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Original scientific paper

Identification and Prioritization of Employee Satisfaction Strategies in Tehran Regional Water Company Using Analytic Hierarchy Process (AHP)

Nasim Bonyadi*, Hormat Asghari, Mojtaba Kiaei

Abstract: Employee satisfaction is one of the main indicators of attitudes assessment in organizations and is one of the factors which can be used to assess the status of an organization. This is important because of the role that this construct plays in improvement of the organization and the workforce. Organizationally, a high level of job satisfaction reflects a highly desirable organizational climate which leads to recruitment and retention of employees and increases efficiency and effectiveness. Accordingly, this study tended to identify and prioritize employee satisfaction strategies in Tehran's Regional Water Company using analytic hierarchy process (AHP). The data was analyzed using AHP method by Expert Choice software. The statistical population included 16 experts in human sciences and in management science working in the Tehran Regional Water Company. Due to the limited number of statistical population, sampling was not used and census method was used; that is, all people in the statistical population participated in the study. Prioritization of the criteria showed that organizational strategies are the most important, followed by organizational policies and organizational achievements. Sub-criteria of these criteria were also prioritized.

Keywords: analytic hierarchy process; employee satisfaction; organizational policy; organizational strategies

1 INTRODUCTION

In the present era, movement towards specialization of works has become increasingly evident due to complexity of human life. This has led to actions by scholars and intellectuals of various societies in order to solve problems of the modern man. Solving these problems in any society is possible through dynamic, strong and progressive organizations that can take effective steps in dividing social functions into specific goals to meet social needs. Speaking of the organization and working groups formally and informally to meet social needs, management and leadership are the focus of its activities, because the necessary material, human and functional resources will not be used properly until there are professional human resources and qualified effective managers. Among these resources, human resources are the most important factor in survival of organizations. Studying and reviewing the history of industrial development shows that the skilled, committed and highly satisfied human resources have had an undeniable effect in transformation of traditional society into industrial society, so that human resources have been considered as the most important and main factor for development of societies and organizations [1]. Undoubtedly, committed employees can bring future organizational success. By concentrating on commitment, these forces move towards organizational strategic goals and pave the way for organizational excellence. The study of job satisfaction is important from two dimensions: first, the human aspect in which employees deserve to be treated equitably and with respect; second, the behavioral aspect in which attention to job satisfaction can direct employee behavior to influence their function and organizational tasks and lead to positive and negative behaviors [2]. Job satisfaction refers to all feelings of a person about their job. Job satisfaction depends on the nature and expectations of the jobs. Therefore, job satisfaction is the emotional orientation that employees have about their job [3, 4]. Job satisfaction leads to functional outcomes in the organization. Scholars argue that job satisfaction leads to productivity and organizational commitment [5]. In addition to examining the consequences of job satisfaction, recognizing effective factors on job satisfaction also helps managers improve their work and achieve organizational goals, so that mutual benefits of the employees and the organization are provided [6,7]. Accordingly, it is important to study employee satisfaction strategies; given the fact that this has been investigated rarely by scholars in the Tehran Regional Water Company, the resulting gap is explicitly evident. Therefore, this study tends to help fill this research gap. In this research, we have proposed a methodology based on AHP. Furthermore, experts' judgment is used for prioritizing the global weights of employee satisfaction strategies.

2 LITERATURE REVIEW

Job satisfaction: job satisfaction is a set of feelings and beliefs that people have about their current occupations. Job satisfaction is one of the important factors in job success, which increases efficiency and individual satisfaction [8].

Organizational strategies: Decision on policies related to organizational goals and changes in those goals, the resources used in them, the characteristics of these resources and their distribution and application, and in a shorter definition in the same sense, the strategy is a complete set of certain policies and goals of an organization [9].

Organizational policy: Policy is the principle that determines the scope of decision-making for managers of an organization or board of directors. Planning and implementation managers in each organization always take into account the scope determined by the policy and make decisions which are consistent with the policy [10].

Organizational achievement: In a brief definition, each organization brings along a set of practices and procedures and employees are exposed to these achievements and outcomes [11].

Hojat Panah and Heidarnattaj [12] studied the effective factors on job satisfaction in the administrative workplace. According to overviews carried out in this study, it was concluded that physical conditions in workplaces play a major role in satisfaction, comfort, welfare, effectiveness, or even mental health of people. Therefore, physical environment of the departments should be planned, designed and managed more carefully; otherwise, the physical environment would have a negative effect on health and well-being of people and cause occupational anxiety in employees. Zare Mehrjordi [13] studied organizational, occupational and individual effective factors on job satisfaction through a case study on Meybod Industrial Town workers. The results of the hypothesis testing show that women, married people and those with formal employment have higher job satisfaction. Older workers with more dependents and lower monthly household expenses have higher job satisfaction. In other words, workers with more difficult living conditions are more satisfied. Munir and Abdul Rahman [14] determined the dimensions of job satisfaction using factor analysis. The findings showed that many respondents in the survey suffer from dissatisfaction in the workplace. For this reason, remarks and suggestions were proposed to raise the level of employee satisfaction. Ayranci [15] studied factors of job satisfaction among private entrepreneurs through a case study in an industrial town. The results show that business owners can raise productivity in their company by employing motivational factors and providing conditions for employee satisfaction. Ledimo and Martins [16] tended to validate employee satisfaction through a structural equation with model approach. This study validated a model of employee satisfaction using structural equation modeling (SEM). The results of this study showed that the identified variables were effective on employee satisfaction. Neog and Barua [17] studied effective factors on employee job satisfaction through an experimental study in employees of auto service workshops in Assam. The results showed that salary and wages present the most important effective factor on employee job satisfaction. With the exception of salary and wages, it was determined that the effect of supervisor support, healthy working environment, proper balance between work and life, job opportunities and promotion, proper education and development opportunities are also important factors in determining job satisfaction of employees. Hong et al. [18] studied effective factors on job satisfaction among factory workers in Seremban, Malaysia. The results show that the work environment, payment and salaries, and promotion criteria had a significant effect on the level of employee satisfaction, while it was concluded that justice had no effect on employee satisfaction.

3 MATERIALS AND METHODS

In terms of objective, this was an applied research and the results can be directly used in Tehran Regional Water Company. In terms of control of variables and data collection method, this was a descriptive survey. Through archival studies, data was collected from relevant resources, including data collection instruments and literature review. After collecting the necessary data and sampling from the statistical population, the questionnaire was distributed among the statistical sample and its results were analyzed.

3.1 Population, Sampling and Sample Size

The statistical population of this study included 16 experts in human sciences and management science in Tehran Regional Water Company. It should be noted that since AHP was used in this study, a limited statistical population was required. Considering the limited number of statistical population, sampling was not used and the census method was used. In other words, the number of samples was equal to the number of people in the statistical population and included 16 experts in human sciences and management working in the Tehran Regional Water Company. One of the necessities of any study is availability of reliable information and the speed and ease of access to it [19].

3.2 Data Collection Instrument

The data collection instrument in this study was a Likert-type questionnaire as well as a researcher made questionnaire using AHP. In the Likert-type questionnaire, the effect of criteria and sub-criteria were measured on satisfaction of Tehran Regional Water Company employees. The Likert-type questionnaire consisted of 13 items; items 1 to 3 measured organizational strategies, items 4 to 10 measured policies, and items 11 to 13 measured organizational achievements. In fact, the instrument used was evaluative and it evaluated the criteria and sub-criteria of employee satisfaction for prioritization. This section consisted of four questionnaires which prioritized the strategies and sub-criteria. In the first questionnaire, organizational strategies, organizational policies, and organizational achievements were evaluated. In the second questionnaire, priority sub-criteria of the organizational strategies (vision and mission, values and leadership) were prioritized. The third questionnaire prioritized sub-criteria of organizational policies (change management, health and security, organizational communications, equity, job diversity, human resources management, and education and development). In the fourth questionnaire, sub-criteria of achievements including working relations, group work and job satisfaction were prioritized.

3.3 Model of Variables

The model of the variables studied is shown in Fig. 1. These criteria, which are in fact employee satisfaction strategies, are the most important identified criteria, derived from Ledimo and Martins [16].

Figure 1 Model of variables

3.4 Data Analysis

Analytic hierarchy process (AHP) is one of the most popular multivariate decision-making techniques first developed by Saaty in 1980 [17]. This method can be used when decision-making has multiple choice alternatives and decision criteria. The proposed criteria can be quantitative and qualitative. The choice of criteria is the first part of AHP. Based on the identified criteria, candidates are evaluated. The term alternatives or candidates are used interchangeably. This method is one of the most widely used methods for ranking and determining the importance of factors, which uses a paired comparison of alternatives to prioritize each criterion. AHP has been applied widely for investigating different decision-making problems such as selecting simulation software package [18], information systems outsourcing decisions [19], cloud adoption in healthcare [21], sector risk managements [21, 22], and etc.

4 RESULTS

4.1 Demographic Characteristics of Respondents and Population

Tab. 1 shows demographic characteristics of experts.

Table 1 Demographic characteristics of respondents

		%	*N*, %
Gender	Male	14	88
	Female	2	12
Age	<40 years	1	6
	40-50 years	12	75
	>50 years	3	19
Education	Bachelor	2	12
	Master	11	69
	PhD	3	19
Experience	5-10 years	0	0
	10-20 years	4	24
	>20 years	12	76

4.2 Inferential Data Analysis

Factor Analysis of Questions*:* Before performing any analysis on the collected data and statistical inference, reliability and validity of the measuring instrument must be ensured first. Reliability of the questionnaire was measured by Cronbach's alpha test and the test results indicated that the questionnaires used were reliable and accurate. In order to evaluate the validity based on the fact that the variables consisted of several dimensions (criteria), confirmatory factor analysis was used. In conducting factor analysis, it should be ensured whether existing data can be used for analysis. For this purpose, *KMO* index and the Bartlett test were used [23]. Based on these two tests, the data are suitable for factor analysis if *KMO*>0.6 and close to one and *Sig*<0.05 for the Bartlett's test. The outputs of these tests are presented in the following tables.

Table 2 KMO and Bartlett's test for questions of the questionnaire

KMO		0.662
Bartlett's test	$\chi 2$	192.119
	Df	78
	Sig	0.000

According to this table, *KMO*=0.62 (>0.6) indicates that the sample number (number of respondents) is sufficient for factor analysis. Moreover, *Sig*<0.05 indicates that the factor analysis is suitable for identifying the structure of the factor model and rejects the assumption that the correlation matrix is known.

4.3 Prioritization

The second question stated that how employee satisfaction strategies can be prioritized in Tehran regional water company? To answer this question, AHP was used.

AHP Results for Criteria: Three criteria and a number of sub-criteria were identified to prioritize factors of employee satisfaction strategies in Tehran Regional Water Company based on AHP. The matrix of paired comparisons integrated of 16 decision makers is as follows.

Table 3 Matrix of paired comparisons of criteria

Criteria	Strategies	Policies	Achievements
Strategies	1		
Policies		1	
Achievements			1

By modelling by the Expert Choice software and inserting the matrix of paired comparisons, the weights of criteria and sub-criteria were obtained as shown below. Organizational strategies (relative weight 699) was the most important factor, followed by policy (0.156) and organizational achievements (0.145). Inconsistency rate of paired comparisons was 0.02; because *IR*<0.10, comparisons are acceptable.

Table 4 Prioritization of criteria of employee satisfaction strategies

Criteria	Weight	Priority
Strategies	0.699	1
Policies	0.156	2
Achievements	0.145	3

Relative weight of criteria of organizational strategies: Using the literature and relevant experts, 7 criteria and a number of sub-criteria were identified in order to prioritize factors of organizational strategies based on integration of decision-making methods using AHP. The matrix of paired comparisons integrated of the decision makers are shown in the tables below. The paired comparisons of each criterion with respect to economic factor are presented in Table 5. According to the table, it is indicated that the relationship between all sub-criteria is bilateral.

Table 5 Prioritization of criteria based on organizational strategies

Criterion	Weight	Priority
Mission and vision	0.706	1
Values	0.172	2
Leadership	0.123	3

Considering the main weight obtained, the most important criterion is *mission* and *vision*, followed by *values* and *leadership*. Given that the inconsistency rate obtained is 0.01, which is less than the standard level of 0.1, the questionnaire was completed with high precision by the respondents.

Relative weight of criteria of organizational policies

Using the literature and relevant experts, seven criteria and a number of sub-criteria were identified in order to prioritize factors of organizational policies based on integration of decision-making methods using AHP. The matrix of paired comparisons integrated of the decision makers are shown in the tables below. The paired comparisons of each criterion with respect to economic factor are presented in Table 6. According to the table, it is indicated that the relationship between all sub-criteria is bilateral.

Considering the main weight obtained, the most important criterion is education and development, followed by communications, change management, HR management, health and security, job diversity and equity. Given that the inconsistency rate obtained is 0.09, which is less than the standard level of 0.1, the questionnaire was completed with high precision by the respondents.

Table 6 Prioritization of criteria based on organizational policies

Criterion	Weight	Priority
Change management	0.149	3
Health and security	0.130	5
Communications	0.161	2
Equity	0.110	7
Job diversity	0.130	6
HR management	0.145	4
Education and development	0.175	1

Relative weight of criteria of organizational achievements: Using the literature and relevant experts, 7 criteria and a number of sub-criteria were identified in order to prioritize factors of organizational achievements based on integration of decision-making methods using AHP. The matrix of paired comparisons integrated of the decision makers are shown in the tables below. The paired comparisons of each criterion with respect to economic factor are presented in Table 7. According to the table, it is indicated that the relationship between all sub-criteria is bilateral.

Table 7 Prioritization of criteria based on organizational achievements

Criterion	Weight	Priority
Working relations	0.623	1
Team work	0.234	2
Job satisfaction	0.143	3

Considering the main weight obtained, the most important criterion is working relations, followed by team work and job satisfaction. Given that the inconsistency rate obtained is 0.09, which is less than the standard level of 0.1, the questionnaire was completed with high precision by the respondents.

5 DISCUSSION

The participants in the study were 16 experts in human sciences and management working in the Tehran Regional Water Company; 14 of them were men and 2 of them were women. One of the participants was aged younger than 40 years, 12 were between 40 and 50 years, and 3 were older than 50 years; 12% had bachelor's degree, 69% had MA and 9% had PhD. After identifying the number of participants, distribution of questions based on central indicators, dispersion and distribution was determined and inferential analysis of data was done. In this section, reliability and validity of the instrument were first measured. The reliability of the questionnaire was measured by Cronbach's alpha test and the results of the test showed that the questionnaires used had the required reliability and accuracy. To assess the validity, the confirmatory factor analysis test was used. For this purpose, the *KMO* index and the Bartlett test were used. According to this study, *KMO*=0.62 (>0.6) indicates that the number of samples (number of respondents) was sufficient for factor analysis. Moreover, the value of Sig of Bartlett's test was less than 0.05, which showed that the factor analysis is suitable for identifying the structure of the factor model and the assumption that the correlation matrix is known is rejected. Subsequently, ranking of variables was performed using AHP. At the beginning of this study, criteria and then the sub-criteria were ranked. Tab. 8 summarizes the prioritization of criteria and their sub-criteria from top to bottom, respectively:

Table 8 Prioritization of criteria and sub-criteria

Prioritization of criteria	Strategies	Policies	Achievements
Strategies	Vision and mission	Education and development	Working relations
Policies	Values	Communications	Teamwork
Achievements	Leadership	Change management	Job satisfaction
		HR management	
		Health and security	
		Job diversity	
		Equity	

Neog and Barua [24] have shown that the level of job satisfaction is moderate, and it is imperative for managers to increase the level of job satisfaction of employees. One of the differences of this study with our study is the difference in statistical population and spatial scope. Moreover, the difference in effective factors and strategies is also significant. With these interpretations, it can be claimed that this study is almost consistent with our study. Hong et al. [25] found that the workplace, payment and salaries, and promotion criteria had a significant effect on the level of employee satisfaction, while the present study concluded that justice has no effect on employee satisfaction; therefore, our study is almost consistent with this study. Zadeh Tabari and Fallah [26] evaluated the effective factors on job satisfaction using fuzzy AHP through a case study on Iran-Zamin Bank. The results of both studies indicate the effect of the factors and strategies on employee satisfaction. In general, our study can be consistent with this study.

6 CONCLUSION

In this paper, for the first time, a methodology for identifying and prioritizing the employee satisfaction strategies in water sector based on AHP is proposed. Various criteria were considered such as Organizational strategies, Organizational policy, and Organizational achievement. These criteria were then structured hierarchically into different sub-criteria. Finally, a case study in water industry was conducted to apply this methodology in identifying and prioritizing as a case by using judgments of 16 experts who had worked in the human resource field and then the outcomes were represented. Ranking were as follows: organizational strategies in criteria, vision and mission in organizational strategies, education and development in organizational policies, working relations in organizational achievements. For the extension of this work, multi-criteria decision making methods or fuzzy methods for evaluation employee satisfaction strategies can be used. Also, other factors or strategies may be applied.

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Original scientific paper

ICT in the Primary School: Practice and Attitudes of Informatics Teachers

Darko Dukić*, Slavko Petrinšak, Pavao Pinjušić

Abstract: The aim of the study was to explore various issues related to the introduction and use of ICT in primary schools in eastern and central Croatia from the viewpoint of informatics teachers. A total of 232 respondents participated in the survey. Both descriptive and inferential statistics were applied in data analysis. The results indicate that the equipment in computer classrooms is only partially satisfactory. LCD projectors and multimedia computers are mostly used in teaching informatics. The research also revealed that teachers are aware of the importance of ICT implementation in classrooms. However, they are less satisfied with the professional development opportunities. Their responses also suggest that they are ready to participate in the curriculum development process, undertake continuing education, and focus on pupils and their learning. In addition, the analysis showed that teachers, regardless of their background characteristics, share similar views. So far, the issues discussed in this paper have only been superficially examined. The present study expands previous research by providing insight into the practice and attitudes of informatics teachers in Croatian primary schools.

Keywords: equipment; ICT; informatics teachers; practice and attitudes; primary school; professional development

1 INTRODUCTION

Information and communication technology (ICT) has become essential in all aspects of modern life, including education. Today, the process of teaching and learning is inconceivable without technology. The use of ICT contributes greatly to the improvement of quality and efficiency of education at all levels, from primary school to university. There are many reasons why ICT is an important teaching and learning tool, and according to Meadows and Leask [1] they can be divided into five groups: political, personal / professional, professional / pupils´ needs, professional / curriculum, and professional / pedagogic theory. Political reasons are related to the government´s wish to provide pupils with skills needed for life and work in the information society. Furthermore, teachers also have to use ICT in their personal and professional lives. In addition, pupils need to master modern technologies that surround them, not only in school, but also at home. A curriculum must keep pace with such changes, and preparation and revision of curriculum require the use of ICT. Finally, one must not forget the development of pedagogical theories that are necessary to establish the best possible framework for acquisition of knowledge and skills in the technology dominated world.

ICT may contribute to creating high-quality teaching and learning environments in many ways. In this context, Smeets [2] points out that ICT provides access to a wide range of information from a variety of sources and allows viewing information from multiple perspectives. According to Danče [3], the use of ICT in primary schools does not only help pupils to find and select information, but also to recognize patterns and behaviors, to model, predict and hypothesize, to test the authenticity and correctness, to evaluate and modify the work in order to improve its quality, to communicate and present ideas, to assess achievements, to increase the efficiency, and to build self-confidence and independence. Moreover, ICT helps pupils to be more creative and take risks. The insufficient use of ICT in the teaching process and neglecting its potential is unacceptable today, since pupils are deprived of the opportunity to acquire the necessary competencies, which greatly diminishes their chances of success in the future. However, it is not enough just to bring the new technology in the classroom. Summarizing several previous studies, Lim and Oakley [4] concluded that having ICT in the primary school curriculum and classroom does not guarantee improved learning. It is also important to support the implementation of ICT in education by appropriate policies and provide professional development for teachers. In order to be successful, the integration of ICT in the education system should be carefully designed and implemented. Kler [5] distinguished three main phases in this process. The first is the establishment of an institution-wide technological infrastructure. In the second phase, emphasis is placed on the pedagogical use of ICT and its effective integration into teaching and learning activities. The third phase is characterized by the strategic use of ICT with a focus on different target groups.

ICT integration into the educational setting is not an easy task. On the contrary, there are many factors that must be taken into account when introducing a new technology. Prior research has identified a number of different barriers to ICT adoption and integration into teaching practices. Lawrence and Tar [6] classified these barriers into groups of teacher-level barriers (lack of ICT knowledge, lack of time, resistance to change, and complexity of integrating ICT) and institutional-level barriers (limitation of infrastructure, lack of training, lack of access, and lack of technical support). In their analysis, Almaki and Williams [7] made the distinction between teacher factor (lack of self-confidence, lack of competencies, and negative attitudes towards ICT), school / institution factor (lack of time, lack of efficient training, lack of local technical support, and leadership barrier), and extrinsic factor (local culture, lack of financial support, and inadequate planning). According to Goktas, Gedik, and Baydas [8], external barriers include hardware and software inadequacies, and lack of time and technical support, while internal barriers encompass attitudes and beliefs towards the uses of technology in education, and the approaches that are used in teaching.

Teachers use ICT in their classrooms and organize technology-supported teaching and learning activities. In addition to playing a pivotal role in implementing educational innovations, they are directly responsible for curriculum realization [9]. Therefore, teachers are the most important and essential factor influencing ICT adoption and use in education [10]. The integration of ICT in the teaching process cannot be successful if it is not accepted by teachers. Among them, informatics teachers have a special role and responsibility as people who equip pupils with ICT knowledge and skills. Thus, it is of the utmost importance to gain insight into their experiences, beliefs, and perceptions. With this in mind, the present study aimed to explore the practice and attitudes of informatics teachers regarding the introduction and use of ICT in primary schools located in eastern and central Croatia.

2 PREVIOUS RESEARCH

The development of ICT and its application to education has attracted the attention of scholars and practitioners worldwide. This has resulted in the publication of papers dealing with different aspects of ICT implementation in teaching and learning at all levels of education, including primary schools. However, research focused on the attitudes and experiences of primary school teachers of informatics is still relatively rare. Given the subject of this paper, the most important findings and conclusions of such studies, published over the last ten years or so, are presented in chronological order below.

