCG160 gearbox. Value K' ranges from 0.0858 to 0.0835 for the individual gearbox types. If simplification of $I_1 \approx 0$ is accepted (weight moment of worm is not taken into consideration) and after inclusion of variable stiffness of toothing into series with weight from part of motor, K' is achieved within the range from 0.0178 to 0.014, i.e., influence of variable stiffness becomes negligible.

Influence of External Actuation

Programs for dynamic analysis allow calculation of deviation, speed, or acceleration in any random node of dynamic model. In a similar way, it allows the determination of force or moment in any random element of the model.

$$\text{Mesh duration} = 2707,\ b_{\text{p}} = 0.3$$

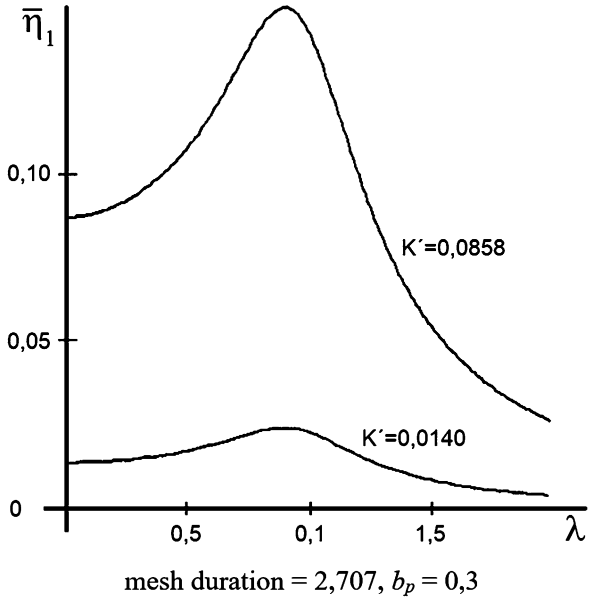


Fig. 28.5 Development of values—Gearbox UCG160

Development of additional dynamic force was determined by the implementation of external sinusoid unit force and by detection of value of additional dynamic force in toothing at random frequency of actuating force. Development is shown in Fig. 28.6 for dynamic model. The values of relative dampings are indicated below respective graph.

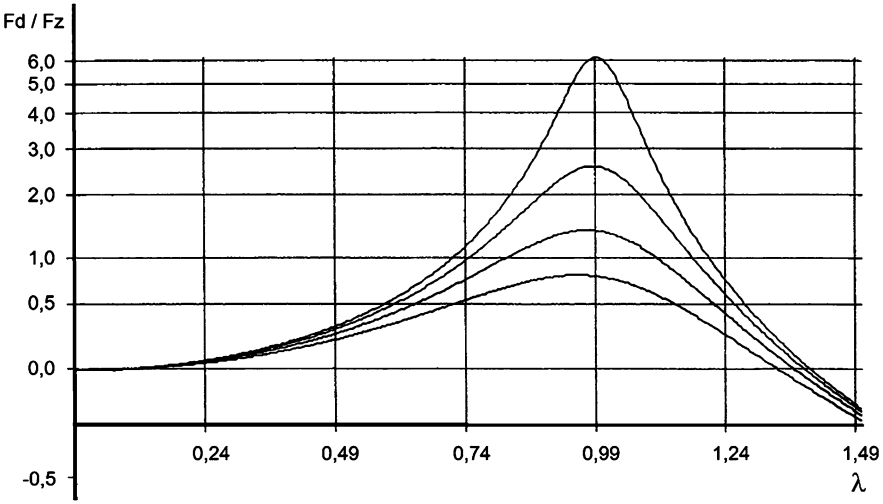
$$\text{UCG160} : 1 - b_p = 0.1, 2 - b_p = 0.2, 3 - b_p = 0.3, 4 - b_p = 0.4.$$

28.4 Conclusion

Contrary to generally accepted opinion on absence of dynamic phenomena in worm gears the paper provides detailed analysis of meshing process of teeth of worm wheel with worm threads and whether dynamic load is possible in worm gears as well.

It has been proved that in case of reverse gears and drives operating in the mode of frequent start-ups and halts, the impacts can occur in the result of which lubricating medium is forced out of contact zone of wheel teeth and worm threads and that leads to metal contact and further on to abrasion and wear.

It has been shown that to alleviate and to prevent the impact the elastic adjacent element should be located among the teeth of wheel teeth and worm threads which would serve as a damper of impact system and at the same time it shall assure



UCG160: 1-b_p=0,1, 2-b_p=0,2, 3-b_p=0,3, 4-b_p=0,4

Fig. 28.6 Development of additional dynamic force acting in toothing in case of external actuation and diverse damping

minimal coefficient of friction during relative slip of work areas of worm threads and teeth of worm wheel. The character of collision of worm threads and wheel teeth depends on type and properties of elastic adjacent element among wheel teeth and worm threads.

Reduction of vibroactivity of worm gears which increases their service life can be achieved by the use of modern original structures of worm wheels in which elastic elements eliminating dynamic load get integrated. Polymer films on work areas of worm threads and teeth of worm wheels or cluster lubricant, which is standard lubricant with added Teflon particles, can serve as elastic adjacent element.

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Chapter 29
Analysis of Available Information and Communication Solutions and Services for Railway Passenger Information in the EU

Petra Zorić, Matea Mikulčić, Mario Musa, and Tibor Mijo Kuljanić

29.1 Introduction

The ability to provide information and transport services anytime and anywhere makes the rail network more efficient and easier to use for end users. Real-time and accurate information is the most crucial item in informing passengers. The basis for obtaining this information is a stable and comprehensive passenger information system that uses a specific architecture to deliver the service. This system has the possibility of real-time transmission of information and data, for example, on the timetable from different sources, their connection into one whole, and providing through various interfaces. The system includes updated information related to any timetable change and timetable changes that are combined with timetable data and delivered to the information systems. The passenger information system relies on multimedia network technology in which the central computer provides information services to passengers using screens at stations or stops and in vehicles.

Elements of the architecture on the railway network enable computing capacity and telecommunications to collect, transmit, and process data related to stakeholders' management and information. From the management point of view, the passenger information system is divided into the source of information, central

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management level, the level of management in stations and on the train, and control equipment at stations and on the train.

This paper aims to present the functionalities of currently available information and communication (IC) solutions and services that enable informing passengers in rail traffic in the European Union (EU). The analysis will include passenger information systems in the EU countries with the highest realized passenger traffic in the last year, measuring it in billions of passengers transported. Furthermore, these systems will be compared with the passenger information systems currently used in the Republic of Croatia (Croatia). Based on this, the most important recommendations for improving the existing passenger information system rail transport in Croatia will be summarized.

29.2 Literature Review

Digitization encompasses the processes by which organizations create some new value for their services [1]. According to [2], the combined cost of digitization for industry and society could exceed US$100 billion by 2025. Digital rail solutions in Europe are part of the Shift2Rail project, which provides a platform for innovation and research activities in this field [3]. Globally, the railway passenger information system segment is projected to be one of the most lucrative parts of the service market [4].

The passenger information system is a solution for providing relevant real-time information to passengers. It includes a passenger information system, passenger information screens, surveillance, and physical address. It is responsible for the automatic or manually programmed provision of visual and audio data to passengers at stations and stops. Passengers have access to the system through various channels, such as Internet-connected devices, computers, and mobile devices [4].

Mobile application-based passenger information systems are rapidly gaining ground due to the increased penetration of smartphone use. It is most common in passengers who use public transport [5]. Namely, passengers prefer to use data available on mobile devices, rather than data displayed on screens at stations or through a public address system [6]. Through the railway operator's website or travel planning applications, passengers can be informed about the planned timetable, possible difficulties in the ordinary course of traffic in the event of line maintenance or other traffic disruptions.

Research on existing and future passenger information concepts [7] has shown that innovative and new passenger information technologies represent a great benefit not only for passengers by shortening their waiting time but also for providers of information services by increasing users' flow in stations. The development of IC in the transport sector has resulted in services focusing on customers and their needs by changing the previous perception of passenger transport. The most used services based on IC technologies in public transport are the subject of research in the paper [8].

The use of mobile devices has contributed to the healthy growth of e-commerce in the last year. It is important to note that mobile wallets and m-shops are becoming increasingly important in people's daily lives around the world. Mobile devices generate approximately 60% of the volume of all Internet traffic [9]. Thus, mobile applications of railway passenger operators are introducing or have already submitted the possibility of purchasing tickets through these applications. According to [10], the number of smartphone users in the world today exceeds three billion, and future forecasts refer to an additional increase of several hundred million in the next few years.

Given the above, an increasing number of travel planning applications are also available. Therefore, further development of transport services is expected that will be individually designed and tailored to end users. According to their characteristics, the research [11] grouped end users of train systems into four categories to obtain the requirements that innovative technologies must meet for end users to be satisfied.

However, there is not enough research on the possibility of providing information using screens at train stations that passengers use to obtain travel information. The last such study was conducted in 2014 in the United Kingdom and concluded that passengers prefer a conventional main information board while nonstandard boards can confuse them [12].

Passenger satisfaction with rail services is the subject of a European survey [13] published in 2018. The survey was conducted on a total of 25,537 respondents. Providing information during train travel, especially in case of delay, is satisfactory for 55% of respondents. Nearly three-quarters of respondents are satisfied with the provision of information on timetables and platforms. Forty-nine percent of respondents are satisfied with the availability of travel information displayed at the station. Providing quality information about timetables and platforms is very important for 69% of respondents, while for 68% of respondents, the ease of buying a ticket is essential. A 2020 Eurostat survey on the impact of rail passenger transport at the EU level shows that the largest number of passengers in 2018 was carried in Germany (2,880,558,000), the United Kingdom (1,783,232,000), and France (1,246,804,000) [14].

Analysis of the current scientific and professional literature shows a lack of research topics that focus on informing passengers on the railway network based on up-to-date technologies. The same goes for research at the national level. In the last few years in Croatia, informing passengers on the railway network has been expanding. This paper presents the achieved level of IC solutions and passenger information services in Croatia and its comparison with the systems used by the countries with the largest number of passengers per year in the EU.

29.3 Currently Available Information and Communication Solutions and Services for Railway Passenger Information in the EU

Passenger information is one of the most critical services in all transport systems, including rail transport. Providing all the necessary information to passengers in the rail system directly affects their impression of the system's quality and the decision to reuse the said mode of transport.

The railway system can be divided into structural area subsystems and functional area subsystems. The structural area subsystem includes infrastructure, energy, monitoring, control and signaling, control orders, and signaling in the vehicle and the vehicle fleet. Furthermore, the functional area's subsystems are traffic management, maintenance, and telematics applications for passenger and telematics services [15].

By the EU Commission Regulation [16], each station manager must provide the user with train departure data at railway stations. According to the Regulation, the telematics application subsystem consists of two elements: a passenger transport application and a freight application. Passenger transport applications further include systems for providing information to passengers before and during the journey, reservation and payment systems, baggage management, and the management of train connections and other modes of transport. The Regulation is based on the Technical Specifications for Interoperability (TSI) in Directive 2001/16/EC of the European Parliament and of the Council of March 19, 2001, on the trans-European interoperability conventional rail system, which details the provision of passenger information and the implementation of the passenger information system. The purpose of the TSI is to establish procedures and interfaces among all stakeholders to provide relevant information and issue tickets to passengers via currently available technologies [17].

The current passenger information systems on the rail network in Germany, the United Kingdom, and France, which are developed according to the TSI guidelines and the Regulation of the EU Commission, can be divided into passenger information systems before and during the trip. Passenger information systems before the trip include information via the website and mobile applications. During the trip, passenger information systems refer to audio and visual information via screens in the stations themselves or at the stops.

29.3.1 Passenger Information System During the Trip

Generally, the architecture of the solution for providing services at stations consists of devices and technologies in the information center and at the stations. They are all connected via switches to the IP network. The information center located a passenger information system (central server, database, workstations, server interface, video content server, and advertising server), a public address system (server, public address controller, workstation, and call station), and clock system (Network Time Protocol server, master clock, GPS, and workstation). The stations have screens, workstations, a server, public address controllers, a power amplifier, speakers, master, and auxiliary clocks. The timely joint interaction of all elements provides passengers with the necessary information at stations. All these elements create vast amounts of dynamic data, thus enabling communication between the subsystem at the station and the train from the departure point to the destination.

The need to obtain travel information during the trip is variable depending on the different parts of the station and between arriving and departing passengers. The essential requirement to get information is the same for all passengers. Still, the equipment for providing information, i.e., information carriers, differ in the number, design, and functionality they provide depending on the country's location. The types of information presented by information carriers can be divided into:

- Visual dynamic information
- Voice travel information and
- Interactive information.

Visual dynamic information is mainly used for real-time information related to the time of arrival/departure of the train and notifications about route changes and/or train delays. They are also used for promotional content or as a pointer when finding individual facilities at large stations. Screens that provide this type of information are located on the station's platforms and in the central information hub (waiting rooms) and are divided into internal and external. Voice travel information passengers are delivered via a loudspeaker system. They are used when notifying passengers of important messages (train delay, absence of train arrival, lost items, etc.). Interactive information on the main stations' unique platforms is designed to help people with hearing, vision, or cognitive impairments. However, people without impairment are also used, and the information is provided visually and audio-visually.

Deutsche Bahn (DB) uses internal and external TFT-LCD (thin film transistor—liquid-crystal display) visual information screens and audio speakers to inform passengers at its rail stations and platforms in Germany. This is part of the *DB Colibri* portfolio, which includes core products, applications, and maintenance solutions [18]. In addition to the possibility of providing information to passengers about routes and timetables, screens are also used to direct passengers to stations and platforms. At larger stations in Germany, touch screens have been installed to achieve interactivity. Indoor TFT-LCD screens are designed for public places where 24/7/365 display operation is required [19]. Travelers and visitors can use free Wi-Fi at 127 stations in Germany, making it even easier for them to obtain information [20].

The control centers for monitoring train traffic (timetable) in real time using the appropriate software solution (the Aramis program of the Thales program). A complete overhaul of the passenger information support system in the form of the development of the IRIS+ IC system is currently underway [21]. Also, testing of a clock system whose data will be transmitted using LoRaWAN wireless technology is underway. This would allow real-time remote monitoring to identify and eliminate errors (displaying incorrect weather, switching off lighting, and damage caused by water) and improving passenger information [22].

The *National Rail Network* (NRN) uses LED (Light Emitting Diode) screens for dynamic visual information at stations in the United Kingdom, which provide information on the arrival/departure of trains and the main facilities' position at the station. Also, passengers have at their disposal a display of the timetable via a screen that is customized in such a way that filtered indexes are created. Shortcuts are provided to the most frequently searched destinations. In addition to LED screens, there are information kiosks at the main stations that display real-time data related to the arrival/departure of trains and platform numbers with diagrams and real-time statuses. These screens and kiosks' technical characteristics are adapted depending on whether it is an open or closed space. The screens differ only in dimensions (42 "for open spaces and 47" for indoor spaces), while their features are multi-touch interface, Ethernet, and WiFi, 1080 HD are enabled. Outdoor kiosks have tempered antireflective glass. The power supply is resistant to voltage, they have protection against vandalism, NEMA4 protection rating, while the indoor kiosk is characterized by being thin and suitable for all enclosed spaces [23].

Société nationale des chemins de fer français (SNCF) is a French national railway infrastructure provider that uses TFT flat screens equipped with antireflective glass at its main stations and the most frequent stops. With the arrival/departure times and line markings displayed at the screens, train logo and speech synthesis are also enabled. On the platform itself, the screens show the first incoming train, the list of stations to the destination, and at the very end, there are notifications. Speech synthesis is integrated into screens at regional stations, enabling the oral distribution of information in written form. Also, passengers are provided with free Wi-Fi access at the main stations, which gives passengers more available access to information from the mobile application or the operator's web page.

However, usage time is limited to 30 min. They are currently in the phase of gradual implementation of dynamic and light screens intended to facilitate the reading of the information provided on stations [24]. The clock system installed at the Persan–Beaumont station consists of a Profile TGV 950E clock model synchronized with the Sigma Master main clock. It is a wired time distribution system that transmits a complete-time message and is suitable for large clock networks. It uses an IRIG-B/ANFOR coded time receiver, whereby the time setting of the receiver is realized automatically after connecting to the clock line [25].

29.3.2 Passenger Information System Before the Trip

This way of informing passengers is to provide accurate real-time information to passengers before the start of the trip. Informing passengers via a website and a mobile application are ways of distributing this information.

Many railway undertakings are represented on the railway network in Germany, Great Britain, and France, and each of them has at least its website, if not a mobile application. Given their number, this paper analyzes passengers' possibilities by the websites and mobile applications of railway infrastructure providers in these countries.

29.3.3 *Informing via Websites*

The DB website is available in German, English, Czech, Danish, Spanish, French, Italian, and Dutch. It is adapted for people with visual impairments in a way that offers font size adjustment. Passengers can purchase a ticket directly on the site after registration and login to the system depending on the status (private or business user). When buying tickets, passengers are offered a wide choice of payment methods: credit cards, PayPal, SEPA direct debit cards, mobile banking, and PayDirect. Replacement or cancellation of the purchased reservation or ticket is also possible. The site provides information related to passengers' rights as well as a book of complaints and a display of all available services. It is possible to display the fleet (regional, intercity, international) and additional benefits offered by a train (Wi-Fi, sockets, seat size, meal offer, etc.). The website also contains information related to the mobile application [20].

The National Rail website for informing passengers is available in English only and is not adapted for the visually impaired persons. The services offered to passengers are related to searching for train departure times and selecting tickets, stations, travel destinations, and timetable changes. Ticket purchase is enabled directly on the page. It is unnecessary to register in the system beforehand, but the passenger can register as a guest. When buying tickets, passengers have the option of choosing a specific seat on the train and how to pick up a ticket. Two payment options are available: credit cards and PayPal. The traveler can get acquainted with his rights and get answers to the most frequently asked questions [26].

The French national railway infrastructure provider has a website available in three languages: French, English, and German. Unlike the previously analyzed websites, it is completely adapted for people with visual impairments (adjustment of font, contrast, animations, and line spacing). The purchase of tickets is not possible directly on the website, but the passenger is redirected to another website to perform the specified action. In doing so, he is provided with various payment methods. It is also possible to view all stations, travel duration, train type, timetable by the station, view by date, or train number. The amount of CO_2 emitted during a trip, and the choice of route to avoid during the trip are some of the exciting things that the website offers [27].

29.3.4 Informing via Mobile Applications

Mobile applications are one of the most widespread passenger information systems. The number of mobile applications for transport companies is continuously growing, and they provide many types of services. The advantage of mobile applications is the interaction with users, i.e., passengers. Since passengers provide certain information to the carrier when using mobile applications (most requested line, passenger departure and arrival station, most used services), the carrier can improve the current level of service it provides to passengers.

The DB Navigator mobile app is free and available for Android, IoS, and Windows Phone platforms. In addition to displaying timetables and travel planners, it is possible to check a specific train's delay via the application. If the passenger wants to find out information about a train, he can easily display the carrier's name, station, time platform, and transfer point of the selected train. Through the mobile application, it is possible to set various weather notifications related to driving. One of the options provided by the application is the use of another mode of traffic whereby passengers are redirected to other mobile applications or websites that offer the above.

National Rail, as well as DB Navigator, has a free app available for devices on Android, IoS, and Windows Phone platforms. Through the mobile application, it is possible to plan trips and buy tickets from all railway operators. In addition to the numerous opportunities it provides to passengers, information can also be obtained about the facilities located at individual stations and the services offered. Offline display of maps and information is not enabled. It is also possible to set alerts about individual lines as well as alarms about departure time. The option of combined transport (bicycle and train) is highlighted on the mobile application.

The SNCF mobile app is free and available in four languages: French, English, German, and Spanish. Offers offline map display as well as traffic information. Instant notifications and notifications related to individual train delays are enabled. As with the website, the reservation and purchase of tickets are not allowed with the mentioned mobile application. The traveler must use another application called OUI.sncf for the specified actions. In this application, it is possible to use voice search, making the mobile application adapted for people with visual impairments. The passenger is provided with information on the duration of the journey of a train and the benefits provided by the train (space for prams, access for passengers with disabilities, and room for changing children). The application also offers an overview of passenger trips and sending notifications of schedule changes.

29.4 Passenger Information System: Croatia Versus EU Best Practices

The passenger information systems applied in the countries involved in the analysis of work are the best example of the implementation of passenger information practices in railway transport. To position the passenger information system's possibilities and the level of availability of passenger information in Croatia to the EU, a comparison of the features of this system with the previously analyzed systems will be presented.

29.4.1 The Comparison of the Passenger Information System Features

On the rail network of the infrastructure manager in Croatia, HŽ Infrastructure (HŽI), out of a total of 545 stations and stops in Croatia, only 256 are equipped with the possibility of providing visual information for passengers. Of the 124 stations equipped with the listed equipment required to provide information, six stations also provide dynamic screens for displaying information to passengers. There are 60% of stations and stops with the possibility of providing visual information to passengers, with only about 1.4% of them having dynamic screens [28].

The service of informing passengers at stations and stops is provided via loudspeakers or visually via fixed bulletin boards displaying the all-day timetable, i.e., screens with information on the time and place of train arrival and departure, train delays, possible change of transport route, and other necessary information related to rail traffic. Data on railway lines exist in digital form on the passenger transport operator's website, as well as on the mobile application.

Most stations and stops have a passenger information system consisting of several subsystems:

- Classic fixed timetable
- Boards (LED screens)
- Clock subsystems
- Loudspeaker subsystems
- UPS (uninterruptible power supply) and
- Communication equipment that allows it.

Analog clock screens located at stations and stops are composed of SMD (surface-mount device) LED light modules designed to display various alphanumeric messages in multiple lines at rest. Each side of this screen consists of a display part (LED screen), a processor assembly, a power supply module, a communication interface, a light sensor, and lighting and switching assemblies. The information is created in a control center that sends it to the processor assembly, where it is processed and displayed on an LED screen. The communication interface is

Table 29.1 Comparison of passenger information systems during the trip

	DB	NRN	SNCF	HŽI
Visual informing	+	+	+	+
Voice informing	+	+	+	+
Dynamic screens	+	+	+	+
Touch screens	+	+	+	−
Type of screens	TFT–LCD	LED	TFT	LED
Pointer direction	+	+	+	−
Diagnostic feature built into the screen	+	−	−	−
Time and date display on the screen	+	+	+	+
Display of train arrival/departure on the screen	+	+	+	+
Promotional content on screens	+	+	+	−
Adapted for disabled people	−	−	+	−

optically separate and connects the information screen and the control computer. The lighting and switching assemblies' sensors have the task of illuminating the mechanical clock and the inscription on display.

The clock subsystem consists of a master clock developed in modular technology, a two-wire transmission system (enables independent installation of auxiliary clocks without maintenance and a remotely synchronized computer system), and the MOBAWNT software program. The loudspeaker subsystem consists of a digital output module, a power amplifier, a universal interface module, a digital telephone exchange/digital key module, and a converter. The UPS subsystem is designed to prevent interruptions and impacts on computers and valuable electronic equipment. It filters out small fluctuations in utility lines and isolates equipment from significant interference by the service network's internal disconnection. It also provides uninterrupted power from its internal battery until the service line returns to a safe level or is discharged. Communication equipment in stations is numerous and can be divided into the following elements: media converters, relay modules, power relay modules, input modules, smart web input/output Ethernet module, interface converter, various connectors, data cable shielding, and industrial server serial devices over a TCP/IP-based Ethernet network.

The technology used and how information are displayed to passengers at stations and stops in the analyzed countries differs. Table 29.1 shows the main differences between passenger information systems during the trip.

According to a comparison of the passenger information system features during the trip, the systems used in Germany and France provide the most opportunities for informing passengers. On the other hand, informing passengers in Croatia is limited only to the necessary information such as the display of time and date and departure time by visual or audio means. It should be noted that the above information is not available to passengers in all stations and that LED screens are in a limited number of large stations.

Tickets can be purchased on the website of the currently only passenger transport service provider in Croatia, i.e., HŽ Putnički prijevoz (HŽPP). When buying, there

Table 29.2 Comparison of passenger information systems before the trip websites

	DB	National Rail	SNCF	HŽPP
Availability in more languages	+	−	+	+
Adaptation for the visually impaired persons	+	−	+	−
Enabled direct purchase of tickets through the website	+	−	−	+
Multiple ticket payment methods enabled	+	+	+	+
Obligation to register and register when buying tickets	+	+	+	−
Seat reservation enabled	+	+	−	−
Travel planner	+	+	+	+
Benefit overview	+	+	+	+
Available information related to bicycle and pet transport services	−	+	+	+
Timetable display	+	+	+	+
Information about timetable changes	+	+	+	+
Passenger rights information	+	+	+	+
Canceling a ride or changing the ticket directly on the page available	+	−	−	−

is a possibility of choosing with registration in the system or without registration, which facilitates purchase tickets for frequent users of the service. Still, it is not suitable for people with visual impairments. Credit and debit card payment methods are available. Passengers can get acquainted with their travel rights, existing tariffs, regulations/ordinances/instructions, transport documents, and access information on the HŽPP website. Also, information related to the services offered to them, traffic conditions, timetables from the current year is provided as an approach to the most common questions [29].

Table 29.2 shows the differences between the services offered through websites in the analyzed countries. It is evident that Croatia does not lag the leading countries in rail passenger transport in terms of display and availability of information on the website.

Comparing the possibilities of informing passengers via websites among the considered infrastructure managers, it is evident that DB provides the broadest range of services to passengers. In Croatia, the possibility of booking a seat, canceling, or exchanging tickets and registration when buying tickets is not available and is directly related to the passenger carrier. These shortcomings are not justified, given that there is still only one passenger transport operator in Croatia. In other countries, there are many more due to the liberalization of the passenger transport market.

The mobile application for informing passengers HŽPP Planer is free and available in Croatian and English for devices on the Android platform. An application for the IoS platform is currently being developed. A timetable display is also possible without internet access. Among other things, the application offers the possibility of calculating the price of a ticket (with discounts, if the passenger is entitled to them), tracking the GPS position of trains, travel details, and the similar. The possibility of warning information for the specified line is provided if there is a need. It is also

Table 29.3 Comparison of mobile applications of passenger information systems before the trip

	DB Navigator	National Rail	SNCF app	HŽPP Planer
Availability in multiple languages	+	–	+	+
Availability for devices on Android, IoS, and Windows Phone platforms	+	+	–	–
One application that contains all the services	+	+	–	–
Enabled ticket purchase directly through the application	+	–	–	–
More ways to pay for tickets	+	+	+	–
Possibility to book a ticket	+	–	–	–
Possibility to reserve a seat	+	–	–	–
Travel planner	+	+	+	+
Offline map display and traffic information	–	–	+	+
Driving time schedule	+	+	+	+
Notices related to timetable changes	+	+	+	+
Additional offers	+	+	+	+
Adaptation for people with visual and hearing impairments	–	–	+	–

possible to search by the desired point of view from which all the data about a train and the lines are visible. HŽPP Planner mobile application cannot purchase tickets, which is the biggest drawback of the application. For this reason, another HŽPP Karte mobile application is also in use, which enables the above. Table 29.3 shows the essential characteristics of the analyzed applications.

According to the parameters listed in Table 29.3, it can be concluded that the mobile application for passenger information DB Navigator satisfies the broadest range of parameters considered.

29.4.2 Opportunities to Improve Passenger Information System in Croatia

Based on the analysis of possible ways of informing passengers in rail transport, the countries with the largest number of passengers per year in the EU provide similar services and solutions for passenger information. For Croatia, which has a significantly smaller number of passengers than the analyzed countries, it is necessary to modernize the way of informing passengers at stations and stops if the railway network's competitiveness is to be increased. Thus, it is needed to monitor the development of modern IC solutions and services and within the defined TSI recommendations to implement optimal solutions on the railway network.

Given that passengers today need to obtain specific information related to travel and the possibility of choosing such information, it is necessary to equip stations and stops with solutions that have touch screens to achieve interactivity with passengers. Promotional materials can also be placed on such screens while passengers are not using them, and they could be adapted for people with visual and hearing impairments. Improving the passenger information service at stations is possible by incorporating diagnostic features into the displays. In this way, the passenger operator could react promptly to any interference, which would raise the quality of information delivery.

The most significant current disadvantage is visible in providing information to people with visual and hearing impairments, as the screens at the stations are not adapted to these groups of users. The mentioned shortcoming is also visible when informing passengers before the trip, i.e., when informing via the website and mobile applications. The information that the railway undertaking must provide to users with visual or hearing impairments must comply with the WCAG (Web Content Accessibility Guidelines) 2.1 guidelines. Also, the assistance reservation service provided by the railway undertaking should be based on modern communication solutions.

By applying the passenger information system and a certain TSI and the modernization of communication equipment on railways in the Republic of Croatia, it is possible to achieve greater passenger interest in using this form of transport. The improvement of the passenger information system in Croatia should imply its harmonization with the integrated passenger transport systems, the introduction of which in the Republic of Croatia's territory is yet to follow. Better informing users according to personalized criteria or travel needs is achievable by establishing a multimodal national access point. This point relies on a digital interface that provides relevant data and metadata from all transport service providers. Combining existing public and private access points into one point would further increase the availability of accurate and real-time information to passengers and increase the level of customer satisfaction with the requested service.

29.5 Conclusion

Advances in digital technology and the way data are used drastically changing aspects of society, including industrial production, the private lives of individuals but also traffic in general. Thanks to it, travelers can more easily get all the necessary information related to travel planning. Travel planning is essential for passengers, with IC solutions and services playing a pivotal role. Thanks to the development of these solutions and services, passengers are provided with developed information systems.