Deryakulu et al. [11] conducted a study aimed at determining the most satisfying and frustrating aspects of ICT teaching in Turkish schools and examining whether there were differences in these aspects between two groups of teachers with respect to their self-efficacy. The sample was overwhelmingly comprised of primary school ICT teachers. The analysis revealed that for teachers with high self-efficacy the most satisfying aspects of ICT teaching were the dynamic nature of ICT subject, highly motivated students, the opportunity to help other teachers, and lecturing in well-equipped classrooms, whereas the most frustrating aspects were extra jobs and duties, shortage of computers and technical problems, indifferent students, insufficient time for teaching, lack of appreciation from colleagues, and the status of ICT subject in curriculum. Teachers with low self-efficacy listed the same most satisfying aspects of ICT teaching as their high self-efficacy colleagues. The most frequently cited frustrating aspects of ICT teaching by teachers with low self-efficacy were extra jobs and duties, shortage of computers and technical problems, insufficient time for teaching, the status of ICT subject in curriculum, lack of appreciation from colleagues, and the attitude of other teachers and school administrators that ICT subject is not needed. Based on the results, the authors concluded that both groups share similar views on the most satisfying and frustrating aspects of ICT teaching.

Özer, Uğurlu, and Beycioglu [12] examined the attitudes and awareness of ICT teachers in Turkish primary schools regarding the ethical use of computers in classrooms. Most of the teachers surveyed stated that they did not have computer ethics courses during their higher education and professional careers. Respondents cited print and/or visual media as the most popular source of information on the ethical use of computers, followed by the Internet and workshops. The results suggest that women were more concerned with the ethical use of computers than men. The study also found that teachers who have taken computer ethics courses were more aware of ethical issues than those who did not. In addition, it has been confirmed that beliefs about ethical use tend to decrease as the teaching experience increases.

In order to determine how ICT is taught in primary schools, Akbiyik and Seferoğlu [13] investigated the opinions of Turkish computer teachers. Analysis of their responses showed that demonstration and practice, questions and answers, and lecturing methods were most frequently used in teaching pupils. Problem solving, group discussions, and teamwork were also popular teaching methods, while the project-based approach was not preferred by teachers. The study further revealed that computer teachers most often use course books and written instructions as their teaching materials. Other sources, such as websites, animations, and videos were significantly less preferred. Akbiyik and Seferoğlu also found that teachers face difficulties in implementing the curriculum. A limited amount of time for lessons was identified as the main problem.

The aim of the study by Cakir and Yildirim [14] was to explore the professional growth of ICT teachers in the Turkish primary education system in terms of their perception of teaching and their own pedagogical and subject matter competencies. The results showed that the respondents assessed their own competencies positively and that they experienced difficulties in teaching, such as classroom management, number of students, and problems associated with the efficient use of the latest technology. According to the teachers surveyed, the integration of technology in the classroom was negatively affected by time constraints, poor ICT classroom design, lack of flexibility, and overcrowded classrooms. The findings of the study suggest that the effective use of technology in primary education is highly dependent on the active involvement of ICT teachers in the process of technology integration. Thus, training programs should be provided to ensure their professional development. Cakir and Yildirim concluded that salaries and employment opportunities also influence teachers' performance.

In their study, Konstantinos, Andreas, and Karakiza [15] examined the views and attitudes of informatics teachers about the introduction of ICT in Greek primary schools. The results revealed that there was considerable confusion among teachers regarding their role in a changing learning environment. Respondents pointed out several external and internal barriers to effective teaching and factors that hinder the successful integration of ICT into the classroom. The research indicated that although ICT teachers have a positive attitude towards interdisciplinary practice, they rarely collaborate with other teachers.

The acquisition of ICT literacy has become a mandatory part of the primary and secondary school curriculum in developed countries. In order to determine the current state and trends in the Czech education system, Rambousek et al. [16] conducted a survey on a sample of ICT teachers. Based on the answers received, the authors concluded that ICT-related educational activities were mainly carried out within a compulsory subject. Respondents identified the following key ICT topics: searching and retrieving information on the Internet, word processing, Internet security, copyright and ethical principles, the use of an operating system and file management, working with presentations, and communication and collaboration in the digital environment. On the other hand, they cited the creation and publication of websites, the use and design of databases, and programming and development of algorithmic thinking as less important topics in the context of ICT literacy development. The study also showed that the structure and level of teachers' ICT skills significantly influenced the conception and orientation of their classes.

Zovkić and Vrbanec [17] pointed out that informatics teachers in Croatian primary schools in addition to teaching often have the role of ICT administrators in computer classrooms. Their work is further complicated by the different hardware configurations and the fact that computers are relatively old. The average age of computers was eight years, indicating that many of them were not meeting the needs of the educational process. The problem is also that classrooms had on average 19 computers, and usually there were more pupils than available computers. Furthermore, informatics teachers are often tasked with maintaining all other computers in the school and helping colleagues. In their paper, the authors particularly highlighted the issues related to ICT security in Croatian primary schools, which should be improved at all levels. In this context, the professional development of informatics teachers is of utmost importance.

Aziz and Rahman [18] investigated the use of ICT in Malaysian rural primary schools attended by Indigenous children from the ethnic group known as 'Orang Asli'. The researchers explored the expectations and experiences of their teachers who are responsible for the maintenance of ICT equipment. The findings suggest that the technological infrastructure in Indigenous primary schools is inadequate and that pupils have limited ICT knowledge. Since Indigenous children usually have low-level ICT facilities at home or do not have ICT at all, they need the steady guidance and support of their teachers. However, continuous ICT training is necessary not only for pupils, but also for teachers. The results of the study confirmed that there is a huge gap between primary schools attended by Indigenous children and other primary schools in Malaysia in terms of ICT availability and use.

The purpose of the study by Nordlöf, Höst, and Hallström [19] was to examine the attitudes of Swedish technology teachers, who teach at levels ranging from pre-school to ninth grade, towards their subject and to determine how these attitudes were related to background variables. The analysis revealed four dimensions of attitudes. Three clusters of teachers were identified and interpreted in terms of the underlying dimensions. The clusters were characterized as positive, negative, and mixed with respect to attitudes towards the subject and its teaching. The results lead to conclusion that efforts to increase teachers' qualifications and to establish a fixed number of teaching hours, as well as overall teaching plan for the subject, contribute to more positive attitudes of teachers.

Panselinas et al. [20] sought to identify and describe the competencies and knowledge required of computer teachers in Greek primary and secondary schools. According to the results, teachers showed a great interest for programming and robotics, which was in line with the changes in educational policy. Respondents also believed that they needed more training in the area of website design, advanced collaboration tools, and e-learning and learning management systems. Teaching and pedagogical competencies were also considered important by teachers who participated in the survey.

3 PURPOSE OF THE STUDY AND RESEARCH QUESTIONS

Today's world is profoundly affected by ICT. Therefore, ICT education should be started as early as possible. Recent studies have confirmed that the application of new technologies in the classroom is essential for the development of students who are ready and prepared for the information society [21]. In order to improve their knowledge and skills, the integration of ICT in learning and teaching is becoming a major task for primary schools worldwide [22]. Thereby, it should be kept in mind that ICT has a strong impact on all aspects of school life, from altering teaching practices and providing opportunities for teacher development to the improvement of the learning environment [23].

Taking into account the importance of the elementary level of education in acquiring ICT competencies, the purpose of this study was to investigate the adequacy of technological infrastructure and the use of ICT in Croatian primary schools. Conclusions were drawn from the attitudes and experiences of the surveyed informatics teachers. In addition, the aim of the research was to find out teachers' opinions on particular issues of interest to this study and to determine their willingness for improving the teaching process and professional development. Some of these issues were explored by Pinjušić [24]. However, the present study goes further by examining in more detail the factors that influence teaching practices in computer classrooms. For this reason, the current research included questionnaire items that were not previously analyzed.

Specifically, the study sought to answer five research questions:

- What are the conditions for teaching informatics, i.e. how appropriately are computer classrooms equipped?
- What devices and tools do informatics teachers use in teaching?
- What are the attitudes of informatics teachers towards the introduction and use of ICT, adjustment of the curriculum to technological changes, and professional development opportunities?

- To what extent are informatics teachers willing to participate in curriculum development, acquire new competencies, inspire and help pupils, and adapt to their needs?
- Are there statistically significant differences in the attitudes and motivations of informatics teachers with respect to age, gender, type of study completed, type of employment contract, and length of service?

4 SAMPLE AND METHODS

The study was conducted on the sample of 232 primary school informatics teachers from eight eastern and central Croatian counties. The survey took place in 2015. The data were collected using self-administered structured questionnaires that were distributed to participants of teachers' workshops. Despite efforts, it was not possible to repeat the survey with a sample large enough to be representative and yield statistically reliable results. Due to this limitation, statistical analysis was performed on the available data. An additional survey was conducted in November 2019 to verify their relevance. The latter sample consisted of 21 teachers who had also participated in the first survey. The results of both surveys were very similar, suggesting that the previously collected data are still applicable and can be employed in the analysis.

Among the respondents, 50% were between 24 and 37 years of age, 38.8% were between the ages of 38 and 50, and 11.2% were between 51 and 65 years old. The sample consisted of 44.8% men and 55.2% women. Out of all respondents, 69% had a degree in education, while 31% of those surveyed had a background in engineering or computer science. There were 73.3% participants with a permanent contract and 26.7% with a fixed-term contract. Most of the respondents (53%) had less than 10 years of experience, followed by 28.4% teachers with 10 to 20 years of service. Those with more than 20 years of experience accounted for 18.5% of respondents.

Statistical methods were used to answer the research questions. Both measures of central tendency and dispersion were calculated to summarize and describe the data collected. Nonparametric statistical tests (Mann-Whitney test, Kruskal-Wallis test, and multiple pairwise comparisons) were applied to analyze the differences between the studied groups. Statistical significance was set at $p < 0.05$.

5 RESULTS AND DISCUSSION

Respondents were first asked to rate the equipment of their classrooms and conditions for teaching informatics on a scale from 1 (completely dissatisfied) to 5 (completely satisfied). Descriptive statistics (mean, median, mode, standard deviation, and interquartile range) were calculated for each item. The results obtained are shown in Tab. 1.

Table 1 Descriptive statistics for satisfaction ratings

Item	Mean	Median	Mode	Standard deviation	Interquartile range
Satisfaction with the equipment of classrooms with up-to-date devices	3.31	3.00	4.00	1.12	1.00
Satisfaction with the ratio of pupils to computers	3.67	4.00	4.00	1.00	1.00
Satisfaction with Internet speed and reliability	3.60	4.00	4.00	1.01	1.00
Satisfaction with the reliability of computers	3.31	3.00	3.00	0.98	1.00
Satisfaction with the availability of software applications	3.80	4.00	4.00	0.98	2.00

The responses of the surveyed informatics teachers suggested that they were only somewhat satisfied with the equipment provided. According to the means, the availability of software applications was rated most positively. However, even in this case, the mean was less than 4. The ratio of pupils to computers and Internet speed and reliability were similarly assessed by the teachers. The means indicated that respondents were least satisfied with the equipment of classrooms with up-to-date devices and reliability of computers. In the case of these items, the median was less than the mean. Standard deviation and interquartile range are measures of dispersion or variability. The largest standard deviation was obtained for the first item (satisfaction with the equipment of classrooms with up-to-date devices), while the largest interquartile range was found for the last item (satisfaction with the availability of software applications).

Therefore, according to the teachers who participated in the study, computer classrooms in primary schools in eastern and central Croatia were not adequately equipped, which implies that conditions for teaching informatics were not optimal. Since 3 is the midpoint of the scale and indicates a neutral attitude, it can be concluded that respondents were inclined to agree that the teaching process was not sufficiently supported with technology. This result was expected, given that Croatian primary schools are not able to keep pace with technological developments and acquire modern equipment due to the lack of funds. In such circumstances, the question is to what extent schools can provide pupils with the required ICT-related knowledge and skills. Education has been neglected in Croatian society for many years. As a result, Croatian education system is lagging far behind world leaders in teaching and learning. Such trends must be reversed. The recently initiated educational reform is an important step forward, but without a substantial increase in funding for equipment and staff, it will not produce desirable outcomes.

In the next part of the survey, respondents were asked to rate on a scale of 1 (never) to 5 (always) how often they use each type of devices and tools in the classroom. Descriptive statistics calculated to summarize the data are shown in Tab. 2.

According to the mean, median, and mode, primary school informatics teachers from eastern and central Croatia regularly use a LCD projector and multimedia computer in teaching, while other devices and tools are used much less frequently. The results indicate that interactive whiteboards are the least used in working with pupils. More than 70% of respondents said they never used them, and only slightly more than 8% stated that they used them regularly. According to the findings, learning management systems, such as CARNet's Moodle-based platform named Loomen, and digital video cameras are used to a somewhat greater extent than interactive whiteboards. However, the majority of teachers use neither the learning management system nor the digital video camera. It can be concluded that informatics teaching in eastern and central Croatia is mostly supported by presentation tools and multimedia computers. This is certainly a reflection of inappropriate position of informatics courses in the curriculum and insufficient investment in people and infrastructure. The findings on the teachers' use of devices and tools are consistent with the results from Tab. 1.

Table 2 Descriptive statistics on the frequency of use

Device / tool	Mean	Median	Mode	Standard deviation	Interquartile range
Multimedia computer	4.50	5.00	5.00	0.78	1.00
Interactive whiteboard	1.76	1.00	1.00	1.32	1.00
Learning management system	2.23	2.00	1.00	1.28	2.00
LCD projector	4.69	5.00	5.00	0.68	0.00
Digital video camera	2.28	2.00	1.00	1.16	2.00
Digital camera	2.77	3.00	3.00	1.16	1.00

Table 3 Descriptive statistics of the surveyed teachers' attitudes

Item	Mean	Median	Mode	Standard deviation	Interquartile range
ICT should be used in teaching to improve its effectiveness	4.42	5.00	5.00	0.72	1.00
Integration of ICT into the curriculum is necessary	4.55	5.00	5.00	0.74	1.00
ICT needs to be implemented more systematically into primary school education	4.31	4.00	5.00	0.70	1.00
The curriculum must respond to the rapid technological development	4.30	4.00	4.00	0.71	1.00
Introduction of ICT in teaching has to be planned more carefully	4.16	4.00	4.00	0.82	1.00
Teachers should be better prepared for ICT integration in their classrooms	4.22	4.00	4.00	0.71	1.00
ICT training is appropriate and beneficial	3.47	4.00	4.00	0.96	1.00
Education authorities provide ICT training for teachers at all levels	3.51	4.00	4.00	1.13	1.00

Tab. 3 provides the descriptive statistics of respondents' attitudes towards the introduction and use of ICT in schools, necessity of curriculum adaptation to technology innovations, and training opportunities. Responses were made on a five-point scale ranging from 1 (strongly disagree) to 5 (strongly agree).

The results suggest that informatics teachers are aware of the importance of ICT implementation in classrooms. The respondents mostly agreed that the integration of ICT into the curriculum was necessary and that technology should be used in teaching to improve its effectiveness. The highest means were found for these two items. For both of them the median and mode were 5. The participants also largely agree that ICT needs to be implemented more systematically into primary school education, that curriculum must respond to the rapid technological development, that teachers should be better prepared for ICT integration in their classrooms, and that the introduction of ICT in teaching has to be planned more carefully. For all the above items, the mean values were greater than 4, indicating a high level of agreement. The surveyed teachers were significantly less likely to agree that ICT training was appropriate and beneficial, and that education authorities provided ICT training for teachers at all levels. The means of these items were 3.47 and 3.51, respectively. The largest standard deviations were associated with these variables, while the interquartile ranges were 1 in all cases. Therefore, the teachers who participated in the survey have a high level of awareness of the role that ICT has to play in education, but they are less satisfied with the support and opportunities for professional development.

In the questionnaire, respondents were also asked to evaluate their willingness to participate in the curriculum development process, acquire new ICT skills, adapt instruction to pupils' needs, and help them to learn more effectively. Teachers' responses were again measured on a five-point scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Table 4 Descriptive statistics of motivation items

Item	Mean	Median	Mode	Standard deviation	Interquartile range
I am willing to actively engage in the curriculum development process	4.34	5.00	5.00	0.79	1.00
I am willing to participate in ICT training	4.32	5.00	5.00	0.82	1.00
I find myself motivated to acquire new ICT skills	4.37	4.00	5.00	0.74	1.00
I am ready to respond to pupils' needs and interests	4.52	5.00	5.00	0.64	1.00
I am willing to help and motivate pupils to acquire digital skills	4.44	5.00	5.00	0.61	1.00

Based on all three measures of central tendency, it can be concluded that primary school informatics teachers from eastern and central Croatia are motivated to improve their practice and acquire ICT competencies that are necessary for successful teaching. As indicated by the means in Tab. 4, the participants mostly agreed that they were ready to respond to pupils' needs and to help and motivate them to acquire digital skills. Thus, the surveyed teachers are aware of the need to focus on pupils and their success in learning. In addition, the respondents indicated that they were willing to participate in ICT training and found themselves motivated to acquire new ICT skills. A mean value of 4.34 suggests that they were also willing to actively engage in the curriculum development process. Overall, the measures of dispersion show that there was some variability in the responses.

Educational institutions cannot fulfil their mission and cope with a rapidly changing environment without well-trained, dedicated, and enthusiastic teachers. In this context, the results of this study are encouraging and promising. Although a self-report instrument was used to assess participants' motivation towards educational activities, it is believed that their answers are honest and straightforward. Many teachers are dissatisfied with various aspects of their jobs, such as salaries, workload, amount of paperwork and record keeping, working conditions, school's administration, social status, future career prospects, and professional support, but it seems that these issues do not significantly affect their motivation. Nevertheless, even highly skilled and motivated informatics teachers will not be able to accomplish their tasks without proper equipment, continuing professional development, a well-defined curriculum, and support of authorities at all levels of the education system.

In order to answer the fifth research question, differences in the attitudes and motivation of informatics teachers with respect to age, gender, type of study completed, type of employment contract, and length of service were examined. The results of the difference analysis are summarized in Tab. 5.

Table 5 Analysis of differences in the attitudes and motivation of informatics teachers

Item	Statistics	Age group			Gender		Type of study completed		Type of employment contract		Length of service		
		24 – 37	38 – 50	51 – 65	Male	Female	Degree in education	Degree in engineering or computer science	Permanent contract	Fixed-term contract	Less than 10 years	10 –20 years	More than 20 years
Attitude													
ICT should be used in teaching to improve its effectiveness	Mean rank	116.38	111.61	133.96	115.22	117.54	121.13	106.22	114.13	123.00	115.63	116.38	119.19
	p	$p = 0.245$			$p = 0.769$		$p = 0.080$		$p = 0.319$		$p = 0.945$		
Integration of ICT into the curriculum is necessary	Mean rank	112.04	119.48	126.10	113.33	119.08	118.61	111.81	114.24	122.69	110.46	122.64	124.37
	p	$p = 0.417$			$p = 0.438$		$p = 0.393$		$p = 0.310$		$p = 0.216$		
ICT needs to be implemented more systematically into primary school education	Mean rank	118.70	111.45	124.15	118.00	115.28	116.24	117.08	115.16	120.16	119.45	112.23	114.63
	p	$p = 0.556$			$p = 0.736$		$p = 0.924$		$p = 0.582$		$p = 0.723$		
The curriculum must respond to the rapid technological development	Mean rank	115.23	117.46	118.85	120.03	113.63	113.58	122.99	111.39	130.52	118.73	113.42	114.85
	p	$p = 0.946$			$p = 0.429$		$p = 0.279$		$p = 0.035$*		$p = 0.835$		
Introduction of ICT in teaching has to be planned more carefully	Mean rank	121.92	110.92	111.63	117.89	115.37	118.44	112.19	114.88	120.95	120.36	114.09	109.15
	p	$p = 0.409$			$p = 0.757$		$p = 0.476$		$p = 0.508$		$p = 0.552$		
Teachers should be better prepared for ICT integration in their classrooms	Mean rank	122.13	110.14	113.38	113.05	119.30	119.72	109.35	113.80	123.90	119.36	114.98	110.65
	p	$p = 0.357$			$p = 0.435$		$p = 0.228$		$p = 0.262$		$p = 0.699$		
ICT training is appropriate and beneficial	Mean rank	109.80	126.28	112.52	112.99	119.36	122.94	102.18	113.32	125.23	111.11	116.46	131.98
	p	$p = 0.159$			$p = 0.438$		$p = 0.019$*		$p = 0.197$		$p = 0.166$		
Education authorities provide ICT training for teachers at all levels	Mean rank	119.68	110.42	123.37	108.10	123.33	119.53	109.76	117.09	114.89	120.04	103.71	125.99
	p	$p = 0.502$			$p = 0.073$		$p = 0.286$		$p = 0.819$		$p = 0.142$		
Motivation													
I am willing to actively engage in the curriculum development process	Mean rank	114.38	115.61	129.02	105.27	125.62	116.26	117.03	110.74	132.30	116.49	108.90	128.19
	p	$p = 0.534$			$p = 0.012$*		$p = 0.930$		$p = 0.017$*		$p = 0.272$		
I am willing to participate in ICT training	Mean rank	118.41	112.67	121.23	116.34	116.63	117.32	114.68	116.54	116.39	117.14	114.93	117.07
	p	$p = 0.732$			$p = 0.972$		$p = 0.761$		$p = 0.987$		$p = 0.970$		
I find myself motivated to acquire new ICT skills	Mean rank	117.12	112.34	128.13	116.57	116.44	118.08	112.98	113.54	124.61	119.28	104.20	127.41
	p	$p = 0.498$			$p = 0.988$		$p = 0.554$		$p = 0.219$		$p = 0.112$		
I am ready to respond to pupils' needs and interests	Mean rank	115.41	112.84	134.06	111.39	120.65	116.17	117.24	116.07	117.68	115.87	113.91	122.29
	p	$p = 0.250$			$p = 0.228$		$p = 0.897$		$p = 0.853$		$p = 0.751$		
I am willing to help and motivate pupils to acquire digital skills	Mean rank	126.64	103.33	116.85	112.78	119.52	119.79	109.19	114.59	121.74	124.01	103.34	115.21
	p	$p = 0.021$**			$p = 0.393$		$p = 0.211$		$p = 0.420$		$p = 0.075$		

* Statistically significant at $p < 0.05$ (Mann-Whitney test); ** Statistically significant at $p < 0.05$ (Kruskal-Wallis test)

The analysis shows that groups of teachers with different background characteristics have similar views regarding the issues discussed in the paper. Only a few statistically significant differences were identified by the Mann-Whitney and Kruskal-Wallis tests. The results of the Kruskal-Wallis test indicate that at least two age groups differ from each other in their willingness to help and motivate pupils to acquire digital skills. The pairwise comparisons confirmed that younger teachers are more willing to do so than their middle-aged counterparts, while differences between other age groups were not significant. According to the Mann-Whitney test, women are significantly more willing than men to actively engage in the curriculum development process. Also, fixed-term contract teachers are more willing to participate in such activities than those with a permanent contract. In addition, it was found that informatics teachers with a degree in education tended to agree significantly more than their engineering or computer science counterparts that ICT training they had received was appropriate and beneficial. The analysis also reveals that fixed-term contract teachers are significantly more likely than those having a permanent contract to agree that the curriculum must respond to the rapid technological development. In all other cases, the differences between the studied groups were not statistically significant.