Understanding and effective management of railway requirements, such as providing information to passengers, cannot be seen only in a functional subsystem of telematics applications. Only one of the integrated subsystems is listed, which is interdependent with others and can only fulfill its role. For example, without the efficient maintenance of the railway infrastructure, the flow of railway traffic is disrupted, which leads to a decrease in the quality of the transport service, and thus to customer satisfaction.

Germany, the United Kingdom, and France are at the very top of the EU regarding the number of passengers transported by rail per year. Their passenger information systems do not differ too much in the offer of services. On the other hand, currently available passenger information systems in Croatia are still not enviable. The modernization of IC equipment at stations and stops is indispensable regarding technological solutions developed daily. With the modernization of IC equipment, more satisfied passengers are expected to use the railway more often as a form of transport for the necessary going to work or school and as the primary form of transportation to more distant destinations.

An analysis of mobile applications available to passengers shows that mobile applications available in Croatia offer their users the least opportunities. One of the crucial things that are missing in the current system of informing passengers in Croatia is the greater inclusion of people with visual or hearing impairments, given that the current system is not adapted to this group of people. The most significant emphasis is placed on the publicly available set of open data of data providers, which would increase the availability of necessary, accurate, and real-time information provided to end users.

Above mentioned is one of the biggest obstacles to passenger information systems in Croatia. This paper is the basis for further research in passenger information systems on the railway network in Croatia and its integration with other subsystems of railway management such as ticket management adaptive for individual user groups. It also opens the possibility of comparing data with other passenger information systems in the neighboring countries of Eastern and Central Europe. In addition to the above, future research will be based on the improvement of detected difficulties in the existing system to improve the information service to end users at the national level.

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Chapter 30
Use Case: Information Security Risk Assessment for Providers of Services in a Virtual Environment

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30.1 Introduction

In the world of high technology, organizations have become extremely dependent on information systems, while various forms of information and data kept on numerous media have become the most valuable resource of business systems. In that context, the business system reputation has also become a form of information asset. On the other hand, there are many threats to such property. The number of threats and their manifestations is increasing on an everyday basis. For that very reason, many organizations identify their information as very important assets they need to protect by internal security checks.

Information security must be taken care of because the value of companies is mostly concentrated in the value of information. In order to fully understand and be able to protect their information, organizations must be acquainted with the concept of information security. It is one of the key parameters which influence organizational exposure to business risk. Control of information starts with the assessment of its risk exposure. The world has been growing and technologically improving for years without questioning the security in the way it is questioned now. This resulted in cyber threats and vulnerability deeply integrated in the architecture of information systems and systems which support their correct functioning. As

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a result, a cyberattack represents a level of challenge the organizations are only preparing for.

Scenario development to predict and prepare for causal accidents and extraordinary events in nuclear, chemical, and energy sector has been used for risk prioritizing and quantification and undertaking of actions. Probabilistic risk assessment (PRA) is one of the methodologies based on scenario development elaborated for the needs of high-risk and complex systems in nuclear power plants. This methodology allows for quantification of the probability of events related to various types of accidents and quantifies the occurrence of various incidents.

This paper presents a use case of information security risk assessment by means of fault tree and event tree methods as part of PRA methodology. The operational concept is based on the availability of service providers' data essential for service delivery in the virtual environment of games of chance. The paper also presents the application of these methods in a complex information system such as that of the company Hrvatska Lutrija.

30.2 Information Security Concept

According to [1], information security is a state of data confidentiality, integrity, and availability achieved through the application of the prescribed measures and standards and organizational support to the planning, implementation, checking, and improvement of the measures and activities aimed at maintenance of data security. Information security is mainly focused on the so-called CIA triad: confidentiality, integrity, and availability of data [2]. Information security concept is based on the triad. Data availability is basic for games of chance, while user data in such an environment must be confidential and the system must be 100% reliable. The focus is on the security of all data and that of the information systems involved in the processing of such data. In an organization, information security is a process linked to its information system that ensures the achievement and maintenance of its basic features at the level required by the organization [3].

Information security aims to protect information and information assets from threats, which might result in interrupted operations, authority abuse, errors, and omissions in the performance of regular activities, as well as to ensure business continuity and reduce potential risks.

To achieve and maintain all the above information security features, it is necessary to consider all information assets, which consist of:

- Information that can be stored as hard copies, data files, databases, etc.
- Software that includes applications, system and management software, auxiliary software.
- Computer equipment consisting of computers, servers, storage systems, etc.
- Communication equipment, i.e., routers, switches, telephones, physical connections, etc.

- Other tangible equipment, such as rooms, air conditioners, keys, installation software, etc.
- Internal or external services.
- Personnel, i.e., their health, knowledge, experience, and skills.

Threats, as potential cause of unpredicted and unwanted security incidents can cause various business damage or even interrupt business operations [4]. They come from various sources, such as organization's staff activities or hackers' attacks. Since financial loss caused by security rules breaches is often not accurately determined, managers should be aware of the threats which affect their assets. Also, it is necessary to recognize the impact of such threats in order to determine the steps necessary for attack prevention [5]. Security risk is the possibility for threats to take advantage of an organization's information assets vulnerability, which can cause business damage.

The assets are subject to numerous threats. They come up because of organizational omissions, causal or intended human actions and omissions, technical reasons, lack of compliance with regulations, policies and procedures, and force majeure as well.

The mitigation of security threats to information assets has become an important area of organizational strategy. Information security strategies apply principles and practices based on prevention and reaction. Prevention manages the predicted threats, while reaction is oriented toward the management of the unpredictable threats [5]. As part of information assets, knowledge represents an especially important segment of organizations. There are few researches on specific, but also technical, knowledge protection measures, which are automatically applicable [6].

Organizations' focus is on the application of information security products. Some of them are complete security systems, public key infrastructures, antivirus systems, database, and content security. Apart from the abovementioned, information security also requires a strategy to determine the modality of performance of specific security checks (policies, processes, procedures, organization of business processes) in order to protect information assets of a specific organization [7]. Organizations' management should strive to achieve an appropriate level of information security by applying the appropriate set of security checks and security software and information technology resources, while considering the basic principles of information security. Selection and performance of the appropriate security checks and mechanisms in data processing and storage in traditional and electronic business environment represent the basis for preserving basic security and privacy principles [8]. Strategic cybersecurity planning in the Republic of Croatia is performed by using the guidelines adopted by ENISA as the leading European Union body in the area of cybersecurity. However, there are numerous shortcomings that appear while reaching compliance with and adopting the guidelines [9]. The implementation of information security measures is a demanding procedure which must constantly be under control. This gives organizations the possibility to take right decisions which will result in huge financial savings [10].

Given the above, the development of information and communication systems leads to the possibility of reducing data security in organizations. Great efforts are currently being made to protect information security to the maximum. One of the ways of protection is the methods of information security risk assessment in organizations. For this reason, this paper will present the application of the error tree and event tree methods to the example of a real information system.

30.3 Management of Information Security Risks

A risk management system aims at setting up a permanent mechanism for the control and management of an acceptable level of organizational risks. All risk owners are responsible for the assessment and definition of the risk management procedures relating to their assets. They are also responsible for the definition of acceptable levels of risk and maintenance of risks within acceptable limits. Risk management consists of [11]:

- Identification and classification of all information assets (software, hardware, documentation, services, persons, etc.)
- Identifying and analysis of all possible risks (threats, vulnerabilities, and impacts on business) and calculation of the real probability of occurrence.
- Identification of damage to the operations if a risk occurs.
- Risk level assessment.
- Definition of risk management modality.
- Definition of controls to minimize the risk of system crash.

Risk assessment of information security management systems is often based on the list of information assets with the data necessary for risk analysis. Since the above list of information assets is often very exhaustive, organizations sometimes opt for specific information assets for reasons of similar characteristics and security requirements. It is also necessary to link the interdependent information asset items (especially hardware and software), in order to make a risk assessment for the so formed groups. When grouping the assets, it is necessary to pay attention and consider any possible peculiarities of specific information assets.

After defining the assets that are within the scope of the risk assessment, it is necessary to select an appropriate risk assessment methodology. One of the simple methodologies considers risk through the function of threat probability (P_T), level of information asset vulnerability (L_V), and asset value (V_A):

$$R = f\,(\mathrm{PT}, \mathrm{LV}, \mathrm{VA}) \tag{30.1}$$

For each information asset group and/or item, it is necessary to assess the value, level of vulnerability, and probability of threat occurrence. The details of this methodology have been provided in ISO/IEC 27005 standard which describes information security risk management. Once those information assets are listed and grouped by business and/or security features, risk value for each information asset item and/or group is defined by using the following steps [12]:

1. Determination of the value of each single information asset item or asset group.
2. Identification of possible threats for each single information asset item or asset group.
3. Determination of the probability of occurrence of each threat.
4. Identification of possible vulnerabilities that each specific threat can take advantage of.
5. Determination of the level of easiness of taking advantage of each of the identified vulnerabilities.
6. Calculation of risk value.

Risk value is obtained by combining the abovementioned variables (probability of occurrence, level of vulnerability of information assets, and value of these assets). Risk assessment describes risks in terms of quality or quantity and enables managers to give priorities to risks based on their perceived severity or other previously determined criteria. It is often performed in two (or more) iterations. A high-level risk assessment is performed firstly, in order to identify the potentially high risks which require further assessment. Next iteration can include a further level of examination of potentially high risks identified in the initial iteration. If the information provided in such a way is insufficient for risk assessment, further detailed analyses must be performed, most frequently encompassing parts of the scope and very often by using other methods of risk assessment.

After the risk assessment has been performed, information assets owners can choose one of the possible risk management options:

1. *Risk mitigation* by application of the appropriate checks.
2. *Risk acceptance* (no additional checks can be implemented or would be too expensive).
3. *Risk transfer* to third parties (insurance company, provider, etc.)
4. *Risk avoidance* by identifying and suspending the activities which would cause the risk.

Considering the simplest risk assessment and evaluation modality, based on the assessed risk level, the procedures could be the following:

- Risk has been assessed as low.
  - This risk is accepted and there is no need for any additional controls.
- Risk has been assessed as medium.
  - The risk is registered and accepted.
  - Additional checks are considered based on the cost-benefit analysis.
  - The owner of information assets informs the lead information security engineer regarding further steps and risk processing procedure.

- Risk has been assessed as high.
  - Implementation of additional checks aimed at mitigating the level of risk is necessary.
  - If implementation of additional controls is not possible, risk should be transferred to a third party or avoided.
  - The owner of information assets informs the lead information security engineer regarding further steps and risk processing process.

30.4 Information Security Risk Assessment by Using PRA Methodology

As previously mentioned, when a detailed asset-specific or critical business process-specific analysis is needed, more complex methodologies, that can encompass the complexity of relations between information assets, are applied. One of such methodologies is PRA. It represents a systematic and comprehensive modality of assessment of the risks relating to complex technical systems. The first significant PRA methodology application was registered over 30 years ago in a study known as WASH-1400 Reactor Safety Study for nuclear industry.

PRA methodology assesses the risks relating to all aspects of life cycle of a complex technological entity, from concept definition, design, building, and operation to withdrawal from use. Although these methods were initially used for analyzing the risks to which nuclear stations are exposed, they found their use in other technical systems as well [13].

Today's business operations' dependence on information systems is extremely high in certain industries. Also, information systems have become more and more complex, they contain more and more mutually dependent parameters such that this methodology started being applied for the assessment of information security risks as well [14].

According to PRA, risk is defined as a possible adverse effect of a specific activity. It is characterized by two components [15]:

- Scope/strength/impact of a possible adverse effect.
- Probability of occurrence of any effect.

By creation of various scenarios, it is possible to make qualitative and quantitative risk assessments. In general, creation of such scenarios uses terms such as initiating event, transitional event, and event tree. The consequences are expressed numerically, while the probability is expressed as perceptual value or frequency. Total risk is composed of the expected loss expressed as a sum of products of the effects multiplied by the corresponding values.

Traditional PRA methodology uses [13]:

1. Event trees for listing possible scenarios, i.e., sequence of events from initiating event to the final state.

2. Fault trees for finding the cause of individual scenarios and modeling possible failure of the checks applied to mitigate risks, including the interdependence of system components.
3. Assessment of frequency and probability for model elements such as initiating event (accident), component defects, and similar.

Most often PRA can provide answers to the following questions [16]:

- Which events can lead to adverse consequences?
- What is, in terms of quality and quantity, potential damage or negative consequences of an initiating event?
- What is the probability or the frequency of undesired consequences?

The two methods used for providing answers to the above questions are the event tree analysis (ETA) and the fault tree analysis (FTA). Traditional PRA methodology uses event tree to list possible scenarios, while fault trees are used for finding the causes of occurrence of certain scenarios.

30.4.1 Event Tree Analysis—ETA

The analysis that uses an event tree (Fig. 30.1) is a method of identification and assessment of sequences of events in a potential scenario (accident scenario) which is realized after the occurrence of the initiating event. ETA uses a visual tree structure to present the logic and event development. It aims at determining whether there is possibility for the initiating event to develop in a series of faults or it is sufficiently controlled by security systems and procedures implemented in the system design. ETA can result in multiple outcomes arising from a single initiating event and allows probabilities to be obtained for each outcome. Various outcomes represent various branches of event tree [13].

ETA is a very powerful tool for the identification and assessment of all effects in the analyzed technical system, for which it is possible that will occur after the initiating event. The process starts with the definition of the group of initiating events that can have adverse effects on a technical system (e.g., they can cause a configuration change). For each initiating event, additional conditions that might contribute to the realization of adverse effects are defined. The consequences and probabilities of each scenario are assessed for each initiating event. The group of values of all scenarios represents a technical system risk profile.

The modeling of incident scenarios starts with the initiating event and advances through pivotal events until the final incident. The probability of the pivotal event can be assessed by using FTA (fault tree analysis). Most often, pivotal events are divided by using a binary principle—the event will or will not occur, the system will or will not fail.

ETA aims at the determination of the probability of all consequences caused by the initiating event. By analyzing the possible consequences, it is possible to

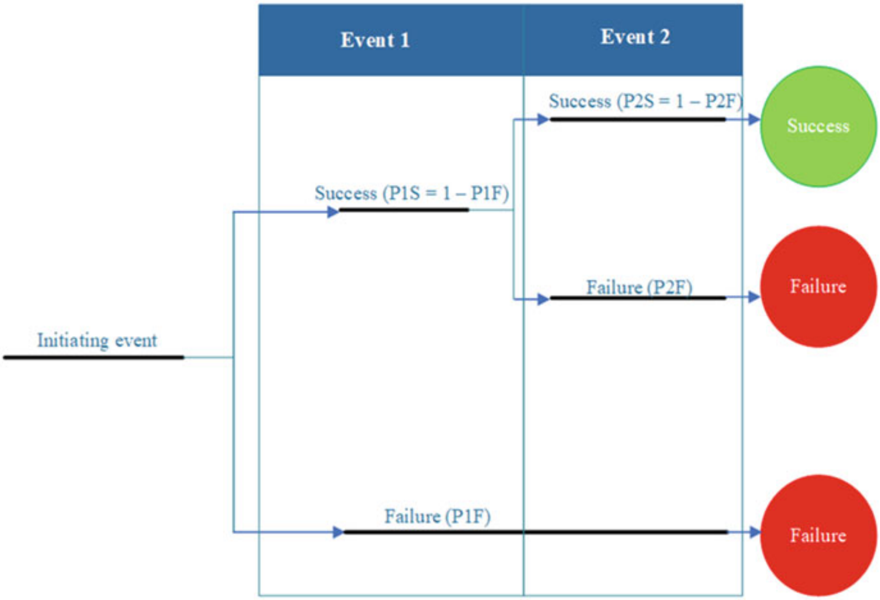

Fig. 30.1 An example of event tree

determine the percentage of consequences which lead to a wanted or unwanted result. In cases when risk exposure is too high, i.e., when consequence path is unacceptable, one proceeds to the development of the strategies that can change risk exposure.

30.4.2 Fault Tree Analysis—FTA

Fault tree analysis (Fig. 30.2) is a technique that allows for a systematic description of the combinations of possible underlying events in the system which results in an undesired peak event. The analysis consists of the determination of the undesirable consequence and the underlying events that contribute to the predictable undesirable peak event. The basic events are connected by using standard logical operators (AND, OR, and similar) via the so-called gates. The events that must exist or occur together with another underlying event, in order to cause an undesirable event, are described by using AND conjunction. Basic events that can individually cause an undesirable consequence are described by using OR conjunction [13].

Risk assessment starts with identification of critical events and combination of the events that lead to the peak undesirable event. The probability of peak event is estimated based on the probability of underlying events. The analysis is based on Boolean Logic. Unlike logic diagrams in ETA where binary values (true or false)

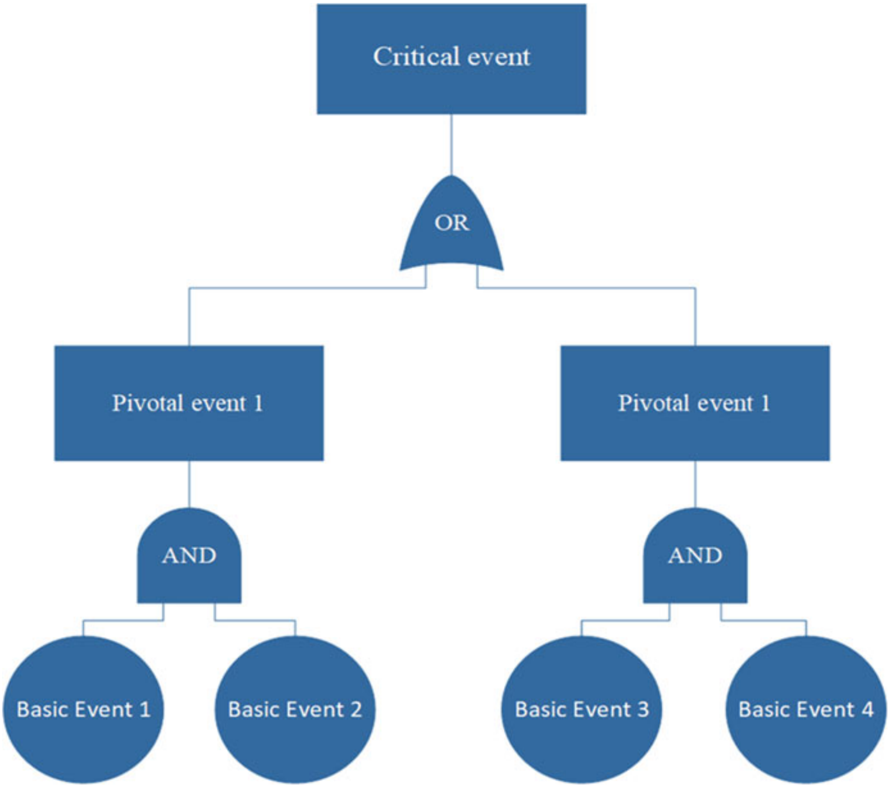

Fig. 30.2 An example of fault tree

are applied, the probability of the consequences of events in FTA depends on the probability of the underlying events that lead to the analyzed consequences.

30.5 ETA and FTA Methodology use Example—Air-Conditioning System Failure

As a use case of the two risk assessment methods, we have considered the case of failure of the air-conditioning system of a system room in which important information system computer and network devices of Hrvatska Lutrija are located. Hrvatska Lutrija is equipped with systems that require high availability, and temperature rise in the system room (over 40 °C) can cause hardware components to stop working (most equipment is declared to operate smoothly only at temperatures below 40 °C). Temperature rise in the event of failure of the air-conditioning system in the system room takes place quickly because of the large amount of computer and network resources that heat the space.

This paper presents the following problem:

Protection measures that ensure the operation of the air-conditioning system are part of that system. There is a redundant unit which must be turned on manually in the event of primary unit failure. Therefore, for uninterrupted functioning of the air-conditioning system, it is necessary that all elements (additional redundant unit, temperature sensor, human reaction) are functional.

The traditional risk analysis method does not provide a possibility to combine all elements to detect all failures which lead to the interruption of functioning. For that reason, event tree analysis method will allow the identification of the series of events which might lead to the failure of air-conditioning system and to assess the probability of these events based on the statistics of previous events. By fault tree analysis method each individual event from the event tree will be analyzed. The result will be a display of the list of causes of interruption of air-conditioning and a display of the probability of that individual subsystem fault to influence the functioning of the whole system.

30.5.1 ETA Analysis

In this use case, methodology of event tree use will be demonstrated through the following four steps: initiating event identification, identification of security checks established in response to the possible occurrence of the initiating event, event tree construction and evaluation, and description and interpretation of the obtained incident sequences.

Identification of the initiating event

The initiating event considered in this use case is the failure of the system room air-conditioning system. The system room from this example is used for key hardware infrastructure (servers, various network equipment, data storage system) of the information system of Hrvatska Lutrija. The equipment kept in this room requires humidity and temperature maintenance according to the guidelines prescribed by single producers. The organization satisfies these requirements through a separately constructed and implemented air-conditioning system. The system comprises two air-conditioning units—the primary and the secondary. Only one of them is active at the time, while the other is used as support and it is redundant. The functioning of the air-conditioning system is monitored by means of a sensor for measuring system room temperature and humidity. In the event of temperature or humidity rise, human intervention is needed to regulate the settings of the air-conditioning system and/or turning the redundant unit on.

In the event tree (Fig. 30.3), the upwards branching represents a positive outcome, while the downwards branching represents a negative outcome of the event.

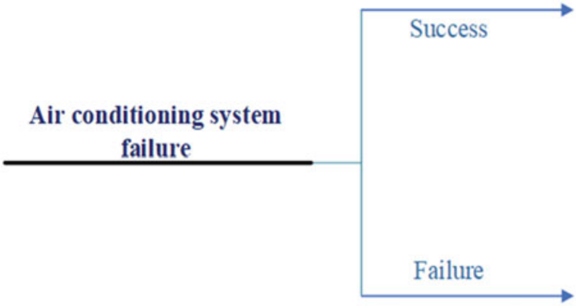

Fig. 30.3 Initiating event

Identification of security checks

For the purposes of managing, surveillance, and protection of air-conditioning system functioning, a sensor system for measuring temperature and humidity has been implemented, as well as a system of e-mail reporting of nonregulated values read from the sensor, 24/7 monitoring by technical staff, and the possibility of introducing a substitute air-conditioning unit, if needed.

The events which can be examined in the system implemented and controlled in this manner are:

1. Temperature sensor reports temperature increase in the system room which exceeds the permitted limit.
2. A member of responsible technical staff notices the alarm activated by the sensor.
3. A member of responsible technical staff turns on the redundant unit.

Construction and evaluation of events tree

The data registered by now, identified by monitoring of the incidents that occurred in relation to the air-conditioning system indicate the following:

- Air-conditioning system failure occurs on average twice a year.
- The expected accuracy of alarm activation by temperature sensor is 99.9%.
- A member of responsible technical staff perceives the alarm in 90% of cases.
- A member of responsible technical staff successfully turns on the redundant unit in 95% of cases.

The event tree for the described system is presented in Fig. 30.4.

The marks P1S, P2S, P3S, P1F, P2F, and P3F of the event tree in Fig. 30.4 represent the probability of single events:

- P1S—The sensor *successfully* activates the alarm after system room temperature increase which exceeds the permitted limit.
- P1F—The sensor *unsuccessfully* activates the alarm after system room temperature increase which exceeds the permitted limit.
- P2S—A member of responsible technical staff *successfully* notices the alarm activated by the sensor for system room temperature monitoring.
- P2F—A member of responsible technical staff *unsuccessfully* perceives the alarm activated by the sensor for system room temperature monitoring.

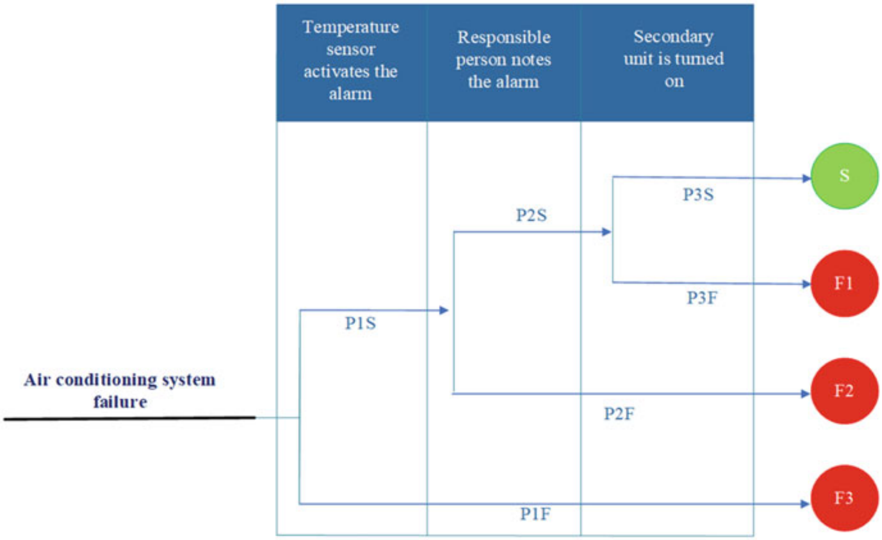

Fig. 30.4 Air-conditioning system failure—event tree

- P3S—A member of responsible technical staff *successfully* turns on the system room air-conditioning redundant unit.
- P3S—A member of responsible technical staff *unsuccessfully* turns on the system room air-conditioning redundant unit.

The probability of single marks of the events can vary depending on the presumptions. According to the data collected, the expected accuracy of alarm activation by temperature sensor is 99.9%, i.e., 0.999. If

$$P1F = 1 - P1S = 1 - 0.999 = 0.001 \tag{30.2}$$

then the event is complementary to P1S event. If P2S = 0.9, a member of responsible technical staff will notice the alarm in 90% of cases, according to the data collected.

P2F event is complementary to P2S event because.

$$P2F = 1 - P2F = 1 - 0.9 = 0.1. \tag{30.3}$$

And, according to the data collected, a member of responsible technical staff will successfully turn on the redundant unit in 95% of cases. P3F event is complementary to P3S event because.

$$P3F = 1 - P3S = 1 - 0.95 = 0.05. \tag{30.4}$$

In the same figure, possible outcomes marked with F1, F2, and F3 have the following meanings:

- S—after the failure of air-conditioning system, system room temperature monitoring sensor registered an increase in temperature which exceeded the permitted limit and successfully activated the alarm, which a member of responsible technical staff successfully noticed and successfully turned on the secondary air-conditioning unit of the system room, which resulted in the fall of temperature to the permitted level.
- F1—system room temperature monitoring sensor did not register the increase in temperature exceeding the permitted limit and the temperature in the room rose uncontrollably until the automatic shutdown of the installed equipment and its probable damage.
- F2—system room temperature monitoring sensor registered temperature increase exceeding the permitted limit and successfully activated the alarm, but a member of responsible technical staff did not notice it, which lead to the same consequences as in F1 case.
- F3—system room temperature monitoring sensor registered temperature increase exceeding the permitted limit and successfully activated the alarm, which a member of responsible technical staff noticed, but did not manage to activate the redundant unit.

The final results of F1, F2, and F3 outcomes are the same, but the probability of their occurrence is different, as presented in the following:

$$\mathrm{P}\,(\mathrm{F1}) = \mathrm{P1S} \times \mathrm{P2S} \times \mathrm{P3F} = 0.999 \times 0.9 \times 0.05 = 0.044955 \tag{30.5}$$

$$\mathrm{P}\,(\mathrm{F2}) = \mathrm{P1S} \times \mathrm{P2F} = 0.999 \times 0.1 = 0.0999 \tag{30.6}$$

$$\mathrm{P}\,(\mathrm{F3}) = \mathrm{P1F} = 0.001 \tag{30.7}$$

The probability of a positive outcome is as follows:

$$\mathrm{P}\,(\mathrm{S}) = \mathrm{P1S} \times \mathrm{P2S} \times \mathrm{P3S} = 0.999 \times 0.9 \times 0.95 = 0.854145 \tag{30.8}$$

Description of event sequences

The above analysis leads to the conclusion that air-conditioning system failure will be resolved with a positive outcome in slightly over 85% of cases:

1. In about 4.5% of the cases, system room temperature monitoring sensor will not register temperature increase above the permitted limit.
2. In almost 10% of the cases, when the sensor registers temperature increase and the alarm is activated, this will not be noticed by operators who will not react.
3. In only 1% of the cases, it was not possible to activate the redundant unit.

30.5.2 FTA Analysis

Fault tree analysis methodology will deal with the three key events identified relating to the control mechanisms of the air-conditioning system management:

- Temperature sensor does not register temperature increase.
- A member of responsible technical staff does not notice temperature monitoring sensor alarm.
- It is not possible to turn on the redundant unit.

A failure tree will be drafted for each of these cases in order to register possible reasons for the occurrence of these events. Apart from that, for every event, it is possible to define the probability of its occurrence as well.

Temperature sensor is not functioning

Temperature sensor in the system room has the task of monitoring the temperature and activating the alarm if the temperature read exceeds the defined permitted limits. Temperature increase is the most common situation registered by the sensor. The reason for which the sensor does not perform its task may be either sensor defect or interruption of the link between the sensor and alarm system (Fig. 30.5).

Alarm system can be composed of a device that gives a sound and/or light signal or something else such as reporting by e-mail or SMS message to the mobile telephone of members of responsible technical staff.