6 CONCLUSION

Teachers are a key pillar and component of any education system. The quality of education and students' achievements depend heavily on them. The responsibility of informatics teachers in the ICT era is particularly pronounced. Their main task is to provide students with knowledge and skills related to modern technologies and thus prepare them for active participation in the information society. Due to the very important role that informatics teachers play, educational policy makers need to know their views, attitudes, expectations, and problems. Such information is necessary to make meaningful and valid decisions at all levels of education.

The first years of education are crucial in a child's development and have a huge impact on personal and academic success in life. Primary school informatics teachers are expected to equip pupils with the basic ICT competencies. They should discuss with pupils the advantages and disadvantages of various technologies and stimulate their interest in ICT. Informatics teachers are certainly the most qualified to evaluate the school's technology resources, teaching conditions, and the subject curriculum. It is therefore surprising that the use and integration of ICT in primary schools has been poorly explored from the perspective of informatics teachers. The present paper aims to fill this gap by focusing on the practice and attitudes of Croatian informatics teachers.

The results of the study reveal that the equipment of computer classrooms in primary schools in eastern and central Croatia is only partially satisfactory. Teachers need to have at their disposal modern devices and tools in order to effectively teach their pupils. They will not be able to fulfil their role without adequate ICT infrastructure, which includes hardware, software, network resources, services, protocols, and procedures. The study further finds that informatics teachers regularly use LCD projectors and multimedia computers in their classrooms. Other devices are used much less frequently, which is largely a consequence of the poor classroom facilities. According to the results of the analysis, the surveyed teachers are aware of the importance of ICT implementation in the teaching process, but they do not find the professional development opportunities very positive. Despite the problems, informatics teachers are willing to actively participate in the development of the curriculum, educate themselves in order to keep their knowledge and skills up-to-date, and respond to pupils' needs and help them achieve learning outcomes. Finally, it was found that groups of teachers with different background characteristics shared similar attitudes towards the issues examined in this study.

At the time of the development and implementation of the new informatics curriculum, the present study provides valuable insight and useful information for education authorities and policy makers. Based on the results, it can be concluded that there is a lot of room for improvement of informatics teaching in Croatian primary schools. Education reform will not achieve the desired outcomes if schools are not equipped with adequate ICT infrastructure. It is also important to provide informatics teachers with a wide variety of professional development opportunities. These are just some of the issues that have to be addressed and resolved. Given the role of education as a vehicle for growth and prosperity, radical and fundamental changes in this system are urgently needed in order to foster social and economic development in Croatia.

The issues discussed in this study gain further importance due to the coronavirus (COVID-19) pandemic. Primary and secondary schools around the world, as well as higher education institutions, have been closed to stop the virus' spread. In such circumstances, online learning has become central to the education of students since it represents the most efficient way to continue with classes. As in other countries worldwide, primary schools in Croatia have also shifted to delivering online lessons to their pupils. It is too early to conclude how effective Croatian schools are in implementing online learning, but introducing virtual instruction has been very challenging. Many participants have experienced various difficulties, especially in the first days of distance education classes, which was to be expected. Such problems need to be solved on the fly and it seems to be succeeding. In the current situation, informatics teachers have a particular professional interest in supporting the transition from traditional to technology-based teaching practices. Their knowledge, skills, and experience can be of great value and assistance in achieving the learning objectives and outcomes through the online platforms. Today, more than ever before, informatics teachers have an opportunity to point out the relevance of their subject and to show that they are an important part of the educational process.

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Tolerance Analysis of Mechanical Parts

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Abstract: The determination of tolerances has a huge impact on the price and quality of products. The objective of tolerance analysis is to provide the widest possible tolerance range of parts, without disturbing the functionality of the assembly. Tolerance analysis should be performed during the design process because then there is still the possibility for change. For the purpose of carrying out the analysis, three methods will be used: Worst Case method, Root Sum Square method and Monte Carlo Simulation. Methods are explained through simple examples and applied on the one-way clutch.

Keywords: Monte Carlo simulation; one-way clutch; Root Sum Square; tolerance analysis; Worst Case analysis

1 INTRODUCTION

In the construction of individual machine parts, the decision on the design, position and dimension of these parts must be made in order to consider the function of the assembly. The designer can prescribe very narrow tolerances which would make the parts close to perfection and certainly satisfy the function of each system. Such a method of determining tolerances would be the simplest and fastest, but it has one major drawback: the high cost of production. On the contrary, setting wide tolerances on the machine part reduces costs, but can completely lose product function. In order to allow the widest possible tolerances to be used, while keeping the part within the limits of functionality, tolerance analysis is carried out. Tolerance analysis is a set of calculations that seeks to determine the influence of individual machine parts on the function, shape and position of the entire system. In technical terms, tolerance analysis actually determines the clearance of the assembly with the known tolerances of the individual components.

Statistical analysis is becoming more widely used in industrial production, especially in the automotive industry. The commonly used tolerance analyses are: Worst Case analysis, Root Sum Square (RSS) analysis and Monte Carlo Simulation. Each of the mentioned analyses has some advantages and some disadvantages. In the following sections these methods are described and applied on a one-way clutch assembly.

2 PERFORMING TOLERANCE ANALYSIS

The main purpose of tolerance analysis is to predict the matching of machine parts. Like all other types of analysis, tolerance analysis is performed during the construction process, i.e. before the machine parts are manufactured [1]. Fig. 1 shows a simple switching assembly consisting of casing and two belonging cubes. This example is used in order to explain the steps in performing tolerance analysis.

2.1 Cognition of a Potential Problem

The first step in conducting tolerance analysis is to identify the problems that may occur when assembling the parts. Neglecting the dimensions of the individual cubes in Fig. 1, and considering only the internal dimensions of the casing (i.e. dimension 50 mm), the question which arises is what problems can be encountered during the assembly phase. The first problem is that the sum of the dimensions of the cubes is greater than the internal dimension of the casing, i.e. one cube goes into the casing and the other does not. Another problem is that the sum of the dimensions is much smaller than the internal dimension of the casing, so the cubes could fall out of the casing in use. For this example, this was easy to determine; however, for some more complex circuits, it is necessary to know what one really wants to analyze in order to obtain the optimal solution.

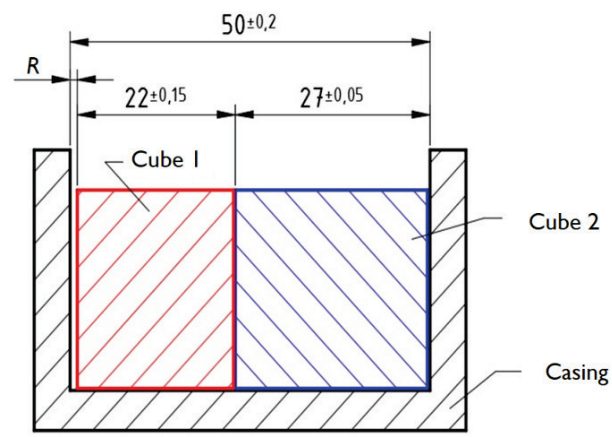


Figure 1 Example for conducting tolerance analysis

2.2 Definition of the Clearance

Clearance is the space between two objects that represents a critical point in the tolerance analysis. Too small a clearance means that parts cannot be assembled, while too much clearance can lead to a loss of system function. In the example in Fig. 1, the clearance is the space between the left edge of the cube 1 and the inner surface of the casing (marked with R).

2.3 Defining Requirements

The requirement is a value that represents the boundary between an acceptable and an unacceptable clearance. The requirement for any system is to fulfill a particular function. In order for the assembly in Fig. 1 to function, the cubes must fit into the casing, i.e. the clearance must be larger than zero. Another requirement is that the clearance should not be larger than 2 mm to prevent the cubes from falling out of the casing:

$$0 \text{ mm} < R < 2 \text{ mm} \tag{1}$$

2.4 Creating a Tolerance Chain

This step determines the dimensions that are essential to the tolerance analysis. The tolerance chain begins on one side of the clearance and ends on the other. This chain can be thought of a vector summation and the result must be a clearance which is going to be analyzed. There are three types of tolerance chain according to dimensionality: one-dimensional (linear), two-dimensional (non-linear), and three-dimensional (spatial) [2]. For performing the one-dimensional analysis for the example in Fig. 1, important dimensions are as follows: internal dimension of the casing (50 mm), the length of the cube 1 (22 mm) and the length of the cube 2 (27 mm). The graph of the tolerance chain is then plotted as shown in Fig. 2. It is defined that if vector is inclined to the right, it is positive, and it is negative if it is inclined to the left. The tolerance chain graph begins with the internal length of the casing (L_1) and is inclined to the right, and continues with the length of the cube 2 (L_2) and the length of the cube 1 (L_3) which is inclined to the left. Summing these vectors, the clearance can be obtained as shown in Eq. (2).

$$L_1 - L_2 - L_3 = R \tag{2}$$

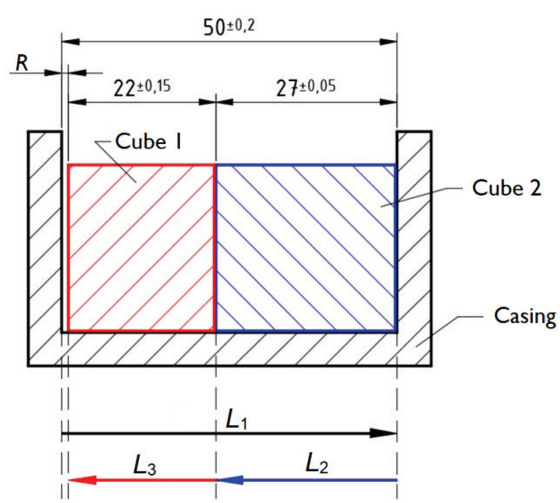


Figure 2 Tolerance chain

2.5 Research of Dimensions

If the tolerance chain is made correctly, then this step is very simple. The value of the dimension corresponding to each vector in the chain is searched and then entered in the commemorative table. Fig. 2 shows that L_1 = 50 mm, L_2 = 27 mm and L_3 = 22 mm. In this example, the tolerance chain vectors correspond exactly to the given dimensions on the design, but it may happen that some dimensions that are important for the tolerance chain are not specified in the drawing and have to be calculated using other dimensions.

2.6 Drawing a Table and Getting a Solution

After determining which dimension value corresponds to which vector, a table is formed. The table is used to improve the transparency of the analysis and to obtain solutions. Once the table is filled, the solution will be obtained by simply summing the values of the vectors in the tolerance chain as shown in Tab. 1.

Table 1 Summing of vector values and tolerances

Vector	Description	Amount, mm	Tolerance, mm
L_1	Housing internal length	50	± 0.2
L_2	Length of cube 2	−27	± 0.05
L_3	Length of cube 1	−22	± 0.15
	Clearance	1	± 0.4

Table 1 shows that the clearance value is equal to 1 mm with a tolerance of ± 0,4 mm. The result of analysis shows that the selected dimensions satisfy requirement given in (1).

3 STATISTICAL CONSIDERATIONS

Fig. 3 shows a symbol that indicates statistical tolerances in technical drawings. The symbol was addressed for the first time in standard ASME Y14.5M-1994. The standard establishes rules, symbols, definitions and requirements for the geometric dimensioning and tolerancing (GD&T). The latest revision of the standard is Y14.5-2018.

Figure 3 Symbol for marking statistical tolerances [3]

Depending on the different circumstances, the resulting solution from the tolerance analysis can be evaluated on an arithmetic or statistical basis. Each of these methods has its advantages and disadvantages. The arithmetic method only touches on the minimum and maximum values of the solution, and the statistical method is more focused on determining the probability that the given requirements will be fulfilled. In simple terms, the arithmetic method describes what can happen, and the statistical method what is most likely to happen.

3.1 Arithmetic Method

Arithmetic method uses a simple summation model of tolerances. In literature, it can be found under many kind of names, such as the extreme value method, the minimum-maximum method, and the worst case method. Basically, this method means that parts will always be able to be assembled, i.e. no inconsistencies are anticipated [4]. This is not very desirable in large-scale production because it causes high costs, so this method is only used for critical systems [5].

The arithmetic method calculates the tolerance of clearance as the sum of the tolerances of all the vectors that make up the tolerance chain as shown by the Eq. (3).

$$T_{\mathrm{R}} = \sum_{i=0}^{n} T_i \tag{3}$$

3.2 Statistical Methods

In order to see the purpose of the statistical method and to show the difference against the arithmetic, a simple example is clarified. Two companies produce the same product in million pieces. The first company decided that each of these millions of pieces has to meet the given tolerances, costing them 10 kn/pc. Another company decided to pay a little less attention to the given tolerances and it costs them 9.9 kn/pc, but they have 1000 non-compliant products. The question is which company made the better decision. By a simple calculation, this can be verified. The total cost of the first company is HRK 10 million. The total cost of another company is HRK 9.9 million, but costs for non-compliant products still need to be added to this value, and then the total cost climbs to slightly less than HRK 9.91 million. It is obvious that the second company has made the right decision.

This is the basic difference between the arithmetic and the statistical method. The arithmetic method ensures that all products meet the requirements, which causes high costs, and the statistical method allows for some products to not meet the requirements in order to reduce production costs.

The terms that are important for studying this method are the following: output (the measurement we are interested in, i.e. the result we want to get), input (variables that determine the output), and the functional equation (the relationship, i.e. the relationship between input and output).

In order to get the most accurate result from the analysis, the method of distributing data, i.e. whether it is normal, continuous, triangular or similar, must also be known. The distribution of data answers the question of whether a product will be closer to the nominal measure or closer to the extreme values. The manufacturing process is usually approximated by the normal distribution.

Statistical method answers the following questions [6]:

- What is the mean value of the output?
- What is the standard deviation of the output?
- What is the percentage of output that is within the set limits?
- What is the distribution of the output?
- Which of the input variables has the greatest impact on the changeability (variability) of the output?
- Which of the input variables must satisfy the given conditions and how is quality control of the product tested?

3.2.1 Root Sum of Squares

When referring to the statistical method of analysis, one actually refers to RSS method. Root Sum of Squares or RSS method is a more reasonable method than arithmetic, and requires milder tolerance of components, thereby obtaining lower manufacturing costs. This method involves the possible occurrence of nonconformities in the production process. It is the most commonly used method in large-scale production. RSS method is based on the assumption that individual parts of a system are manufactured with a capability level of $\pm 3\sigma$ and that the distribution of data can be approximated by a normal distribution. RSS method guarantees that 99.73% of products in the batch will be within the given limits; respectively, for 0.27% of products, RSS method does not guarantee that they will be in defined specification limits. For a linear tolerance chain, this method is written mathematically as shown by the Eq. (4).

$$3\sigma_{\mathrm{R}} = T_{\mathrm{R}} = \sqrt{\sum_{i=0}^{n} T_i^2} \tag{4}$$

For nonlinear tolerance chains, the RSS method is calculated by linearizing the input function using Taylor orders. Taylor order is a common way of linearizing nonlinear functions. In the tolerance analysis, the Taylor orders are limited to the first (linear analysis) or second order. The output as a result of the RSS method is used to predict the expected mean value and the standard deviation of the process. To calculate this data, a functional connection of the input and output data is required as shown in the relation (5), where Y represents an output variable, and X input variable of the process. Applying the Taylor order to the input function (5), it is obtained that the total variance of the process is equal to the sum of the squares of the individual variances and their first derivatives as shown by the Eq. (6). The standard deviation is calculated according to Eq. (7), and the expected mean value according to Eq. (8).

$$Y = f(X_1, X_2, X_3, ..., X_n) \tag{5}$$

$$\sigma_Y^2 = \sum_{i=1}^{n} \left(\frac{\partial f}{\partial X_i} \right)^2 \cdot \sigma_{X_i}^2 \tag{6}$$

$$\sigma_Y = \sqrt{\sum_{i=1}^{n} \left(\frac{\partial f}{\partial X_i} \right)^2 \cdot \sigma_{X_i}^2} \tag{7}$$

$$\mu_Y = f(\mu_{X_1}, \mu_{X_2}, \mu_{X_3}) + \frac{1}{2} \sum_{i=1}^{n} \left(\frac{\partial^2 f}{\partial X_i^2} \cdot \sigma_{X_i}^2 \right) \tag{8}$$

Generally speaking, the process is considered satisfactorily efficient at $\pm 3\sigma$ which includes 2700 nonconformities per million pieces. While this may seem very good at first glance, this level is considered to be less and less satisfying in some areas of production. In large-scale production, the mean value of the characteristic curve changes due to the influence of various factors (tool and tool wear, temperature changes, etc.), so for safety reasons it should be moved to 1.5σ (Fig. 4). This increases the number of non-conformities and then there are 66,810 non-conformities per million pieces. As a result, new solutions are being sought to reduce this number.

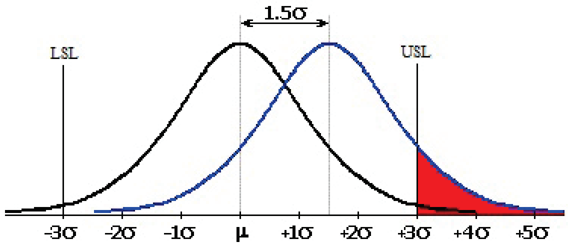


Figure 4 Shift of a mean value for 1,5*σ* [7]

3.2.2 Monte Carlo simulation

Monte Carlo simulation is recognized as an approach that incorporates the basics of modern technology. The method is widely used for non-linear statistical tolerance analysis [8]. It is a statistical simulation based on random events. Each random event generated represents one experimentally set outcome. Using a proper data scatter curve and a random value generator, a real data distribution of the output variable is obtained. This technique is used to describe a measurement whose value depends on several factors or variables, the relationship between these variables and the measurement is known, and random data is assumed. The algorithm to perform the simulation is as follows: for the input variable X, the output variable is formulated using a previously written algorithm Y, the process is repeated M times to obtain the M values of the output variable Y, which is used to determine the scattering function of the output data [9]. The expected value of the output variable Y, the standard deviation and the interval for the given probability level P are then estimated from the experimental curve.

4 TOLERANCE ANALYSES FOR ONE-WAY CLUTCH

One-way clutch is a mechanism used in two-way drive when the movement of the working member in one direction is required. The torque is transmitted by friction, i.e. by removing the bearing between the outer ring and the inner hub. As the direction of rotation changes, the bearings come out of the grip and rotate freely, while the driven member is stationary. There are several ways to perform such a mechanism, but here a one-way clutch made using spring-loaded bearings is analyzed as shown in the Fig. 5. Some examples of using one-way clutches include the following: a tool (feeder), printer input, fishing rod, sewing machine, bicycle, and similar.

The one-way clutch shown in Fig. 5 consists of an outer ring, an inner hub, ball bearings and springs that ensure contact of the bearing balls with the hub and outer ring. The result of such a system is that the outer ring rotates freely in counterclockwise direction, but not in clockwise direction. For the hub, the reverse is true; it rotates freely clockwise, and not counterclockwise. What is important for conducting the analysis is to ask the question of what the critical values for which the analysis will be carried out are, i.e. to identify potential problems. For the system in Fig. 5, a potential problem exists when the outer ring rotates clockwise or the hub counter-clockwise. The problem in these cases is that there may be too much bumps and jerks, so one needs to know where the rotation will stop and how much potential variation around that stop point. In this regard, the critical values for this system are the stopping angle α and spring length L. Too large stopping angle would mean that the system would not lock, and too small angle would mean it would not unlock. None of the critical values can be defined by a linear tolerance chain, so the analysis will be performed accordingly. The two-dimensional tolerance chain for the one-way clutch is shown in Fig. 6.

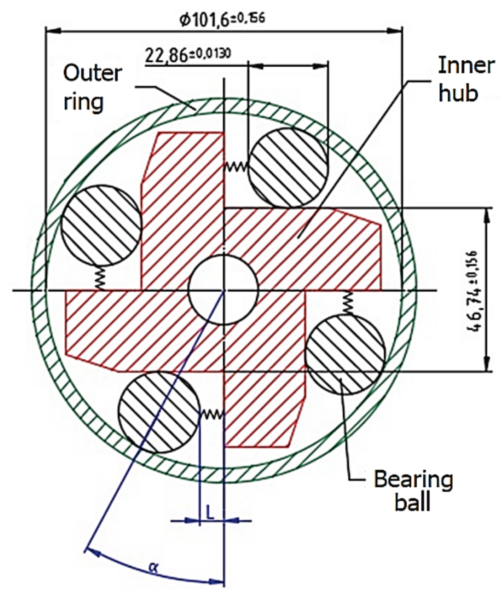


Figure 5 One-way clutch used for analysis

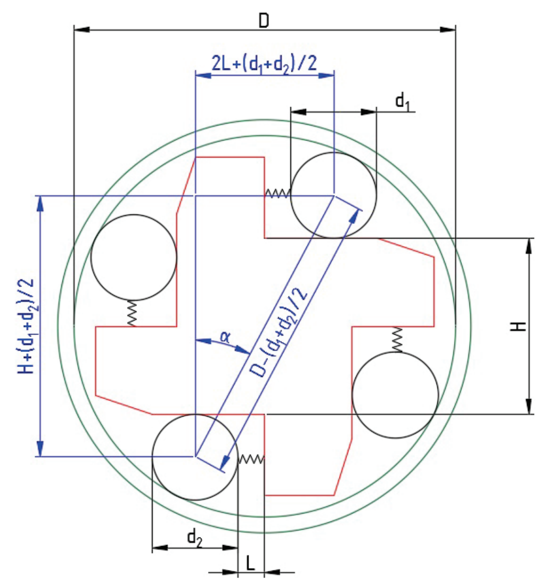


Figure 6 Tolerance chain for one-way clutch

Tab. 2 shows the nominal values and their tolerances for the given input variables. Tab. 3 shows the output values and their upper and lower specification limits.