A member of responsible staff does not notice the alarm

It is the task of members of responsible technical staff of the examined system to monitor the alarm system and turn on the redundant unit if necessary. It is possible

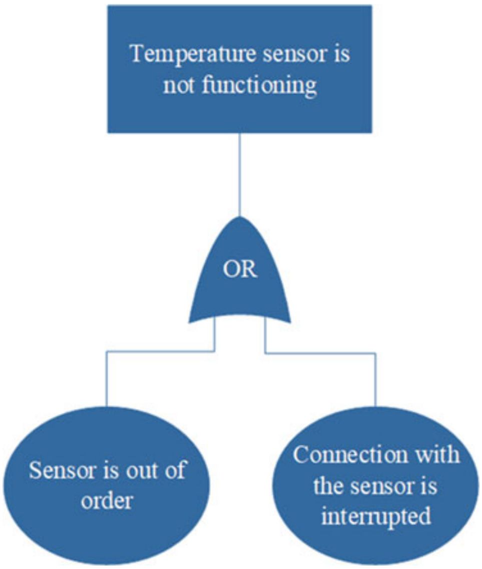

Fig. 30.5 FTA—temperature sensor does not register temperature increase

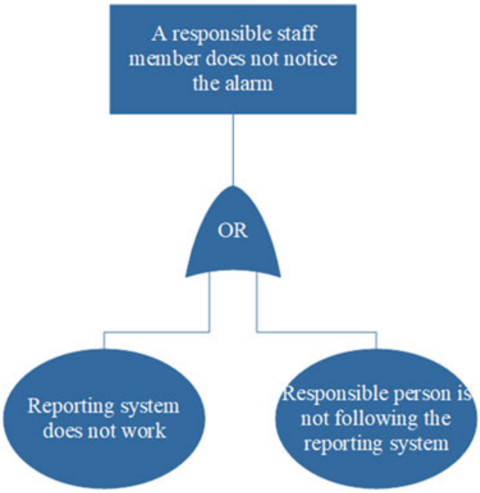

Fig. 30.6 FTA—responsible staff does not notice the alarm

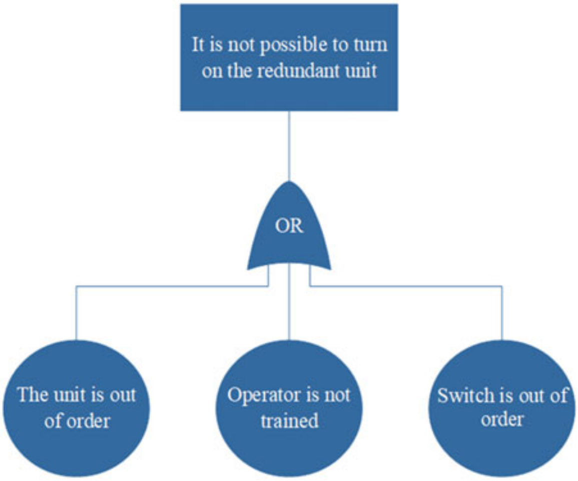

Fig. 30.7 It is not possible to turn on the redundant unit

that the responsible staff does not notice the alarm. The reason can be either an alarm system defect or failure to monitor the alarm (Fig. 30.6).

It is not possible to turn on the redundant unit

If needed, i.e., in case of primary air-conditioning unit failure, a member of responsible technical staff must turn the redundant unit on once the alarm has been registered. However, there might be cases when it is not possible to turn the redundant unit on. The above diagram shows that among possible reasons there are a defect of redundant unit, defect of the switch used for turning on the redundant unit in the primary system or failure to train the appointed responsible technical staff in charge of air-conditioning system supervision (Fig. 30.7).

30.6 Conclusion

Risk management is one of the basic processes in the successful management of an organization's information security system. Information security risk management has become highly complex due to the growing interconnectedness and interdependence of various information systems. Consequently, attacks on systems are becoming increasingly difficult to predict. Information security risk analysis is enhancing in today's world, from an approach based on the analysis of security checks or static observation of information assets' state to a scenario-based approach and determination of such scenarios' probability. Scenarios reflect system, equipment, and component configurations, as well as key interactions between humans and the system, associated with event detection, diagnosis, mitigation, and system recovery.

This paper has presented the application of two PRA methodology approaches on a selected subsystem that can be found in almost every modern information center. An initiating event, the implemented system protection checks, possible events related to the implemented checks, and probabilities of their occurrence have been identified. Through an analysis of the created trees, it has been concluded which sequences of events are possible, as well as their certainty and their possible causes. By using this approach, probable scenarios with an undesirable impact on information system functionality have been identified and additional data were provided for optimal selection of protection measures.

It can be concluded from the use of PR methodology and the methods based on event tree and fault tree is possible outside the industries in which these methods were initially designed. The reason for the applicability of these methods, despite their demanding nature, is the fact that today's information systems, like aerospace manufacturing and chemical plants systems, consist of many subsystems and that the level of expected availability of these systems, i.e., unacceptability of interrupted functioning, has become equivalent to the requirements of high-risk industries such as nuclear power plants. Given the complexity of the implementation of these methods, the most effective application of a methodology is in the second or third risk assessment iteration, i.e., it is used for a deeper consideration of potentially high risks detected in the initial iteration. The results of this research give room to further research in the field of data availability in a virtual environment to increase the level of information security. Further research will focus on qualitative and quantitative risk assessment. Also, the methodology implemented in this paper will be used to model possible failures in other fields of information security.

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Chapter 31
Technological Assurance of Bracket-Type Parts Manufacturing

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31.1 Introduction

Recent trends in the manufacturing engineering industry indicate that in a competitive environment, manufacturers are trying to reduce the time to market, while the complexity of products and requirements for their accuracy and quality is continually growing. In this regard, it is crucial to introduce flexible fixtures, which provide a quick readjustment to a different size of parts within the specific design and technological characteristics of the workpieces. Increasing the range of products in modern machine-building enterprises requires the production of frequent readjustments to machining another batch of parts, which raises questions about the economic feasibility of designing and manufacturing dedicated fixtures for parts of a specific size [1].

Constant updating of the nomenclature of parts due to minor design changes, as well as small batch sizes, makes the topic of design, simulation, and manufacturing of flexible fixtures topical and timely. Increasing the flexibility and expansion of technological capabilities of fixtures, reducing the preparatory and final time for their readjustment, and, consequently, increase the efficiency of metal-cutting machines is provided by developing and implementing fast-adjusting functional units [2].

The research aims to increase the efficiency of bracket-type machining by intensifying the process, and the implementation of flexible fixtures allows multiaxis machining.

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31.2 Literature Review

The parts of this type are characterized by the complexity of the locating charts, insufficient tool availability due to the complex spatial arrangement of work surfaces. Therefore, it leads to difficulties in the realization of multiaxis machining. In this regard, it is an urgent task to develop a fixture that provides the necessary tool availability and allow multiaxis machining.

In single and small-batch production, which characterized the modern manufacturing engineering, the degree of automation was achieved using the CNC machining centers, built into automated systems due to high flexibility and productivity [1, 2].

In modern production, the main task is the contradiction between the need to reduce the time required for the design and manufacture of products and the increasing complexity of product design. The modern global market requires increasing the number of product types. Therefore, equipment and processes need to be more flexible. Fixtures play an essential role in the production of high quality and competitive products in multiproduct manufacturing. Ways to increase the efficiency of machining parts are considered. Fundamentally new designs of functional modules of reconfigurable modular fixtures for locating and clamping workpieces are introduced. The use of the proposed fixtures with the possibility of automated control provides an expansion of the technological capabilities of CNC metal-cutting equipment, reducing the preparatory and final time and time for readjustment, and therefore contributes to the efficiency of production planning [3].

In the face of increased global competition, which encourages every manufacturer in the industry to make every effort to improve their competitiveness by improving product quality [4, 5], reducing the time required to bring new products to market, and reducing production costs, there is a need to improve the design methodology for fixtures. The design is expected to be more efficient and less expensive. The design and technological features [6, 7], material properties [8, 9], coatings of functional surfaces [10, 11], cutting, and working conditions [12, 13] should be considered for fixture design. The design of fixtures is a very complicated and time-consuming process that requires many years of practical experience. Using the latest advances in CAD/CAM systems and artificial intelligence techniques, it is possible to limit the variety of solutions so that only those solutions are considered in the design that allows increasing productivity [14].

The automated design of fixtures is the focus of research in process planning and the integration of CAD/CAM technologies. The CAFD system has been developed, where when specifying surfaces and mounting points, the elements of the fixture are automatically selected under the specified assembly conditions. Also, the accuracy analysis of fixtures and the planning of a system for the fastening of preparation are presented [15].

Innovations in the technology of manufacturing parts are also due to the requirements to reduce the duration of the production cycle and maintain a consistently high level of product quality in production conditions. A systematic approach to improve the accuracy and functionality of multiaxis machine tools for precision machining is proposed. Error correction and error modeling systems have been developed for more accurate modeling and compensation [16].

In the study of systems "fixture–workpiece," the primary attention is paid to the analysis of the contact interaction between the workpiece and functional elements of the fixture [17]. The friction between the elements of the fixture and the workpiece was investigated. As a result, deformations that occur at the places of their contact were determined.

The study [18] focuses on the analysis of the interaction between the clamping elements of fixtures and workpieces under dynamic loading during machining. The proposed approach allows optimizing a large number of input parameters, which are critical for the analysis of interaction. The results of experimental researches have shown that under certain conditions, clamping elements with spherical tips of larger radius provide much less consistency.

In the study [19], a simplified model was developed for determining the deformation between the clamping elements of the fixture and the workpiece, and a finite element model for estimating the contact deformation.

In the study [20], a finite element model was developed for determining the stability of a workpiece during its fixing in a fixture. As a result, the influence of various factors on the rigidity of the fixture was investigated.

Due to the rapid change in market requirements and short product life cycle, flexibility is one of the most critical characteristics of automated systems; in addition to the cost of acquisition and operation, flexibility allows the system to adapt to future product requirements and production processes [21].

The ability of a production system to easily adapt to various uncertainties in their production system is described as production flexibility. Flexibility has become an essential part of many manufacturing systems. Many technological features that are common to production systems are considered and included in the development of two models of production flexibility that evaluate the efficiency of production systems [22].

Productivity, quality, and flexibility are critical indicators of production efficiency to justify investment in production systems. Definitions and quantification are established for the above characteristics, which are integrated into the model for evaluating the production system as a whole [23].

A fixture, a workpiece, and a cutting tool are elements of the comprehensive dynamic system. During machining, the contact of the cutting tool with the workpiece causes vibration, which leads to error, which in turn affects the accuracy of machining. To minimize the vibration level, the finite element simulation was performed, and the vibration amplitude was determined by harmonic analysis. It is proved that the amplitude of vibrations can be minimized by optimizing the design of the fixture [24].

The need to reduce costs and the production cycle while maintaining or improving quality is a current trend in production. Additive production methods, such as Fused Deposition Modeling, are effectively used to create process equipment, such as templates, molds, intensifiers, plates, assembly tools, mandrels, machining, and drilling tools [25]. Flexibility is a key factor in responding quickly to a wide range of needs. Specific examples of useful solutions for technological equipment are presented.

A fixture is an essential element of the machining system. Promising is the development and implementation of intelligent fixtures that allow to identify critical conditions of the machining process, compensate for the effects of errors, and minimize deformation [26]. The influence of fixing force and workpiece characteristics at different stages of machining is investigated in work.

A strategy for the automated design of fixtures is developed, based on design information about the object of machining. The analysis of accuracy at the creation of new technological processes is formed with a comparison from a database. The efficiency of the system has been tested by several production examples [27].

31.3 Research Methodology

31.3.1 Classification of Bracket-Type Parts

Based on problem-oriented analysis of bracket-type parts, design, and technological classification was proposed, which considered all possible designs of brackets that may occur in the car (Figs. 31.1).

According to the length of the locating surfaces, the parts are classified into brackets with long ($l/d > 1$) and short ($l/d < 1$) locating surfaces, which fundamentally determines the method of their locating during machining and, accordingly, the fixture design.

Brackets usually have one or more design bases that are parallel or nonparallel to each other. The locating surfaces in cross section can be round or non-round, which determines the shape of the locating surfaces of the mounting elements.

By weight, the brackets are classified into light (less than 1 kg), medium (1–10 kg), and heavy (more than 10 kg), which are made of steel (e.g., DIN C10, GS-45, GS-60, and G45), cast iron (e.g., DIN GG15, and GG18), as well as for nonmetallic materials, which affects the choice of equipment, cutting tools and the appointment of cutting modes during machining.

Depending on the purpose, the brackets are divided into brackets with high (IT 6–IT 7), medium (IT 8–10), and low (IT 11–14) accuracy of locating surfaces. The production of base surfaces with high accuracy, other things being equal, guarantees a more reliable and durable operation of the bracket and the product as a whole. The overall dimensions of the brackets are divided into small (less than 50 × 50 mm), medium (from 50 × 50 mm to 300 × 300 mm), and large (more than

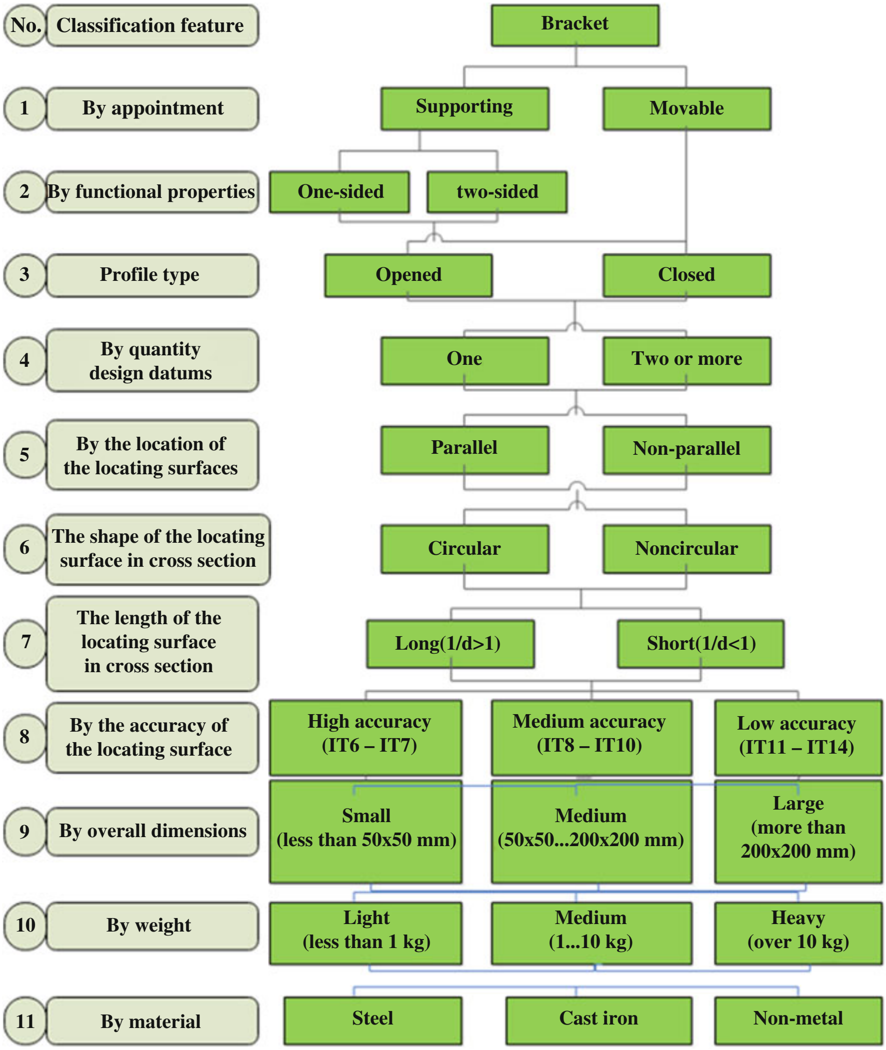


Fig. 31.1 Design and technological classification of brackets

300 × 300 mm), which determines the overall dimensions of the fixture and the required working space of the machine during manufacture. The surface roughness of the brackets is performed at Ra 0.8–6.3.

Based on the developed classifications for complex parts, the structural codes that characterize any of the above-stated parts on design and technological signs containing alphanumeric designations are offered. These codes can be used in the CAFD and information retrieval systems to select the fixture for the above parts (Fig. 31.2).

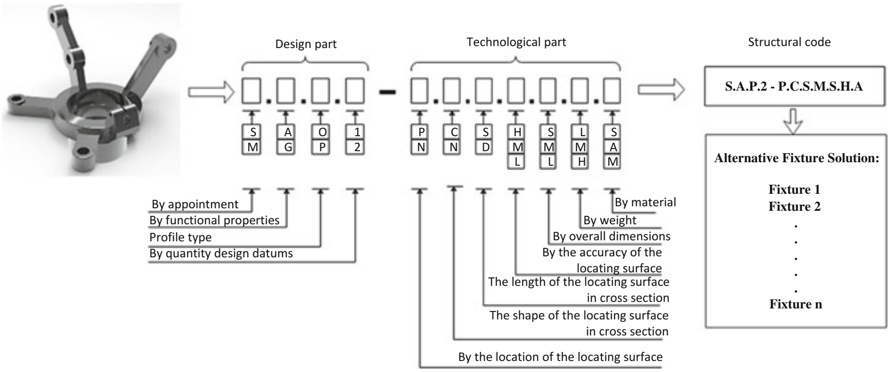


Fig. 31.2 The structural code of bracket-type parts

Given the information obtained from the design and technological documentation, the structural code in a formalized form can be represented by a set containing design (d_features) and technological (t_features) features:

$$\text{CODE} = \langle \text{d\_features; t\_features} \rangle\,. \tag{31.1}$$

Design features, which are a set of classifications by purpose (purpose), functional properties (functional), type of profile (profile), the presence of design datums (datums), recorded in the form:

$$\text{d\_features} = \langle \text{purpose, functional, profile, datums} \rangle\,. \tag{31.2}$$

Technological features, which include the location of the locating surfaces (locsurf), the shape of the locating surfaces in cross section (formsurf), the type of locating surface (typesurf), the accuracy of the locating surface (accuracy), the overall dimensions of the part (sizes), weight (mass), material (material), recorded as a set:

$$\text{t\_features} = \left\langle \begin{array}{c} \text{locsurf, formsurf, typesurf,} \\ \text{accuracy, sizes, mass, material} \end{array} \right\rangle. \tag{31.3}$$

Based on the analysis, the configuration of a detail (Fig. 31.3), which is most widespread in products, namely in the fastening of wheels, is revealed.

The bracket of this design is included in the vehicle of any purpose, be it a car or a truck, a tractor, or a bus, and may differ only in size and the slight change in shape.

Most brackets are made of steel and cast iron. Metal brackets are mostly high-strength products. They are made of materials resistant to various mechanical loads, temperature, and chemical influences, such as steel. The leading characteristic of

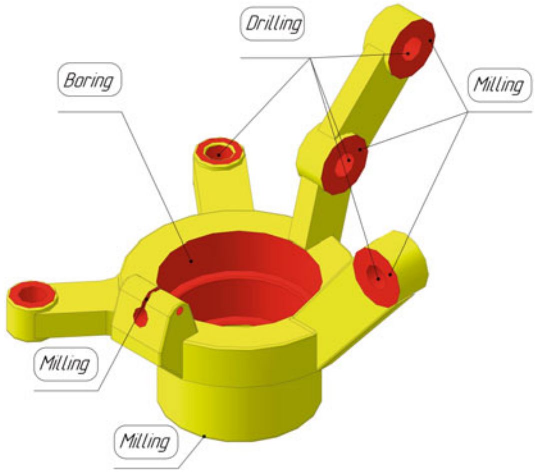


Fig. 31.3 A typical design and work surfaces of the bracket

various brackets is loading capacity—that is such weight which the given arm can withstand guaranteed.

31.3.2 The Typical Manufacturing Process of Bracket-type Parts

Most parts, such as brackets, have a complex geometric shape, which creates some difficulties in locating and fixing the workpieces in machining operations. Dedicated or flexible fixtures (usually modular fixtures) are used to install the workpieces, which provides a given accuracy of surface treatment, but increases the complexity and cost of manufacture. Thus, it is essential to analyze the typical technological process of manufacturing brackets and identify opportunities for optimization of the technological process considering current trends in machining, as well as functional and technological capabilities of modern equipment.

31.3.3 Expediency Substantiation of Machining Intensification of Bracket-Type Parts

The comparative analysis of the manufacturing processes is presented in Fig. 31.4.

Figure 31.5 shows the classification of the surfaces of the part that requires machining on a complex operation on the CNC machining center: machining holes (positions K, M, O, and P), machining bumps (positions A, B, D, G, H, and I), milling groove (position J) (Fig. 31.6).

Fig. 31.4 Comparison of the manufacturing routes for the bracket-type parts machining: (**a**) typical manufacturing process; (**b**) proposed manufacturing process

31.3.4 Fixture Design for Bracket-Type Parts

The development of a fixture with a high level of flexibility, allowing to implement fundamentally new schemes for their setup, is an essential task that requires further in-depth research.

To implement the scheme based on a complex operation on the CNC machining center, a flexible fixture for machining bracket-type parts is proposed (Fig. 31.7).

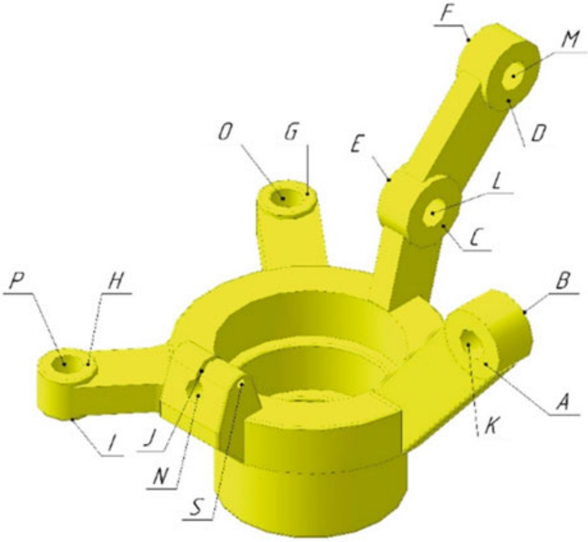


Fig. 31.5 Surface manufacturing

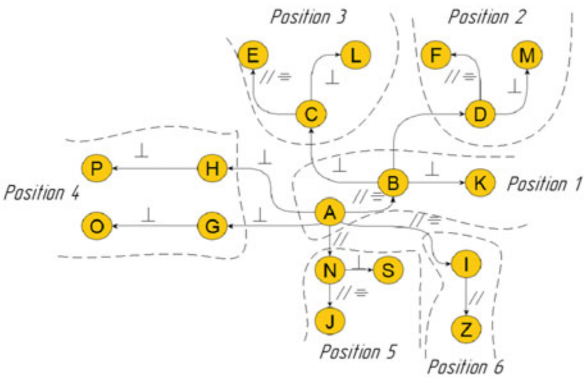
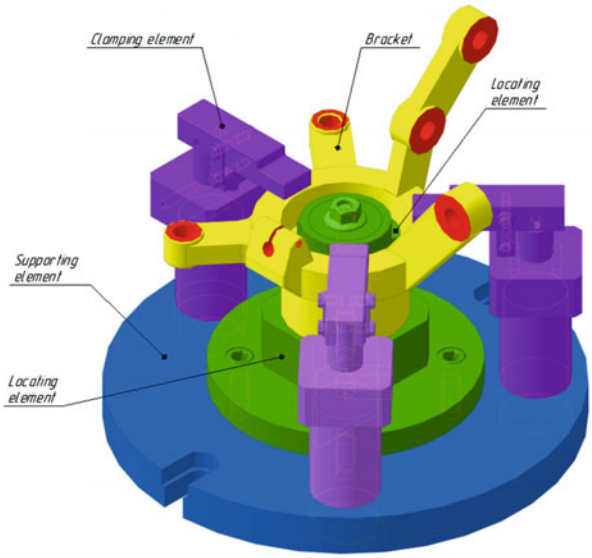


Fig. 31.6 Graphical relationship between the spatial position of work surfaces on the operation 15 "CNC multiaxis machining"

The flexible fixture for machining of bracket-type parts can be established both on a table and on the basic plates, which are included in various sets of modular fixtures.

The developed flexible fixture at its installation in various positions (Fig. 31.5) allows carrying out all drilling and milling operations at one setup. The use of a flexible fixture provides increased flexibility and reduced costs of preparatory time for readjustment during the transition to the machining of workpieces of other sizes, as well as provides comprehensive machining of the part.

Fig. 31.7 Flexible fixture



31.4 Results

It is proved that the efficiency of machining bracket-type parts is increased by reducing the number of operations, unproductive time, which reduces the complexity of machining, in particular, the number of operations is reduced from 11 to 6, the number of units from 6 to 4, the auxiliary is reduced by two times, and additional time—eight times, which has a positive effect on the cost of manufacturing parts. When calculating the complexity of machining, it is assumed that the batch size of parts $N = 50$ pieces. Cutting tools and cutting modes are similar for a typical and proposed process. Comparative analysis of time norms for the implementation of a typical and proposed manufacturing process is shown in Fig. 31.8.

The analysis showed that almost all all-time norms of the proposed manufacturing process are less than the time norms of a typical manufacturing process, which is due to fewer operations and auxiliary transitions. That is, it makes sense to reduce the number of operations and ancillary transitions through the use of advanced modern equipment in combination with flexible fixtures that provide the maximum possible tool accessibility.

According to the obtained results, the auxiliary time of the proposed manufacturing process is reduced from 8 min to 3 min per part, and therefore, increases the productivity of machining.

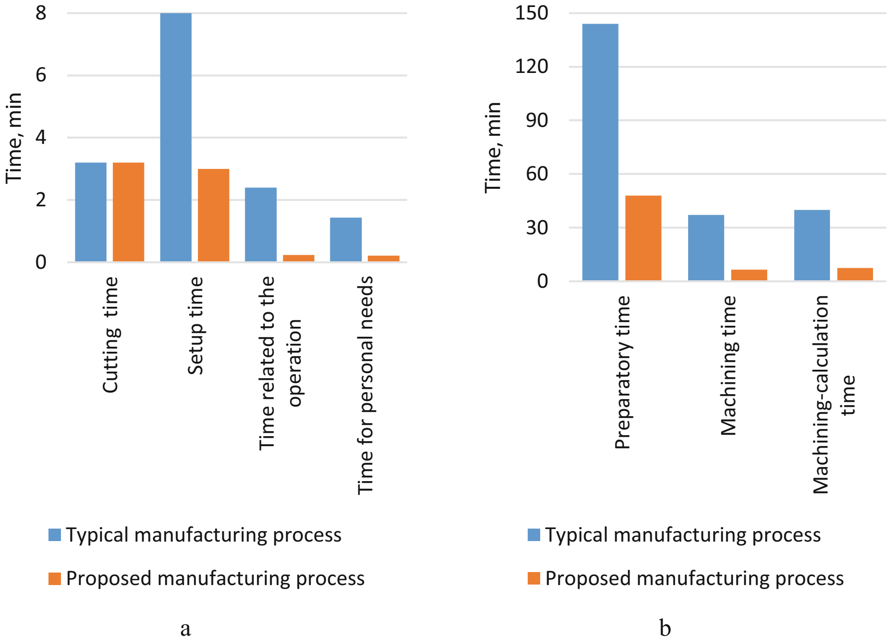


Fig. 31.8 Norms of time: (**a**) for steps that are continuously performed; (**b**) for batch workpieces

31.5 Conclusions

Based on the analysis of modern scientific literature, which discusses the methodologies and approaches to the study of the fixture, identified areas of research that have been insufficiently studied, namely, the study of accuracy and rigidity of the fixture, as well as contact interaction in the system "fixture–workpiece."

Based on the analysis of complex parts, which represent a considerable share of the nomenclature of parts in manufacturing engineering, the classification of bracket-type parts on design and technological parameters is developed. According to the design and technological classification, a method of coding bracket-type parts has been developed, which allows automating the fixture design.

A new design of the flexible fixture has been developed, which provides sufficient tool accessibility, thanks to which multiaxis machining of bracket-type parts in a specific size range has been implemented. It is determined that the practical scope of application of a flexible fixture for machining bracket-type parts is the volume of the batch of parts up to 50 pieces, which is confirmed by the calculated data of the level of flexibility of the fixture. It is proved that for the proposed fixture, the level of flexibility is 2.5 times higher than for a typical fixture under similar production conditions.

Based on the developed design and technological classification, the technique of coding of bracket-type parts, which will provide a search of corresponding designs of fixtures in an information retrieval system, is created.

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Chapter 32
Analysis of the Transport Market During the COVID-19 Pandemic Based on Freight Exchange

Mateusz Kurowski and Katarzyna Huk

32.1 Introduction

The functioning of the company is dependent on a variety of internal and external factors. In the literature, those factors are settled in the organization environment. All changes in law regulations, technology, supply chain, and even in sociocultural dimension can lead the company to success or into bankruptcy.

Transport companies are not an exception in this matter. They are the subjects of the same rules like other entities but as the link between actors inside supply chains, their activity is directly dependent on fluctuations in the economy. The worsening situation in transport companies has often been the first sign of an upcoming crisis, so usually, managers do not have any time to prepare for difficult times.

According to official information in December 2019 China faced the problem of a new kind of virus, which was rapidly spreading all around the world [1]. On one hand, the fear of illness limited the global population's urge to travel, and on the other hand communication became more complicated due to new law regulations. It was a sudden turnaround in the transport market. This negative effect was amplified by limited operations in many other sectors.

The purpose of the article is to present the situation on the transport market in Poland and Slovakia in directions to Germany, Italy, and Spain during the COVID-19 pandemic. The article is literature–empirical and based on the analysis of the publications on the subject and own research. Empirical input is based on data from two of the biggest freight exchanges in Europe.

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Analyzing changes taking place in the transport market during the COVID-19 pandemic requires prior knowledge of the nature of the pandemic itself. It is also important to understand the role and the functioning of freight exchanges, which screen the current situation of transport companies.

32.2 Freight Exchange Systems in Transport and Forwarding Management

There are various information systems that support transport management in companies. Starting from managing working hours, transportation units, through GPS and telematics to systems improving information flow. In this group, freight exchanges are crucial for financial results and become more and more popular. They are defined as "platforms for exchanging information on offers for the transport of products, goods, materials, etc. as well as loads between market participants" [2].

Online freight exchange systems are organized in a similar way to traditional marketplace where contractors gather in one place and look for possibilities to fulfill their needs. In the transportation market, one side of the contract has cargo to transport and the second side has an idle transportation unit. Their complementary needs can be fulfilled through a realized transportation contract.

There are two basic types of freight exchange systems: open and dedicated [3]. There are no special constraints to use the first type of exchange. The registration process consists of various formal steps, and in most cases, membership requires cyclical payments. The biggest group of members in this kind of exchange is small and medium transport companies and forwarders. Dedicated freight exchange systems are created by companies with significant transportation needs. Systems are open only for selected partners. This kind of freight exchange provides lesser number of offers but potentially better match and lower operational risk.

The main feature of freight exchange is constant accessibility. Users can search for offers and preview the catalog of partners and competitors regardless of time and date [2]. The use of the Internet network allows to overcome the geographic barrier and gathers a considerable number of users. What is more, freight exchange allows reducing costs resulting from empty runs and administrating the transaction. Companies can save time through simultaneous negotiations with different parties and it is easier for them to set the proper price for the service when they can preview thousands of actual offers from many countries [4]. These advantages are especially important for small players on the market with a limited range of business contacts and low market impact.

Using freight exchange has also negative sides. Firstly, it generates costs which can be divided into three groups: registration, subscription, and provision. Costs vary among the providers. Secondly, freight exchange users must abide by security rules. It is obvious that the computer system needs to be protected against unauthorized access, but this is not the only safety issue. There is no ideal solution for verifying new clients available [4]. Companies try to monitor users but cases of abuse still happen. More initial requirements could reduce the risk but on the other hand, this could disincline some companies to join the network as a formal entry barrier.

The first freight exchange Teleroute was established in France in 1985 [5] and was based on the Minitel system. Currently, companies can choose between many providers. Except for Teleroute, the most popular open freight exchange systems in Europe are Trans.eu, TimoCom & Cargo, Cargopedia, 123 Cargo, Wtransnet, and LKWonline. Although they all differ in pricing, the basic difference between them is the specialty. In most cases, they focus on specific countries or regions. These are two of the conditions which determine the number of users and, as a result, the number of available offers. The network of the market leader TimoCom consists of over 127,000 users which have an access to up to 750,000 offers daily [6].

Over the years of market presence, freight exchanges evolved from the basic function of load and unit offers to list being a sophisticated tool with additional features. Now it can be used for immediate contact, document flow, optimizing the route, tracking, and cost calculation. Through tender platforms, companies can realize not only single freight orders but also establish long-term cooperation. What is more, some platforms provide an extension for warehousing orders, and business contact database [7].

Except for the important role freight exchanges plays in supporting transport management, it collects a big amount of data picturing the actual situation on the transport market. The data concerns, for example, supply and demand for transportation, amount, types, directions of the freights, and price dynamics.

32.3 Analysis of Disease Dynamics and State Restrictions in Selected Countries due to the COVID-19 Pandemic

Changes occurring in the economy are generated by various factors representing different aspects of human life. One of these aspects is health and well-being. We have seen this kind of relation in 2020. A new virus named coronavirus has appeared in China's Wuhan city. It was identified on January 7, 2020, and designated as COVID-19 (or 2019-nCoV). It belongs to the same group as MERS and SARS viruses. It causes fever and cold symptoms, mainly from the respiratory tract. However, it is dangerous for immunocompromised and elderly people, because the symptoms can turn into bronchitis and/or pneumonia, which cannot be treated with an antibiotic. Work is currently underway to develop an effective drug and vaccine for COVID-19.

On March 11, 2020, the World Health Organization (WHO) announced a pandemic. WHO declared, that the best way to prevent and slow down the transmission of the virus is to be well informed about the COVID-19, the disease it causes, and how it spreads. It is important to protect yourself and others from infection

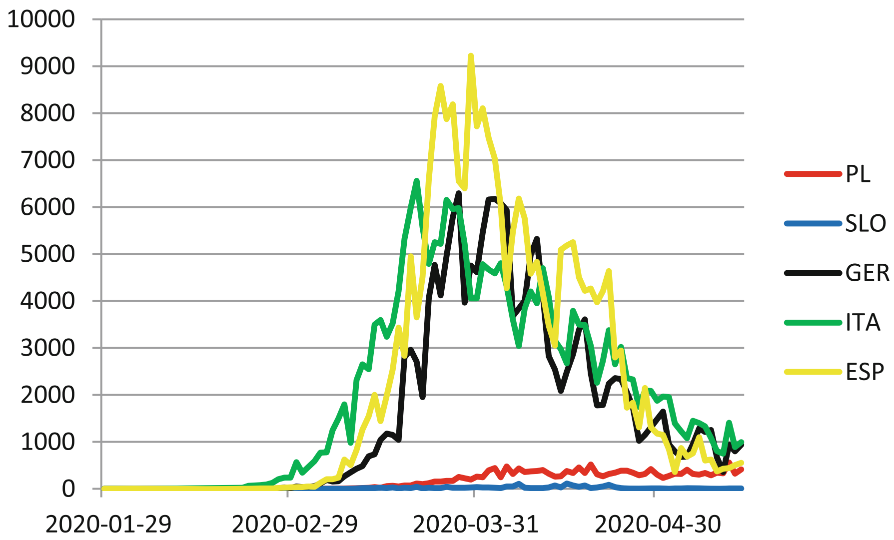

Fig. 32.1 COVID-19 daily confirmed cases in selected countries

by washing hands or using an alcohol-based rub frequently and to not touch the face [8]. There are three main characteristics of a pandemic: the extent of occurrence, the speed of spread, and the long period of the possibility of infection. In the first stage of a pandemic, the disease has local coverage, after that, it occurred in several countries in the world, and finally, infections were recorded on at least two continents. COVID-19 pandemic already represents the final stage.

In Europe, the highest incidence rates were observed in March–April 2020. Statistics on the number of cases in the analyzed period are presented in Fig. 32.1. The chart presents the number of COVID-19 daily confirmed cases for selected countries: Poland, Slovakia, Germany, Italy, and Spain.

Italy was the first country in Europe to observe the significant number of patients and the fastest upward trend in confirmed cases. The other countries where the epidemic had the greatest dynamics were Spain and Germany. In Poland and Slovakia, a steady tendency to increase the number of patients can be seen.

The most important aspect taken into account in the fight against pandemics was the assembly ban, keeping safe distances, and carrying out frequent disinfection. Individual European countries, along with the influx of newly infected people, have taken further decisions and established more restrictions for their citizens. The basic ones were closing borders and returning compatriots to the state, closing education and childcare units (schools, kindergartens, universities), remote work recommendations, then closing state administration facilities and organization of culture and entertainment (hotels, cinemas, restaurants, etc.), a ban on the operation of some companies providing services (beauticians, hairdressers), and restrictions on religious organizations. Some rulers introduced in the countries concerned an order to wear masks, stay at home, and a ban on moving in public space. Actions taken were aimed at curbing the number of cases and reducing a pandemic. The number of reported cases and their dynamics depended primarily on the introduction of restrictions by the government and society's approach to the current situation. Community culture and other socioeconomic factors were also important factors in reducing the risk of spreading the virus.

It is a matter of medical research to have closer look at the COVID-19, and how dangerous it really is, but the fact is the current pandemic situation has had an impact on the economies of all affected countries. In most of them, a major crisis is anticipated, which will be a consequence of the situation in the coming years. China alone, 2 months after the outbreak of the epidemic, noted a decrease in industrial production of 13.5%, retail sales fell by 20.5%, investments by 24.5% compared to the same period of the previous year, and the unemployment rate reached the level of 6.5% [9]. Economic indicators for the coming years are already estimated in countries most affected by the epidemic. Although some industries took advantage of the restrictions and isolation, it is possible that all affected countries will observe declines in production, retail sales, GDP with a simultaneous growth of the unemployment rate.

32.4 Situation on the Slovak and Polish Transport Market

Road transport was one of the areas of the economy that was affected by the pandemic. In the survey conducted by the authors of the article, as much as 88% (100% in the transport and forwarding sector) of 200 respondents said that the epidemic had an impact on their activities. Around 62% indicated that the biggest problem was organizational problems related to the closing of borders, 61% indicated a decrease in the number of orders carried out, and 48% had to reduce jobs. In addition, the interviewees indicated an increase in operating costs (30.5%) and the inability to complete orders for contractors (28%). One percent of respondents said that they had to terminate an employment contract with a driver as a result of the current market situation.

The article analyzes demand and supply for transport and prices of freight in terms of data derived from two major transport exchanges operating on the European market—Trans.eu [10] and TimoCom [11]. Transport offers and freight prices for Poland and Slovakia were analyzed in cycles from Monday to Friday. Three destination countries were selected for the study, in which they are direct contractors of these countries and the number of transports in these directions is high according to transport exchanges, and in which large outbreaks of COVID-19 were recorded. These are Italy, Spain, and Germany. The analysis covers the period January–May 2020. It should be noted that the previous point indicated that the pandemic in these countries began around March this year and was very intense, first in Italy, then in Spain, and finally in Germany.

First of all, the analysis of demand and supply was made based on the data of transactions carried out on transport exchanges. The transport was divided into two groups for analysis [12]:

– FTL (blue on the charts)—full truckloads, means the transport during which a truck transports one load and thus is fully loaded.
– LTL (red on the charts)—less than truckload, bulk transport, the term for a partial load on a truck. Usually, if the truck is not fully loaded, further partial loads are consolidated so that transportation is profitable. An alternative to transporting partial loads is collective freight.

Due to the limited possibility of a detailed description of individual graphs, the first graph was presented as an overview (large), and the next ones were minimized due to the limited length of the paper.

32.4.1 Analysis of Demand for Transport Services

The analysis of the demand for transport services was made in relation to FTL and LTL transports. In Fig. 32.2, the transport offers on the Slovakia–Germany route are showed.

The outbreak of the COVID-19 pandemic and associated restrictions was recorded in mid-March. The point of the highest number of cases in different countries was different, but mid-March can be set as the moment of introduction of all restrictions. The above chart shows a significant drop in demand for transport services, especially FTL, due to the outbreak of a pandemic. There are also two

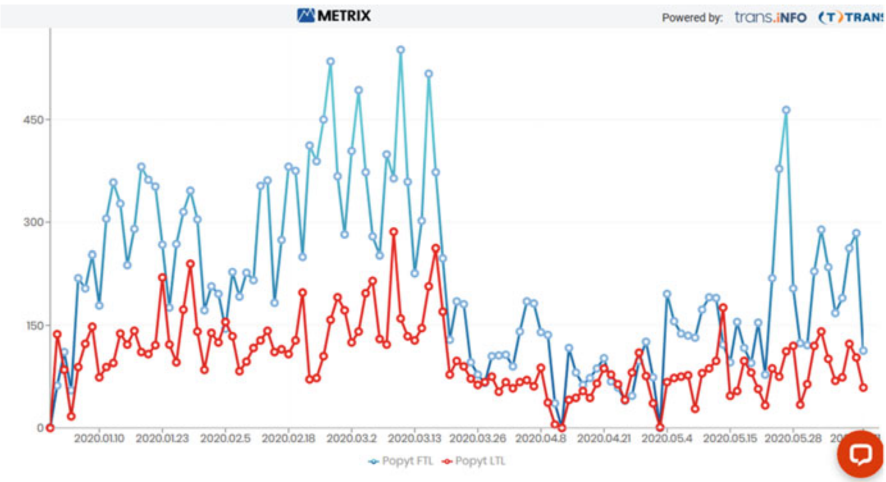

Fig. 32.2 Demand for transport services from Slovakia to Germany [13]

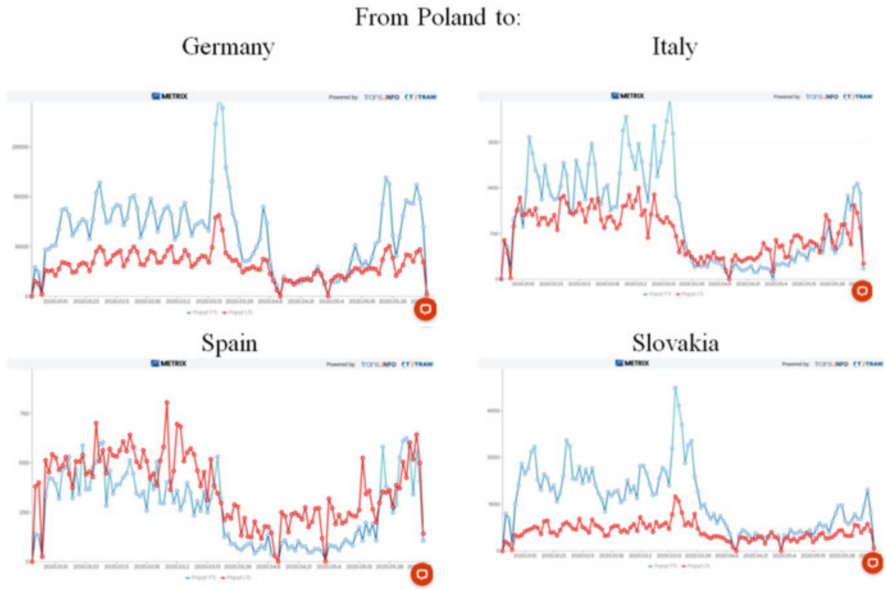

Fig. 32.3 Demand for transport services from Poland to Germany, Italy, Spain, Slovakia [13]

drops (in April and May) to zero which stand for the holiday season. There is already an upward trend in interest in transport services in May, but this is not the pre-pandemic level yet.

Figure 32.3 shows the demand for transport services from Poland to all analyzed destinations.

The number of offers representing the demand for transport services has fallen in both FTL and LTL, but a stronger decline was observed in FTL. The decrease can be seen in mid-March which is the period of development of the pandemic and the increased number of reported cases. In May, a slow increase can be noted for these services and the most significant for the Poland–Spain route. From the above observations, it can be seen that the market situation is slowly returning to its previous state. This is a direct reflection of increasing production and exports in individual countries. Figure 32.4 shows similar charts for Slovakia.

It is worth noting that in the analyzed period a considerable difference between the demand for FTL and LTL transport to Germany, Italy, and Poland was reduced. A significant drop in demand for transport services can be seen in mid-March this year and it applies especially in FTL. In the case of Germany, the positive trend started to bring the demand to pre-pandemic level, when in three other directions the situation is still stable.

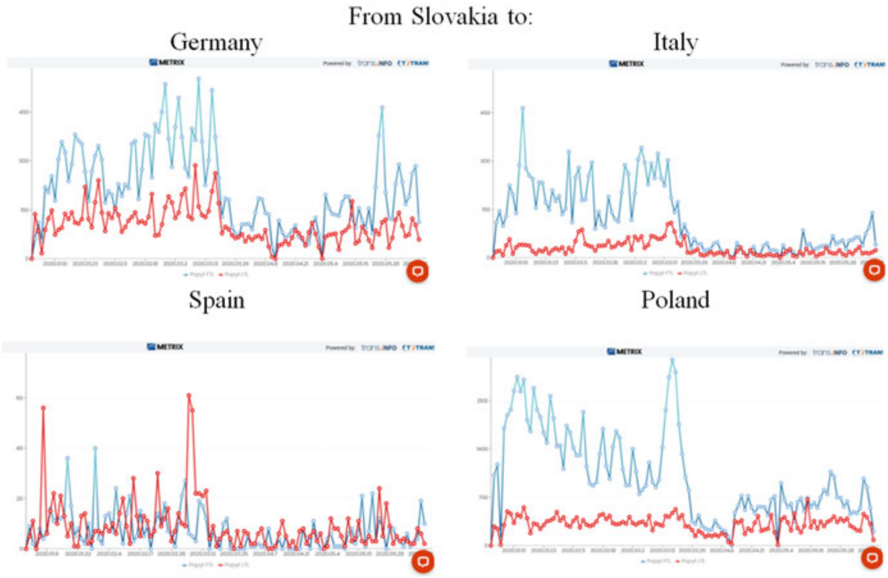

Fig. 32.4 Demand for transport services from Slovakia to Germany, Italy, Spain, and Poland [13]

32.4.2 Analysis of the Supply of Transport Services

An analogous analysis was made in the area of supply of transport services displayed on transport exchanges. Fig. 32.5 shows the supply of transport from Poland to selected countries.

A steady supply trend for transport services can be observed. A slight decrease occurred in the analyzed period of March this year. However, it is less significant than in the case of the demand for transport services. Fall to zero represents holidays or nonworking days. A similar tendency can be observed in Slovakia (Fig. 32.6).

In the case of supply, we deal with the number of transport service offers in the markets. Theoretically pandemic should not affect the supply which translates into the number of transport units. It is relatively constant and its decline could be caused by the closure of transport and forwarding companies, the sale of transport units, or other activities that would result in a decrease in the number of transport services offered on the markets. The slight decline in transport service offers in March could have been the result of psychological issues and restrictions in traveling to endangered areas. The increase in supply in April and May could be the result of a potential rise in prices for transport services as a result of a pandemic and the economic situation in individual countries. However, this was not a direct factor (see Sect. 32.4.4). This drop and rapid increase in transport services supply are characteristic to Slovakia and Poland in all directions.

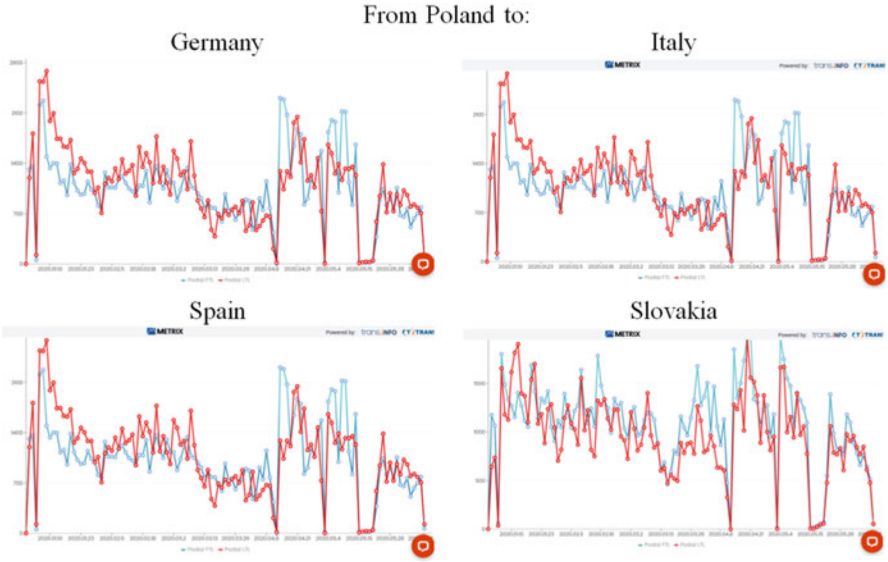

Fig. 32.5 Supply of transport services from Poland to Germany, Italy, Spain, and Slovakia [13]

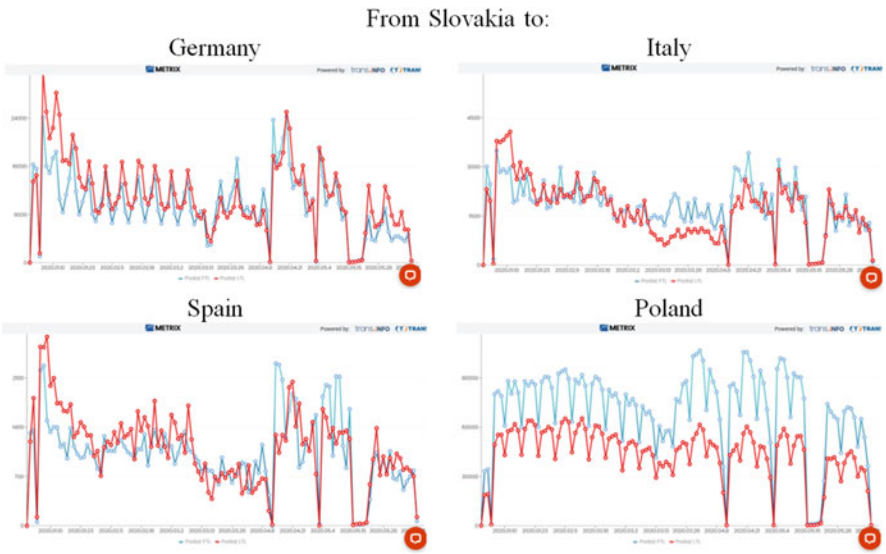

Fig. 32.6 Supply of transport services from Slovakia to Germany, Italy, Spain, and Poland [13]

32.4.3 Analysis of Freight Demand/Supply Ratio

The situation in the transport market can be also described by the demand/supply ratio which shows the direction and the scale of the market's inequality. Data for this phase of the research was derived from TimoCom. Figures represent demand/supply ratios calculated from the numbers of offers in the periods from January to May for 2018, 2019, and 2020. The indicators for Poland are shown in Table 32.1.

What can be seen is the fact that in all four directions there was a considerable decrease of demand in relation to supply of transport services in March/April 2020 It could be considered as seasonal fluctuation but data for previous years shows different.

The corresponding data for Slovakia are shown in Table 32.2.

There is also a significant decrease in demand for transport services in relation to supply in March/April 2020 in all analyzed directions.

32.4.4 Analysis of Freight Rates

The last of the analyzed parameters are prices for transport services, calculated on the basis of transactions made on Trans.eu exchanges. Figure 32.7 presents average freight rates for transport services provided from Poland to selected countries. The analyzed indicator to the greatest extent reflects the actual state of transport and forwarding services and the number of transactions carried out because the demand and supply indicators on transport exchanges mean the willingness to carry out a given transaction, not its execution. Indication of the price for which the service has been performed is real data, which indicates its actual implementation.

Table 32.1 Freight demand/supply ratio in offers from Poland [%] [11]

Direction	Year	January	February	March	April	May[a]
Germany	2018	38	44	44	55	53
	2019	45	50	49	44	36
	2020	32	41	44	18	25
Italy	2018	23	23	23	24	31
	2019	23	16	11	14	14
	2020	10	15	24	3	5
Spain	2018	16	14	12	20	24
	2019	9	9	7	8	10
	2020	5	7	7	0	3
Slovakia	2018	32	37	33	39	54
	2019	26	22	30	28	35
	2020	25	28	28	10	12

[a]Ratio for May 2020 is estimated based on data gathered until May 29, 2020

Table 32.2 Freight demand/supply ratio in offers from Slovakia in [%] [11]

Direction	Year	January	February	March	April	May[a]
Germany	2018	32	33	37	49	53
	2019	41	43	35	31	38
	2020	24	29	28	11	13
Italy	2018	30	25	29	40	43
	2019	36	25	10	20	21
	2020	42	45	49	15	5
Spain	2018	10	9	9	20	23
	2019	7	7	2	4	4
	2020	2	3	2	0	0
Poland	2018	32	20	17	40	52
	2019	43	27	27	32	37
	2020	38	33	23	12	28

[a]Ratio for May 2020 is estimated based on data gathered until May 29, 2020

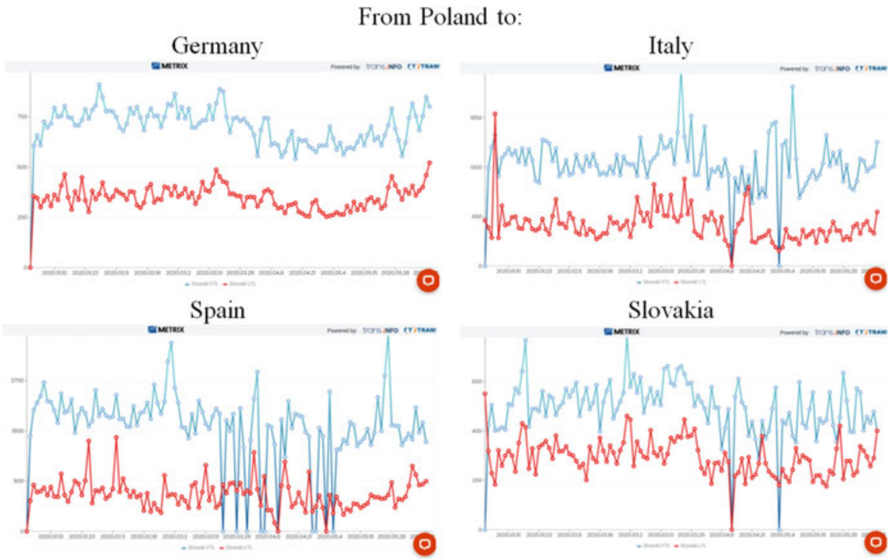

Fig. 32.7 Freight rates for transports from Poland to Germany, Italy, Spain, and Slovakia [13]

Freight rates were relatively constant in Poland. There was a slight decrease in mid-March and a continuous return to a pre-pandemic level of freight rates. In Fig. 32.8 freight rates from Slovakia are presented.

It can be noticed that after the peak of the pandemic in countries of destination there were more days without executed transactions. It applies especially to Spain where the low number of transactions makes it impossible to draw the trend of the freight rate. While freight rates for transport to Germany and Poland remained relatively constant, freight rates to Italy are lower than in pre-pandemic time.

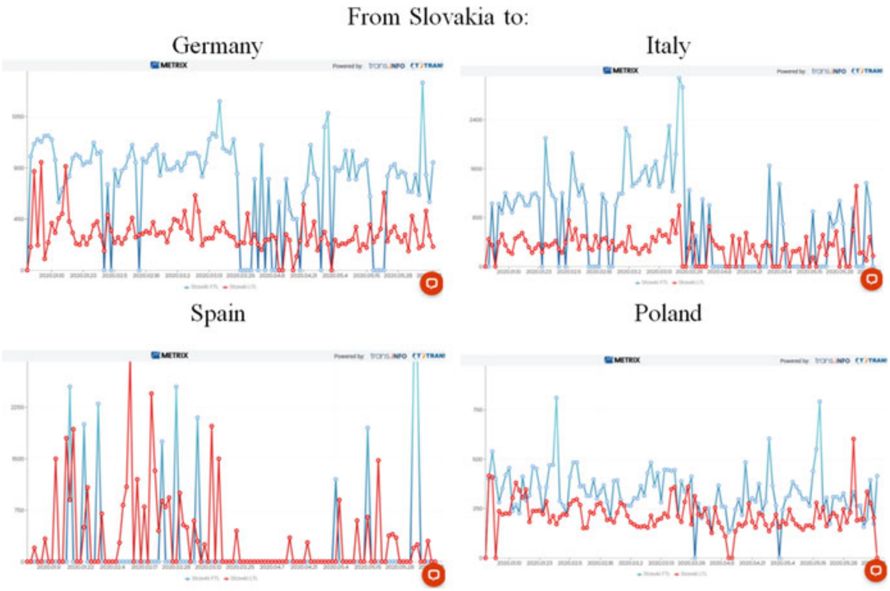

Fig. 32.8 Freight rates for transports from Slovakia to Germany, Italy, Spain, and Poland [13]

32.5 Summary

Conducted research showed that the COVID-19 pandemic had an impact on the transport market. Survey showed that companies had formal problems with crossing the borders, they suffered from less amount of transport offers, and higher operational costs. Some of them were forced to reduce the number of workers.

Data derived from freight exchanges illustrate the significant decrease in demand for transport services in Slovakia and Poland to each other, Germany, Italy, and Spain in mid-March. The decline was more severe for FTL than LTL transactions.

In both compared countries supply of transport services was more constant than demand, but the mid-March drop is also noticeable. These observations reflect in demand/supply ratio which shows that the relative decline in transport service demand in March/April was not a seasonal fluctuation for Slovakia and Poland.

The analysis of freight rates shows that there are more days without successful transactions, especially in Slovakia. Higher count of transactions in Poland allows us to follow the general trend. It should be noted that after an initial drop of freight rates in mid-March they started to return to the pre-pandemic level.

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Chapter 33
Analysis of the Possibilities of Increasing the Efficiency of a Manufacturing Company Through the Application of an Innovative Marketing Strategy

Annamária Behúnová, Marcel Behún, and Juraj Tomeček

33.1 Introduction

Most people think that marketing is just about selling and advertisement. There is nothing weird about that opinion, every day we are flooded with advertisements on TV, the Internet, or leaflets [1]. Of course, sale and advertisement are important but those are just two parts of marketing functions, and most of the time they are not the most important. Today's marketing is not just about the ability to sell products, but mainly about the fulfilment of customer needs. Marketing starts before the product is even made. Marketing is an English word that is derived from the word "market." In Slovak, the word marketing means marketplace. We can read "marketing" also as a set of activities, which are connected to creating the market [2].

Marketing was invented in the United States as a consequence of huge supply and inadequate demand. Most of the west European states follow this trend after the United States in the late 1950s of the twentieth century. At that time Europe faced many problems. Most of the problems related to economic growth, expanding, and huge differences of European nations (language, culture, and legislation) [3]. A huge mass of people is interested in marketing, which means that there is a lot of different definitions of marketing but the fundamental is the same. In general, it means that marketing relies on production, propagation, and the sale of the products or services to the final consumer. Mr. P. Kotler defines marketing as a social and managerial process, which helps individuals or groups to fulfil their needs in the production process, product exchange, and values [4].