Table 2 Input variables and their tolerances

Input variable	Symbol	Unit	Nominal values	Tolerance ±
Hub height	H	mm	46.74	± 0.156
Diameter of ball bearing 1	d_1	mm	22.86	± 0.013
Diameter of ball bearing 2	d_2	mm	22.86	± 0.013
Inner ring diameter	D	mm	101.6	± 0.156

Table 3 Output variables

Output variables	Symbol	Unit	LSL	USL
Stopping angle	α	°	27.5	28.5
Spring length	L	mm	6.5	7.5

The relationship between input and output values is shown in Eqs. (9) and (10). Once the relationship between input and output variables is defined, analysis can be accessed. An analytical and statistical method will be implemented, and results will be compared.

$$\alpha = \cos^{-1}\left(\frac{H + \frac{d_1 + d_2}{2}}{D - \frac{d_1 + d_2}{2}}\right) \tag{9}$$

$$L = \frac{1}{2}\cdot\left(\sqrt{\left(D - \frac{d_1 + d_2}{2}\right)^2 - \left(H + \frac{d_1 + d_2}{2}\right)^2} - \frac{d_1 + d_2}{2}\right) \tag{10}$$

4.1 Example of the Worst Case Method

As this is not a linear analysis, the tolerances of individual members from the tolerance chain cannot be summed up. In order to perform the arithmetic method, it is necessary to determine the minimum and maximum dimensions for critical values. It is evident from Eq. (9) that the stopping angle will be minimal when the variables H, d_1 and d_2 are maximal, and variable D minimal. The maximal stopping angle value will be obtained in reverse, i.e. when variables H, d_1 and d_2 are minimal, and D maximal. In Tab. 4 minimal and maximal values for the individual input variables are given. The length of the spring in term (10) will be minimal when variables H, d_1 and d_2 are maximal, and variable D minimal, and opposite. Eqs. (11) to (14) show the computational portion of obtaining these critical values.

Table 4 Minimum and maximum values for input variables

Input data	MIN, mm	MAX, mm
H	46.584	46.896
d_1	22.847	22.873
d_2	22.847	22.873
D	101.444	101.756

$$\alpha_{\min} = \cos^{-1}\left(\frac{46.896 + \frac{22.873 + 22.873}{2}}{101.444 - \frac{22.873 + 22.873}{2}}\right) = 27.38° \tag{11}$$

$$\alpha_{\max} = \cos^{-1}\left(\frac{46.896 + \frac{22.847 + 22.847}{2}}{101.756 - \frac{22.847 + 22.847}{2}}\right) = 28.371° \tag{12}$$

$$L_{\min} = \frac{1}{2}\cdot(\sqrt{(101.444 - 22.873)^2 - (46.896 + 22.873)^2} - -22.873) = 6.631 \text{ mm} \tag{13}$$

$$L_{\max} = \frac{1}{2}\cdot(\sqrt{(101.756 - 22.847)^2 - (46.586 + 22.847)^2} - -22.847) = 7.325 \text{ mm} \tag{14}$$

From the results obtained by the arithmetic method i.e. worst case method, it is possible to calculate the mean value of results. The mean value is calucated as the arithmetic mean of the maximum and minimum values. The results of are shown in Tab. 5.

Table 5 The results of worst case method

Symbol	MIN	MAX	Mean value	Range
α, °	27.380	28.371	27.876	0.496
L, mm	6.631	7.325	6.978	0.347

When the obtained results are compared with the set requirements in Tab. 3, then it can be seen that the obtained minimum value for the stopping angle is less than the set requirement (27,380° < LSL). That means a number of non-confirming units will occur in the process. Assuming a normal distribution in the process, 1000 simulations for both stopping angle and spring length were undertaken. Seven non-conformities have occurred.

With aim of eliminating non-conformities for given dimensions and specification limits, it is necessary to improve manufacturing process and therefore lower the result deviations.

4.2 Example of RSS Method

The Eqs. (7) and (8) will be used to perform that statistical method Root Sum Square for the one-way clutch. According to these terms, it is evident that the first and second derivatives need to be calculated in order to obtain the standard deviation and the mean value. These derivatives will be calculated using the MathCad computer program. To facilitate derivation, the ball bearing diameters d_1 and d_2 will be assumed to be the same in each case and will only be denoted by d_1. Eqs. (15) to (20) show first and second derivations for the stopping angle, and from (21) to (26) for the length of spring. It should be noted that the results for the stopping angle in radians were obtained, so this should be taken into account when calculating the mean value and standard deviation. In order to obtain the derivation result, the nominal values from Tab. 2 are entered as variables. After the derivatives are calculated, the standard deviation is calculated as shown in relations (27) and (28), where the value for the stopping angle in radians and for the spring length in millimeters is obtained. In Eqs. (29) and (30), the mean expected value for stopping angle and spring length were calculated.

$$\frac{\partial \alpha}{\partial H}=\frac{-1}{\sqrt{1-\left(\frac{H+d_1}{D-d_1}\right)^2}}\cdot\frac{1}{D-d_1}=-0.027 \tag{15}$$

$$\frac{\partial \alpha}{\partial d_1}=\frac{-1}{\sqrt{1-\left(\frac{H+d_1}{D-d_1}\right)^2}}\cdot\left(\frac{D+H}{\left(D-d_1\right)^2}+\frac{1}{D-d_1}\right)=-0.051 \tag{16}$$

$$\frac{\partial \alpha}{\partial D}=\frac{1}{\sqrt{1-\left(\frac{H+d_1}{D-d_1}\right)^2}}\cdot\frac{H+d_1}{\left(d_1-D\right)^2}=-0.024 \tag{17}$$

$$\frac{\partial^2 \alpha}{\partial H^2}=\frac{-1}{\sqrt[3]{1-\left(\frac{H+d_1}{D-d_1}\right)^2}}\cdot\frac{H+d_1}{\left(D-d_1\right)^3}=-0.0014 \tag{18}$$

$$\frac{\partial^2 \alpha}{\partial d_1^2}=\frac{-2\cdot\left(\frac{H+d_1}{\left(D-d_1\right)^3}+\frac{1}{\left(D-d_1\right)^2}\right)}{\sqrt{1-\left(\frac{H+d_1}{D-d_1}\right)^2}}-\frac{\left(\frac{H+d_1}{\left(D-d_1\right)^2}+\frac{\left(H+d_1\right)^2}{\left(D-d_1\right)^3}\right)\cdot\left(\frac{H+d_1}{\left(D-d_1\right)^2}+\frac{1}{D-d_1}\right)}{\sqrt[3]{1-\left(\frac{H+d_1}{D-d_1}\right)^2}}=-0.0063 \tag{19}$$

$$\frac{\partial^2 \alpha}{\partial D^2}=\frac{2\cdot\frac{\left(H+d_1\right)^2}{\left(d_1-D\right)^3}}{\sqrt{1-\left(\frac{H+d_1}{D-d_1}\right)^2}}-\frac{\frac{\left(H+d_1\right)^3}{\left(d_1-D\right)^5}}{\sqrt[3]{1-\left(\frac{H+d_1}{D-d_1}\right)^2}}=-0.0017 \tag{20}$$

$$\frac{\partial L}{\partial H}=-\frac{1}{2}\cdot\frac{H+d_1}{\sqrt{\left(D-d_1\right)^2-\left(H+d_1\right)^2}}=-0.9451 \tag{21}$$

$$\frac{\partial L}{\partial d_1}=-\frac{1}{2}\cdot\frac{D+H}{\sqrt{\left(D-d_1\right)^2-\left(H+d_1\right)^2}}=-2.514 \tag{22}$$

$$\frac{\partial L}{\partial D}=-\frac{1}{2}\cdot\frac{d_1-D}{\sqrt{\left(D-d_1\right)^2-\left(H+d_1\right)^2}}=1.069 \tag{23}$$

$$\frac{\partial^2 L}{\partial H^2}=-\frac{1}{2}\cdot\left(\frac{\left(H+d_1\right)^2}{\sqrt[3]{\left(D-d_1\right)^2-\left(H+d_1\right)^2}}+\frac{1}{\sqrt{\left(D-d_1\right)^2-\left(H+d_1\right)^2}}\right)=0.062 \tag{24}$$

$$\frac{\partial^2 L}{\partial d_1^2}=-\frac{1}{2}\cdot\left(\frac{\left(D+H\right)^2}{\sqrt[3]{\left(D-d_1\right)^2-\left(H+d_1\right)^2}}\right)=-0.22 \tag{25}$$

$$\frac{\partial^2 L}{\partial D^2}=-\frac{1}{2}\cdot\left(\frac{\left(D-d_1\right)^2}{\sqrt[3]{\left(D-d_1\right)^2-\left(H+d_1\right)^2}}-\frac{1}{\sqrt{\left(D-d_1\right)^2-\left(H+d_1\right)^2}}\right)=-0.0485 \tag{26}$$

$$\sigma_\alpha=\sqrt{(-0.027)^2\left(\frac{0.156}{3}\right)^2+(-0.051)^2\left(\frac{0.013}{3}\right)^2+(-0.024)^2\left(\frac{0.156}{3}\right)^2}=0.0019 \tag{27}$$

$$\sigma_L=\sqrt{(-0.945)^2\left(\frac{0.156}{3}\right)^2+(-2.514)^2\left(\frac{0.013}{3}\right)^2+(1.069)^2\left(\frac{0.156}{3}\right)^2}=0.075 \tag{28}$$

$$\mu_\alpha=0.487+\frac{1}{2}\left((-0.0014)\left(\frac{0.156}{3}\right)^2+(-0.0063)\left(\frac{0.013}{3}\right)^2+(-0.0017)\left(\frac{0.156}{3}\right)^2\right)=0.4866\ \text{rad} \tag{29}$$

$$\mu_L=6.981+\frac{1}{2}\left((-0.062)\left(\frac{0.156}{3}\right)^2+(-0.22)\left(\frac{0.013}{3}\right)^2+(-0.0485)\left(\frac{0.156}{3}\right)^2\right)=6.9806\ \text{rad} \tag{30}$$

Table 6 Results of Root Sum Square method

Symbol	MIN	MAX	Mean value	$\pm 3\sigma$
α, °	27.5533	28.2067	27.8801	0.3266
L, mm	6.7556	7.2056	6.9806	0.225

The minimum and maximum values in Tab. 6 are obtained when triple values of standard deviations from Eqs. (27) and (28) are added to the expected mean values from Eqs. (29) and (30). What is noticeable from the obtained results is that they, against the Worst Case method, satisfy the given conditions in Tab. 3. It will now be examined to which extent is non-compliance foreseen by this method. 1000 results of both stopping angle and spring length dimensions were simulated. Simulation confirmed no non-conforming products for given tolerances.

4.3 Example of Monte Carlo Simulation Method

For example, one-way clutches will prove the true purpose and advantage of Monte Carlo simulation. As can be seen from section 4.2, the statistical method can be very complex and time consuming, and errors in computation can easily occur, which is of course undesirable. Analyses can be even more complex than the one-way clutch example, so manual computation becomes almost impossible. For this reason, Monte Carlo simulation is a desirable tool when tolerance analysis is required in a quick and efficient way.

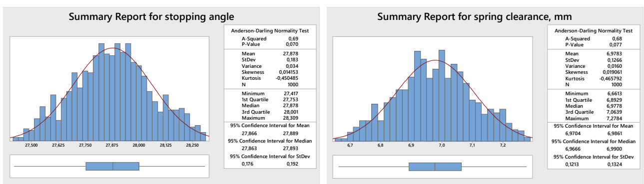
Monte Carlo analysis requires some computer software package. Some of them are Excel extensions such as: Oracle Crystall Ball, MonteCarlito, RiskAMP, Ersatz, ModelRisk, Insight, etc. All these extensions have in common that you first need to enter the input data and calculate the output data functionally. Subsequently, the distribution, standard deviation, and mean for the input data are defined. The higher the number of simulations, the more accurate the results will be, but the simulation will be slower. After everything is defined, simulation is initiated.

In order to conduct statistical tolerance analysis using Monte Carlo simulation, software package *Minitab trial version* was used. Input variables H, d_1, d_2 and D were simulated. Each input variable was simulated 1000 times, and uniform data distribution was assumed. The output variables α and L were calculated using the expression given with Eqs. (10) and (11).

Tab. 7 shows the results of the Monte Carlo simulation. The output data follow normal distribution (Fig. 7).

Table 7 Results of Monte Carlo simulation

	μ	σ	MIN	MAX	$\pm 3\sigma$
α , °	27.878	0.183	27.329	28.427	0.549
L, mm	6.978	0.127	6.597	7.359	0.381



a) b)

Figure 7 Monte Carlo Simulation output: a) stopping angle, b) spring clearance

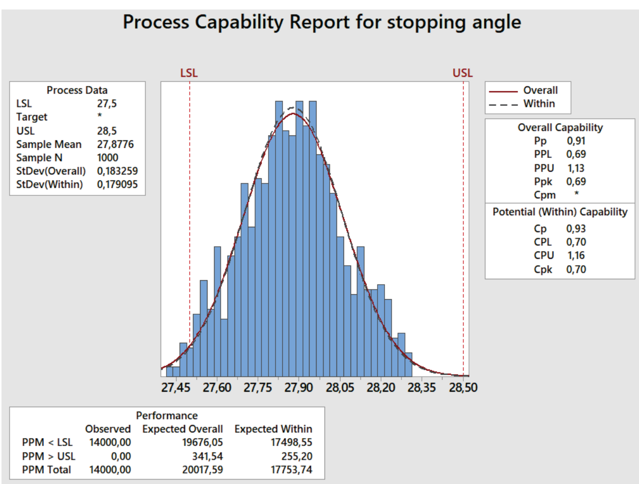


Figure 8 Process capability report for spring clearance

The process capability analyses were calculated using the normal distribution. The process capability report for stopping angle α is given in Fig. 8, while the process capability report for spring clearance L is given in Fig. 9.

Potential process capability for stopping angle is 0.91, which means that the process is not capable to produce conforming units. The Monte Carlo simulation predicts 20,018 non-conforming units per million pieces, i.e. 2 %. According to the simulation, all non-conforming products have stopping angle smaller than lower specification limit (LSL).

Potential process capability for spring clearance L calculated from simulated data shows that the process is capable (P_p > 1). The Monte Carlo simulation predicts 98 non-conforming units per million pieces, i.e. 0.01 %.

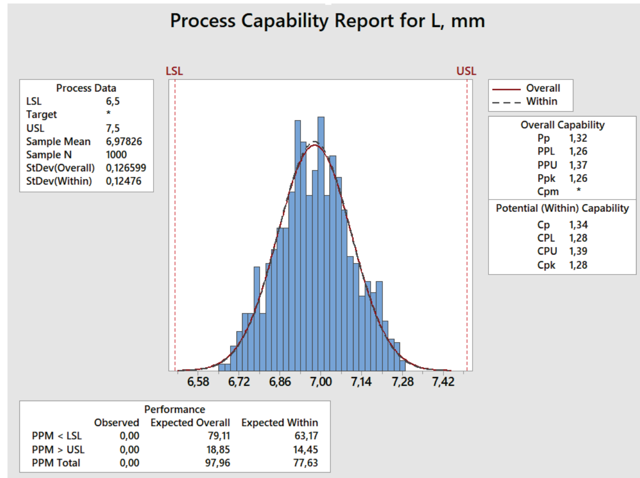


Figure 9 Process capability report for spring clearance

5 CONCLUSION

Tolerance analysis is performed to allow for the widest possible tolerances of the components of a system without compromising its functional properties. In order to carry out tolerance analysis, it is necessary to determine the critical value, i.e. the problem to be solved. After that it is necessary to determine what influences this problem and describe it with some functional connection. For linear systems, this is easy to determine, and a tolerance chain is drawn to further reduce the analysis to simple addition and subtraction. For nonlinear systems, computing becomes quite complex, and in some cases impossible.

The analysis methods used were: Worst Case method, Root Sum Square method and Monte Carlo simulation method. Each of these methods has its advantages and disadvantages. The advantage of the Worst Case method is that it is easy to understand, but no inconsistencies are anticipated, which causes high production costs. Therefore, this method is only used for critical systems. The Root Sum Square is provided for wider dimensions of the assembly components, thereby automatically reducing the cost of production at the expense of inconsistent components in the process. The disadvantage of this method is that for nonlinear systems, computing becomes complicated and time consuming, sometimes impossible. Monte Carlo simulation method is based on generating random numbers from probability density functions for each input variable and calculating output variables by combining different statistical distributions of input variables.

In the example of the one-way clutch, the limits of the requirements were set and it was compared how the individual methods would predict the behavior of the process with respect to these requirements. The Worst Case method showed the occurrence of a small number of non-conforming products.

The RSS method turned out to be quite complicated and time-consuming for this example. The result predicted none of non-compliant pieces in the process. The Monte Carlo simulation showed that in case of stopping angle, process is not capable to produce conforming parts, and the predicted number of non-conforming products is around 2 %. In case when analyzing dimension of spring length, simulated data shows that the process is capable. Potential capability is 1.32 and only 0.01 % of non-conforming products is expected.

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Original scientific paper

Detection of Escherichia Coli Bacteria in Water Using Deep Learning: A Faster R-CNN Approach

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Abstract: Considering its importance for vital activities, water and particularly drinking water should be clean and should not contain disease-causing bacteria. One of the pathogenic bacteria found in water is the bacterium Escherichia coli (*E. coli*). In the commonly used method for the detection of E. coli bacteria, the bacteria samples distilled from the water sample are seeded in endo agar medium and the change in the color of the medium as a result of the metabolic activities of the bacteria is examined with the naked eye. This color change can be seen with the human eye in approximately 22 ± 2 hours. In this study, a new bacteria detection scheme is proposed – using deep learning to detect *E. coli* bacteria both in shorter time and in practical way. The proposed technique is tested with experimentally collected data. Results show that the detection of bacteria can be done automatically within 6-10 hours with the proposed method.

Keywords: deep learning; Escherichia coli; Faster R-CNN; prediction; TensorFlow

1 INTRODUCTION

Water is what humans need most to survive. Water has an important role in metabolic activities, such as ensuring the balance of heat in the body, transporting the nutrients taken into the body to the target destinations, ensuring the lubrication of joints [1]. Therefore, the water used must be clean and not contain any disease-causing microorganisms. The Turkish Standards Institute's TS 266 drinking and using water standard (2005) specifies the quality criteria that water must satisfy. As reported there, one of the most important criteria to be considered in water is microbiological parameters [2]. Furthermore, "Water Quality and Health Strategy" study of World Health Organization (WHO) reports a projection of 589,854 water-borne infections in 58 countries around the world in the 2013-2020 period [3].

One of the disease-causing bacteria found in water is the bacterium Escherichia coli (*E. coli*) which was discovered by the Austrian doctor Thedor von Escherich in Enterobacteriaceae family. *E. coli* is actually one of the species of bacteria that live in the large intestines of living beings. However, it causes water pollution with the feces of living creatures and can survive in water for 4-12 weeks depending on the environmental conditions [4].

E. coli is divided into different pathologies according to the diseases caused. Each pathotype causes different disease symptoms. One of these diseases is hemolytic uremic disease (HUS) which can cause bloody diarrhea and death. Escherichia coli O157:H7 serotype is the strongest reason underlying HUS [5]. In 2011, WHO reported 4,075 *E. coli* contaminations and 50 deaths related to HUS in 16 European countries and North America [6].

Considering the causes of diseases, the rapid and effective detection of *E. coli* bacteria is of great importance in terms of preventing epidemics and reducing deaths. A wide variety of methods has been developed to detect *E. coli* bacteria. Among these methods, the detection of bacteria is usually carried out using agar media [7-12], since agar is suitable for growth of microorganisms and contains the components that microorganisms need to perform metabolic activities. Using this growth culture, many different purposes can be achieved, such as the development, isolation, identification, counting and susceptibility testing of microorganisms, examination of clinical specimens, food, water and environmental controls. Also, there are studies in which bacteria are labelled with radiant chemicals or examined under a microscope after using various minerals such as manganese-added zinc [13-17]. It is also possible to detect *E. coli* bacteria without using a microscope and magnification. For this, some changes in the medium which are characteristic for *E. coli* bacteria are examined with eye, or using digital image processing techniques such as hyperspectral imaging, thermal imaging or optical imaging [18-21]. Endo agar solid media can also be used for this purpose. *E. coli* bacteria metabolize the lactose in the agar media by forming acid and aldehyde. The resulting aldehyde releases fuchsine in the fuchsine-sulfide compound, and thus the colony color becomes red. In *E. coli* and some other coliform group members, this reaction occurs very strongly, and the fuchsine crystals in the colony ensure that the colony color is metallic bright green (metallic sheen). As the optimal temperature for *E. coli* development is 37 °C, incubation is performed at 37 °C in an aerobic condition. The appearance of metallic sheen becomes visible with naked eye in about 22 ± 2 hours [22, 23]. Generally, this process is used in most laboratory studies and the change of the color is generally tracked manually with human eye.

In recent years, deep learning algorithms can also be considered as a useful tool for detection and classification of bacteria colonies automatically [24-26]. Deep learning is an artificial intelligence algorithm that uses several layers and as layers progress, it extracts higher-level features from a given input. In deep learning, convolutional neural networks (CNNs) are a subfield of deep neural networks which is applied to analyze computer vision processes such as image classification. The capability of deep neural networks in image classification questions the possibility of success in object detection. The image classification process generally works on the estimation of an object in an image. Different from this, detection of the object and its boundaries are the processes of object identification. When the challenges of object detection are taken into consideration, CNNs have a dominant and improved success in that field compared to the traditional neural network models [27-31]. Over the last few years, region-based CNN (R-CNN) object detection methods have become the main approach. With improved performance and faster processing speed, more advanced CNN detection models have been proposed to deal with the problem of efficient object localization in object detection [32-41]. Unlike the previous CNN methods, R-CNN uses a different region proposal algorithm called Selective Search which uses both segmentation of objects and Exhaustive Search to determine the region proposals in a faster and accurate way. The Selective Search algorithm proposes about 2000 region proposals for image to be passed into the CNN model which produces a 4096-dimensional feature vector as output from each region proposal. By placing this feature vector into the SVM model and bounding box regressor, classification and localization of object is provided. But the biggest problem with R-CNN is that 2000 region proposals have to be classified in each image. This increases duration of training the network. Since it requires a long time to detect objects in an image, real time applications cannot be implemented even on a graphical processing unit (GPU). To overcome this problem, Fast-R-CNN was proposed [40]. Not only in R-CNN but also in Fast-R-CNN, computational burden was still high and most of the time taken by Selective Search algorithm. To reduce this train duration in both R-CNN's, the Faster R-CNN was developed by Ren et al [41]. In this method, other than Selective Search algorithm, Region Proposal Network (RPN) is used for the network to learn region proposals. In this network, image gets into a backbone network to generate a convolution feature maps which will pass into the RPN that takes another feature map and generates anchors for classification and regression layers for object detection and localization. The general network for region-based model is given in Fig. 1.

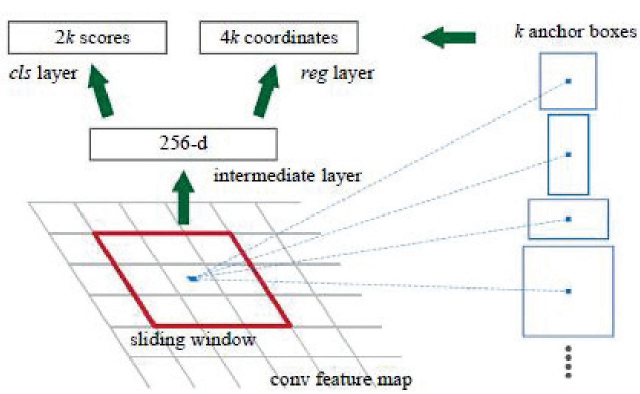


Figure 1 Region proposal network [33]

In this study, it is aimed to determine the color change of agar medium containing *E. coli* bacteria contaminated water which can be used in the analysis of water samples, automatically and in a faster way compared to traditional methods. For this purpose, a deep learning approach is used as the color differences between image samples are the key points of determination. Detection of *E. coli* bacteria was performed using convolutional neural networks; a Faster R-CNN approach has been established in Tensorflow framework [42]. Experimentally collected image dataset was used for performance evaluation and comparison.

2 MATERIALS AND METHODS

2.1 Experimental Setup and Generated Image Dataset

Images used for training and testing the proposed algorithms were obtained experimentally in this study. For this purpose, endo agar solid growth culture was prepared in petri dishes and *E. coli* contaminated water was sowed on the medium as explained in [43]. Prepared medium is of light pink color at time of preparation. If *E. coli* contaminated water is sowed on the medium, dark red formation occurs first, and then, at higher density contamination site, this turns into bright green, or namely metallic sheen with the passing of time. Metallic sheen layer may also spread over the surface of the growth culture. As mentioned earlier, the time of seeing this metallic sheen with the naked eye is about 22 hours. If the water is non-contaminated, then the surface color of the medium does not change, only darkening of the pink color may be seen due to the ongoing dissolution of the colorant in the medium. Fig. 2 shows a sample image of an *E. coli* contaminated water sowed plant used in the study after 24 hours with a visible metallic sheen.

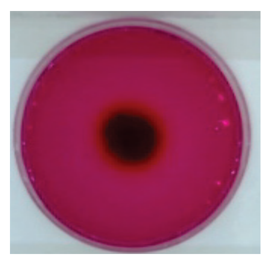


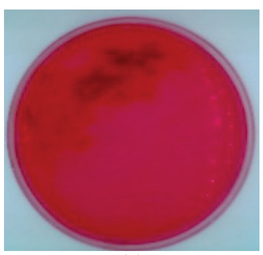
Figure 2 Captured image of the growth culture with bacterial sowing

For the acquisition of the images, the photographic imaging setup proposed in [43] was used. This setup has a rectangular prism shape, with dimensions 40 × 30 × 25 cm, closed and dark medium, in which the petri dished are placed. The medium is illuminated with white led lights prior to every photo shooting. A camera with a resolution of 1920×1080 (full HD) is placed on the top of the setup for automatic image capture. Electronic design details can be found also in [43].

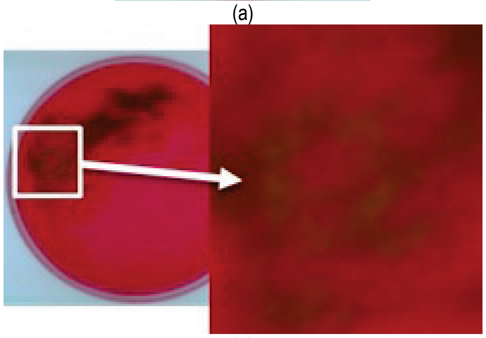
Photo shooting and image acquisition process were carried out at room temperature in the experiments. A new *E. coli* contaminated water sawed growth culture medium was prepared and placed in the imaging setup prior to each experiment. Photographing continued for 24 hours, including one frame per ten minutes. Therefore, for one medium, 144 images were acquired in 24 hours. Ten different contaminated media were used as the medium with bacteria (experimental) group and therefore, automatic photo shooting was continued for ten days and 1440 images were acquired as experimental group. The same process was repeated in the next ten days with growth cultured petri dishes without sowing *E. coli* bacteria and another 1440 images were obtained as control group.

2.2 Proposed Faster R-CNN Approach

In the proposed method, a Faster R-CNN approach was developed and used in the Tensorflow framework. Pre-trained Faster R-CNN Model with Inception ResNet v2 was selected as the base network. The dataset that the model was trained was MS-COCO dataset [44]. COCO set is publicly available and published in the Tensorflow Object Detection API [45] model zoo repository. The algorithm was written in Python and run on a computer with a 2.4 GHz Intel I7 CPU and an NVIDIA GeForce GT950m GPU with 4 GB memory. Two classes were defined: a medium with bacteria and a medium without bacteria. As explained above in section 2.1, ten days of data were taken for each medium. Eight days of data from each group which corresponds to total of 2304 captured images were selected as training data. The remaining data were used to test and validate the algorithm.



(a)



(b)

Figure 3 Sample images: a) Labelled as a non-bacterial medium, b) Labelled as a bacterial medium

In the labelling phase of training, two labels were used to define mediums: bacterial (*E. coli* contaminated medium) and non-bacterial. All labelling operations were done by using open-source software "LabelImg" [46]. Only the images in which the metallic sheen became visible in the medium were defined as bacterial and the other images were labeled as non-bacterial even if it was known that the medium was contaminated with *E. coli* bacteria. Sample images were given in Fig. 3.

For example, image in Fig. 3a was labeled as non-bacterial medium as the metallic sheen does not appear, although it was contaminated with *E. coli* bacteria. On the other hand, image in Fig. 3b was labeled as bacterial medium due to the appearance of green metallic sheen which can be seen in the white box in the image. By following this strategy, it was aimed that the algorithm only focuses on metallic sheen appearance on medium which is the main characteristic for detection of *E. coli* bacteria, instead of dark red color changes which can be related to contamination of oxygen or another bacteria to the medium. Considering this features and requirements, a Faster R-CNN model was developed as given in Fig. 4.

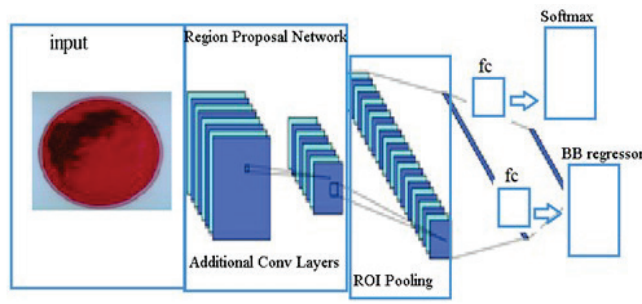


Figure 4 Proposed Faster R-CNN framework

Here, the RPN ranks anchor boxes and proposes the ones most likely containing objects – growth culture samples. Output of a RPN is a variety of boxes that will be examined by a classifier and regressor to eventually check the occurrence of objects for localization and detection. It searches the image from the first frame to the last as tensors and scores the similarity. Fig. 5 shows 12 anchors which were used in this study for object detection.

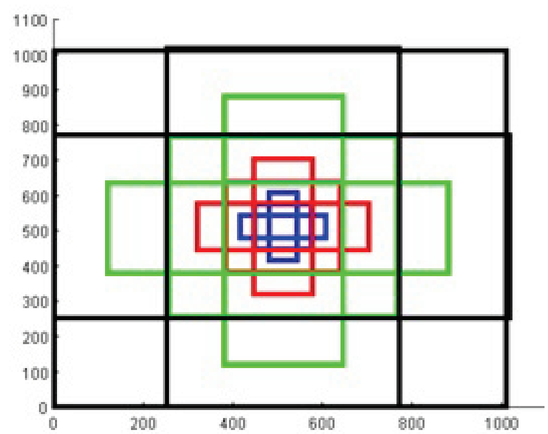


Figure 5 Anchor boxes at (1024, 1024)

In Fig. 5, the four colors (blue, red, green and black) represent four scales: 128×128, 256×256, 512×512 and 1024×1024 pixels. Also, three aspect ratios 1:2, 1:1 and 2:1, which correspond to the width/height ratio of an anchor box were used as shown in Fig. 5. After RPN, proposed regions were obtained with different sized CNN feature maps.

Region of Interest (ROI) Pooling was used to simplify the problem by reducing the CNN feature maps into the same size. Output features from ROI Pooling layer were converted to a one dimensional array and fed into fully connected (fc) layers for classifying and regression operations in which the CNN decides whether the medium is with bacteria or not. The classification branch of Softmax layer in the model gives probabilities for every ROI and the prediction of labels were done in this phase. Here, detection scores were obtained and given to the last layer for decision of medium. In the Bounding Box (BB) regression branch generates four anchor box regression offsets t_i^k where $i = x$, y, w, and h; in which (x, y) stands for the top-left corner and w and h denote the height and width of the anchor box. The true bounding box regression targets for a class u are indicated by v_i where $i = x, y, w$, and h. Algorithm decides whether there is a growth culture or not, which depends on both localization and classification losses. The localization loss chosen as a smooth L1 loss is given in Eq. (1). The joint multi-task loss for each ROI is given by the combination of the classification and localization losses as shown in Eq. (2) [41]

$$L_{\text{loc}}(t^u, v) = \sum_{i \in \{x, y, w, h\}} smooth_{L1}(t_i^u - v_i) \quad (1)$$

$$L(p, u, t^u, v) = L_{\text{cls}}(p, u) + \lambda [u \geq 1] L_{\text{loc}}(t^u, v) \quad (2)$$

where L_{cls} is the classification loss and L_{loc} is the localization loss, λ is the weight coefficient to balance these two losses. Pseudocode of the framework is given below:

Pseudocode of the proposed model for *E. coli* detection

```
Start Tensorflow (tf) session
Input tensor: image
Output tensors: detection boxes, scores, masks and classes
Initial target bounding box b = [x,y,w,h]
for n= 1:number of images
    if the frame i>1
        search b to the image by rotating
        if detection masks = True
            extract slices from detection masks and boxes
            reframe detection masks
            remove dimensions of size 1 from detection boxes and masks
            add batch dimension
        end
        run tf session to create output tensors
    end
    find maximum similarity class on tensors
    visualize detection boxes, classes, and scores on image
end
```

Learning rate was selected at 0.001 and after 25K iterations, another 25K iterations were run with the learning rate of 0.0001. With these adjusted parameters, the algorithm took about 1.2 seconds to train and process images for each iteration.

3 RESULTS AND DISCUSSION

As explained in section 2.1, two set of photographic images, as control (without *E. coli*) and experimental (with *E. coli*), were taken using the imaging setup. All these images were then pre-processed, leaving only the petri dish in the image. Details of this pre-processing are given in [43]. Fig. 6 shows the pre-processed sample images in every 8 hours of a 24 hours experiment with non-*E. coli* contaminated medium. From the figure, it is seen that there is no metallic sheen, but just a little darkening on the surface of the non-bacterial medium in 24 hours.

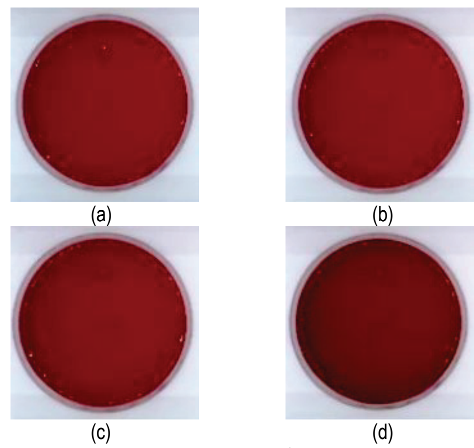


Figure 6 Pre-processed sample images of a non-contaminated medium: a) Initial image, b) After 8 hours, c) After 16 hours, d) After 24 hours

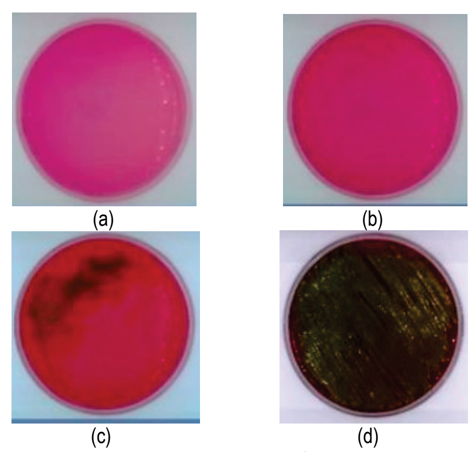
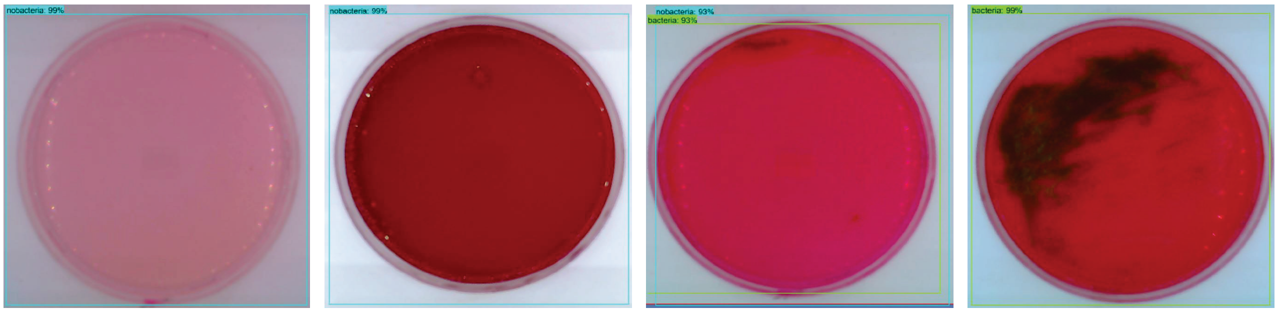


Figure 7 Pre-processed sample images of a contaminated medium: a) Initial image, b) After 8 hours, c) After 16 hours, d) After 24 hours

Fig. 7 shows the sample images in every 8 hours of a 24 hours experiment with *E. coli* sowed on growth culture. In this case, the presence of bacteria causes metallic sheens on the medium and these sheens becomes visible with naked eye after 22 hours, as seen from Fig. 7-d. It is important to note here that, before 22±2 hours, dark green coloration starts but metallic sheens are not visible with naked eye on the surface of the growth cultures.

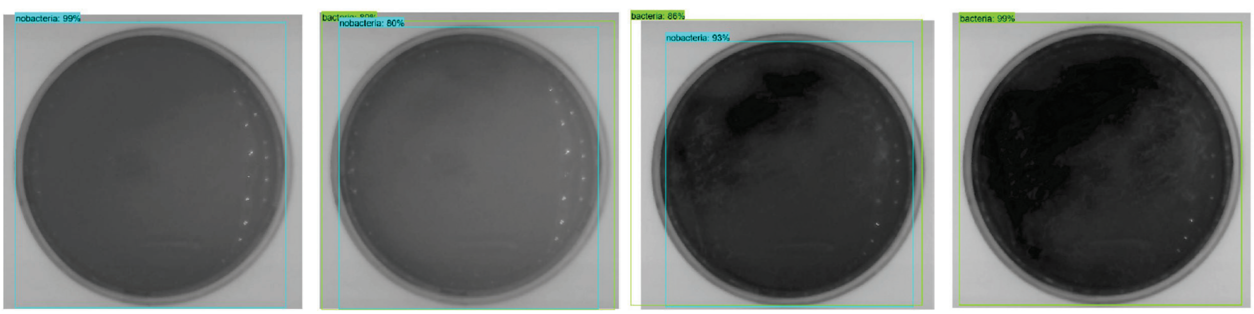
After training the proposed algorithm with 80% of these two sets of images and testing it with the remaining 20% of both image set, some of the obtained results from both non-bacterial and *E. coli* contaminated mediums at different hours from different experiments are given in Fig. 8.



(a) (b) (c) (d)

Figure 8 Result images of the algorithm: a) image from a bacterial medium: initial image, b) image from a non-bacterial medium: After 4 hours, c) image from a bacterial medium: After 8 hours, d) image from a bacterial medium: After 12 hours

As seen from the results in Fig. 8, the proposed model can detect the bacteria at about 8th hour of the experiment, but the probability of the decision is not high enough for an absolute judgement. In order to increase the decision accuracy of the proposed model, a variation in existing image data set was proposed such that, the green layers of the existing RGB images were extracted first and then these layers were saved in grayscale. Green layers of the images were selected since metallic sheens start with dark green coloration at the beginning. After this process, same number of images in two groups constituted the new grayscale image data set for training and testing of the proposed model. Fig. 9 shows the results of the model for this grayscale image data set.



(a) (b) (c) (d)

Figure 9 Result images of the algorithm with grayscale data set: a) image from a bacterial medium: initial image, b) image from a bacterial medium: After 3 hours, c) image from a bacterial medium: After 6 hours, d) image from a bacterial medium: After 9 hours

Table 1 Confusion Matrix after 3, 6 and 9 hours for grayscale images

After 3 hours to 6 hours			
$n = 72$ (no. of images)	**Predicted:** bacterial	**Predicted:** Non-bacterial	**Total**
True: bacterial	8	28	36
True: Non-bacterial	1	35	36
After 6 hours to 9 hours			
$n = 72$ (no. of images)	**Predicted:** bacterial	**Predicted:** Non-bacterial	**Total**
True: bacterial	26	10	36
True: Non-bacterial	2	34	36
After 9 hours			
$n = 360$ (no. of images)	**Predicted:** bacterial	**Predicted:** Non-bacterial	**Total**
True: bacterial	177	3	180
True: Non-bacterial	6	174	180

Here, Fig. 9-a shows the result for an initial image from an *E. coli* contaminated growth culture medium, while Fig. 9-b, 9-c and 9-d show the results of the model for the same medium at 3, 6 and 9 hours, respectively. As seen from the results, decision accuracy was increased with this addition to the algorithm. Furthermore, training of the model with grayscale images was faster compared to training with colored images.

As explained in Section 2.1, a total of 2880 images were captured during ten different measurement durations and 2304 of these images were selected as training and 576 of dataset was used for testing and validation of the algorithm. Half of test images were selected from the non-bacterial medium and the other half were selected from the bacterial medium. Twelve images were selected for every hour over 24 hours for each group. Thus, 576 images of testing dataset were created. Accuracy after 3 to 6 hours, 6 to 9 hours, and after 9 hours was investigated to reveal the success of the algorithm. To see all the values in a tabular form, a confusion matrix was prepared as given in Tab. 1.

In the Tab. 1, detection rate or accuracy was calculated using Eq. (3):

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \tag{3}$$

Here, *TP* is the true positive; correctly predicted bacterial medium events, *TN* is the true negative; correctly predicted non-bacterial medium events, *FP* is the false positive; incorrectly predicted bacterial medium events, and *FN* is the false negative; incorrectly predicted non-bacterial medium events. As seen from the results in Tab. 1, after three hours, the algorithm starts to respond and labels the bacterial medium with the accuracy of ~59%, and after 6 hours, the image detection accuracy increases and labels the medium as ~83% bacterial but *FP* rate is still considerable. After 9 hours, it becomes totally stable and detects the *E. coli* bacteria with the accuracy of ~99%.

Cumulative test results of the algorithm for both colored and grayscale data sets were given in Tab. 2:

Table 2 *E. coli* detection average accuracy (%)

Framework	Coloured data set	Gray-scale data set	Images per batch	Time interval	Accuracy
TensorFlow	Yes	No	1	0-8 hours	~30%
TensorFlow	No	Yes	1	0-8 hours	~50%
TensorFlow	Yes	No	1	After 8 hours	~99%
TensorFlow	No	Yes	1	After 8 hours	~97%

As seen in colored image data set, the algorithm detects *E. coli* bacteria after 8 hours with a 99% accuracy. On the other hand, the algorithm can detect *E. coli* bacteria from gray-scale image data after 9 hours with an accuracy of 99%. But in early phases of bacterial growth, accuracy of detection was higher in gray-scale images compared to the colored data set. In addition to that, the algorithm works faster and computational cost is reduced in grayscale data set. This tradeoff can be evaluated according to the needs of the user.

4 CONCLUSION

E. coli is a lethal for humans. It can mix into the clean water reservoirs such as dam lakes or big water distribution tanks of municipalities and the contaminated water may reach to the end user's taps in a short time. Therefore, *E. coli* bacteria must be detected quickly when they are contaminated to any water source. In order to detect *E. coli*, the most used and the cheapest technique takes approximately 22 ± 2 hours and the results are obtained with naked eye. However, this is too long and during this test, pathogenic bacterial contaminated water can be consumed. In this study, analysis tools, which can automatically perform the bacteria detection process and can give an immediate alarm when the detection provided were proposed. Materials and the method have been tested in different ways using bacterial growth media. When the findings were examined, it was seen that the bacteria detection process can be performed in 8±2 hours. In addition, the proposed method was tested with the growth cultures at room temperature, considering the possibility of not finding the appropriate equipment, such as the incubator, in place of water reservoirs. It is predicted that, if the tests were carried out at 37° C and in an incubator environment with more favorable humidity conditions for bacterial growth, the detection time of bacteria would be further shortened. In future studies, it is planned to establish a mechanism and method that will enable the quick, easy and automatic investigation of bacteriological water examination in real-time applications. The results of this study are promising for these future studies.