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33.1.1 *Company Marketing Strategy*

Verbalizes like market, market activity, and marketing mechanism relate to marketing. The success of the existing or future market economy directly relies on marketing, its modification, and implementation in everyday functionality of the company [5]. It means that the marketing strategy of a company has to be the most important and critical. On the other hand, the company can try very hard to be successful in the long term [6].

We can meet with two expressions in practice "strategic marketing" and "marketing strategy." These expressions are different and we can characterize them as follows. Under the expression "strategic marketing" we can imagine theoretical knowledge for strategic planning in a market environment. These are knowledge and experiences which we can use for our benefit. Otherwise, under the expression "marketing strategy" we can imagine an exact strategic plan in the company. This follows exact described conditions and imagines and relies on the companies' targets. Mr. P. Kotler likens marketing strategy to marketing logic which helps to achieve the company their marketing targets. Marketing strategy consists of decisions about marketing costs, marketing mix, and allocating marketing resources in relation to expected environmental and competitive conditions [1, 4].

Based on different targets which the company wants to achieve through implementation of marketing strategies we sectionalize strategies into different types, which we can see in Table 33.1.

33.2 Innovative Marketing Strategy

Marketing strategies directions have changed since the past many years because companies have to deal with big changes, concerning new economic developments. Changes happened and changes are happening mainly in a competitive, political control, social–cultural, economic, and technological environment. These changes forced managers to think about a new approach to strategies and a philosophy of business [7, 8].

33.2.1 *Buzz Marketing and Viral Marketing*

We include these two types of marketing in which the main task is to attract customers so that they will propagate the product of their free will. Thanks to the Internet this type of marketing goes viral, which grew enormous in 20 years. It is typical to use social media for viral marketing. Many companies use Facebook which has a tool to propagate posts integrated with it. Simply said, a company offering a product or service pays for advertisements on Facebook. The advertisement

Table 33.1 Sectionalize of Marketing Strategies [6]

Division of strategy	Types of strategy
Based on the marketing mix	– Product strategy – Price strategy – Distribution strategy – Communication strategy
Growth strategies	– Ansoff strategy – Segment choosing strategy – Strategy of integration
Competitive strategies	– Porter strategy – Bowman hour strategy
With regard to market share and rate of innovation	– Kotler strategy – Innovative strategy
With regard to the market life cycle	– Entering new market strategy – Grow—strategy for a growing market – Mature—strategy for a mature and saturated market – Decrease—strategy for decreasing market
Based on market trends	– Growing strategy – Maintaining strategy – Regression strategy
Based on market behavior	– Offensive strategy – Defensive strategy – Expansive strategy – Fight strategy
Based on environment behavior and competitive behavior	– Cooperative strategy – Confrontational strategy
Other types of strategies	– Positioning strategy – Competitive strategy focused on purchaser – Internet strategy

shows up based on information that Facebook collects from people, what they are looking for, or what they are buying on the Internet. Viral marketing condition is that the post has to be interesting or funny so people will be so excited that they will share it with other people. That is the difference between viral marketing and classic paid advertisement [9].

33.2.2 E-marketing

Another modern marketing strategy that became popular thanks to the internet is E-marketing. Thanks to the Internet E-marketing companies can continue to grow and address a wider spectrum of customers even outside the borders of the city where it is located [10]. All you need for this is an e-shop, advertisement, or social media. As an example, we can look at “Deichmann Company” that sells shoes in their stores in Slovakia. They came up with the idea of an e-shop a few years ago so that their customers do not have to go for new shoes to their stores but they can order products to their doors.

33.2.3 Product Placement

The main task of this strategy is to place the product in a TV show or on the Internet. The product should be in the background of the show and it should match the detail with other things in the show. This way the potential customer will see the product and everything else will do the customer. The perfect example would be French cinematography. French use in their films only French-made cars—Citroen, Peugeot. The car company is a sponsor of their show and thanks to cars in the show or film they will be engraved in the memory of potential customers [11].

33.2.4 Event (Experiential) Marketing

Big pioneer of this strategy is The Walt Disney Company. The company did not achieve the interest of people just for their movies or fairytales but also thanks to their glorious Disneyland. A similar approach was used by LEGO. In Legoland, they offer a lot of attractions and souvenirs. The main purpose is to deliver strong experience and memories to their customers while they are in Legoland. Smaller companies choose a little cheaper approach to experiential marketing. We can include here charity events, exhibition matches, and so on. They deliver a strong emotional experience that connect the customers to the exact company [12].

33.2.5 Relationship Marketing

As the name implies it is about building a relationship between companies and customers. Relationship marketing is good to use when companies and customers try to build their business relationship. The building of this type of relationship consumes a lot of money and time. In Slovakia, they are trying to build this type of strategy for companies like Orange, O2, Telekom, and the latest also “4 ka.” Their main task is to keep existing customers. It is typical that they use a remuneration system where the long-term customers have bigger discounts, mobile phones, or better conditions prepaid mobile services [13, 14].

33.2.6 Aftermarketing

In aftermarketing, it is not important to sell a product or service. More important is building a relationship between the company and customer who already buys the product or service. As an example, we can mention "Google" which uses aftermarketing as a support of the product or service for customers. Support is on a high level. On daily basis, it solves thousands of problems for ordinary people, answers their questions, performs market analysis, obtains customers' feedback which helps the company to make another decision [15].

33.2.7 Guerilla Marketing

Being a relatively aggressive marketing strategy, it is always on the edge. The main weapons in guerilla marketing are inconspicuousness and moment of surprise. It is cheap but it is very difficult for creativity. A customer has to be addressed in an inconspicuous and funny way. Examples of companies that choose this type of marketing to propagate their products or services are Nestlé, McDonald's. FedEx. FedEx company uses guerilla company a little bit more aggressively. Sign ALWAYS FIRST has to create a feeling that they are really the fastest [2].

33.2.8 Mass Customization

The most important point in mass customization is to sell one product that can fulfil different customers' specifications. It means that the company lets the customer make changes on products but not so big that the product price won't grow too much [16, 17]. Skoda auto company make it easier to decide what they want by giving them a few options to choose from and with this decision they also save customers money on things they do not need. Customers can configure their new car simply through a configurator. The assortment is big. You can choose the color, wheels, motor and so on. In the end, customers can see the final price of their configured car [18, 19].

33.3 Methodology

Every creative process, which has some systemic essence, must support its path to the set goal by planned pre-marking—a specific algorithm of the process. Figure 33.1 shows an algorithm for creating a business marketing strategy [6].

Fig. 33.1 An algorithm for creating a business marketing strategy [6]

The essence of the algorithm consists of eight basic steps, which are located in two horizontal planes, which are simultaneously divided into two four-step sets. This division is emphasized in particular [6]:

- The crucial importance of honest training
- Systemic balance and complementarity of both parts
- The importance of the preparatory part for estimating one's own possibilities
- Preparedness for unexpected changes in the market, to which there is a constant response

The first four steps can be called the starting points for the creation or even as a preparatory part of the marketing strategy. Its main essence is analytical. The company is waiting for the time when it will start to create a specific marketing strategy. The second part can be called "creating and executing a marketing strategy." These steps are a creative process in which the marketing strategy itself is formed. There can be even more steps, as the further division is governed by the company's internal rules [6].

If the company has determined the set plan (strategic, tactical, or operational), the implementation process begins, in which the planned and anticipated proposals are changed and incorporated into marketing management practice [6, 20]. It is very important that the company's management distinguishes between the preparation phase, the implementation phase, and the control phase. These three control functions are often overlapped and complicated. Implementing plans into practice, the implementation of which is managerial, costly but also very time consuming for the company (see Fig. 33.2) [6].

In Fig. 33.2 we can see the whole development process, which takes place from the development idea to the adoption of a specific marketing strategy, through its use in practice in the implementation. After implementation, the development process continues through performance and ends with the final control of all performed activities [6, 21, 22].

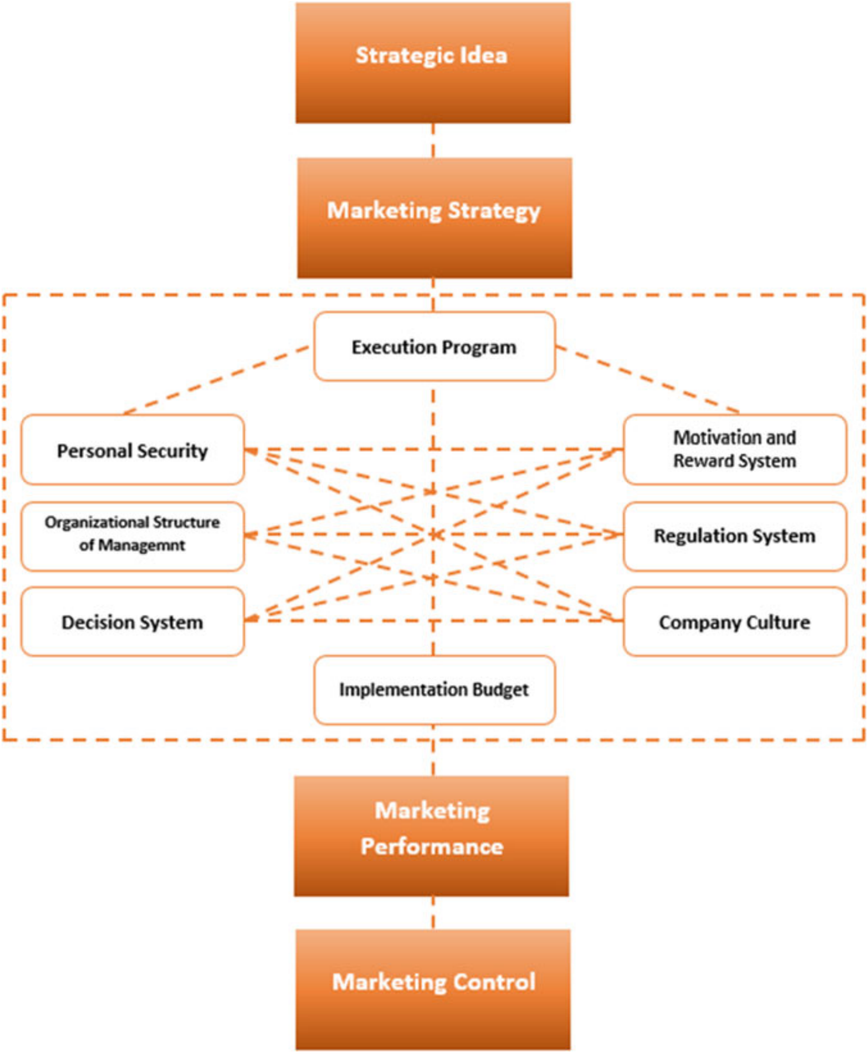

Fig. 33.2 Implementation in the marketing strategic process [6]

33.4 Results

Every marketing strategy mentioned earlier has its own specification and is characteristic for specific types of marketing campaign. There is no universal formula to choose the correct marketing strategy. Every strategy has its pros and cons. It is up to the manager to analyze the situation and choose which strategy is best for their needs [23, 24].

	Typ of business			Financial complexity			Main objectives	Means of achieving the objectives	Taking into account the needs of the customer	
	Small	Medium	Big	Small	Medium	Great			Yes	No
Event marketing		○	○		○		Creating an unforgettable experience	Introducing the benefits of the productv	○	
Relationship marketing	○		○	○			Creating a long-term relationship	Feedback, analysis	○	
Aftermarketing	○		○		○		Creating a relationship after selling a product	Purchases benefits and bonuses	○	
WOT marketing		○			○		Oral dissemination of product information among customers	Providing quality products and services		○
E-marketing	○	○	○		○	○	Finding new potential customers	Advertising and positive feedback on the Internet		○
Mass customization			○	○			Meet customer requirements	Possibility to configure the product	○	
Guerilla marketing	○	○	○	○			Reach the customer either indirectly or aggressively	All available forms of advertising		○

Fig. 33.3 Analysis of the possibilities of implementing modern marketing strategies

Mass customization is great for big companies where it is a reasonable choice. Here we can include companies with mass production or continuous production. In specific cases, it makes sense to create batch production in different combinations of the product even if it means ineffective production and higher produce price but in the end it is all about fulfiling the customer needs (Fig. 33.3).

Relationship strategy is a good choice for smaller companies. There is nothing better than building a relationship with companies and make a strong base for further cooperation. With relationship marketing, it is not about financial assets rather about time consumption. Every customer or consumer needs some time to gain trust and obtaining feedback which is crucial for this type of marketing strategy.

Experiential marketing is suitable for small and big companies. Bigger events can consume bigger input capital but this type of propagation will engrave in memory. A potential customer can try the product or service right at the event. If the product can attract the customer, he will buy it and if the manager is skilled then he can sell it right at the event.

Guerilla marketing is one of the cheapest strategies. Costs to propagate products are low but this type speaks right to the customer. They can be used for almost everything, the company has limitless options. All you need is creativity and a campaign is done. This strategy is suitable for every company.

E-marketing does not have to be used just for selling products but it can also be used to propagate the company. We focus on selling products here and it is why this solution is good for companies that are selling products. Product is delivered right to the customer's home. Input costs are higher (internet page, web design, site propagation, buying products on warehouse, place). Lately, potential customers find about e-shops from good feedbacks. Communication and respectability are very important. E-marking can be perfectly matched with viral marketing. Viral marketing is not good just for companies that profit from selling products but also for web pages where income is based on an advertisement or product placement. Here we can see how we can match and use different types of marketing strategies to achieve our goal.

It follows that is suitable to combine different marketing strategies. Today's market is overloaded with companies and that is why it is important to focus on customers' needs. A happy customer has no intention to leave the company for their rival. Satisfaction forces him to stay with the company and build a relationship that brings him some advantages and fulfils his needs.

We meet WOT marketing on a daily basis without knowing that. Companies represent themselves mostly on social sites. Financial complexities are decided by the company itself. If the company has built a strong social site all it needs is to share some funny posts that has something in common with the product and all it takes is to wait until it comes to a potential customer. When the company was just formed, social sites offered them paid advertisements. That is when financial complexity will rise but their product will reach a bigger group of potential customers.

After research, we conclude that every marketing strategy suits a different type of company. These modern marketing strategies are suitable for small, middle, and big companies. Its financial complexity is different and changes with a different situation in which the company currently is. For example, e-marketing is expensive at the start but after that maintaining a website is easy.

All of the above-mentioned marketing strategies has their main task. Experiential marketing tries to create an unforgettable experience, relationship marketing tries to create a long-term relationship between customer and company. Aftermarketing invokes feelings after selling the product or service. WOT marketing tries to spread verbal information about a specific product or company. The main task of e-marketing is to push the company to a new area of operation. Mass customization tries to fulfil customer's needs and conditions. In Guerilla marketing, it is all about contacting customers in an aggressive or nonaggressive style.

To reach companies' targets every strategy uses their resources with which they can achieve targets. For creating an unforgettable experience in experiential marketing, it is useful to present the product's advantages or let potential customers try the product. Long-term relationship in relationship marketing can be created by analyzing the feedback. The basic is to communicate with the customer even after the sale of the product or service. Aftermarketing builds a relationship with advantages and discounts given to customers after selling the product or service. Verbal spreading of companies good name and quality in WOT marketing take care offering quality services and selling quality products which force customers to unconscious spread the companies good name. E-marketing uses advertisement and good feedback to reach their goals. In mass customization the most important thing is the customization of the product. Thanks to this strategy, company can fulfil customers' needs. Guerilla marketing uses different forms of advertisement that can help even if it is a bus stop or facade of the building.

Most of these modern marketing strategies look at the customers' needs even before selling products or services based on what production companies have to customize their production, research, and at last sale.

33.5 Conclusion

Companies in recent years have started to realize that customer is an important part of the production process, so they have started contacting their potential customers in nontypical forms. Modern marketing strategies help them in this but it is important to choose the correct strategy because every strategy is specific. It means that not every strategy is suitable for every company. This task depends on the manager who should know which type of strategy suits that specific company. Regarding this, companies should know their customers very well because in modern marketing it is not just about making the product or service but it is important to know which production plan they should choose and what will add value for the customer. By analyzing each modern marketing strategy, we reach the conclusion that even small companies can have quality marketing without investing a big amount of money. The same can be applied in the opposite, it does not mean that if you spend a lot of money in marketing it will be successful. Most of the modern marketing strategies are focused on customer's needs. By using these types of strategies in practice we can see specific cases that were really effective and successful. In this fast-moving world, a lot of companies forget the power of marketing. Even some smaller companies claimed that they do not need marketing. We want to draw attention that every company, even a small company, should not forget about it. In our opinion, they should do at least a small analysis of the market in which they operate and collect feedback from their customers. It is suitable to combine different strategies to achieve a better result and doing that will multiply the power of marketing. There is only one question left. How to choose the correct marketing strategy and which strategies you should combine? This task depends on the managers and the directors of companies to understand which modern marketing strategies they should choose from a wide range of marketing strategies and implement them into their production process and sale strategy.

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Chapter 34
Comparison of Utilization Level of Knowledge-Based and BIM Technology by Contractors in Management of Construction Projects

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34.1 Introduction

Information and communication technologies are one of the most important these days, and we dare to say the necessary tools for management in every sector [1]. This fact is pointed out by several experts and researchers in this field [2, 3]. The validity of the use of ICTs is also confirmed by these days, which are marked by a lower degree of mobility. It is fair to say that ICTs are essential tools for governance and communication in every sector, and their implementation and degree of use also largely indicate the degree of flexibility in governance during this period [4, 5]. New materials and technology in management are largely taken over by various ICT tools [6]. To a large extent, this represents flexibility and the ability to respond better in any sector [7]. Investments in information technology represent the company's assets, which are even more valued in times of crisis or unstable period, when it is necessary to reduce process costs [8]. New technologies should contribute to efficient management and thus cost savings [9]. However, these technologies only bring cost savings, but they have many other advantages [10]. These laws also apply in the construction sector and the management of construction projects.

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34.2 Problem Statement

The current situation confirms the need for transformation and digitization in all industries [8]. Dominant and successful companies, even during the crisis, have a high rate of ICT use in almost every sector [1, 3]. Each industrial area has its own specifics [11]. These often have an impact on the type of ICT and their implementation needs. Construction industry has a number of specifics. It is this industry, together with IT, that represents the largest investment in the country's economy in terms of volume. This also reinforces the importance of solving the problem of using information and communication technologies in the field of construction. One of the basic and recommended technologies in construction is knowledge-based technologies. The field of construction also brings a great challenge in the use of BIM technologies (building information modeling) [12]. This issue is addressed by several studies and is addressed by several researchers who address BIM technologies in construction from several perspectives [13]. The issue of BIM technologies is addressed in terms of benefits in construction project management [14]. In the context of sustainability in construction and environmental effects, this issue is addressed by other authors [15]. BIM issues are also addressed in the context of education in study programs focused on technology and management in construction [16]. BIM (building information modeling) and 3D modeling, including scanning, are also addressed in other studies [17]. The use of BIM technology has been growing over the last decade. However, not a lot of research shows the growth rate in recent years. The worldwide use of BIM technologies is not satisfactory, and the potential is great. On the other hand, they are knowledge-based systems and technologies in general.

Knowledge-based technologies and systems are also a great option in construction. Knowledge management can be defined simply as an effort to identify and optimize a message for the end user who will have added value. This has several advantages, in particular increasing productivity, profitability, and maintaining a competitive advantage [18, 19]. Knowledge management is a key role in building project management. The basis of this system is the efficient use of resources. This is the basis for effective process management and automation of activities. In a construction project, this applies to the design after implementation [20]. Knowledge technologies are the basis for automation, which is part of industry 4.0. It is these processes that should represent the future in construction and the management of construction projects.

Construction project management is a demanding complex of activities. It is characterized by a large number of participants. In construction, the use of information and communication technologies is conditioned by pressure from individual participants in construction. The investor should be the first to request the use of these technologies. The same is true for BIM and know-based technology. Of the large number of participants in a construction project, the investor should be the initiator of the use of these technologies, as it finances the entire construction project. On the other hand, suppliers also strive for cost savings and efficiently set management of construction processes. It is they who know how to make great use of the positive effects of the implementation and use of knowledge-based technology and BIM technology. The degree of use of these technologies depends to a large extent on this group of participants in construction projects. The use of technology is generally increasing. Thus, at least this is the assumption based on an analysis of sources and various researches. However, the question remains as it has been in recent times. It is really a question whether this trend is even in Slovakia. It is mainly a question of whether this trend is also burning in the Slovak construction industry. There is therefore an assumption that the level of use of BIM technologies and knowledge-based technology is growing in Slovakia as well. This research also solves how quickly and whether it is statistically significant at all. Contractors use these technologies at different levels. However, how this trend has evolved over the last 2 years is the subject of this research. Knowledge of these results can be useful in understanding and expanding BIM technologies and knowledge-based technologies in construction project management.

34.3 Methodology

34.3.1 Research Aim and Hypotheses

The analysis of available research in the field of use and implementation of BIM technologies and knowledge-based technology in construction pointed to a trend that presupposes a certain behavior and development of the use of these technologies by suppliers. It is assumed that the level of use of BIM technologies and knowledge-based technology is also growing among suppliers in the Slovak construction industry. It is important to find out whether this is in fact the case and whether it is also statistically significant. The main hypothesis of the research can therefore be focused on two areas, namely the use of BIM technologies and the use of knowledge-based technologies by contractors are increasing last 2 years in the management of construction projects.

Based on this, it was set the main aim of research. Main aim of research is comparison of utilization level of knowledge-based and BIM technology by contractors in management of construction projects last 2 years in Slovakia.

34.3.2 Research Sample and Description of Slovak Construction Industry

Construction in Slovakia is an important component of the economy. The construction industry accounts for approximately 8% of the GDP of the Slovak economy. Investments in IT and construction account for the largest share of public investment. It is mainly about building infrastructure and transport. The private sector invests heavily in the construction of residential buildings. This is especially true for large cities (such as Bratislava and Kosice). From this point of view, large and medium-sized construction companies that implement these projects have a large representation. Eighty percent of construction companies (especially contractors) are classified as small enterprises. The investor is the National Motorway Company for public contracts focused on infrastructure and transport. The private sector is an investor for residential projects. Much of the capital in this area is privately owned. It is in these construction projects that small- and medium-sized enterprises are represented, which form an important part of the construction industry in Slovakia. On the contrary, many large construction companies use know-how from abroad. Many large companies also use foreign private capital, which allows for more investment in this area. The number of researches we have already carried out also shows the influx of new technologies in the field of construction project management.

The research sample consisted of construction contractors and construction project implementers. These suppliers operate on the Slovak construction market, most of the orders are realized in this country. Among the large companies (of which there were 2), companies whose parent companies operate worldwide were also represented. On the contrary, a large number of construction companies are small- and medium-sized enterprises (SMEs) operating in the Slovak construction market. There were exactly 99 such companies, which operate mainly in Slovakia and use capital. These companies also formed microenterprises. In terms of defining the participants in construction projects, this research was focused on suppliers, as already mentioned. Consideration of how other participants in construction projects react, such as investors, designers, or other participants. In terms of numbers, however, contractors and sub-contractors form a substantial part of production and share in construction. Their opinion was therefore important for this research, as practice so requires.

34.3.3 Data Collection and Data Processing

Data collection was secured electronically. Respondents were contacted electronically with a request to participate in this anonymous survey. The selection of respondents was random from the database of entities operating in the construction industry in Slovakia. The rate of return was around 9% of respondents, which can be considered good. The sample roughly reflects the relative distribution of subjects in construction in Slovakia. The questionnaire contained general information about the respondents, such as size, use of foreign capital, area of operation, etc. Another main part of the research was questions focused on the degree of use of knowledge-based and BIM technology in the management of construction projects. These questions have been thoroughly explained as well as a range of answers. To quantify the response, a liqueur scale was implemented, the lowest value of which represented a low rate of use of selected technologies. On the contrary, the highest value represented a high rate of use of selected technologies.

The first step in addressing the issue was to identify a basic research problem. It was mentioned to compare the rate of use of knowledge-based and BIM technology in the management of construction projects. Based on a thorough theoretical analysis, this problem was specified. Several surveys in the field were examined, which were the basis for setting the hypotheses and objectives of this research. The subsequent second step was data collection. In terms of statistical evaluation, the normality of the data had to be tested first. For this purpose, a very common test called Kolmogorov–Smirnov's test of normality was used. The alpha significance level in all assays used in this methodology was 5%. Based on previous results with texts (more described in the results and discussion section), the Kruskal–Wallis test was selected as a nonparametric alternative to the ANOVA test and was focused on all groups at once. The very commonly used Kruskal–Wallis test was used to confirm our hypotheses about the average values in all groups in one group. One-way analysis according to Kruskal–Wallis analysis with variance (or H test) is used to determine whether three or more independent groups are the same (H0) or different (H1) on a desired variable.

34.4 Results and Discussion

This research is focused on the analysis and definition of the use of knowledge-based technology and BIM technology in construction. The aim is to compare the last 2 years for individual groups of technologies and thus define the trend. Assuming that this is a growth in this area, the tests described in the methodology section should be confirmed or not confirmed. The results of the distribution of the research sample are description statistics of the research sample in Table 34.1.

The year 2019 was a period of economic growth and good economic conditions in construction. Real estate prices were still rising and, in many cases, represented their maximum so far. This has probably led many construction companies to invest more in construction project management technologies. Compared to previous research from previous years, there has been an increase in the use of BIM technologies as well as knowledge-based technology by contractors. All this had

Table 34.1 Descriptive statistics of samples and the normality test (Year 2019)

	BIM technology	Knowledge-based technology and knowledge systems
Mean	−0.3636	−0.3113
Standard deviation	2.3753	2.3245
Skewness	−0.1274	−0.1432
Kurtosis	−0.7235	−0.3672
P value	0.03455	0.04234

Table 34.2 Descriptive statistics of samples and the normality test (Year 2020)

	BIM technology	Knowledge-based technology and knowledge systems
Mean	−0.6726	−0.4562
Standard deviation	3.2516	3.2112
Skewness	−0.1274	−0.2451
Kurtosis	−0.8234	−0.3654
P value	0.04627	0.04726

Table 34.3 Kruskal–Wallis test (Utilization level of technology)

	BIM technology	Knowledge-based technology and knowledge systems
2019	2.3753	2.3245
2020	3.2516	3.2112
p-ANOVA	0.03838	0.0478

an impact on the results in 2019. Their level still did not reach the potential of these technologies, which can be seen over time. The results of the descriptive statistics can be seen in Table 34.2.

The year 2020 is somewhat different. More about the reasons for the change in the discussion after the other results (Kruskal–Wallis test) in Table 34.3.

The rates of use of these technologies for individual periods are shown in the table in terms of values. It is encouraging that there has been an increase in usage rates for both technologies. According to the results of these tests, BIM technologies increased compared to 2019. The growth trend was confirmed. However, the interpretation of the results of the Kruskal–Wallis test is important, which confirmed this statement and can be considered statistically significant. However, the results are not as clear-cut as they may seem at first glance. There is room for discussion and reflection on other phenomena and contexts in the use of these technologies. The results of the test confirmed the trend of increasing use of these technologies. Compared to other tests, it is also possible to state a progress in this context, i.e., an increase in use in this sense. What is positive and the results confirmed the researched hypotheses for both types of technology. Knowledge-based technologies are used to a lesser extent than BIM technologies, but their results also point to this trend. However, in explaining and interpreting, it is necessary to point out a number of fundamental phenomena that can further refine these results and their conclusions may point to estimated developments in the future.

The first fact to consider is the period when the data collection was recorded. The year 2019 is clean in terms of its impact on the results, and data collection can now be retrospectively assessed as having not been affected by any significant fundamental phenomena or changes in society. The year 2020 is under discussion. Data collection took place at the beginning of the year, i.e., in the first quarter and also in the month of April. This means that this is the period during which a global pandemic broke out, which resulted in changes in the construction market. The period of restrictions has also begun, and the business environment has begun to change. At this point, it is not yet possible to state the effects of this situation, but they appear to be negatively affecting the business environment. Therefore, the 2020 results so far reflect the situation at the beginning of the year, which may change at the end of the year. Here, two scenarios appear to be possible, which may also have an impact on the use of knowledge-based technology and BIM technology. On the one hand, many companies have seen a decline in sales and production, which may result in lower investment rates in the future. It is very likely that SMEs will invest less in new technologies in order to reduce costs over time, so the level of use of these technologies may not increase as it has been so far.

On the other hand, due to the reduced possibility of mobility, many companies, which are financially well off, are trying to use new technologies, especially for communication, to an even greater extent. Many expert opinions only point to a transformation in the field of digitization and the use of technologies that can also be applied to construction project management processes. If this scenario were to materialize, the use of knowledge-based technologies and BIM technologies could grow even faster. Both scenarios, although opposite, are quite realistic and there is not enough data at this time to predict the probability of one of the scenarios. But what impact does this have on the results of this research? It must be said that the implementation of new technologies is not a short-term process and the effect of their use is usually reflected only in the long run. On the other hand, given the period of conduct of this survey, these results of the current situation cannot yet be influenced and can therefore be considered correct and fully reflecting the real situation in the given period. The situation and development of the pandemic, as well as its consequences in the form of economic downturn, will reflect the coming years.

Based on these results, it is possible to confirm the hypotheses of this research and thus that the growth in the use of knowledge-based technology and BIM technology compared to the last 2 years has been confirmed. This also reflects the trend with other research in this field over the last decade.