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Original scientific paper

Integration of Tactical Aspects into Strategic Production Network Planning

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Abstract: Nowadays, production companies are facing an increasingly volatile environment. Due to increasing globalization, but also de-globalization, taking into consideration an internal production network is becoming more and more important for companies, all in order to be able to counteract in an agile way the uncertainties such as swings in the demand. Current production network planning procedures focus on (re-)locating decisions without delving into what happens inside the plants, neglecting the dynamics of production networks, following a rigid top-down approach during the configuration phase, and they do not integrate the effects of planning tasks at the factory level (tactical and operational planning). In order to be able to make strategic decisions with a well-founded database regarding the production network, the effects on the tactical and operational level must be considered in an iterative way during the strategic decision-making process. The aim of this research is to define the requirements for an approach to strategic production network planning, which considers the effects at the tactical and operational level in an iterative way, and to develop a process model, derived from the requirements, that in its five phases considers the deficiencies of the existing approaches.

Keywords: decision-making; factory planning; production network planning; strategic planning; tactical planning

1 INTRODUCTION

Today's industry is strongly influenced by a globalisation process that has lasted for several years. In recent years, large companies have been expanding their production networks according to strategic market exploitation and cost related decisions [1]. Such decision-making over longer periods leads to historically grown production networks that usually operate at low efficiency levels. Therefore, these networks include a high potential for efficiency improvement potentials, where cost savings of up to 45% can be achieved [2, 3].

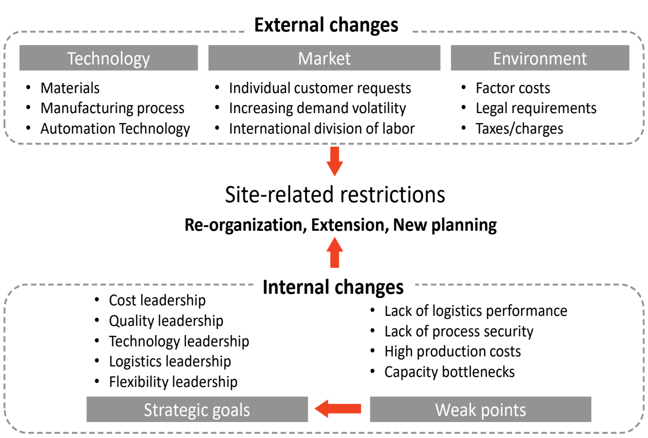

Figure 1 Internal and external change drivers [5]

Because most production networks have grown historically, e.g. through merge and acquisition activities, companies are very susceptible to internal and external uncertainties [1, 3]. Three major change drivers can summarize external uncertainties: (1) technology, (2) market and (3) environment, e.g. tax regulations or factor costs. Furthermore, the so-called black swan events, such as the Covid-19 crisis in 2020, can suddenly occur [4]. Internal changes can occur due to the identification of current challenges of internal processes, as well as due to the changes in strategic goals [5].

After the identification of challenges resulting from external or internal changes, the production network and the factories within this network have to be adapted in order to accordingly keep and/or enhance productivity/efficiency [1]. Re-planning due to the above-mentioned triggers can provide an opportunity for the management to coordinate the factory and network interrelations from a strategic and tactical point of view. The basis is to identify the interactions between the factory and the production network level and to use potentials to achieve a robust and agile overall system to cope with future uncertainties. In practice, the planning and implementation of the changes and the adaption of specific factories are based either on long-term project approaches or on individual, often locally isolated changes or investment decision at the factory level. This current approach involves major challenges of dealing on the one hand with a huge amount of interdependencies in networks, and on the other hand, of having to continuously improve isolated factories and conduct local investments without knowing its impact on the network level [6].

The goal of this research is to develop a proposal for a process model for the planning of production networks by integrating tactical/operational planning into the strategic decision-making process. Therefore, as the first step, an overview of production networks is provided. Afterwards, the problem of decision-making during the configuration process of production networks is discussed in more detail. To complete the planning process sequence on the factory level, goals and tasks of factory planning are briefly discussed upon. Derived from the decision theory, requirements for the configuration of production networks are defined, which are needed to include the tactical/operational view in strategic decision-making. Subsequently, common methods for the configuration of production networks are examined on the basis of a literature analysis and discussed according to the defined requirements for decision-making and the capability for the integration of the tactical/operational factory level in the process. As the last step, a proposal for a process model is outlined, which integrates the tactical/operational view in an iterative manner into the strategic decision-making process during production network planning.

2 CURRENT STATE OF RESEARCH

In this chapter, a classification of different kinds of production networks is given. Subsequently, the challenges occurring during the production network planning procedure are presented, and the requirements according to the decision-making process are defined. The second part describes the goals and tasks of the factory planning process. At the end of this chapter, the derived requirements for a production network planning approach are described.

2.1 Production Network Planning

Production networks are networks in a corporate environment which are connected through the production of products and services by using specific resources and competencies of the partners involved [7]. Production networks (level 1) are characterized by relationships in terms of performance and supply between different production locations of a company [8]. The linked site location (level 2) describes the geographical distribution of a company's production sites, including the long-term allocation of services and resources or operating equipment to these sites [9]. On closer examination, the term linked site location can be used as a synonym for the term production network, as large overlaps become apparent [10].

According to Rudberg and Olhager, a network can be structured from the perspective of supply chain management and production management. From the supply chain management's point of view, the focus is on the structure of sites owned by different organizations. From the point of view of the production management, mainly internal networks are considered, which are completely owned by a company [11].

For the classification and differentiation of both points of views on production networks, the two dimensions of "number of organisations in the network" and "number of sites per organisation" can be used (see Fig. 2) [11].

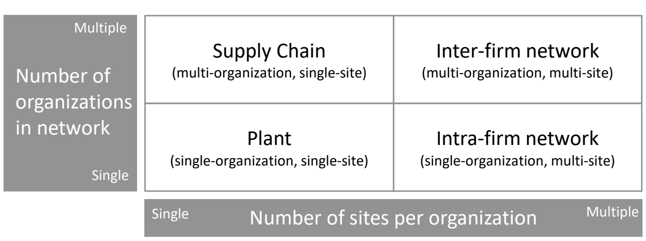

Figure 2 Classification of networks [11]

As it has already been mentioned, linked sites represent a production network. The spatial view of a company can be, according to Wiendahl, divided into six levels [5] (see Fig. 3): production network (level 1), linked site location (level 2), general structure (level 3), buildings (level 4), work areas (level 5) and work station (level 6). According to WIENDAHL, the planning of a production network and site location is a strategic task. Strategic planning covers a long-term period of several years and is carried out by the upper management of companies. Tactical and operational planning, on the other hand, have a lower period and they focus on the lower planning levels, from general structural planning to the planning of buildings, areas and workplaces, and they are assigned to factory planning tasks. [12]

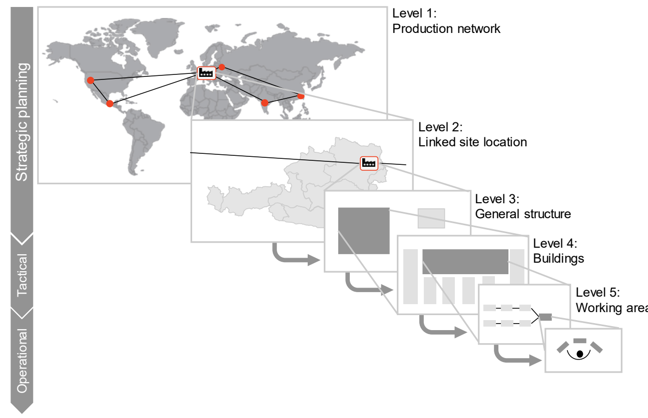

Figure 3 Spatical view of a company [5]

Strategic planning (level 1 and level 2) deals with long-term behavioural principles or measures to achieve long-term goals and is triggered by the corporate strategy [13]. The production strategy is to be understood as a part of the corporate strategy, which serves to make production decisions in terms of high-level goals [14]. Their formulation defines the objectives in which direction production capabilities should be developed in order to contribute to the competitiveness of the company [15]. Among the most common factors that production should strive for are the factors' cost, quality and delivery reliability. In the context of networks, these can be expanded with the terms flexibility, innovation and speed of delivery. [16] According to PAWELLEK, the production strategy is strongly influenced by external changes. These changes can come from the market, environment or technology [17]. If a company produces at several locations, managers are confronted with three central questions [18]:

- Is the company producing (and sourcing) their products at the right places?
- Does each production site have required resources to do what is expected of it?
- How does the company transfer know-how among production sites and how does it improve their operations?

Confronted with those questions, managers have to make decisions according the production network. In the decision-making theory, the term decision is used more broadly and it includes in general all acts of selecting one of several alternatives of action. [19] There are different types of decisions; but in the business context, strategic, tactical or operational decisions, as well as vary by value-at-stake and frequency decisions are considered as the most important [20]. Depending on how predictable the future is, decisions have to be made under certainty, under risk, and under uncertainty [21].

As it has already been mentioned, production networks are nowadays usually historically grown and are rarely the result of long-term strategic planning [12]. The reason for the lack of strategic orientation of the existing networks is to be found in the deficiencies in network configuration, which result from two main challenges associated with the network planning process. According to Mauerer et al., the process of realignment is complex and politically difficult [22]. SCHUH et al. demonstrated the complexity and size of the solution space, as well as the limited time available for decision-makers for the selection of a network alternative [23]. These two aspects summarize the analytical and procedural complexity during the network configuration process. The analytical complexity describes the factors that determine the logical penetration and evaluation of a production network and the available options for action within the situation. Process complexity, on the other hand, entails challenges in terms of the process steps that are necessary to come up with a decision for an alternative solution that is required within a company. [24]

In the past, many authors developed approaches for the decision-making process. Furthermore, the approaches differ in the number of different phases and common steps in different process can be derived, as shown in Fig. 4. [25]

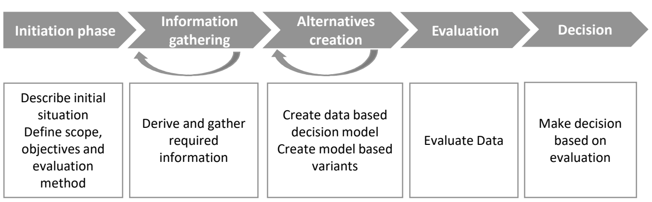

Figure 4 Decision-making process [25]

Many authors add the realisation or implementation as the sixth phase in the decision-making process. It is important to note that the pure sequence of the shown steps does not express a rigid sequence that has to be passed through linearly from the beginning to the end in the decision-making process. If, in the course of problem processing, findings arise that should be taken into account in subtasks that have already been finished, these results should be considered in the sense of a feedback loop in the process [26].

In his research, Ferdows describes one main challenge of current procedures by explaining that in most companies, production network improvements are a result of many individual, incremental decisions which are based on intensive cost-benefit analyses. However, decision makers neglect the holistic, unintended consequences of an incremental improvement decision on a network level. On the other hand, the stronger the focus on an individual decision, the less consideration is given to the effects on the long-term strategy and the overall picture [27].

It can be summarized that production network planning is a complex task, which is triggered by different events. Derived from the goals of the corporate strategy, decision-makers are confronted with multiple alternatives. The limited time available to the decision-makers for the selection of a network alternative results in a poorly founded decision. Furthermore, as external changes constantly occur, the adaption of the production network is an ongoing planning task and an elaborated database should be used in multiple future situations.

As it has already been mentioned, in addition to external change drivers, internal changes can also lead to changes in the strategic goals and trigger a restructuring of the production network and the subsequent tactical and operational planning of tasks at a factory level. The next chapter describes the main goals, tasks and process steps of common planning procedures at the factory level.

2.2 Factory Planning

If the network planning process results in the need for adaptation on the factory level, concrete measures must be developed and evaluated [28]. Various types of factory planning exist in literature, e.g. rescheduling, relocation, adaptation planning or reengineering of factories. The main goal of factory planning is the development of sustainable solution concepts for the future factory. Derived from the main goal mentioned above, the quality of these solution concepts is measured, among other things, by the fulfilment of individual objectives such as profitability, product and process quality, flexibility and adaptability [5].

With the permanent pursuit of these goals, factory planning is assigned a variety of tasks, which generally include both strategic projects (e.g. production planning and technology development strategies), as well as structural (e.g. location/building structure, production organisation) and system projects (e.g. processing/transport systems). In classical factory planning, for example, the first step is to define the goals for the planning procedure, which are usually derived from strategic specifications and requirements. Furthermore, the actual state is then analysed. In subsequent structure planning, the future structure of a factory is to be designed in a way that it fulfils the previously defined strategic objectives. This includes, for example, the dimensioning of the required areas and the planning of the processes (e.g. flow of material and information), which links the individual steps of the value creation process [29].

During the structuring phase, the planned target state is always compared with the actual state, and the need for change is identified. It is not uncommon for adaptation planning to require further investment decisions in order to be able to meet the strategic objectives [6].

A study with industry experts who are holding a management position in the manufacturing industry in Germany pointed out that most investment decisions have been made solely from a local factory perspective, while the impacts on the network have not been considered [30]. CHENG also pointed out that there is still a lack of knowledge about the interactions between the individual plants and the impact of the changes of the processes there on the manufacturing network as a whole [31].

It can be seen in many industrial cases that planning projects not only identify the required adaptions and investments to meet the defined strategic goals, but also expose huge potentials for optimization in terms of resource utilization. This results in more efficient material flows and higher productivity of workers and machine utilizations. With the operational measures such as lean production, process or shop floor redesign potential savings of 10%-20% can be achieved [22].

In classic production network planning projects, decisions for specific goals for factories are a precondition at the starting point. Improvement potentials, which have been identified during the factory planning process, are not taken into account in the decision-making process on the strategic production network level anymore.

2.3 Derived Requirements

From the obtained characteristics of production networks and their planning, and the challenges during the decision-making process and the effects of planning tasks at the factory level, the following requirements for the production network planning process can be derived:

- Target derivation from the corporate strategy,
- Inclusion of multiple alternatives for decision-makers,
- Effort-oriented and practical modelling,
- Integration of the impacts of the tactical/operational planning at the factory level,
- Iterative decision-making,
- Multiple usage by future changes,
- Adjustment to different decision situations.

3 EXISTING MODELS FOR PRODUCTION NETWORK PLANNING

In literature, various methods for the configuration of production networks are available. To structure them, Jacob and Ernst suggested a two-dimensional matrix (see Fig. 5), which clusters the existing models with consideration of the process-related complexity or analytical complexity [12, 32].

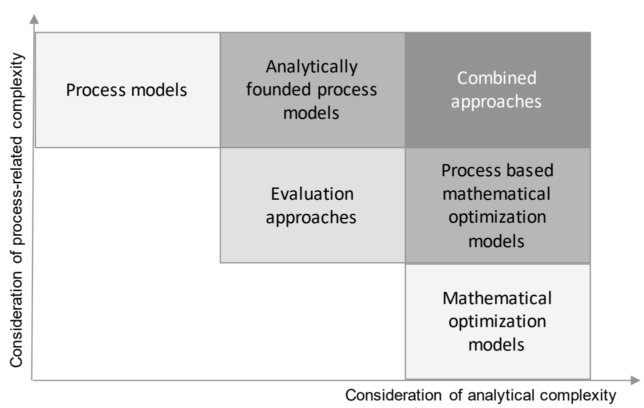

Figure 5 Clustering of the process and analytical models [12, 32]

3.1 Process Models

According to Ernst, process models focus on the one hand on the description of temporal sequences and the explanation of the contents of individual phases, but neglect on the other hand the concrete identification and evaluation of network alternatives [12].

Christodolous et al. developed a process model for the configuration of production networks on the basis of four guiding questions and phases. The first phase deals with the necessity of the adaption of the production network. In the second phase, the topic of the adaptions needed for an excellent market position is defined. Afterwards, the third phase defines the optimal locations for different plants by defining the role and nature of different plants in the network. The last phase covers the topic of how to realize the adaption of the network [33]. One disadvantage of this process model is that it does not answer the question of how to identify attractive network options and alternatives. Furthermore, there is no guidance towards how to define strategic goals [24].

Justus developed a model which consists of five phases. In the first phase, the object under consideration is defined in the form of a product. Subsequently, measures are to be defined in a strategy audit, which contribute to the improvement of strategically important capabilities. The strategy audit is followed by an analysis of the required value-added activities. In the last phase, a network simulation is used to model and visualize complex interrelationships [8]. Disadvantages of this approach are that the output of the strategy audit are not concrete target values on which the development of network alternatives should be based on and that required changes at the plant level are not discussed.

3.2 Mathematical Optimization Models

Mathematical optimization models, which are used to calculate the optimal network configuration while neglecting any process-related requirements, represent the computer-based, analytical models. Due to the frequently omitted practical application of the models, deficits with regard to their suitability for practical use were mentioned in literature. [24]

Lanza & Moser developed a multi-criteria optimization model which includes both the quantitative and qualitative target values. A hybrid approach is used to solve the model by using a reference point and the constraint method. For the consideration of the existing uncertainties in the context of network configuration, consistent future scenarios are determined. The optimization model is solved for each scenario and thus the necessity and the point of time for change under the consideration of multidimensional future uncertainties are defined. [34] The extensive modelling of relevant cost rates and the consideration of quantitative target values and multidimensional uncertainties are the key strengths. [24] One disadvantage of the model is that it seems to be very time demanding during data collection and does not integrate the impacts of tactical/operational planning at the factory level.

3.3 Combined Approaches

Approaches which include a process model and a mathematical optimization model and thus make a contribution to the mastery of both procedural and analytical complexity are called combined approaches [24].

In this model, Meyer introduced four phases which are the identification of the need for action and strategic goals, the modelling of the existing production, development of the strategic network concept, implementation and management of network adaptation [35]. For Meyer, the identification of the need for action is the starting point of network configuration. Five indicators are provided for this. The phase for the modelling of the existing production includes the data collection. For the development of the strategic network concept, Meyer introduces a two-stage procedure. First, a greenfield approach is used to identify an ideal network alternative. The iterative procedure consists of the definition of network alternatives, their discussion and renewed alternative development. To support this task, the optimization model formulated by Meyer with the aim of minimising total landed costs is used. In the second step, the ideal plan of the network structure is developed within the migration planning and adapted to the existing restrictions [35].

Through the gradual development of alternatives with consideration of the newly gained knowledge, Meyer presents an approach that provides iterative data collection, although it is not explicitly mentioned and elaborated in detail [24]. One main disadvantage of the model is that it is not known how the ideal planning is subsequently transferred into the real planning. Furthermore, the generation of multiple action alternatives with consideration of several target values is requested, but not further elaborated. [35] Moreover, the process model does not include the potentials of the current plant situation into the creation of alternatives.

Moser pursues the goal of robust migration paths and risk-efficient converters for production networks in a volatile business environment. The model consists of three phases. The first phase, which is called the configuration phase, consists of the formulation of the global production strategy and the definition of the modelling of network configurations. Based on the prioritization of differentiation factors, strategic network and location capabilities are derived and possible network resources for its realization are modelled. In the optimization phase, the cost-optimal migration strategy is then derived and it determines a robust migration path. For this purpose, a stochastic optimization model is used. Finally, the selection phase serves for the selection of risk-efficient converters with the aim of achieving the optimum level of adaptability for the network resources to be migrated [36].

3.4 Evaluation Approaches

Evaluation approaches belong to the MADM (Multi-attribute Decision Making) field. The decision-making takes place in a discrete solution space between a countable numbers of alternatives [37]. Besides the consideration of process-related aspects, evaluation approaches include detailed analyses of network alternatives, e.g. using model-based simulation approaches instead [24].

Merchiers provides an evaluation support for the design and selection of different site structure approaches. The focus lies on the quantitative evaluation of alternative actions in early phases of site structure planning. The application sets the restriction of an implicit to an explicit solution space. For supporting the solution process, a dynamic profitability calculation is used. With the goal of the cause-related recording of costs and payments, a distinction is made between the module level, site level and network level [38].

The approach of Merchiers offers a comprehensive overview of the relevant cost factors of the configuration of networks in the different areas of the company by dividing it into the module level, site level and network level. In the approach, the analysis does not take into account for example sensitivity or risk assessment to consider existing uncertainties, and nor does it use a multi-criteria target system [24]. The effort for building the cost model is very high and a selection of relevant costs according to the expenditure is not used [39].

The consideration of multidimensional uncertainties in the evaluation of networked production sites form the core of the work of Krebs. While quantitative uncertainties are mapped by using the risk analysis method, qualitative uncertainties are modelled by using the fuzzy set theory. The developed procedure for the evaluation of location alternatives consists of five iterative steps. Only monetary targets of the site selection are considered. All relevant influencing factors and uncertainties as well as their dependencies are to be depicted in a corresponding calculation model. By modelling the individual uncertainties and their dependencies by using the probability theory and the fuzzy evaluation network is then used to generate an uncertainty model set up. The link between the calculation and uncertainty model allows the monetary target value for each alternative to be determined by using the Monte Carlo simulation. For the final phase of the evaluation, various methods for the risk assessment and sensitivity analysis were presented [40]. The evaluation model by Krebs only focuses on the monetary targets of the site selection and it does not derive the targets from the corporate strategy.

3.5 Findings & Conclusion

This chapter summarizes the findings of the literature analysis according to the derived requirements in the chapter before. One goal of this paper is to define the suitable models according to the defined requirements. Therefore, Fig. 6 shows the evaluation of the three introduced focuses of the models. The evaluation of the specific models was described in the previous chapter. As shown in Fig. 6, the mathematical optimization models have major deficits in an iterative process character as they just optimize an existing system to one specific goal. Furthermore, the integration of the impact of tactical/operational planning is not done, as the result of most optimization models is in just one optimal solution and it does not include the required changes on the tactical level. One further big disadvantage of mathematical optimization models is that finding optimal solutions is ambitious for real-life problems due to their complexity. The method can only be applied when the network is well-understood and can be described analytically [41].

Classical process models neglect the concrete determination and evaluation of network alternatives [32].

Additionally, process models overall lack in an iterative character during decision-making, as well as in the multiple usage by future changes.