34.5 Conclusion

Knowledge-based technology and BIM technology are an effective tool for the needs of construction project management. This knowledge has already been based on previous research carried out in the industry. Based on previous research and a thorough theoretical analysis, a problem statement and research goal were set. Comparing the level of use of knowledge-based technology and BIM technology in the Slovak construction industry has certain reserves and their potential is greater than the current scope of use. However, research has confirmed the assumption that the use of knowledge-based and BIM technologies has increased over the last 2 years. Based on statistical tests, we came to the conclusion that this statement is true and can be accepted as one of the conclusions of the research. However, several considerations arose during the interpretation, as a result of which the current situation marked the coping with the pandemic and the crisis after it, which, respectively, entered into, or which we entered into, marked.

During the discussion, we accepted the opinion that the current situation may have an impact on the use of knowledge-based technology and BIM technologies. Especially from the point of view of production. It was the suppliers who represented the research sample. The volume of construction production and the economic situation greatly influence the implementation and subsequent use of ICT. The past period of growth represented suitable conditions for the implementation and use of new technologies. This is not a short-term process and the results can be seen in the long term. It is also the results and growth of the investigated technologies and their rate of use is reflected in the results.

Mention should also be made of some highlights from research, as a trend that large supply companies make greater use of knowledge-based technology and BIM technology. The same applies to companies that use foreign capital or know-how from abroad. However, these results were not directly the subject of research, are interpreted only by descriptive statistics, and have not been tested. However, they point to a possible trend that should be explored in the future, which is one of the other goals where this research should move. These assumptions may lead to certain conclusions or assumptions that are appropriate for the needs of the market and the industry to examine. This fact opens the gates and space for further research, not only in the Slovak construction market. Another space is to move this research to the international level on the basis of cooperation with foreign universities, especially to countries close to Slovakia, such as the Czech Republic and Poland. An interesting view can also be made in comparing the results with Croatia, where there is already some joint research and a beginning for this area as well.

As already mentioned, it must be said that the implementation of new technologies is not a short-term process and the effect of their use is usually reflected only in the long run. On the other hand, given the period of conduct of this survey, these results of the current situation cannot yet be influenced and can therefore be considered correct and fully reflecting the real situation in the given period. The situation and development of the pandemic, as well as its consequences in the form of economic downturn, will reflect in the coming years. There is room and intention to continue the research for years to come because it will be very interesting how the current situation will affect the development of implementation and use of knowledge technologies and BIM in construction. This comparison brought the practice to confirm the assumption and state of use. This is important for contractors who have participated in the survey, but also for other participants in the construction project. In particular, investors and developers should be aware of this situation and have realistic expectations from contractors for the use of these technologies. On the other hand, it is investors who can be stimulators and demand a higher degree of use of knowledge-based and BIM technology in the management of construction projects. This represents an opportunity to increase the rate of implementation and use of these technologies and to move significantly closer to the top countries with a high degree of digitization and the use of BIM and knowledge-based technology.

It is clear from the information that research has several aspects and reasons to continue it. This area is in demand and new technologies can be beneficial in construction production, which can lead to increased productivity in the industry. The fact that the respondents highlighted the advantages of these technologies also speaks for this research. The research was focused on a specific target group and therefore an understanding of the issue was clearly achieved. This results in largely clear conclusions that can be applied in practice.

On the contrary, the research also pointed to some pitfalls that need to be taken into account. The research sample also included large construction companies operating in the country. Due to the number of large companies in the construction market, their extent was significantly included, which to some extent may reflect their view of the issue. On the one hand, it is gratifying that large companies have been heavily involved in the research and that their views are very important from a global perspective. On the other hand, it does not fully reflect the needs of small businesses, which also form a significant part of the economy.

In the context of the topic, we can also talk about future scientific goals in the field. They should reflect the knowledge that this topic is very important and it is important to address it in the coming period. Research should move not only internationally but also above all to focus on the growth rate of the use of BIM and knowledge-based technology, which may also reflect the maturity of the industry in the country in international comparison.

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Chapter 35
Implementation of Biological Samples Monitoring Used UHF RFID Technology: A Concept

Jozef Husár and Lucia Knapčíková

35.1 Introduction

Automation and digitization have hit the world. Health care is no exception. Many countries are trying to digitize health care and create concepts that are acceptable to health professionals as well as citizens. The Slovak Republic is one of the similar pioneers and created the eHealth portal on the website www.ezdravotnictvo.sk. Its task is to develop platforms for the provision of health care in Slovakia. In Fig. 35.1, a brief description of the eHealth platform is presented [1].

The problem area seems to be eLab, which is still in process. It should contain documents from the laboratory examination in digital form. Here there is the problem of converting the entry from the current paper document into electronic form. Therefore, this article deals with the design of the concept of implementation of RFID technology for tubes with biological samples. In general, it is necessary to specify the three areas proposed in Fig. 35.2, which represent the following concept [2].

35.1.1 Description of RFID System

The basic principle of operation of RFID technology is that the RFID reader antenna generates an electromagnetic field that has a specific distance and shape of the range. If an RFID tag comes within range of the electromagnetic field, its antenna

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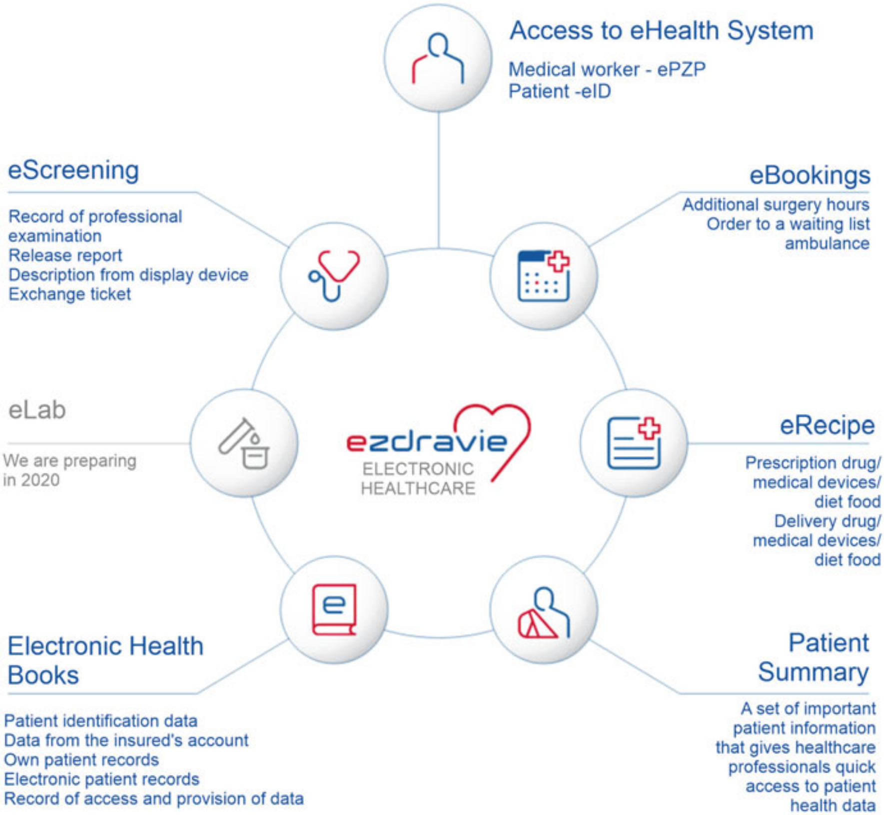


Fig. 35.1 eZdravie portal structure [1]

receives the transmitted signal, and induction in the antenna coil induces a voltage that serves as a power source for the RFID tag. The tag microprocessor processes the signal from the reader and makes available the information about the marked object contained in the EPC code. The antenna of the powered RFID tag starts transmitting a signal that the reader detects and then transmits the object information to the host computer system [3, 4].

There are several different ways an RFID reader can communicate with an RFID tag. The main interconnection methods include [5, 6]:

- **Backscatter**—used for longer distances. The electromagnetic field of the reader is reduced by the attenuation of free space, and only a small part of it reaches the RFID tag. Part of this energy is absorbed to power the RFID tag, but part of the energy has reflected the reader as backscatter. The method of signal reflection depends on the properties of the RFID tag. The amount of reflected energy depends on how well the RFID tag antenna connects to the electromagnetic wave. During reverse data transmission, the load resistor connected in parallel with the

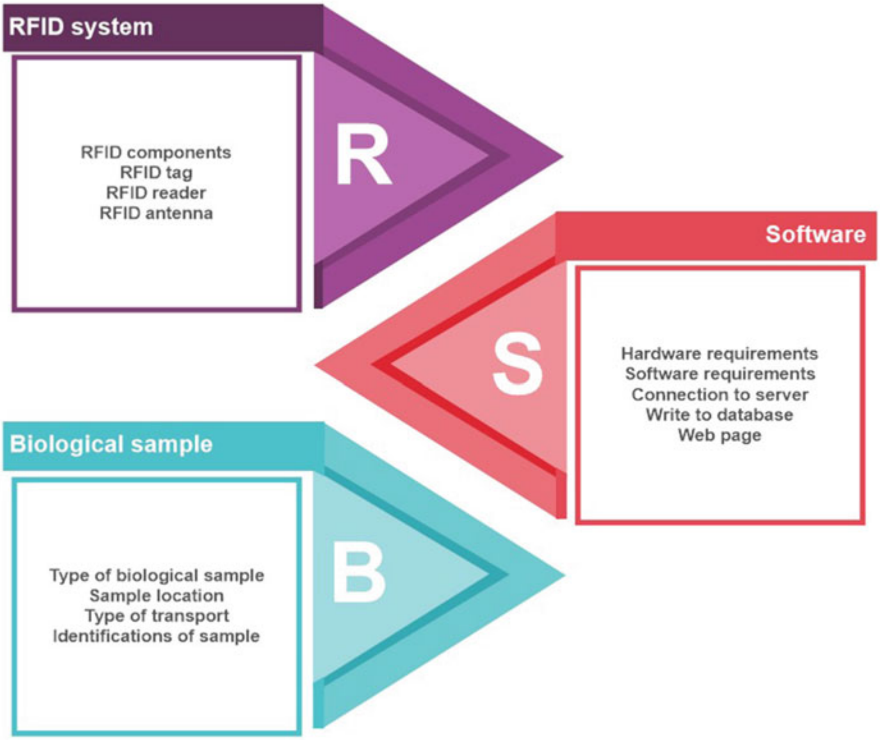


Fig. 35.2 Three elements of proposed eLab system

antenna is alternately switched on and off in time by means of the data stream to be transmitted. By changing the resonant properties of the antenna, the RFID tag is either a bad or good reflector for the reader. The strength of the feedback signal is changed, and a data stream is created to be detected by the reader.

- **Inductive coupling**—is used for shorter distances. The energy transfer between the two circuits takes place using mutual inductance. The RFID reader and tag contain induction (antenna) coils. When the RFID tag gets to the required distance from the reader, its field is connected to the area of the RFID tag and the induced voltage will be used to supply it, which will allow the subsequent sending of data about the object contained in the respective RFID tag.
- **Capacitive coupling**—is used for the shortest distances. Capacitive effects we are using to secure the connection between the RFID reader and the tag. Instead of antennas, electrodes (plates) of a capacitor are used, which transmits the signal generated by the reader and directs it to the RFID tag, where it supplies its components. The data sent back information to the reader, where it is processed.

The type of coupling used depends on the frequency and distance between the RFID reader and the tag. The individual types of RFID system bindings have their characteristics, which are suitable for use at different scanning distances of marked objects. The purpose of the most appropriate form enables the most optimal operation of the RFID system for individual applications [7].

35.1.2 Suggested Software Solution

This category is necessary to divide into two areas. Software that will allow reading and writing data on the RFID tag and software that will work with the database and enable reading data into the web interface [8].

Software for RFID System

The main requirement for this software is to be compatible with the RFID system. RFID systems, therefore, have limitations according to the type of frequency they read and the distance to which the sample needs to be readable. For health care, it is, therefore, necessary to choose UHF RFID tags readable at a distance of more than 1 m. For these conditions, it needs to select software that allows reading the EPC code and writing to the RFID tag memory. This software should support the transfer of EPC code followed by unique encryption to the database [9].

Web Interface Software

Its task is to retrieve personal data about the patient from the eHealth portal. It is then necessary to match the patient data with the requirement to perform laboratory tests and link this information to the EPC code of the individual biological samples.

35.1.3 The Biological Sample

Generally, the biological sample is a sample of organic nature from a living organism; it is immaterial whether this organism is alive or dead at the time of sampling and analysis. We know the following biological samples [10]:

- Biological fluids—blood, urine, plasma, etc.
- Animal tissues, plant tissues, cell cultures, etc.
- Intentionally/unintentionally altered tissues/fluids.

Within the eLab concept, it is necessary to specify that these will be clinical samples. This category includes:

- Blood and blood-related fluids.

- Body fluids other than blood.
- Excreta, residues.
- Other biological material.

The fundamental division specifies how the samples are necessary to transport and what requirements are to prefer on the RFID tags [10].

1. Blood and blood-related fluids
   - Blood—arterial, venous, capillary. It is needed to collect in a test tube with a suitable anticoagulant, store at 4 °C
   - Blood cells—red blood cells, white blood cells. Collect in a test tube with a suitable anticoagulant, store at 4 °C
   - Cerebrospinal fluid (CSF)—CSF
   - Umbilical cord blood
2. Body fluids other than blood
   - Amniotic fluid (amniotic fluid)
   - Chamber water
   - Breast milk, colostrum
   - Stomach juice
   - Lymphoma
   - Peritoneal fluid
   - Saliva
   - Sperm
   - Synovial fluid
   - Tears
   - Vitreous
3. Excreta, residues
   - Bile
   - Exhaled air
   - Excrement
   - Sweat
   - Urine
4. Other biological material
   - Stones—kidney, bile, urinary
   - Dialysis fluid
   - Hair
   - Nails
   - Mucus, nasal swab
   - Tissues

A wide range of test tubes is producing for the collection of biological material. These sampling containers are produced in various volumes from 0.75 mL up to the order of tens of milliliters. The main reason for using is for a great variety of capacities, shapes, and sizes of manufactured tubes. Test tubes with various additives are for blood collection produced, which was the focus of our experiment. These substances are already present in the test tubes and aid in the processes associated with a specific group. The test tubes also have different color markings on the tube caps. Each color determines for a particular type of examination, sampling examination, volume, and additive. This division and categorization we can browse on the websites of companies that sell and distribute such material [11].

35.2 The Work Methodology

In our research, we used the principle of dividing components into hardware and software design the concept of the RFID system. The basis of the hardware part of the RFID system is an RFID tag placed on a test tube, which contains unique information about the marked object to which it is attached. Another component is an RFID reader with an antenna, to read information and then forward it for processing via intelligent software. For the chosen concept, we will use the RFID reader TSL 1128 Bluetooth® UHF, which cooperates with a mobile device using Bluetooth. It sends the RFID tag data to the RFID explorer software, which processes it and sends it to the database [12] (Fig. 35.3).

The design is compatible with all mobile devices. Another item to consider is the RFID tag. Here we can the proposed UHF RFID tag Confidex Silverline Micro. It is characterizing by small dimensions with 480-bit memory and IP 68 resistance (Table 35.1).

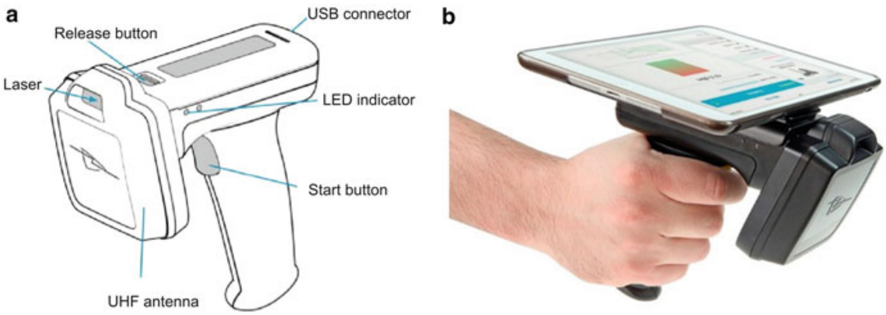


Fig. 35.3 Composition of the TSL 1128 UHF reader and its connection to the tablet [12]

Table 35.1 Parameter of RFID tag Confidex Silverline Micro [12]

Dimension	Memory	Read range	Temperature	IP rating
43 × 13 × 1.1 mm	256 bit EPC + 480 bit (M4E)	Up to 5 m	−35–85 °C	IP68

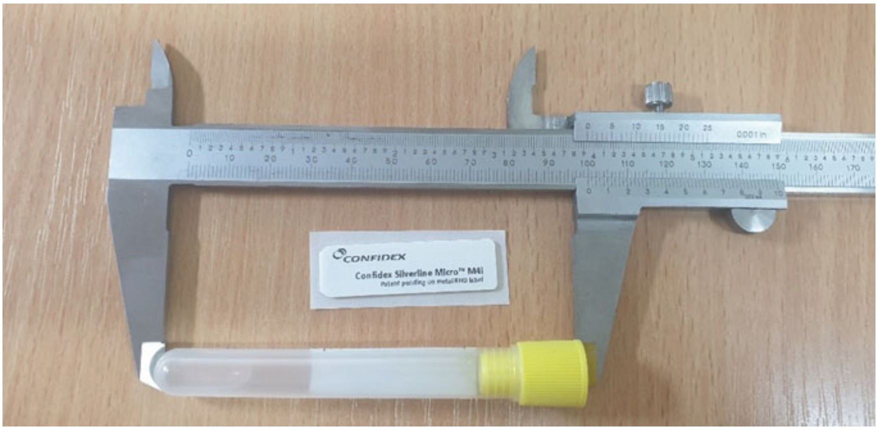


Fig. 35.4 Test tube D1153 and RFID tag Confidex

These RFID tags can be attached to D1153 tubes with a clotting accelerator. The tags must be transported in refrigerated boxes to ensure dust and water resistance IP 68, which means that the tag is dustproof and suitable for permanent immersion underwater (Fig. 35.4).

35.2.1 Suggested Software

As already mentioned by our monitoring we need to use, 1 RFID Explorer software is provided, which allows the pairing of the RFID tag and the patient's number.

RFID Explorer is one of the most widely used software solutions that are compatible with the TSL 1128 RFID reader. RFID Explorer uses the sophisticated ASCII protocol from TSL, which is built-in high-performance and universal RFL TSL readers [12]. The primary uses of the software include:

- Inventory—quickly generates a list of scanned RFID tags and provides an overview of scanning operations
- Localization—search for a specific RFID tag, which is supported by a graphical representation of the signal strength level
- Read, write—read data from the RFID tag memory and write additional information.

The recording would take place as follows:

1. The healthcare professional who takes the biological sample shall take it in a tube marked with an RFID tag. It then retrieves patient data from the eHealth database in the mobile application. Click on the Sticker box when the personal code generated is (Fig. 35.5).

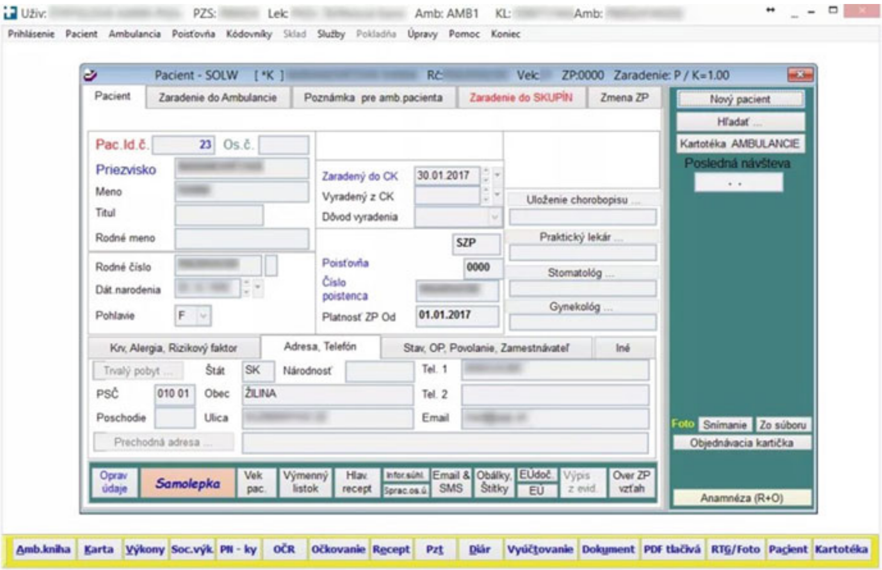


Fig. 35.5 Patient's Card through the portal "eZdravie"

2. Access the sample with an RFID 1128 Bluetooth UHF reader mobile device and a service tablet or smartphone in which it has an application for working with an RFID reader installed.
3. Retrieves the unique EPC code of the RFID tag from the tubes displayed in the blue frame.
4. Then enter the personal number converted from the text into hexadecimal digits in the data field (obtained by clicking on the "Sticker"). This registration enables the first level of personal data protection. By writing data to the selected RFID tag, it is possible to write up to 480 bits (Fig. 35.6).
5. After pairing made of the diagnoses to which the biological sample is to be subjected. The individual tests have divided the sample and writing the patient ID on the RFID tag; a selection is according to the main categories (Fig. 35.7):

- Biochemistry and hematology
- Immunology and allergology
- Microbiology
- Medical genetics
- Pathology and veterinary diagnostics

The patient identification data entered in this way on the RFID tag match with the electronic eHealth system. In the laboratory, the laboratory technician opens the eHealth portal and identifies samples at the first collection. The system will generate how many types of tests to perform according to the main categories. After the

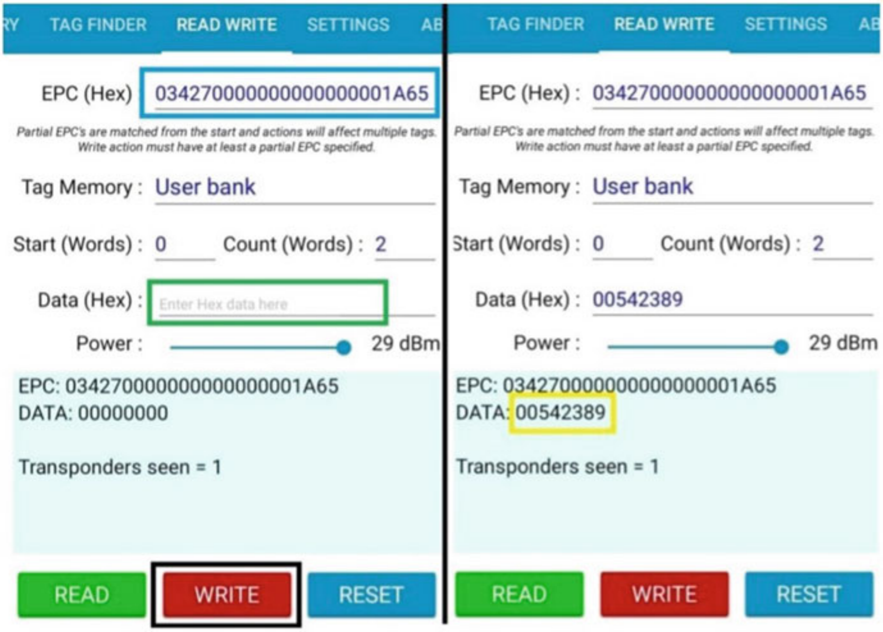
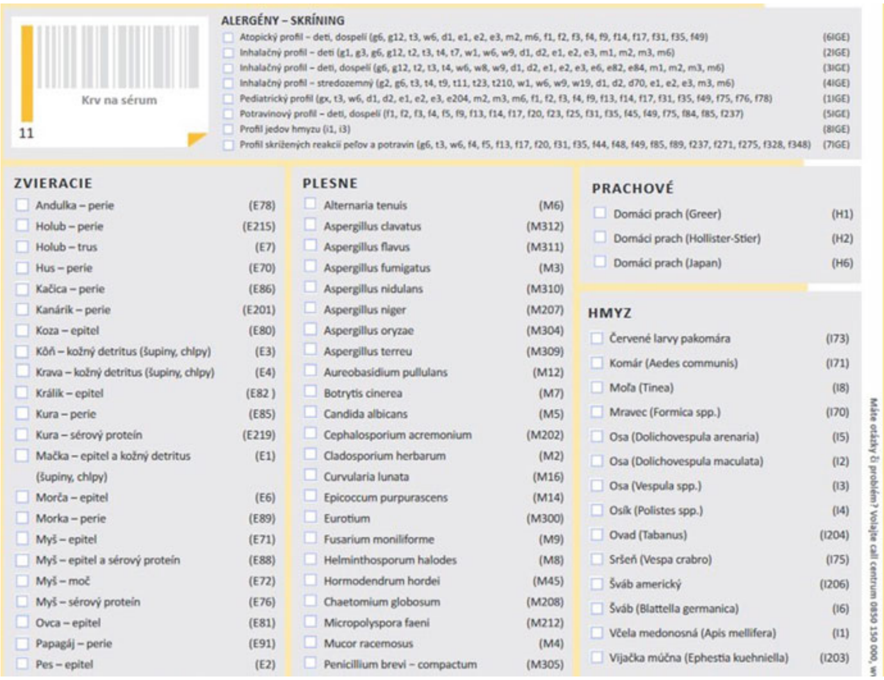


Fig. 35.6 Environment of software RFID explorer



Krv na sérum

11

ALERGÉNY – SKRÍNING

☐ Atopický profil – deti, dospelí (g6, g12, t3, w6, d1, e1, e2, e3, m2, m6, f1, f2, f3, f4, f9, f14, f17, f31, f35, f49)	(6IGE)
☐ Inhalačný profil – deti (g1, g3, g6, g12, t2, t3, t4, t7, w1, w6, w9, d1, d2, e1, e2, e3, m1, m2, m3, m6)	(2IGE)
☐ Inhalačný profil – deti, dospelí (g6, g12, t2, t3, t4, w6, w8, w9, d1, d2, e1, e2, e3, e6, e82, e84, m1, m2, m3, m6)	(3IGE)
☐ Inhalačný profil – stredozemný (g2, g6, t3, t4, t9, t11, t23, t210, w1, w6, w9, w19, d1, d2, d70, e1, e2, e3, m3, m6)	(4IGE)
☐ Pediatrický profil (gx, t3, w6, d1, d2, e1, e2, e3, e204, m2, m3, m6, f1, f2, f3, f4, f9, f13, f14, f17, f31, f35, f49, f75, f76, f78)	(1IGE)
☐ Potravinový profil – deti, dospelí (f1, f2, f3, f4, f5, f9, f13, f14, f17, f20, f23, f25, f31, f35, f45, f49, f75, f84, f85, f237)	(5IGE)
☐ Profil jedov hmyzu (i1, i3)	(8IGE)
☐ Profil skrížených reakcií peľov a potravín (g6, t3, w6, f4, f5, f13, f17, f20, f31, f35, f44, f48, f49, f85, f89, f237, f271, f275, f328, f348)	(7IGE)

ZVIERACIE

☐ Andulka – perie	(E78)
☐ Holub – perie	(E215)
☐ Holub – trus	(E7)
☐ Hus – perie	(E70)
☐ Kačica – perie	(E86)
☐ Kanárik – perie	(E201)
☐ Koza – epitel	(E80)
☐ Kôň – kožný detritus (šupiny, chlpy)	(E3)
☐ Krava – kožný detritus (šupiny, chlpy)	(E4)
☐ Králik – epitel	(E82)
☐ Kura – perie	(E85)
☐ Kura – sérový proteín	(E219)
☐ Mačka – epitel a kožný detritus (šupiny, chlpy)	(E1)
☐ Morča – epitel	(E6)
☐ Morka – perie	(E89)
☐ Myš – epitel	(E71)
☐ Myš – epitel a sérový proteín	(E88)
☐ Myš – moč	(E72)
☐ Myš – sérový proteín	(E76)
☐ Ovca – epitel	(E81)
☐ Papagáj – perie	(E91)
☐ Pes – epitel	(E2)

PLESNE

☐ Alternaria tenuis	(M6)
☐ Aspergillus clavatus	(M312)
☐ Aspergillus flavus	(M311)
☐ Aspergillus fumigatus	(M3)
☐ Aspergillus nidulans	(M310)
☐ Aspergillus niger	(M207)
☐ Aspergillus oryzae	(M304)
☐ Aspergillus terreu	(M309)
☐ Aureobasidium pullulans	(M12)
☐ Botrytis cinerea	(M7)
☐ Candida albicans	(M5)
☐ Cephalosporium acremonium	(M202)
☐ Cladosporium herbarum	(M2)
☐ Curvularia lunata	(M16)
☐ Epicoccum purpurascens	(M14)
☐ Eurotium	(M300)
☐ Fusarium moniliforme	(M9)
☐ Helminthosporum halodes	(M8)
☐ Hormodendrum hordei	(M45)
☐ Chaetomium globosum	(M208)
☐ Micropolyspora faeni	(M212)
☐ Mucor racemosus	(M4)
☐ Penicillium brevi – compactum	(M305)

PRACHOVÉ

☐ Domáci prach (Greer)	(H1)
☐ Domáci prach (Hollister-Stier)	(H2)
☐ Domáci prach (Japan)	(H6)

HMYZ

☐ Červené larvy pakomára	(I73)
☐ Komár (Aedes communis)	(I71)
☐ Moľa (Tinea)	(I8)
☐ Mravec (Formica spp.)	(I70)
☐ Osa (Dolichovespula arenaria)	(I5)
☐ Osa (Dolichovespula maculata)	(I2)
☐ Osa (Vespula spp.)	(I3)
☐ Osík (Polistes spp.)	(I4)
☐ Ovad (Tabanus)	(I204)
☐ Sršeň (Vespa crabro)	(I75)
☐ Šváb americký	(I206)
☐ Šváb (Blattella germanica)	(I6)
☐ Včela medonosná (Apis mellifera)	(I1)
☐ Vijačka múčna (Ephestia kuehniella)	(I203)

Máte otázky či problém? Volajte call centrum 0850 150 000,

Fig. 35.7 Allergology form sample

identification of examinations, tests are showing, and information about the results entering into the eLab portal. After recording the test results by the laboratory technician, the doctor has immediate access to them, as the whole concept works online.