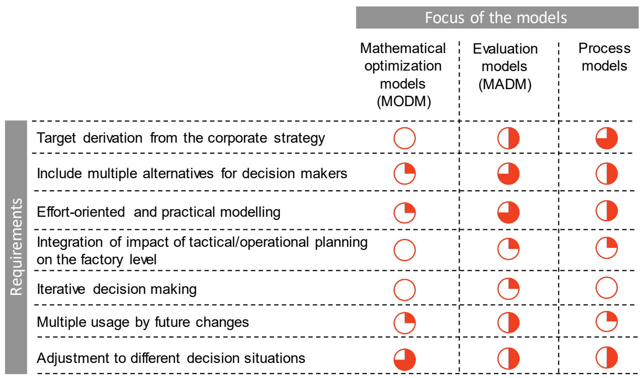

Figure 6 Derived findings from literature

In terms of the effort-oriented and practical modelling and the link to reality, MADM models and process models combined with discrete simulation seem to be a suitable solution for the configuration of production networks in an iterative way. They also include the tactical/operational impacts or potentials into the strategic decision-making process and they do not require such high effort for modelling as it is the case with mathematical optimization models.

Although the existing MADM models already meet certain defined requirements, the analysed models still do not provide the specific tools or process steps in terms of different model adjustments to different decision situations, iterative decision-making and the integration of the impacts of subsequent processes such as the factory planning into the strategic decision-making. To close the gap in literature and to meet the need from the industry, what is required is a process model which focuses on integrating the impact of tactical planning at the factory level into strategic decision-making in an iterative way. Therefore, the following phases are proposed to be included in a model for strategic production network planning: (1) target definition and data collection at the production network level, (2) variant creation for the defined strategic goals, (3) variant analysis and evaluation with simulation models, (4) integration of the tactical/operational view with the results of the factory planning process until a defined process step, and (5) iterative variant creation with a new information base of the pervious step.

4 SUMMARY AND OUTLOOK

In recent years, large and mid-sized companies have expanded their own production network due to strategic decisions regarding market development in emerging markets and cost factors in low-wage countries. These production networks grow historically and contain in most cases huge potential for optimization. Many companies are faced with huge challenges during the planning and structuring phase of production networks due to high task complexity. One main challenge, also described in literature, is the integration of interrelations between the network (strategic level) and the plant level (tactical/operational) during planning. The existing models for production network planning lack in the identified requirements such as integrating the factory level into strategic planning or in the iterative decision-making process. To counteract these challenges, a model with five defined phases was introduced, which integrates tactical impacts in an iterative way and supports managers during the ongoing process of the planning and adaption of production networks, triggered by different changes, and it reduces the risk of wrong decision-making in an effort-oriented and practical way.

Next steps will be a detailed design of the five phases, definition of the performance indicators for the comparison of the different variants and the evaluation of the model within an industrial company in the railway maintenance sector, which owns a historically grown network of over 15 sites.

Notice

The paper will be presented at the MOTSP 2020 – International Conference Management of Technology – Step to Sustainable Production, which will take place from 30th September – 2nd October 2020 in Bol, island Brač (Croatia). The paper will not be published anywhere else.

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Original scientific paper

A Model for the Designing of Multimodal Transport Processes and the Concept of Its Integration with the EPLOS System

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Abstract: The paper proposes a new single criterion mathematical model for the designing of multimodal transport processes by taking into account the cargo's susceptibility and the concept of its inclusion into the EPLOS system, which is done as part of the EUREKA initiative. This system will integrate the data from logistics sources and transport and logistics infrastructure from many sources. In the first phase of its implementation, it will cover the Czech Republic, Poland, and the Baltic States. Using the EPLOS system integrating data from various sources needed to solve this problem is a proposal to overcome the main barrier to the effective planning of multimodal transport processes – a lack of reliable information.

Keywords: designing transport processes; EPLOS; European Portal of Logistics Services; multimodal transport

1 INTRODUCTION

The planning of technological processes in transport, especially when taking into account many of its branches, is a multi-faceted and complex process. It requires comprehensive knowledge of the features of individual transport technologies, as well as the physical configuration options of the supply chain and shipping offers. Thus, the correct implementation of this process is conditioned by the access to a lot of detailed information regarding transport offers, transport infrastructure, and transshipment terminals. An important part of this information is included in the EPLOS system, created as part of the EUREKA initiative. Hence, its use in the planning of multimodal transport processes can significantly simplify this process and, to some extent, automate it. The EPLOS system will integrate the data on logistics companies, as well as transport and logistics infrastructure, from many sources. In the first phase of its implementation, it will cover the Czech Republic, Poland, and the Baltic States.

The issue of modeling the selection of the multimodal transport technology concerning perishable products with particular regard to their transport susceptibility was, in formal terms, first described in scientific articles [1-5][1]. However, in previous years, the issues related to the selection of multimodal transport technologies were considered in partial terms. Namely, some of the authors dealt exclusively with the key transport susceptibility of cargo in this area [7-14], while others, apart from this issue, proposed various approaches to optimizing the supply chain configuration [15-24], or they dealt exclusively with the issue of the selection of the means of transport for tasks [25, 26] or, e.g., optimization of transport routes [27-29].

It is noteworthy that in literature, the modeling of multimodal load-shifting technologies is recognized primarily from the perspective of planning routes for moving material goods and their transshipments between different types of transport (see, e.g. [30] or [31]). In the model proposed in this article, by extending this issue considerably, the focus was also on the selection of freight transport forms and work resources. Additionally, which distinguishes the model presented below, it includes a formalized approach to the mapping of cargo transport susceptibility.

The model described, e.g., in [3], is quite complicated because it includes a significant number of features of perishable loads. The new model offers maximum simplification in this respect, which can be taken into account only in the case of loads sensitive to moisture, solar radiation, and temperature conditions. Some specific conditions necessary for perishable products are omitted here, as well as the issues regarding sensitivity to static and dynamic effects. However, only the costs were taken into account as the evaluation criterion. This model was further simplified by taking into consideration work resources instead of separately analyzing technical measures and employees. At the same time, in the presented model, the issue of the temporal availability of individual work resources was included, which means that it may have significant practical importance. Thus, the article proposes an original single criterion model for designing multimodal transport processes, taking into account the vulnerability of loads, selection of work resources, along with the temporal availability of work resources. Moreover, particular attention was paid to the scope of the required data for this model and references were made to the possibility of obtaining this data from the EPLOS system.

2 A MODEL FOR DESIGNING MULTIMODAL TRANSPORT PROCESSES

In accordance with the previous comments, the following subsections present a single criterion mathematical model for the selection of multimodal technologies for transporting perishable loads sensitive only to moisture, solar radiation,

[1] The simplification of this approach to the issue of the selection of unimodal transport technologies, including the choice of the means of transport and the form of transport loads has been described in the monograph [6].

and/or temperature conditions, taking into account the temporal availability of work resources. The adopted assumptions and elements of the model were characterized, as well as a formal record of decision variables, constraints, and the assessment criterion, which are transport baskets.

2.1 Assumptions and General Form of the Model

The basic assumption is the freedom to choose a transport technology for specific transport tasks, including the ability to choose the work resources with service under each technology. Transport technologies have been defined, taking into account transport forms, performed activities, displacement routes, and work resources with their service. On the other hand, the technological process within the technology was recorded as a series of ordered activities, of which for each is known: the form of the transport of loads, displacement routes and work resources with their service, which may be involved in its implementation.

Transport tasks included in the model relate to the movement of selected products, which may have a number of features determining their transport susceptibility. At the same time, only load features were seen as the most important due to their transport susceptibility and hence were taken into account. For each activity of the technological process, the possibility of choosing different forms of cargo transportation was assumed. The impact of the transport form of loads on their transport susceptibility was also taken into account.

It was also assumed that for each transport form, the number of load units that will fit in is known (equal to 1 in the case of loose cargo). Additionally, for each means of transport, the number of pieces of cargo that will fit in its cargo space when transported is known. This means that the issue of forming load units and planning the distribution of load units in the vehicle's cargo space – such as the problem of allocating employees to devices – has been excluded from this decision problem as a separate optimization issue.

Moreover, it was assumed that the used multimodal transport technologies must guarantee the safety of transported loads, taking into account their transport conditions. On the other hand, the assessment of the selection of multimodal transport technologies is carried out by taking into account the minimization of the costs of moving cargo.

Additionally, it was assumed that the problem of selecting a transport technology for tasks to be carried out within a specified time horizon was considered. As a consequence, individual technical resources, together with human resources, can be allocated in this period to perform only one activity identified in the technological process, and their time availability for individual activities is known due to their current load and location.

Considering the above, the model for selecting multimodal technologies for the transport of perishable products, *MDT*, was formally written as follows:

$$MDT = \langle BF, PF, UF, TF, TM, ZM, O \rangle \tag{1}$$

where:
BF – loads,
PF – form of transport,
UF – work resources and their service,
TF – displacement routes,
TM – multimodal transport technologies,
ZM – transport tasks,
O – organization reflecting the manner of the implementation of transport tasks, including decisions regarding the selection of the transport technology and work resources with employees.

2.2 Model Elements

The loads *BF* were mapped based on a set of their types $\boldsymbol{B} = \{1, ..., b, ..., B\}$ and a set of their characteristics $\boldsymbol{F_B}$:

$$\boldsymbol{F_B} = \{(m_b(b), t_{\min}(b), t_{\max}(b), \Delta t_{dop}(b), ws(b), ww(b)) : b \in \boldsymbol{B}\}$$

where:
$m_b(b)$ – the gross mass of one piece of load or unit package of b^{th} type (for non-unit loads of any small value), kg,
$t_{\min}(b)$ – the lowest permissible temperature for the transport of b^{th} type load, K,
$t_{\max}(b)$ – the highest permissible temperature for the transport of b^{th} type load, K,
$\Delta t_{dop}(b)$ – permissible temperature fluctuations during the transport of b^{th} type load, K,
$ws(b)$ – the sensitivity of b^{th} type load to solar radiation and light,
$ww(b)$ – the sensitivity of b^{th} type load to water.

Similarly, the transport characters *PF* were mapped, taking into account a set of numbers of their types $\boldsymbol{P} = \{1, ..., p, ..., P\}$ and a set of their characteristics $\boldsymbol{F_P}$:

$$\boldsymbol{F_P} = \{(ow(p), os(p), w_t(p), t_{\min p}(p), t_{\max p}(p), \Delta t_{rzp}(p), m_p(p), (N(p,b) : b \in \boldsymbol{B})) : p \in \boldsymbol{P}\}$$

where:
$ow(p)$ – the ability to protect the load against water by the p^{th} form of transport,
$os(p)$ – the ability to protect the load against solar radiation and light by the p^{th} form of transport.
$w_t(p)$ – the ability to change the temperature in the immediate vicinity of the load by the p^{th} form of transport,
$t_{\min p}(p)$ – the min. air temperature in the immediate vicinity of the load for the p^{th} form of transport, K,
$t_{\max p}(p)$ – the max. air temperature in the immediate vicinity of the load for the p^{th} form of transport, K,

$\Delta t_{rzp}(p)$ – the maximum temperature fluctuations in the immediate vicinity of the load for the p^{th} form of transport, K,

$m_p(p)$ – the tare for the load for the p^{th} form of transport, kg,

$N(p,b)$ – the capacity of the p^{th} transport form defined in the number of load units of b^{th} type, pcs.

Moreover, the work resources and their service *UF* were mapped, taking into account a set of numbers of their types $\boldsymbol{U} = \{1,...,u,...,U\}$ and a set of their characteristics $\boldsymbol{F}_U$. However, in this case, the set U was decomposed into a set of numbers of types:

- of means of transport with the service $U1$,
- of loading devices with the service $U2$.

Thus, a set of characteristics of the means of transport with the service $\boldsymbol{F}_{U1}$ and a set of characteristics of loading devices with the service $\boldsymbol{F}_{U2}$ was obtained:

$$\boldsymbol{F}_{U1} = \{(NU(u), t_{\min r}(u), t_{\max r}(u), \Delta t_{rz}(u), v_{sr}(u), ow_u(u), os_u(u), k_{ts}(u), k_{tt}(u), k_{tw}(u), \boldsymbol{UU}(u), \boldsymbol{P}_{U1}(u), (N_p(u,p,b): p \in \boldsymbol{P}_{U1}(u), b \in \boldsymbol{B})) : u \in \boldsymbol{U}1, \boldsymbol{UU}(u) \subseteq \boldsymbol{U}2, \boldsymbol{P}_{U1}(u) \subseteq \boldsymbol{P}\}$$

where:

$NU(u)$ – number of the u^{th} type of the means of transport available with the service, pcs,

$t_{\min r}(u)$ – the minimum air temperature during transport in the cargo space of the means of transport of the u^{th} type, K,

$t_{\max r}(u)$ – the maximum air temperature during transport in the cargo space of the means of transport of the u^{th} type, K,

$\Delta t_{rz}(u)$ – the maximum air temperature fluctuations during transport in the cargo space of the means of transport of the u^{th} type, K,

$v_{sr}(u)$ – the average speed of transport of the means of transport of the u^{th} type, km/h,

$ow_u(u)$ – the possibility of protecting against the direct effects of water on the load by the means of transport of the u^{th} type,

$os_u(u)$ – the ability to provide load protection against light and solar radiation for the means of transport of the u^{th} type,

$k_{ts}(u)$ – the unit cost of operation depending on the mileage for the means of transport of the u^{th} type, PLN/km,

$k_{tt}(u)$ – the unit cost of operation depending on transport time for the means of transport of the u^{th} type, PLN/h,

$k_{tw}(u)$ – unit labor cost dependent on the time of work of all service employees for the means of transport of the u^{th} type, PLN/h,

$\boldsymbol{UU}(u)$ – a set of numbers of the types of loading devices with the service that can be operated by the means of transport of the u^{th} type,

$\boldsymbol{P}_{U1}(u)$ – a set of numbers of the load transport forms served by the means of transport of the u^{th} type,

$N_p(u,p,b)$ – the capacity of the means of transport of the u-th type in the number of units of the p^{th} transport form for the b^{th} type of load, pcs.

$$\boldsymbol{F}_{U2} = \{(F_Q(u), k_j(u), k_w(u), \boldsymbol{P}_{U2}(u), (W(u,p): p \in \boldsymbol{P}_{U2}(u))) : u \in \boldsymbol{U}2, \boldsymbol{P}_{U2}(u) \subseteq \boldsymbol{P}\}$$

where:

$F_Q(u)$ – the load capacity of the u^{th} type loading device, kg,

$k_j(u)$ – the hourly labor cost of the u^{th} type loading device, PLN/h,

$k_w(u)$ – the unit labor cost dependent on the time of work for all employees operating the u^{th} type loading device, PLN/h,

$\boldsymbol{P}_{U2}(u)$ – the set of numbers for the form of cargo transportation supported by the u^{th} type loading device,

$W(u,p)$ – the practical efficiency of the u^{th} type loading device when handling load units in the p^{th} transport form, pcs/h.

The movement routes *TF* in the model were mapped, taking into account the set of their numbers $\boldsymbol{T} = \{1,...,t,...,T\}$ and a set of their characteristics $\boldsymbol{F_T}$:

$$\boldsymbol{F}_T = \{mp(t), mk(t), s(t), \boldsymbol{TU}(t), (t_{dod}(t,u) : u \in \boldsymbol{U}), (k_{dod}(t,u) : u \in \boldsymbol{U}), (t_{dod2}(t,u) : u \in \boldsymbol{U}), (k_{dod2}(t,u) : u \in \boldsymbol{U}) : t \in \boldsymbol{T}, \boldsymbol{TU}(t) \subseteq \boldsymbol{U}\}$$

where:

$mp(t)$ – the starting point of the t^{th} route,

$mk(t)$ – the end point of the t^{th} route,

$s(t)$ – length of the t^{th} route, km,

$\boldsymbol{TU}(t)$ – a set of numbers of the types of work resources together with the service authorized for traffic on the t^{th} route,

$t_{dod}(t,u)$ – the expected time of breaks and stops of the u^{th} type of work for the t^{th} route, h,

$k_{dod}(t,u)$ – the costs of using the infrastructure for the t^{th} route and the u^{th} work resources, PLN,

$t_{dod2}(t,u)$ – the expected working time of the t^{th} route for all employees operating the u^{th} work resources, h,

$k_{dod2}(t,u)$ – additional labor costs for all employees working with the u^{th} type of work equipment during the t^{th} route, PLN.

The multimodal transport technologies TM were mapped, taking into account a set of numbers of their types $\boldsymbol{D} = \{1,..., d,..., D\}$ and a set of technological processes that make up these technologies PT. Additionally, each transport technological process distinguished within the d^{th} type of technology was defined by taking into account the ordered set of activities that create it $\boldsymbol{I}(d) = \{1,..., e,..., E(d)\}$ as follows:

$$PT(d) = \langle (pt_e(d), nt_e(d), tt_e(d), \boldsymbol{UT_e}(d), \mathbf{TD}_{\boldsymbol{e}}(d)) : e \in \boldsymbol{I}(d), \\ pt_e(d) \in \boldsymbol{P}, nt_e(d) \in \{0,1\}, tt_e(d) \in \boldsymbol{T}, \boldsymbol{UT_e}(d) \subseteq \boldsymbol{U} \rangle, d \in \boldsymbol{D}$$

where:

$pt_e(d)$ – the cargo transport form number for the e^{th} activity of the d^{th} technology,

$nt_e(d)$ – the type number of the e^{th} operation of the d^{th} technology, where for loading activities $nt_e(d) = 0$, and for transport activities $nt_e(d) = 1$.

$tt_e(d)$ – the movement route number for the e^{th} activity of the d^{th} technology,

$\boldsymbol{UT_e}(d)$ – a set of numbers of the types of work resources together with the support of technology acceptable for the e^{th} activity of the d^{th} technology,

$\mathbf{TD}_{\boldsymbol{e}}(d)$ – the vector of moment vectors at which subsequent work resources of particular types may be made available, together with the support for the e^{th} activity of the d^{th} transport technology $\mathbf{TD}_{\boldsymbol{e}}(d) = [[td_e(d, u, nu(u)) \in \mathcal{R}^+ : nu(u) = 1, ..., NU(u)], u \in \boldsymbol{U}(z)]$, min.

Whereas the set of numbers of the transport task was defined as $\boldsymbol{Z} = \{1, ..., z, ..., Z\}$, while the z^{th} transport task was defined as follows:

$$ZT(z) = \langle \boldsymbol{B}(z), \mathrm{N}(z), m_p(z), m_d(z), t_p(z), t_d(z), \boldsymbol{P}(z), \boldsymbol{U}(z) \rangle, \\ z \in \boldsymbol{Z}$$

where:

$\boldsymbol{B}(z)$ – a set of load type numbers for the z^{th} transport task,

$\boldsymbol{N}(z)$ – the vector of the number of loads of individual types for the z^{th} transport task, $\mathrm{N}(z) = [n(z, b) : n(z, b) \in \mathcal{R}^+, b \in \boldsymbol{B}(z)]$, pcs,

$m_p(z)$ – the place where the loads are picked up for the z^{th} transport task,

$m_d(z)$ – the place where the loads are picked up for the z^{th} transport task,

$t_p(z)$ – earliest pickup time for the z^{th} transport task,

$t_d(z)$ – the latest delivery of goods for the z^{th} transport task,

$\boldsymbol{P}(z)$ – a set of numbers of the transport form types possible to use for the z^{th} transport task,

$\boldsymbol{U}(z)$ – a set of numbers of the types of work resources together with the service that can be used to carry out the z^{th} transport task.

Considering the above, a set of numbers of types of multimodal transport technologies, which can be used to implement the z^{th} transport task, was defined as follows:

$$\boldsymbol{D}(z) = \{d : \forall e \in \boldsymbol{I}(d) \ ((pt_e(d) \in \boldsymbol{P}(z)) \wedge (tt_{e=1}(d)) = m_p(z)) \\ \wedge (tt_{e=E(d)}(d)) = m_d(z)) \wedge (\boldsymbol{UT_e}(d) \cap \boldsymbol{U}(z) \neq \varnothing)\}, z \in \boldsymbol{Z}$$

2.3 Decision Variables

The model includes the following four types of decision variables:

- a binary decision variable $x(z, d) \in \{0,1\}$ that assumes a value of 1 when the z^{th} transport task is to be performed according to the d-type technology and 0 in the opposite case,
- an integer decision variable $y(z, d, e, u) \in \mathcal{N} \cup \{0\}$ for the interpretation of the number of u^{th} work resources together with the service that should be used to perform the e^{th} action distinguished in the d^{th} technology during the implementation of the z^{th} transport task,
- a binary decision variable $z(z, d, e, u, nu(u)) \in \{0,1\}$ that assumes a value of 1 when the $nu(u)^{th}$ mode of transport of the u^{th} type along with the service should be used to perform the e^{th} action distinguished in the d^{th} technology during the implementation of the z^{th} transport task and 0 otherwise,
- the decision variable $\tau(z, d, e)$ with the interpretation of the moment of commencement of the e-action in connection with the implementation of the z^{th} transport task according to the d-type technology.

In accordance with the above, the next of the considered decision variables relate to the selection of a transport technology for tasks, the selection of work resources with service for the implementation of individual activities under the given technologies, and the moment of commencing the implementation of subsequent activities.