35.3 Conclusions

In conclusion, we can state that the proposed concept of implementation of UHF RFID technology has many advantages. First of all, it is a contactless technology that also works over long distances. By creating portal gates, we can accurately identify the position of the sample with a deviation of 0.5 cm. Another advantage is the durability of the selected RFID tag of the IP68 standard. Also, as an advantage, we can consider the elimination of the paper form of filling out test requests, where the human factor has often failed. This year, the eLab system will be launch in Slovakia, and the presented concept can serve as an inspiring tool. Financially, it would be a costly system, with the initial acquisition cost being a one-time item and the price of RFID tags ranging from a few cents for larger orders. In summary, we can say that the presented concept has a large number of benefits due to the current pandemic situation of COVID 19 when it is necessary to protect oneself.

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Chapter 36
Project Safety Management Systems of Students with 3D Game Development

Olena Sivakovska, Mykola Rudynets, Andrii Yashchuk, Rostyslav Redko, and Oleg Zabolotnyi

36.1 Introduction

One of the main directions for development of the modern state is the sphere of ensuring the safety of the population. In recent years, issues of public safety have become an acute problem in our country. At the same time, the search for new approaches to the development of more effective and at the same time attractive projects to ensure the safety of students in the social direction of marketing and economic policy of the state continues has been continued too.

Today it is impossible to imagine our lives without gadgets. The virtual world attracts children and adults to its webs. Modern children actively use smartphones, tablets, and computers. Of course, on the one hand, perhaps it's bad. Studies have shown that too much gadgets may negatively affect a child's brain on its functioning, and may even cause attention deficit, cognitive delays, impaired learning, increased impulsivity, and decreased ability to self-regulation [1]. However, on the other hand, despite publication by a reputable press, the use of media devices has only increased over the years and has a number of advantages. The developers offer a lot of interactive and social applications, the main function of which is to simplify our lives or teach children something new, for example, through various educational games and puzzles.

As there are restrictions in the legislation on the timing and timing of exercises related to actions in emergencies, our proposed concept involves the use of modern hardware (computers, tablets, smartphones, etc.), equipped with special software in the form of a game that can be used during classes and after school hours, and a system of student incentives too.

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Therefore, the issue of software development with using the technique of virtual modeling is relevant, a key aspect of which would be to help improve the safety of students in case of emergencies in educational institutions.

The object of the study is the project of a safety measurement system for students with the development of 3D simulator as a digital game for training desirable behavior in the event of an emergency of different nature and under different conditions.

The aim of the research is to develop a project of safety management systems for students with 3D game development "Pupils Safety Training Simulator."

In achieving this goal, we typically must perform the following tasks: (1) to analyze the state of student safety in Ukraine in order to implement the project of creating student safety measures; (2) to develop a concept project to improve student safety measures; (3) to conduct a SWOT analysis of the project of creating student safety measures; (4) to formulate the Work Breakdown Structure of the project of creating student safety measures; (5) to develop a project management system to increase student safety in the environment of specialized software MS Project; (6) to describe the stages of the 3D simulator creating; and (7) to evaluate the socioeconomic efficiency of the project.

The developed software will help to increase the level of socioeconomic protection of students through the game in a 3D-simulator, which will be offered to students as homework or before lessons, or as training behavior in emergencies of different nature and under different conditions.

The implementation of the proposed project will reduce the number of injuries and deaths of students that occur for organizational reasons from 25% to 40%.

36.2 Literature Review

On the basis of information of leading scientists such as Qian G., Zhai H., Fan Y. [2], Liudmyla O. Zharko, Victor P. Ovchar, and the other, it was analyzed fire safety problems in the world and Ukraine.

It was carried out the analysis of state document in the field of civil defense or civil protection in the United States and Ukraine [3].

In the software development industry, software games are gaining importance because they are not only used for entertainment but also for serious purposes that can be applicable to different domains such as education, business, and health care [4].

Special attention was paid to the research in 3D-game development. Here can be singled out the scientist Jingming Xie [5] and researchers from School of Art design (ShenYang Ligong University, China) Meng Yang, Zhen Wang, Shilong Xiao [6], who have been engaged in research into modeling and control of 3D game.

Project Safety Management Systems of Students with 3D game development cannot be exist without such sphere as a project management. For this reason, it was used PMBOK Guide as the framework for this project development [7].

36.3 Research Methodology

The fire safety is the set of practices intended to reduce the destruction caused by fire. Ensuring fire safety is one of the priorities for any enterprise, organization, institution, office, and private home. Problems of fire safety in Ukraine are becoming increasingly important.

Existing methods of risk analysis and the causes of their occurrence during the educational process in educational institutions are based on the fact that the occurrence of injury risks is caused by two main components [8]: insufficiently developed system of organizational support, that is, briefings, training, real examples; insufficient material and technical provision of educational facilities with the necessary resources; insufficient material and technical provision of educational facilities with the necessary resources, for example, fire alarms, alarm systems, and other devices and technical means that must ensure the safety of participants in the learning process (see Fig. 36.1).

The raising the level of safety and reducing injury risk to participants in the educational process is possible by improving the quality of organizational and technical components. The possible solution to this problem is to improve curricula and briefings, depending on the type of classes, in the form of reminders of the dangers during classes. The more difficult task is to minimize the risk of injury during an emergency. The basic causes of risk are the physiological and emotional state of the student. Its influence under certain conditions can lead to failure to ensure their own safety, as well as the failure of technical and organizational support, weather conditions, which will lead to catastrophic consequences. Such functions primarily include the ability to properly and quickly evacuate from the scene of danger with the team in emergencies of various kinds, and this in turn depends on

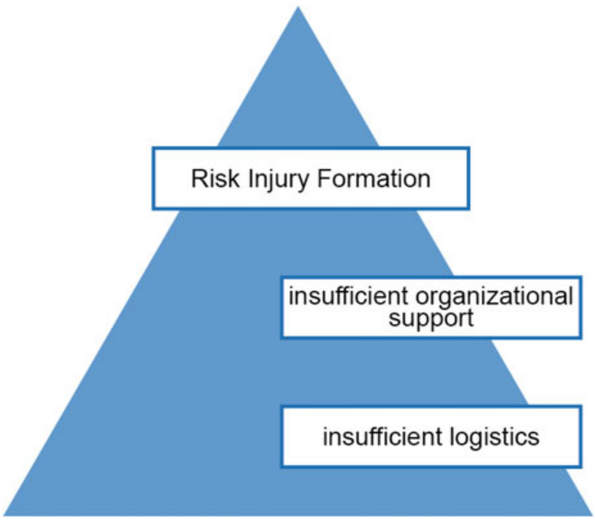
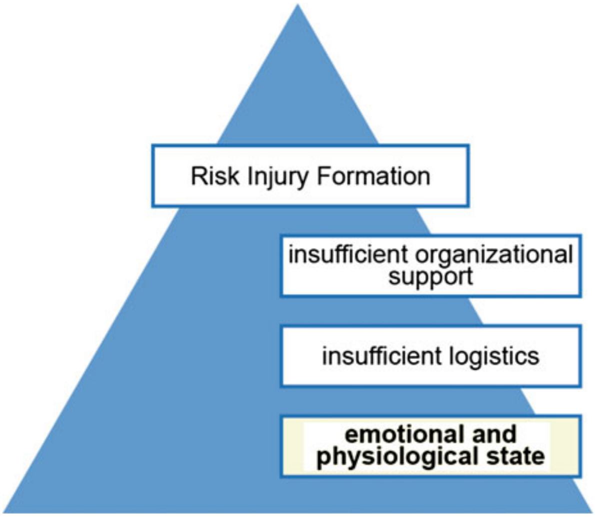


Fig. 36.1 Causes of injury risks

Fig. 36.2 Causes of injury risks during an emergency



the degree of preparedness of students. We can say that the process of risks injury formation consists of three components (see Fig. 36.2).

Analyzing the following components of the security system, we conclude that its operation is directly related to the level of preparation of students for action in emergencies. Trainings in real conditions must be carried out for its preparation. However, such training usually does not give the desired effectiveness. Students are simply not interested in listening to “dry” theory. There is no real threat or encouragement that would motivate to action and, of course, there is no lack of comprehensible practice in emergency situations, which would cause the development of resilience and shock reduction in the event of a real threat.

The great importance in educational institutions is the regular practical training of evacuation. One can only imagine the shock, if this situation occurs. So the lack of behavioral skills of staff and students will lead to panic, unnecessary fuss. As a result, carbon monoxide poisoning or chemical fumes, the possibility of casualties. It has been scientifically proven that the time of evacuation depends on the number of trainings, the width of the passage, and the number of people. Evacuation will be faster, when we give it more training. We determined the dependence of testing time on the number of virtual workouts (see Table 36.1).

During testing, students have become acquainted with photos of rooms and evacuation routes on a real object. It was used a virtual environment of that space. The task of the test is to learn to evacuate quickly from a real object through the use of the student’s visual memory. They made mistakes. After all, mistake-driven training provides students with a risk-free setting to explore different actions and experience their consequences. All wrong actions and mistakes were taken into account. So, each next time a student improved his result better. *This type of test game will introduce certainty to the subconscious automatism of correct behavior, and at the same time will familiarize participants with multidimensional threat situations.*

Table 36.1 Dependence of time evacuation on a number of trainings

Evacuation time, minutes (round to whole number)	Number of evacuation drills (for a year)
13–12	2
12–11	3
11–10	4
10–9	5
8–7	6
6–5	8
4–3	10
3	12
3	13
3	14
3	15

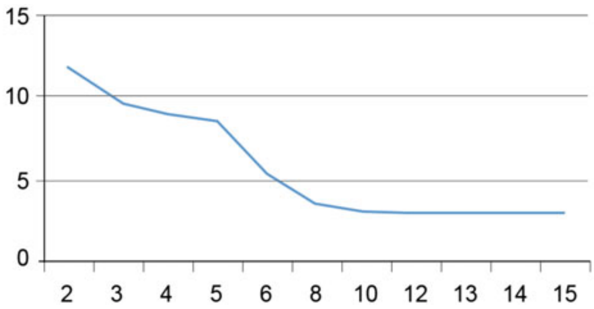


Fig. 36.3 Graph of dependence of time evacuation on a number of trainings

Students and teachers will be able to better orient themselves in the university rooms and improve their skills during such emergencies. The truth of this is reflected in the graph (see Fig. 36.3).

The graph shows a direct relationship between the number of training sessions and evacuation time. Accordingly, the greater the number of training sessions, the shorter the evacuation time, but it must be borne in mind that the dependence operates to a certain extent. Practical studies show that the minimum time that can be achieved with increased training can be 3–4 min. It is impossible to further reduce the time due to the capacity of the corridors, their length, a number of people, and other factors that may affect this process. For example, in the cold season, you need more time to put on clothes; changes in meteorological conditions must be taken into account too (condensate on the floor reduces the speed of movement in buildings).

36.4 Results

The above analysis shows that the safety of students directly depends on the level of their emotional and physiological state during the emergency, which in turn affects the speed of assessment of the situation, making the right decision and the order of actions of the student, and also has a direct dependence on the number of trainings with students.

As there are restrictions in the legislation on the deadlines and timing exercises, related to actions in emergencies, we propose the concept that involves the use of modern technical means (computers, tablets, smartphones, etc.). They are equipped with special software in the form of a game that can be used during classes and after school hours. Our proposed conception includes students' incentive system that provides an addition of points in the relevant classes in safety disciplines in educational institutions. The game environment should virtually simulate possible emergencies with the display of all rooms in the buildings of the real object and allow the participant to assess the situation, make decisions, moving around the object. The ultimate goal of the game is to bring to the automatism of the participant's actions regarding his safety in the event of an emergency at a particular object. The game consists of several stages (depending on customer's wish). After passing each stage, the software evaluates the correctness of the participant's actions, points out errors, and makes an assessment that can be credited during the learning process. The current training standards and the training plan do not allow to increase the number of trainings due to time constraints, it is necessary to look for ways to reduce the evacuation time. To solve this problem, we have proposed a method of virtual training using computer technology at homework or before lessons. To solve this problem, we have proposed a method of virtual training using computer technology at homework or before lessons. The essence of this technique is that first in real conditions is training on evacuation from a real object (according to the law once a year); further students are offered a virtual computer game–test as homework. It is based on the knowledge and skills gained in the process of real training with using our proposed 3D simulator. The virtual environment of the 3D simulator will display the premises of a real object with the help of a panoramic photo taken in advance with details of all the rooms. The task of the game–test is to learn to evacuate quickly from a real object through the use of the student's visual memory (here must be used photographs of premises and evacuation routes on a real object). It includes the ability to take into account all the actions and mistakes made during training, to pass the entire evacuation test from the object in the passing game again.

In this case, the game–test will contain three modes: for students, for employees, and joint actions of both categories. The reason for this division is different responsibilities during the evacuation.

A 3D plan of the institution will be included in the game–test (simulation, virtual reality). IT is based on a previous photo or video of the object and has a holistic structure, as in real life. For the quick search, a first aid kit, fire extinguisher, or

Table 36.2 SWOT-analysis of the project

	Strengths	Weaknesses
Internal environment	Unique and universal product of the project Relatively low project cost The prospect of applying the project to any other objects A wide range of potential consumers of the project product Post-project software service Availability and low cost of project resources A small project team that is much easier for managing	Time spent on the necessary documentation to obtain permission to photograph the object
External environment	No impact on the environment Absence of existing competitors Providing state support through the social orientation of the project	Rapid development of technologies, in which the project software needs constant updating Deterioration of the foreign economic situation Exchange rate fluctuations Deterioration of the political and economic situation in the country Unfavorable investment climate Insufficient level of protection of intellectual property rights

sandbox in the game, they will stand out. It should be also added the most common mistakes that people do during emergencies, and the explanation of why they should not do such mistakes. The game will include the maximum possible number of situations. It will focus on the different ages of participants in the educational process and the nature of emergencies, for example, man-made emergencies; emergencies caused by natural disasters.

Players will be able to choose their actions and direction of movement, which they will check the correctness of their actions and will be able to improve them.

In addition to the game part, this program will include tests: how to provide first aid, what numbers to call the appropriate services, when to use a fire extinguisher, etc.

It is necessary to use SWOT analysis to ensure the achievement of the project objectives and contribute to its efficiency Table 36.2 [9].

For successful implementation and start of the project product, there is a need for a detailed analysis and calculation of all necessary work [10]. It must be created Work Breakdown Structure (WBS) Fig. 36.4 [11].

The V-model methodology was used to develop the software product (3D simulator), which is used to create software products with continuous operation Fig. 36.5 [12].

Project cost management integrates the processes performed during planning, budgeting, and cost management and ensures the completion of the project within

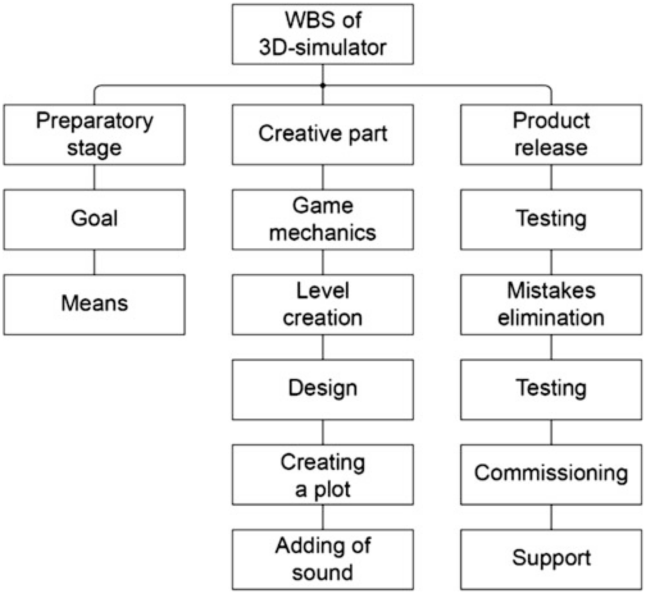


Fig. 36.4 WBS of 3D-simulator project development

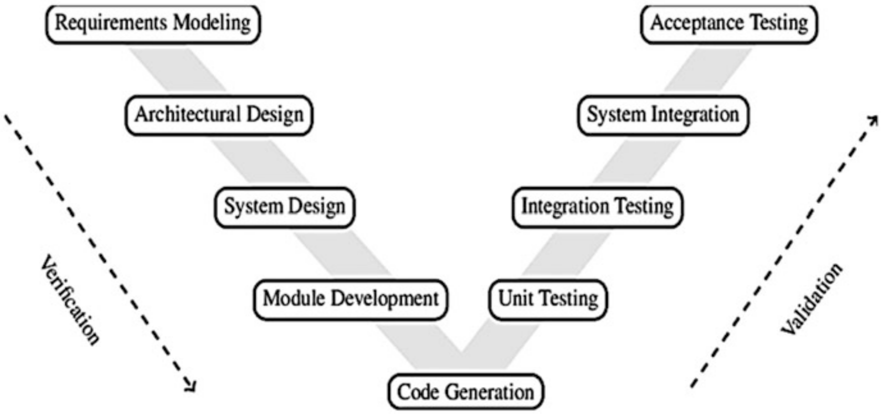


Fig. 36.5 The V-Model for the software development life cycle

the approved budget. The project is limited not only by time but also by material and labor resources. All the necessary resources were allocated to implement the project with the help of MS Project.

Assessing the socioeconomic effectiveness of the project to create measures for the students' safety, we recall that human security is recognized by our state as the highest value. So pupils and students represent the future of our state, which depends entirely on the quality and safety of learning and living conditions.

Table 36.3 Cost of human life and total losses from the consequences of emergencies

	Calculation formula	Cost ($)	Cost (€)
Human life	$P_h = L_{lr} + F_a + L_b$	548.40	459.90
Total losses	$T_l = P_h$ $(F_a = F_{as} \times N_{tl})$	43,323.60	36,320.25

For example, the U.S. Department of Defense is now paying $ 100,000 to the families of the deceased soldier. In the event of the death of the military, insurers pay heirs up to 400,000 dollars. Thus, the life of a soldier costs from 500,000 to 1.5–1.7 million dollars (it depends on the number and age of children). There is no clear assessment of the cost of living and health of a citizen of Ukraine in monetary terms.

However, it can be calculated using the method of assessing losses from the consequences of man-made and natural emergencies.

The total amount of loss of public life and health is calculated by the formula:

$$P_h = L_{lr} + F_a + L_b, \tag{36.1}$$

where P_h—total amount of loss of public life and health, L_{lr}—loss of labor resources from production, F_a—funeral allowances, L_b—the loss of a breadwinner.

So calculate the cost of human life and total losses from the consequences of emergencies (namely fires and explosions) for one Ukrainian in 2019 Table 36.3, where T_l—total losses, F_{as}—funeral assistance, N_{rl}—a number of victims of a particular type of accident.

The social effectiveness of the project, first of all, is the ability to positively influence the protection of the greatest value—human life and health, and specifically the participants in the educational process.

The economic efficiency of the project is to significantly reduce the financial costs of investors, which can also be the state.

So the cost of the project is much less than the cost of monetary compensation to people who were injured or to relatives of those killed in the emergency.

36.5 Conclusions

The scientific research presents the results of generalization and solution of the current scientific and technical problem of creating a system of safety measures for participants in the educational process with the development of the 3D game "Pupils Safety Training Simulator." If we analyze only a small number of fires that have occurred in educational institutions over the last 3 years, we can conclude that students' skills during emergencies are low, their level of emotional and physiological condition is low too. They don't follow fire safety rules, requirements of building codes for firewalls, etc. The current training standards and the training plan do not allow to increase the number of trainings due to time constraints, so it is necessary to look for ways to reduce the evacuation time.

We have proposed a method of virtual training that uses computer technology in the form of various games that will be offered to students as homework or before lessons, or as training behavior in the event of an emergency of different nature and under different conditions.

The economic efficiency of the project is to significantly reduce the financial costs of investors and the state too. The cost of the project to create safety measures for students is much less than the cost of monetary compensation for people in the event of injury or people are affected by the consequences of the emergency and families of those killed in the emergency.

The implementation of the proposed project will reduce the number of injuries and deaths of students that occur for organizational reasons from 25% to 40%.

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Chapter 37
Intangibles in Manufacturing Industry: An Empirical Analysis

Jozef Glova, Alena Andrejovska, and Olga Vegsoova

37.1 Introduction

From the beginning creativity, intelligence, and adaptability of human beings were exactly the thing that distinguished the human race from the rest of nature. The ability of learning and extending their perception of reality leads to simplification of work and increase of productivity with much higher efficiency. The first industrial revolution, which was characterized by a transition from manual production to machine production in eighteenth century, helped many primary sectors like the iron industry, agriculture, and mining to achieve much higher productivity than with hand production methods. The second revolution helped humans to be faster and much more interconnected in a very simple way through transferring people and ideas. Railroad networks and the telegraphs had been built, before the third industrial revolution in twentieth century, affected by two world wars, helped change the business environment and our daily life. The next significant progress in the development of the information and telecommunication technologies continued, whereby the extensive use of new technologies started to abrogate the necessity of human power in daily life. We call it automation or man can also use the term Industry 4.0, which came from the governmental project in Germany that helps support automatization in manufacturing. This new industrial revolution is based on smart technologies like Internet of Things (IoT) or machine-to-machine (M2M).

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As we see from the above-mentioned current economic development is significantly dependent on the creation, distribution, and use of knowledge. It is much more than it has been in the past. Knowledge is linked to human capital, intelligent processes within companies, customer relationships, or even such characteristics as defining a design or brand.

Human capital and generally experienced employees help to significantly define the value of the company. The same is true for business processes. These facts may raise questions in us such as: How to measure these aspects? If we have a way to measure them, are these results accurate and reliable, as well as a way to make such measurements?

Intangibles lack physical substance, even their valuation is difficult. However, from the economics and managerial literature is clearly visible their contribution to the growth of GDP. For evidence see Corrado et al. [1]. Intangibles can be acquired in different ways, however, one can distinguish between internally generated intangibles and externally purchased. When using externally acquired intangibles we always have price relation, what is not the case when intangibles are generated internally.

There are several problems link to valuation of intangibles due to their feature of intangibility. We can split them into two sets: identifiable and unidentifiable intangibles. Identifiable intangible assets are to find in balance sheet. According to IFRS these cover intellectual property rights, such as patents, licenses, copyrights, or trademarks. They clearly fulfil the condition of recognition on balance sheet. Some authors tend to extend the definition of identifiable intangibles and consider R&D expenses as an indicator of intangible intensity. However, the capitalization of research and development expenses is often discussed issue in this area.

37.2 Theoretical Background

There is undoubted reality that intangibles are very often used and discussed topic of policy makers around the globe. The European Commission is also no exception. There are number of different studies and different focus groups as well as expert groups specifically devoted to various problems in the field. Some of them are extremely important for innovation policy within EU, namely The Intangible Economy—Impact and Policy Issues; Study on the Measurement of Intangible Assets and the Associated Reporting Practices; Report on the Feasibility of a Pan-European Enterprise Data Repository on Intangible Assets; Reporting Intellectual Capital to Augment Research, Development, and Innovation in SMEs; Creating a Financial Market for IPR; Final Report from the Expert Group on Intellectual Property Valuation. More on the studies is also to find in Sánchez et al. [2].

Interesting thing, despite this number of studies, is that the definition and classification of intangibles are not closed topic. We could at least have distinguished practical perspectives of companies that classify intangibles into three groups—human capital, structural capital, and relational capital.

Other perspective is that firms consider intangibles as intangible resources or intangible activities. Intangible resources are usually considered as asserts in a broader sense. For instance, Montresor et al. [3] use definition of intangibles in a broader sense as everything, what is nonphysical and thus not touchable, and focus on their identification via survey. This significantly differs to the definition of International Financial Reporting Standards requiring identifiability and controllability. If an intangible asset does not fulfil the conditions and cannot be recognized as an asset, IAS 38 requires the expenditure on this item to be recognized as an expense when it is incurred as provided by International Accounting Standards Board [4]. Ashton [5] defines intangible activities as investments to purchase or generate intangibles (in form of patents, copyrights, licenses, or trademarks). In our paper, we focus on financial statements, specifically on balance sheet for intangible fixed assets and on profit and loss account for research and development expenses.

37.3 Motivation of Research, Data, and Methodology

We consider data of 143 public listed companies in Manufacturing industry for the years 2011–2015 from Amadeus dataset. We applied panel data modeling technique using observations for the time period 2011–2015 are analyzed. Initial data sample consisted of 1092 data observations. Unfortunately, due to missing values, we exclude almost 87% of data. As concluded by Montresor et al. [3], there is a dominant reporting practice of EU firms for research and development expenses. The geographic structure of data is summarized in Table 37.1.

Table 37.1 contains firms from selected countries. It is to mention that there are countries where firms tend to report intangibles in their financial statements. From the original data set some observations have been filtered because of poor quality of data or missing some values. From the table, it is clearly visible that we selected companies from countries with high intensity of reporting the intangibles. According to Corrado et al. [1] Great Britain and Sweden belong to the most intangible intensive countries in the world because of their focus on manufacturing industry.

Table 37.1 Geographic structure of data sample

Country	No. of observations
Belgium	7
Germany	34
France	31
Great Britain	53
Switzerland	3
Sweden	5
Turkey (European portion)	10

Source: own editing

Our data sample covered manufacturing industry, where sufficient intangible fixed assets and R&D expenses reporting data were available. Descriptive statistics are shown in Table 37.2.

Figures in Table 37.2 show that our data are very heterogeneous, with big standard deviations. Median value is significantly lower than mean values, what means that there are always several big firms which highly affect average values. Panel data modeling is frequently used for researching the effects of intangibles as we can find in Kijek [6], 2014; Filatotchev and Piesse [7]; Contractor et al. [8]; or Chen et al. [9]. From this point, the methods are considered to be suitable for the analysis. Our panel model has the form:

$$\mathrm{MCap}_{\mathrm{it}} = \beta_0 + \beta_1 \mathrm{R\&D}_{\mathrm{it}+}\ \beta_2 \mathrm{IA}_{\mathrm{it}}, \tag{37.1}$$

where MCap denotes market capitalization, R&D denotes R&D expenses, and IA denotes intangible fixed assets of an ith firm in time t, and β_0 is an intercept, and β_1 and β_2 are regression coefficients. As seen from the Table 37.3, all our variables are significantly positively correlated and excluding one of them from the model would cause omitting variable bias and therefore inconsistent estimates.

As the next step, we used quantile regression and compare it to the ordinary-least squares results. Quantile regression offers us estimates in different data quartiles what helps us in understanding how data differ in relation to the median value estimates of the ordinary regression, and from this perspective is more suitable for our data set as also discussed by Eide and Showalter [10], Hartog et al. [11], or Martins and Pereira [12]. Because of different expectations for regression coefficient we decided for applying least absolute deviations (LAD) estimation or quantile regression, what is brings according to Wooldridge [13] several advantages.

37.4 Empirical Analysis

We started the analysis by analyzing panel data with numerous observations across several time points. We have 143 individual firms from manufacturing industry within time period of 5 years, from 2011 to 2015. Applying a Chow test for the probability of the data suggests considering panel data structure of the model. Time effects are statistically significant. Usually, one applies Hausman test for a decision whether select fixed effect or random effect panel data model. From the procedure applied the fixed effects panel data model is more relevant. The model was affected with autocorrelation as well as with cross-sectional dependence. For improving the model, we made a decision to apply the heteroscedasticity robust variance-covariance matrix to estimate unbiased regression coefficients under asymptotic properties.

Running a fixed effect panel model indicates that R&D expenses contribute more to the market capitalization value of the company in comparison with intangible fixed assets. Each 1-euro increase of intangible fixed assets will show up in 2.2-euro

Table 37.2 Summary statistics for manufacturing

NACE, Rev. 2 Sector		Obs. per year	Mean R&D (m Eur)	Median R&D (m Eur)	St. Dev. R&D (m Eur)	Mean IA (m Eur)	Median IA (m Eur)	St. Dev. IA (m Eur)
C	Manufacturing	143	164.1	5.3	629.5	1296.9	36.6	3981.9

Source: own calculation

Table 37.3 Correlation matrix of selected variables

	R&D expenses	Intangible fixed assets	Market capitalization
R&D expenses	1	0.7243	0.7901
Intangible fixed assets	0.7243	1	0.8788
Market capitalization	0.7901	0.8788	1

Source: own editing

Table 37.4 Effects of intangible assets and R&D expenses

	Ordinary-least squares estimates	Quantile regression estimates				
		$q_1 = 0.1$	$q_2 = 0.25$	$q_3 = 0.5$	$q_4 = 0.75$	$q_5 = 0.9$
Intangible fixed assets	2.667	1.203	1.445	1.806	3.113	4.263
R&D expenses	8.211	5.258	5.552	12.889	12.168	9.086

Source: own elaboration

increase of market capitalization. Investing 1 euro into R&D will ceteris paribus be represented by 8-euro increase in predicted market capitalization. This model explains the variability of dependent variable of 78%.

We observe a significant linear relationship between research and development expenses and market. The plot clearly reveals the tendency of the dispersion of market value which increases along with increasing investments into R&D. The plot also indicates higher density in upper quantiles of our probability distribution. Ninety-percent quantile includes firms with very low investments into R&D, but having high market capitalization. Such evidence might indicate that R&D expenses are not the only factor, which contributes to market value creation effect. Table 37.4 contains regression coefficients of linear and quantile regression for the year 2015.

We found no specific characteristics for data from the same countries. In upper graph of Fig. 37.1, we see an OLS result, which presents 2.667-euro increase in market capitalization value after increasing balance sheet value of intangible fixed assets about 1 euro. LAD estimates are changing across different quantiles. We also see that values in upper and lower quantiles tend to be more outside the estimates of the OLS regression. The bottom graph displays a change in value of regression coefficients of R&D expenses with changing variability of market capitalization. An average increase in R&D expenses by 1 euro will cause 8.211-euro increase in market capitalization. Quantile regression covers changing variability of market value—R&D expenses relationship along the conditional distribution of the market value increase. In the first quantile, R&D expenses are lower than OLS estimates comparing to our empirical data. In the second and third quartile of R&D expenses, the explained variable (market value) is changing mildly. For the high cap, companies estimate in 90-percentile is significantly beyond the OLS estimates.

To summarize our findings, we can state that the more are firms valued by market the higher the variability of R&D expenses. One might expect gradually increasing

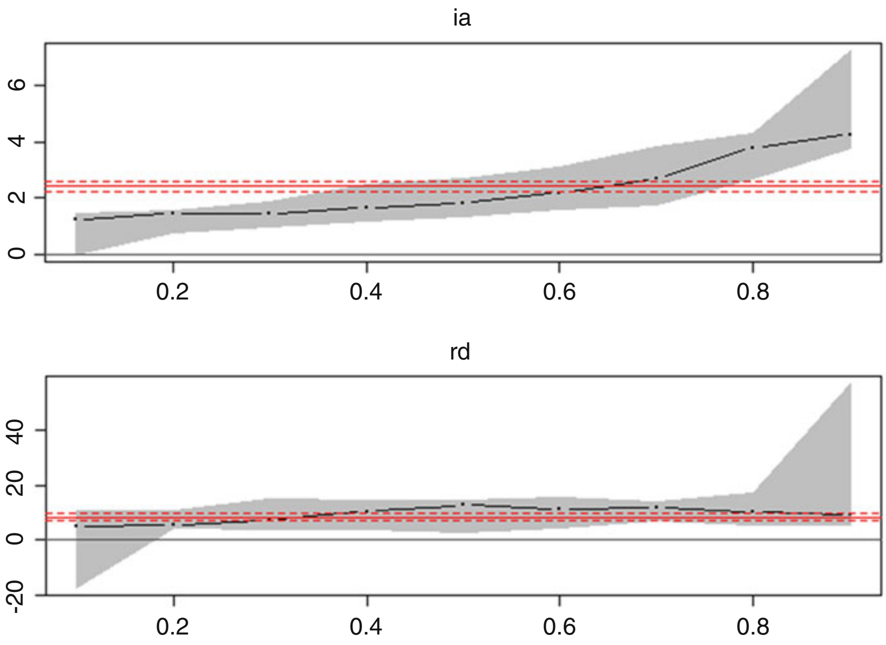

Fig. 37.1 Quantile regression outputs. Source: own elaboration

estimates of regression coefficients, but probably highly valued firms time to time also realize investments in R&D that not solidly lead to increasing of their market value in form of market capitalization.

37.5 Conclusions

The contribution of intellectual capital to market value creation is indisputable. More detailed evidence of this contribution can be found, for example, in Dumay [14].

In our paper, we examined the relationship between intangible assets on the one hand and between market capitalization at the level of quantitative analysis. Since some authors, such as Guthrie et al. [15], perceiving the difference between intellectual capital in the accounting concept and the managerial concept, we decided to use not only intangible assets, but also R&D expenditure as variables to reflect the manifestation of intangible assets, as stated in Skinner [16]. For this reason, these are in our analysis considered as explanatory variables.

Specifically, for the manufacturing industry we examined, we found a significant impact between intangible fixed assets, as well as research and development expenditures, and the value of market capitalization. From our point of view, we examined: the impact of capitalized intangible assets in the form of intangible fixed assets and consumed intangible assets in the form of research and development expenditures.

Results show that values of market capitalization increase significantly stronger in case of R&D expenses variable (ceteris paribus) compared to intangible fixed assets, when considering status quo. Unfortunately, we had been confronted with heterogeneity and homogeneity issue in our data set what we adjusted using proper differencing within the particular values. We followed the remarks and instruction of Pfarrer et al. [17] as well as Duriau et al. [18] and Dischinger et al. [19] in regard to the effect of intangibles. Our data set shows substantial impact of R&D expenses on the market value of firms under study. Regression coefficient was highest for the median quantile and decreasing with higher quantile. The monotonic growth of regression coefficients estimates has therefore not been confirmed. Results of additional quantile regression support our expectations. Specifically, investments into research and development expenses are the most essential for the manufacturing firms with middle value of market capitalization. On the other hand, the influence of intangibles was demonstrably high for quantiles of firms with high market capitalization. This indicates that capitalizing intangible assets is costly and might be the result of previous successful R&D activities. Low R&D regression coefficient estimates in last quantiles might also indicate that part of R&D expenses of the firms with high market capitalization value has been capitalized, which shifted value on balance sheet account.

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Chapter 38
A Systematic Analysis of an Industrial Pickup and Placement Production System

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38.1 Introduction

It is very important in an industrial environment to minimize all types of failures in the process of surface-mount technology (SMT) for obtaining reliable printed circuit boards (PCB) in order to make this process faster, more cost-effective, and more reliable. This can only be achieved after an analysis of the problem and the subsequent implementation of possible solutions [1].

Through the analysis performed in the paper [2], it was found that 0402 components (capacitors and resistors) presented deviations of relief and shape between suppliers. These nonconformities caused vacuum losses during the insertion process. Some preliminary tests were then performed in order to perceive their behavior during placement. It was concluded, firstly, that the nozzles previously used by the company were not the most adequate and, secondly, that to achieve a better performance, both regarding component rejection and defect production in PCBs, the 925 nozzles should be used for the placement of capacitors and the 907 nozzles for resistors [2].

In the context of surface-mount technology, a nozzle change in the placement process has direct consequences on component rejection and on the product's final quality, which may have more or less defects. Therefore, it is of utmost importance

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to carry out comparisons and data analysis, before and after nozzle changes, in order to conclude whether it is really advantageous to make a nozzle change. Additionally, it is essential to understand the relationship between rejection and defects in order to conclude which one is more prevalent in the final product.

This study was carried out in partnership with Bosch Car Multimedia Portugal S. A, a company located in the northern city of Braga dedicated to the development and production of communication, entertainment and instrumentation systems, and safety sensors for the automotive industry [3].

The objectives of this study are:

- To organize rejection and defect values before and after nozzle change.
- To compare the damage caused by defective components with that caused by those rejected.
- To analyze post-alteration productivity growth.
- To prove that preventive maintenance of the nozzles has a positive impact on rejection.

38.2 SMT Process

38.2.1 Placement of Electronic Components

In SMT, machines are able to pick up several components and place them sequentially on each PCB. These machines are very flexible and can place a wide range of different components at high speeds. Some physical parameters as speed, acceleration, inertia, forces, torques, and other similar ones are of upmost relevance in this process. Combined with this, the configuration and the high level of automation make it easier to operate them for different productions. The automatic placement machines (Fig. 38.1) are called pick and place machines. However, the handling of components, usually by vacuum, is not always fully effective and hence the need to know this operating procedure better. On the other hand, component size and variability make this procedure critical.

Rejection. During automatic insertion, it is normal for some components to be rejected as several of them are placed at very high speeds in a short time. Therefore, it is important to ensure minimum rejection values to achieve high productivity.

There are several reasons for a component to be rejected, the main one being vacuum loss in the case of 0402 components (as shown in Fig. 38.2).

38.2.2 Automated Optical Inspection (AOI)

This process inspects possible errors in the arrangement of components via an image analysis algorithm: the board's data file is compared with the actual board

Fig. 38.1 Automatic placement machines

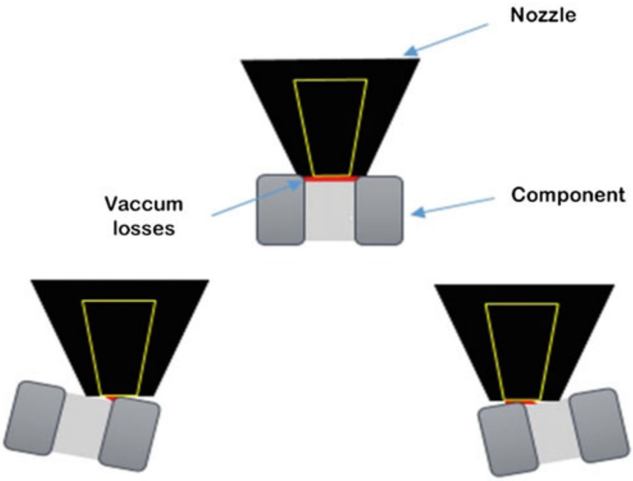


Fig. 38.2 Figurative example of pickup in various positions for 0402 capacitors, in this case for a nozzle with a round cavity type

by checking the components placed on the pads. Only AOI allows an SMT line to operate at maximum capacity. In fact, without this process, the operator would not be able to follow the production in the same way and the probability of error would be higher. The AOI process checks whether the solder paste deposits on the PCB are suitable and also the position of the components. An example of this process is shown in Fig. 38.3.

Defects. A number of errors can usually occur and the AOI is able to identify them. Some examples are presented in Table 38.1.

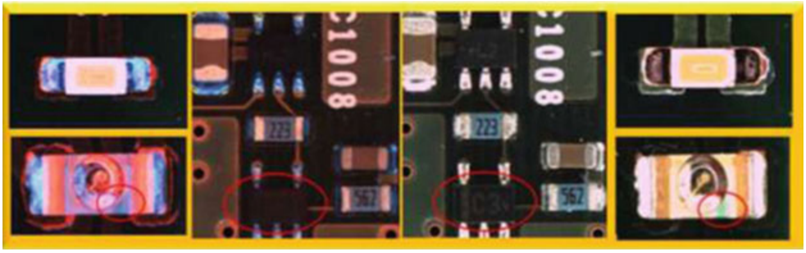


Fig. 38.3 Representation of the AOI check, where two welding errors and missing components are visible [4]

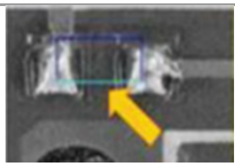
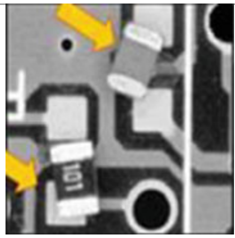
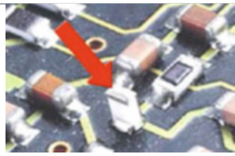
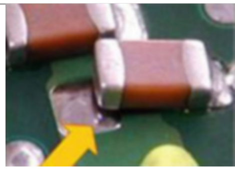
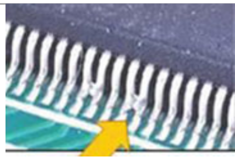
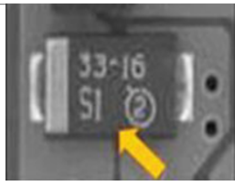
These errors can be determined at inspection speeds of 150.000 cph (components per hour). The operator is essential to validate the presence of errors on the PCB when the remote control classifies the board as bad or possibly bad, in which case the board does not proceed to the unloader. It is up to the AOI programming team to optimize the production program in order to reduce the number of "pseudo-errors" and make the process as fast and assertive as possible [6]. These errors are critical to the company's productivity because they represent considerable costs if they are only detected after the complete manufacture of the PCBs. The competitiveness in the sector is strong, with minimal margins, requiring zero defects to achieve economic profitability.

38.2.3 Maintenance

According to British standard EN 13306 [7], maintenance is defined as the combination of all technical, administrative, and management actions that during the life cycle of a given component are intended to maintain it or restore it to a state where it can perform the desired function, ensuring the best functions of quality, safety, cost, and availability [8]. In the diagram in Fig. 38.4, it is possible to observe the branches of maintenance.

In order to maintain a well-planned organizational structure, it is necessary to differentiate some types of interventions. For this study, the most relevant two are corrective maintenance and preventive maintenance. The main difference between the two is the moment of intervention: while in corrective maintenance the order of intervention is given after the occurrence of a failure or malfunction, the preventive maintenance is done before the machine shows that same failure, because it is planned in advance [8].

Table 38.1 Most common types of defects detected in the AOI on PCBs [5]

Quality defects	
Missing component	
Component moved/misaligned	
Upside-down	
Tombstone	
Incomplete solder joints	
Bridges or shorts	
Polarity changed on component	

(continued)

Table 38.1 (continued)

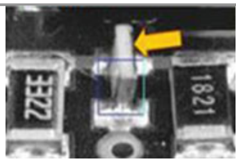
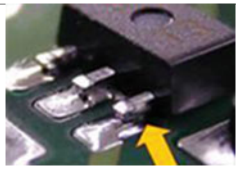
Quality defects	
Billboarding	
Components' terminals bent	

Fig. 38.4 List of maintenance functions, adapted from [9]

38.2.4 Growth Rate

Using Formula (38.1), which represents the uniform growth rate [10], it is possible to estimate the uniform annual growth of a product or event. This value is obtained by calculating the difference between the present value and the past value and the respective quotient of its result by the past value divided by n, which is the period of time used.

$$\text{Growth rate} = 1/n \times (\text{Present value–past value})\,/\text{past value} \tag{38.1}$$

38.3 Case Study

38.3.1 Posttest Changes

According to previously obtained data, it was concluded which nozzles under study would be more suitable for the placement of 0402 components: the 907 nozzle is optimal for resistors and the 925 nozzles for capacitors [2]. The geometry of the two nozzles is visible in Fig. 38.5.

Although it was not possible to make a global change, it was determined that nozzle 925, optimal for capacitors, would be guaranteed to place two critical components. As for the remaining components, as there was no restriction, they could be placed indifferently via nozzles 907 and 925.

However, with this condition defined, the system optimizer of the machine will tend to make the process as quick and simple as possible. Thus, as these components enter into most productions, both the resistors and other capacitors will tend to be placed with nozzle 925 rather than with nozzle 907, as the 925 one will have a wider range of options in the system.

38.3.2 Data Analysis

Several statistical analyses were performed to analyze the data. The statistical package Excel 2016 was used for data entry and graphic construction, while R 3.4.0 was used for data analysis. Considering the nature of the data, nonparametric hypothesis tests were applied to verify if nozzle changes produced significant improvements in the process by comparing performance indicators for two distinct months.

Parametric tests are based on quantitative or even dichotomous measures (proportions), and the use of this type of test requires continuous variables, usually the assumptions of normal distribution, and homogeneity of variance. In case of failure of at least one of these requirements for the application of these tests, nonparametric tests should be used [11].

In this study, due to the nature of the observed variables and their respective distributions, the nonparametric Mann–Whitney–Wilcoxon hypothesis test was

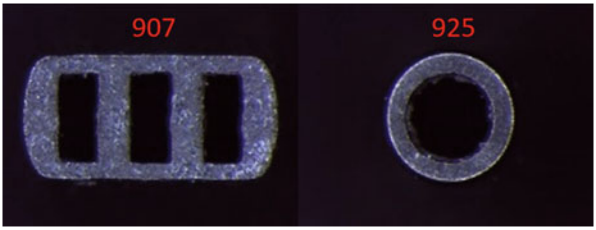


Fig. 38.5 Microscopic photography of nozzles 907 and 925

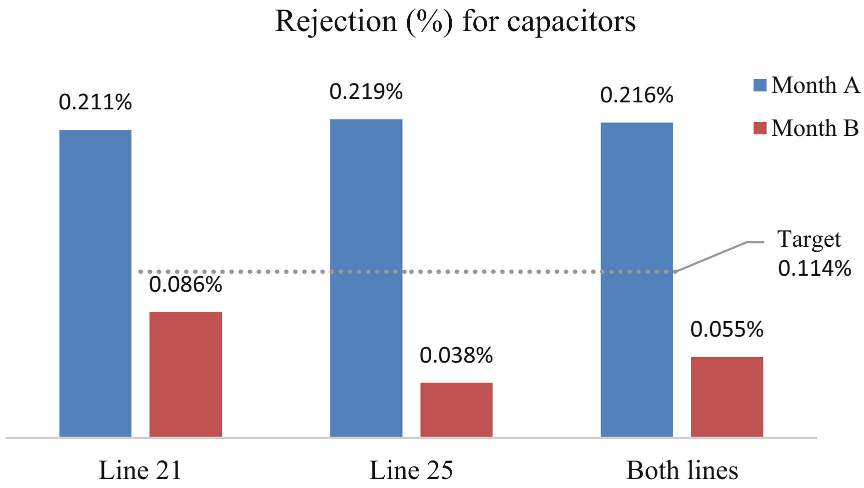


Fig. 38.6 Rejection (%) of 0402 capacitors depending on the line in which they were placed, for months A and B, and their respective target

performed. This test is applied when comparing outcomes between two independent populations, in order to detect if the distributions are equal or to detect changes in location (median).

Statistical test results use a significance level of 5% to distinguish "statistically significant" from "statistically nonsignificant" changes.

Monthly analysis in production. An analysis of 0402 capacitors and resistors was performed in two different months in 2019, before and after the changes made, and quality defects, rejection in automatic insertion, and the impact on the level of costs and growth with the combination of the previous factors were evaluated. The month before the changes will be designated A and the month after the changes will be designated B. The data were collected in two different production lines: line 21 and line 25.

Rejection in automatic placement. In line with the findings of [2], the graph in Fig. 38.6 suggests that, in fact, nozzle change in the machine system led to a reduction in the percentage of capacitor rejection, both by analyzing the production lines separately and as a whole. However, at a 5% significance level of there is no statistical evidence that the location measurements for months A and B on line 21 are different (test statistic $W = 42$, p value $= 0.183$), i.e., the nozzle change did not result in significant changes in the rejection of capacitors on that line. On the other hand, the results for line 25 show that the median of month A is higher than the median of month B (test statistic $W = 620$, p value $= 0.002$), thus confirming the suspected improvement in the process. By looking at the two lines as a whole, there is also a significant decrease in the percentage of capacitor rejection (test statistic $W = 919.5$, p value < 0.001). Besides, with this change, the rejection percentage is

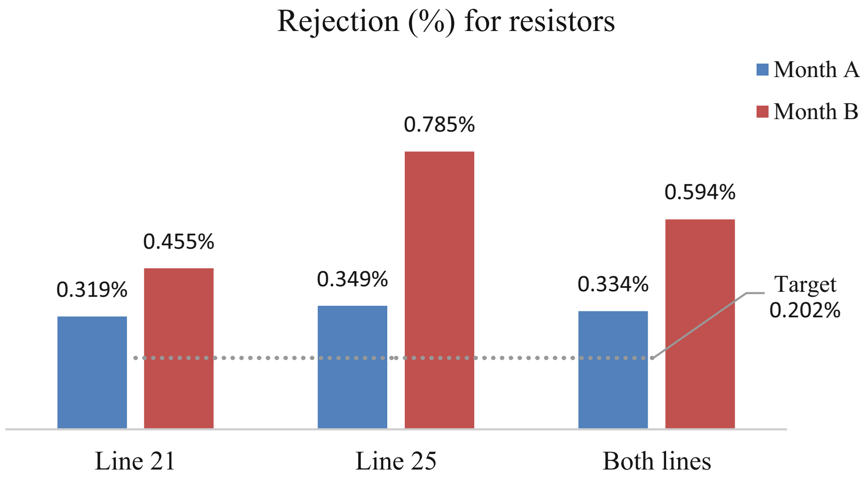


Fig. 38.7 Rejection (%) of 0402 resistors according to the line on which they were placed, for months A and B, and their respective target

positioned below the target set by the company (0.114%), contrary to what happened before the change was introduced.

In the case of resistors, the graph in Fig. 38.7 shows an increase in the percentage of rejection from month A to month B in the various situations under analysis. As for the capacitors in line 21, the differences in the location measurements for months A and B, regarding the rejection of resistors, are not statistically significant (test statistic $W = 33$, p value $= 0.061$). For the remaining situations under study, when the rejection percentages for the 2 months are compared, the assumptions of rejection aggravation are corroborated by the results of the nonparametric Mann–Whitney–Wilcoxon hypothesis tests. Indeed, at a 5% significance level of there is statistical evidence that the median of rejection percentage in month A is lower than the median of rejection percentage in month B, both in line 25 (test statistic $W = 583.5$, p value $= 0.007$) and in an overall analysis of the two lines under study (test statistic $W = 909.5$, p value $= 0.002$), i.e., nozzle change negatively affects the placement of resistors. In fact, as mentioned in 3.1, the most suitable nozzle for the placement of resistors would be 907 and not 925, whose use has become more recurrent. With this change, the percentages of resistor rejection moved further away from the target defined by the company (0.202%).

Product quality defects. Regarding quality, the number of defects in EDT (portion of a PCB) caused by 0402 capacitors and resistors were reduced, as suggested by the graph in Fig. 38.8.

In the case of capacitors, the number of defects has increased from 374 PPM to 158 PPM on line 21 and from 545 PPM to 467 PPM on line 25, from month A to month B, respectively. Despite the worsening of resistance rejection, it is also

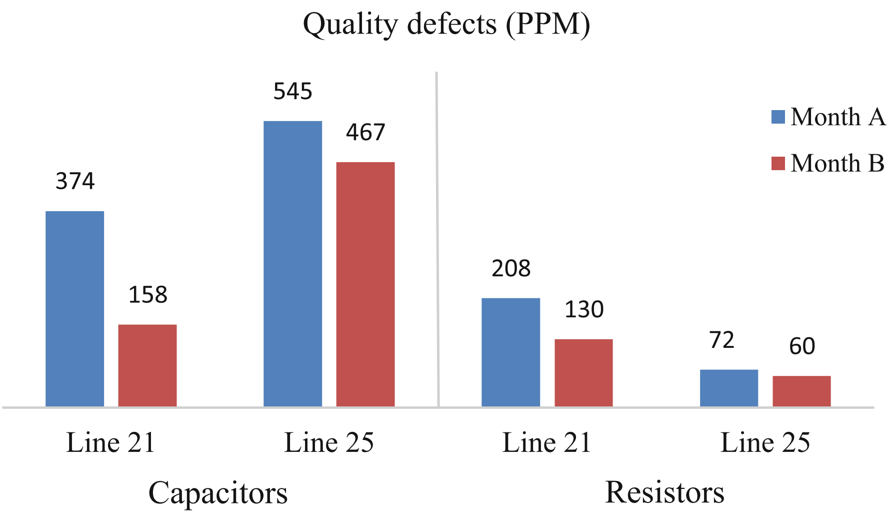


Fig. 38.8 Quality defects (PPM) in 0402 capacitors and resistors, depending on the line in which they were placed, for months A and B

possible to observe a reduction in the number of defects caused by them, from 208 PPM to 130 PPM on line 21 and from 72 PPM to 60 PPM on line 25.

Monetary impact. The monetary impact of this reduction is important and it is possible to analyze the level of rejection in placement and quality defects. The 0402 components are inexpensive components and are purchased in large quantity rolls; hence their loss in thousands of rejects is negligible.

Quality defects may refer to EDT scrap. Components with shape 0402 are repairable, except when the product is repair-free, i.e., when components poorly placed on the board cannot be repaired. This implies damage to the board itself, together with the other components making the losses more significant. In addition to these consequences, there is also a decrease in productivity, which becomes a monetary loss, since the machines have to work to compensate the loss. In this particular case, on lines 21 and 25 all products are repair-free, which makes the analysis of losses more simplistic. In order to estimate the percentage growth of productivity from one month to the next, Formula (38.1) was applied, listed in 2.4.

In this case, as we are working in months, we will estimate the monthly growth between month A and B, so variable n will take value 2. As the present value (month B) is lower than the last value (month A), because it translates monetary loss, the results will be transmitted in absolute value.

Through the data represented in the graph of Fig. 38.9 it can be seen that there was an improvement from month A to month B, in both lines, for capacitors and resistors.

In the case of capacitors, on lines 21 and 25 there was an improvement of 23% and 35% from A to B on the respective lines. In the case of resistors, there was an

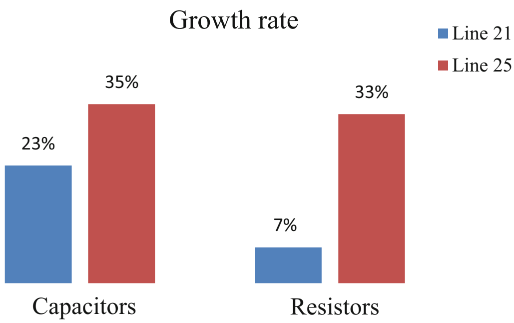


Fig. 38.9 Representation of growth figures (%) between months A and B according to the line and type of component

improvement of 7% and 33%. In short, in the case of resistors, the savings were not as high as in capacitors, and it should be noted that much of this growth is due to the visible improvement in quality after nozzle exchange, not least because in the case of resistors there was an increase in rejection. Therefore, it is concluded that, in terms of costs, the values associated with rejection in the case of 0402 components are not as significant as those of quality.

Impact of preventive maintenance on 0402 capacitor rejection. Through the daily rejection data, the impact of maintenance on the production of 0402 capacitors was also analyzed. In this analysis, only preventive interventions, previously programmed, were considered, since the corrective ones are casual and sporadic, as previously mentioned. It should be noted that one of the interventions carried out is nozzle exchange, on a weekly basis, and hence it is possible to estimate the impact caused.

For this purpose, month C (month after all the changes) was then analyzed, taking into account all the previous assumptions.

Figure 38.10 suggests a certain tendency to rejection decrease after maintenance, and this is most evident in the last nozzle change, where rejection remains below target. In fact, during successive productions, the nozzles may accumulate dirt from dust and even slag, and fragments of the components themselves, so it is concluded that nozzle exchange, in the case of 0402 capacitors, should be performed weekly.

38.4 Conclusion

In short, the use of the 925 nozzle option for two critical 0402 capacitors and 907 and 925 nozzles for the remaining 0402 components was found to be positive in terms of placement costs, productivity, and quality.

The monthly general analysis proved a significant improvement in the placement of capacitors, from 0.216% in month A to 0.055% in month B, and a worsening of resistor rejection, the latter explained by the high probability of using the 925 nozzles to the detriment of others. In terms of quality, there was a decrease in the number of defects, both for capacitors and resistors. Furthermore, by relating the

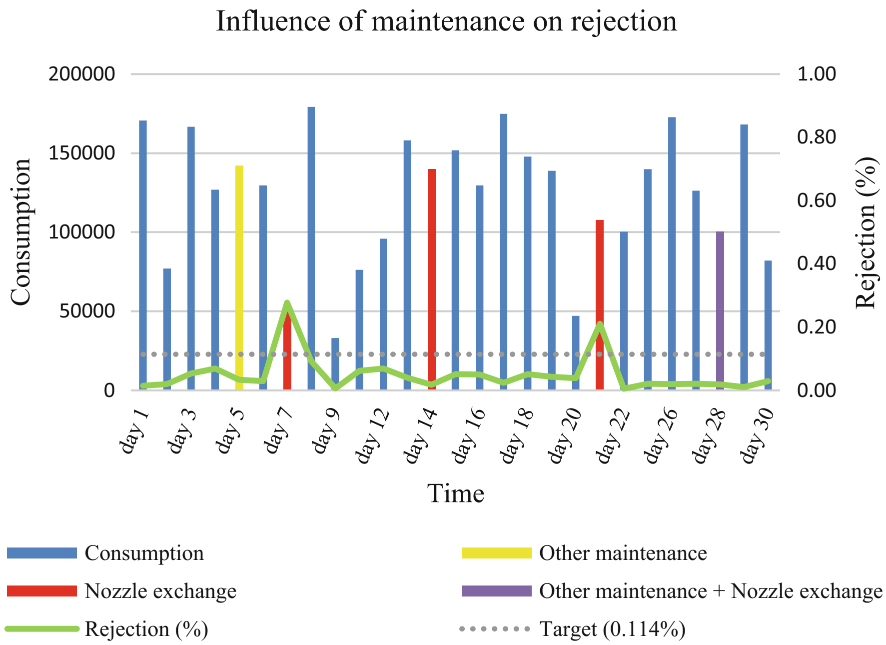


Fig. 38.10 Influence of maintenance on rejection in month C in relation to material consumed and rejected

rejection costs to the quality costs, it can be stated that the proposed changes resulted in a positive growth rate of around 23% and 35% for capacitors and 7% and 33% for resistors for lines 21 and 25, respectively.

Finally, the impact of nozzle maintenance on component rejection has been studied and was verified a reduction in rejection on the date immediately following their change, and it has been concluded that this change should be carried out weekly so as not to compromise production.

This research gives an important contribution to understand the impact of the nozzle choice on a production cycle. In fact, a detailed study of each component can bring significant improvements to the process, both in terms of the rejection rate and the number of defects, which can result in considerable cost reductions. However, implement this type of work on a large scale is a very time-consuming process, as it requires an in-depth study of the characteristics of each component in addition to conducting tests in the production line.

In a near future, it would be useful to study the viability of implement 907 nozzles for the placement of 0402 resistors, after checking their impact in terms of production cycle time. In addition, other problematic components will be studied, and current nozzles evaluated. If required, new nozzles may be developed in order to improve the entire production process.

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Index

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