2.4 Constraints

The constraints included in the model result from the characteristics considered to be significant, i.e. load characteristics, characteristics of loading forms, and means of transport, as well as from the characteristics of multimodal transport technologies themselves. It was assumed that the implementation of tasks should be ensured by selecting technologies for them (1), while for the activities included in the selected technologies, it is necessary to choose work resources with service (2) and (3). It is also necessary to take into account the constraints resulting from the available number of these work resources (4). Additionally, the requirements regarding the transport temperature (5)-(7), as well as the protection of the load against the adverse effects of water (8) and solar radiation and light (9), were taken into account. The following constraint includes the possibility of cooperation of the means of transport with the loading devices (10) and (11), as well as the possibility of handling the selected forms of transport by the chosen means of transport (12) and (13), the possibility of using them to perform specific tasks (14), the selection for individual technological activities (15) and their movement on individual routes (16), or admissibility of a selection of individual technologies for the considered transport tasks (17). The conditions resulting from the permissible loading of loading devices (18) are also important. The last of the constraints result from the temporary availability of work resources for the implementation of tasks and the earliest start and end moments of completion of individual tasks (19)-(22), and from the unambiguous allocation of subsequent work resources of individual types (23).

$$\forall z \in \boldsymbol{Z} \quad \sum_{d \in \boldsymbol{D}(z)} x(z,d) = 1 \tag{1}$$

$$\forall z \in \boldsymbol{Z} \quad \forall d \in \boldsymbol{D}(z) \quad \forall e \in \boldsymbol{I}(d): nt_e(d) = 0 \quad \sum_{u \in \boldsymbol{UT_e}(d) \cap \boldsymbol{U}(z) \cap \boldsymbol{U}2 \,:\, pt_e(d) \in \boldsymbol{P}_{U2}(u)} \sum y(z,d,e,u) \geq x(z,d) \tag{2}$$

$$\forall z \in \boldsymbol{Z} \ \forall d \in \boldsymbol{D}(z) \ \forall e \in \boldsymbol{I}(d): nt_e(d) = 1 \ x(z,d) \leq \sum_{\substack{u \in \boldsymbol{UT_e}(d) \cap \boldsymbol{U}(z) \cap \boldsymbol{U}1: \\ pt_e(d) \in \boldsymbol{P}_{U1}(u)}} y(z,d,e,u) \cdot \sum_{b \in \boldsymbol{B}(z)} \frac{N_p(u, pt_e(d), b)}{n(z,b)} \tag{3}$$

$$\forall u \in \boldsymbol{U}1 \quad \sum_{z \in \boldsymbol{Z}} \sum_{d \in \boldsymbol{D}(z)} \sum_{e \in \boldsymbol{I}(d): u \in \boldsymbol{UT_e}(d)} y(z,d,e,u) \leq NU(u) \tag{4}$$

$$\forall z \in \boldsymbol{Z} \ \forall d \in \boldsymbol{D}(z) \ \forall e \in \boldsymbol{I}(d): nt_e(d) = 1 \ \forall u \in \boldsymbol{U}1 \quad t_{\min r}(u) \cdot [1 - w_t(pt_e(d))] + t_{\min p}(pt_e(d)) \cdot w_t(pt_e(d)) > \operatorname{sgn}\left(y(z,d,e,u)\right) \cdot \max_{b \in \boldsymbol{B}(z)} \{t_{\min}(b)\} \tag{5}$$

$$\forall z \in \boldsymbol{Z} \ \forall d \in \boldsymbol{D}(z) \ \forall e \in \boldsymbol{I}(d): nt_e(d) = 1 \ \forall u \in \boldsymbol{U}1 \quad \operatorname{sgn}\left(y(z,d,e,u)\right) \cdot [t_{\max r}(u) \cdot [1 - w_t(pt_e(d))] + t_{\max p}(pt_e(d)) \cdot w_t(pt_e(d)] \leq \min_{b \in \boldsymbol{B}(z)} \{t_{\max}(b)\} \tag{6}$$

$$\forall z \in \boldsymbol{Z} \ \forall d \in \boldsymbol{D}(z) \ \forall e \in \boldsymbol{I}(d): nt_e(d) = 1 \ \forall u \in \boldsymbol{U}1 \quad \operatorname{sgn}\left(y(z,d,e,u)\right) \cdot [\Delta t_{rz}(u) \cdot [1 - w_t(pt_e(d))] + \Delta t_{rzp}(pt_e(d)) \cdot w_t(pt_e(d)] \leq \min_{b \in \boldsymbol{B}(z)} \{\Delta t_{dop}(b)\} \tag{7}$$

$$\forall z \in \boldsymbol{Z} \ \forall d \in \boldsymbol{D}(z) \ \forall e \in \boldsymbol{I}(d): nt_e(d) = 1 \ \forall u \in \boldsymbol{U}1 \quad \max_{b \in \boldsymbol{B}(z)} \{ww(b)\} \cdot \operatorname{sgn}\left(y(z,d,e,u)\right) = \max\{ow(pt_e(d)); ow_u(u)\} \tag{8}$$

$$\forall z \in \boldsymbol{Z} \ \forall d \in \boldsymbol{D}(z) \ \forall e \in \boldsymbol{I}(d): nt_e(d) = 1 \ \forall u \in \boldsymbol{U}1 \quad \max_{b \in \boldsymbol{B}(z)} \{ws(b)\} \cdot \operatorname{sgn}\left(y(z,d,e,u)\right) \leq \max\{os(pt_e(d)); os_u(u)\} \tag{9}$$

$$\forall z \in \boldsymbol{Z} \ \forall d \in \boldsymbol{D}(z) \ \forall e \in \boldsymbol{I}(d): nt_e(d) = 1 \ \forall u \in \boldsymbol{U}1 \cap \boldsymbol{U}(z) \cap \boldsymbol{UT_e}(d) \quad NU(u) \cdot \sum_{u' \in \boldsymbol{U}2 \cap \boldsymbol{U}(z) \cap \boldsymbol{UT_{e-1}}(d) \cap \boldsymbol{UU}(u)} y(z,d,e-1,u') \geq y(z,d,e,u) \tag{10}$$

$$\forall z \in \boldsymbol{Z} \ \forall d \in \boldsymbol{D}(z) \ \forall e \in \boldsymbol{I}(d): nt_e(d) = 1 \ \forall u \in \boldsymbol{U}1 \cap \boldsymbol{U}(z) \cap \boldsymbol{UT_e}(d) \quad NU(u) \cdot \sum_{u' \in \boldsymbol{U}2 \cap \boldsymbol{U}(z) \cap \boldsymbol{UT_{e+1}}(d) \cap \boldsymbol{UU}(u)} y(z,d,e+1,u') \geq y(z,d,e,u) \tag{11}$$

$$\forall z \in \boldsymbol{Z} \ \forall d \in \boldsymbol{D}(z) \ \forall e \in \boldsymbol{I}(d): nt_e(d) = 0 \ \forall u \in \boldsymbol{U}2: pt_e(d) \notin \boldsymbol{P}_{U2}(u) \quad y(z,d,e,u) = 0 \tag{12}$$

$$\forall z \in \boldsymbol{Z} \ \forall d \in \boldsymbol{D}(z) \ \forall e \in \boldsymbol{I}(d): nt_e(d) = 1 \ \forall u \in \boldsymbol{U}1: pt_e(d) \notin \boldsymbol{P}_{U1}(u) \quad y(z,d,e,u) = 0 \tag{13}$$

$$\forall z \in \boldsymbol{Z} \ \forall d \in \boldsymbol{D}(z) \ \forall e \in \boldsymbol{I}(d) \ \forall u \notin \boldsymbol{U}(z) \quad y(z,d,e,u) = 0 \tag{14}$$

$$\forall z \in \boldsymbol{Z} \ \forall d \in \boldsymbol{D}(z) \ \forall e \in \boldsymbol{I}(d) \ \forall u \notin \boldsymbol{UT_e}(d) \quad y(z,d,e,u) = 0 \tag{15}$$

$$\forall z \in \boldsymbol{Z} \ \forall d \in \boldsymbol{D}(z) \ \forall e \in \boldsymbol{I}(d) \ \forall u \notin \boldsymbol{TU}(tt_e(d)) \quad y(z,d,e,u) = 0 \tag{16}$$

$$\forall z \in \boldsymbol{Z} \ \forall d \notin \boldsymbol{D}(z) \quad x(z,d) = 0 \tag{17}$$

$$\forall z \in \boldsymbol{Z} \ \forall b \in \boldsymbol{B}(z) \ \forall d \in \boldsymbol{D}(z) \ \forall e \in \boldsymbol{I}(d): nt_e(d) = 0 \ \forall u \in \boldsymbol{U}2 \quad y(z,d,e,u) \cdot \left(m_b(b) \cdot N(pt_e(d),b) + m_p(pt_e(d))\right) \leq F_Q(u) \tag{18}$$

$$\forall z \in \boldsymbol{Z} \ \forall d \in \boldsymbol{D}(z) \ \forall e \in \boldsymbol{I}(d) \ \forall u \in \boldsymbol{U}(z) \cap \boldsymbol{UT_e}(d) \ \forall nu(u) \in \{1,\dots,NU(u)\} \quad td_e(d,u,nu(u)) \cdot z(z,d,e,u,nu(u)) \leq \tau(z,d,e) \tag{19}$$

$$\forall z \in \boldsymbol{Z} \ \forall d \in \boldsymbol{D}(z) \quad t_p(z) \leq \tau(z,d,e=1) \tag{20}$$

$$\forall z \in \boldsymbol{Z} \ \forall d \in \boldsymbol{D}(z) \ \forall e \in \boldsymbol{I}(d) \setminus \{1\} \ \forall u \in \boldsymbol{U}(z) \cap \boldsymbol{UT_e}(d) \ \forall nu(u) \in \{1,\dots,NU(u)\} \quad \tau(z,d,e-1) + \left[nt_{e-1}(d) \cdot \left(\frac{s(tt_{e-1}(d))}{v_{sr}(u)} + t_{dod}(tt_{e-1}(d),u) \right) + \frac{(1 - nt_{e-1}(d))}{W(u, pt_{e-1}(d))} \cdot \sum_{b \in \boldsymbol{B}(z)} \frac{n(z,b)}{N(pt_{e-1}(d),b)} \right] \cdot z(z,d,e-1,u,nu(u)) \leq \tau(z,d,e) \tag{21}$$

$$\forall z \in \boldsymbol{Z} \; \forall d \in \boldsymbol{D}(z) \; \forall u \in \boldsymbol{U}(z) \cap \boldsymbol{UT_e}(d)$$
$$\forall nu(u) \in \{1,..., NU(u)\} \quad t_d(z) \geq \tau(z, d, e = E(d)) + \\ + \left[nt_{e=E(d)}(d) \cdot \left(\frac{s(tt_{e=E(d)}(d))}{v_{sr}(u)} + t_{dod}(tt_{e=E(d)}(d), u) \right) + \\ + \frac{(1 - nt_{e=E(d)}(d))}{W(u, pt_{e=E(d)}(d))} \cdot \sum_{b \in \boldsymbol{B}(z)} \frac{n(z,b)}{N(pt_{e=E(d)}(d), b)} \right] \cdot \\ \cdot z(z, d, e) = E(d), u, nu(u)) \tag{22}$$

$$\forall z \in \boldsymbol{Z} \; \forall d \in \boldsymbol{D}(z) \; \forall e \in \boldsymbol{I}(d) \\ \forall u \in \boldsymbol{U}(z) \cap \boldsymbol{UT_e}(d) \\ \sum_{nu(u)=1}^{NU(u)} z(z, d, e, u, nu(u)) = y(z, d, e, u) \tag{23}$$

2.5 Assessment Criterion

In the model, as the criteria for assessing solutions, the criterion of the total transport costs was included, including the cost of the work of the means of transport and loading equipment, as well as the labor costs of employees servicing them. Formally, this criterion was written as follows:

$$\sum_{z \in \boldsymbol{Z}} \sum_{d \in \boldsymbol{D}(z)} \sum_{e \in \boldsymbol{I}(d)} \sum_{u \in \boldsymbol{UT_e}(d)} y(z, d, e, u) \cdot \left[nt_e(d) \cdot s(tt_e(d)) \cdot \right. \\ \cdot k_{ts}(u) + nt_e(d) \cdot \left[\frac{s(tt_e(d))}{v_{sr}(u)} + t_{dod}(tt_e(d), u) \right] \cdot k_{tt}(u) + \\ + \frac{(1 - nt_e(d)) \cdot k_j(u)}{W(u, pt_e(d))} \cdot \sum_{b \in \boldsymbol{B}(z)} \frac{n(z,b)}{N(pt_{e=E(d)}(d), b)} + \\ + k_{dod}(tt_e(d), u) + \left[nt_e(d) \cdot \frac{s(tt_e(d))}{v_{sr}(u)} + t_{dod2}(tt_e(d), u) \right] \cdot \\ \cdot k_{tw}(u) + \left[\frac{(1 - nt_e(d))}{W(u, pt_e(d))} \cdot \sum_{b \in \boldsymbol{B}(z)} \frac{n(z,b)}{N(pt_{e=E(d)}(d), b)} + \right. \\ \left. \left. + t_{dod2}(tt_e(d), u) \right] \cdot k_w(u) + k_{dod2}(tt_e(d), u) \right] \longrightarrow \min \tag{24}$$

3 THE CONCEPT OF THE INTEGRATION OF THE MODEL FOR THE SELECTION OF MULTIMODAL TRANSPORT TECHNOLOGIES WITH THE EPLOS SYSTEM

In its basic form, the EPLOS system, created as part of the EUREKA initiative, is a database system which integrates, from various sources, information taken into account when making strategic and operational decisions in the area of logistics related to the movement of material goods between economic entities. In the first phase of its implementation, it will cover the Czech Republic, Poland, and the Baltic States. The primary assumed functionality of this tool is to provide information to the TMS class systems and other systems used by individual enterprises (for more detailed characteristics of the EPLOS system, see [30] and [31]). Nevertheless, there is a great potential of the EPLOS tool in terms of their extension with the individual methods of solving decision problems - especially those that are not included in the TMS class systems. One such issue is the selection of multimodal transport technologies for fixed transport tasks.

Assuming that the problem of the selection of multimodal transport technologies is formulated following the model presented in Chapter 2, to solve it, it is justified to use the EPLOS database in the scope of:

- information about the available means of transport (their type, number and supported forms of transport),
- information about the available loading devices (their type, number, capacity, and supported transport forms),
- data on the transport routes for external transport (mileage, length, authorized means of transport, costs of using the infrastructure),
- generating variant solutions for the technological process in transport (searching for transport offers and transshipment options together with the assessment of the availability of the loading equipment and means of transport – the assumed target functionality of the EPLOS system).

The use of the proposed model by using the EPLOS system will, therefore, involve the need to enter additional data regarding:

- cargo characteristics,
- characteristics of transport characters,
- characteristics of the means of transport in terms of guaranteed transport conditions, labor costs, the capacity and the possibility of handling by loading devices,
- characteristics of loading devices in terms of labor costs,
- characteristics of transport routes in internal transport (reloading relations)
- characteristics of the routes of transport in the external transport in terms of the estimated stopping time of the means of transport, the working time of other employees carrying out the movements and their additional labor costs,
- transport tasks.

In the case of extending the functionality of the EPLOS system by planning multimodal transport technologies, it is also possible to include in it a number of catalogs useful in this field, such as the catalog of loads and their characteristics, or the catalog of transport forms. Moreover, it is possible to implement a number of algorithms that estimate the data required to solve the analyzed problem (e.g., characteristics of reloading relations, predicted stoppages of the means of transport, and anticipated times of work of other employees serving them). This approach will minimize the need to manually enter the data that reflects the decision problem in the selection of multimodal load handling technologies.

The described concept of the integration of the model for the selection of multimodal transport technologies with the EPLOS system, taking into account its variant, is schematically presented in Fig. 1.

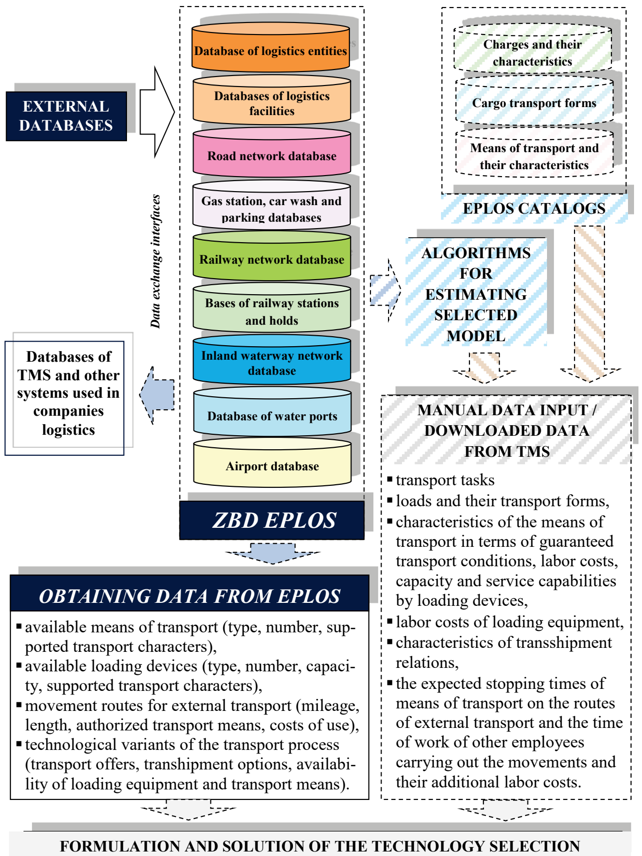

Figure 1 The concept of using the EPLOS system and its development in the selection of multimodal transport technologies

4 CONCLUSIONS

The issue of the selection of multimodal transport technologies analyzed in the article can be considered for a specific company that has a specific transport potential, while the implementation of the agreed transport tasks can be carried out with the involvement of both its own logistics potential, as well as the logistics potential of transport and forwarding companies as well as providing reloading services. Assuming that the transport tasks taken into account may relate to the movement of loads with different characteristics and forms of transport in various relations, the problem of the selection of multimodal transport technologies becomes very complex, and its solutions require a number of data that are subject to constant changes in the market economy conditions. This makes it justified to use the EPLOS system and even its extension with additional functionalities (estimation of some model parameters, catalogs).

At the same time, it should be noted that in real conditions, the selection of the best solution in the field of transport technology is often determined by non-cost criteria, such as transport time and load safety. Importantly, these factors are often taken into account simultaneously. This means that it is justified at the next stage to develop the proposed approach by a multi-criteria assessment method of transport technology variants, including, e.g., the point method or the MAJA method [32-34].

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Preliminary communication

Validation of a Lean Smart Maintenance Maturity Model

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Abstract: Rising complexity in industrial asset and maintenance management due to more volatile business environments and megatrends like Industry 4.0 has led to the need for a new perspective on these management domains. The Lean Smart Maintenance (LSM) philosophy, which focuses on both the efficient (lean) and the learning (smart) organization was introduced during the past few years, and a corresponding maturity model (MM) has been developed to guide organizations on their way to asset and maintenance excellence. This paper discusses use cases, in which the usability and the generic aspect of the LSM MM are validated by using data from three different asset management assessment projects in organizations with different types of production. Research results show that the LSM MM can be used as a basis for management system improvement, independent of production types such as one-of-a-kind industry, mass production and continuous production.

Keywords: asset management; capability maturity model; digitalization; digitization; Industry 4.0; Lean Smart Maintenance (LSM); maintenance; smart factory

1 INTRODUCTION

The volatile market conditions are exerting more and more pressure on companies and the management level, which needs to increase productivity, save resources and improve organizational processes to remain competitive. With increasing automation and digitalization, the focus is placed on asset and maintenance management as an even more significant value-adding function. As a result of this need for management tools to facilitate digitization and digitalization, a variety of maturity models around the topic of Industry 4.0 (I4.0) have been developed and published [1–6]. However, maturity models (MM) that focus on asset and maintenance management are still rare. Therefore, the authors of this paper proposed in a previous publication [7] a generic maturity model which takes a holistic approach on asset management, maintenance processes and organization, and finally I4.0 aspects. Further research questions arose from this previous publication and this paper focuses on answering one of these questions: *Is the new LSM MM generically applicable for different production types?* In this context, the applicability of the LSM MM is validated with project data of previous reorganization projects with differing production types. The paper is structured in a way to create a comprehensive understanding of the authors' approach to transforming the gathered information from existing LSM projects into the LSM MM. In section 2, a summary of the theory of asset and maintenance management, as well as the associated I4.0 aspects, is given. It is followed by an introduction into the LSM MM, which was first published in 2020. Next, the methodological approach is explained in section 3. In section 4, the project data around the business cases which were used to prove the generality of the LSM I4.0 model is presented. Section 5 takes a look at the maturities of the companies based on the new LSM MM. Finally, a critical reflection of the results is performed, and further steps of investigation and development are presented.

2 THEORETICAL BACKGROUND

This section takes a look at the theoretical background around the terms Industry 4.0, asset and maintenance management and finally, the Lean Smart Maintenance maturity model.

2.1 Industry 4.0

In 2011, the term 'Industry 4.0' (or Industrie 4.0) was introduced by the German government, and thus laid the cornerstones of the current industrial orientation, not only in Europe, but also in the rest of the world. The concept of I4.0 is mainly known in Europe, but 'Industrial Internet' [8] 'Smart Industry' or 'Smart Manufacturing' [9–12] are only a few examples of comparable industry concepts. Industries – from steel to automobile manufacturing – are inspired by the concepts of collaborating machines and factories, connected suppliers and manufacturer, and I4.0 enablers, such as the Internet of Things (IoT), cloud computing, Internet of Everything (IoE), additive manufacturing, hyper-automation, etc. [13, 14]. The deployment of IoE is the final step in connecting not only machines and server with each other, but also in creating an interconnection between processes, data, things and people, resulting in generating more value out of existing configurations [15]. This interconnection is only possible by the increase of processor performance, data storage availability and the increasing data transfer capacity. With the growing number of sensors and connections, the amount of data to be processed increases enormously. [16] This available data enables optimization of processes, reduces costs, increases efficiency, and enhances interoperability between different organizational units [17].

2.2 Maintenance & Asset Management

According to DIN EN 13306, *"maintenance is the combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in or restore it to, a state in which it can perform the required function"* [18]. Asset management (AM) takes a more holistic approach [19], as it *"involves the balancing of costs, opportunities and risks against the desired performance of assets, to achieve the organisational objectives"* [20]. Asset management is based on a set of four fundamental principles: assets provide value to an organization and its stakeholders; asset management is aligned to the organizational objectives; leadership and organizational culture are the basis for value creation; and, the goal of AM is to assure that assets will fulfil their required purpose [20]. In practice, the terms maintenance management and AM are often used interchangeably. However, the authors of this paper see maintenance management as a function of AM and also use AM, as defined above, as the basis for the model presented in section 2.3.

2.3 Lean Smart Maintenance Maturity Model

LSM is a holistic management concept used to meet the highest reliability and availability requirements for critical plant components as well as minimize losses [21]. The smart perspective of the approach encompasses all those management aspects which drive the effectiveness part of LSM, with a focus on continuous improvement, a dynamic strategy adaption and a learning maintenance management. Output control replaces the cost-oriented input control. The lean perspective looks at the aspects relevant for an efficient asset and maintenance management system and focuses on the reduction on the input side of the management system, with resource conservation as a central pillar for a sustainable orientation. [22, 23]

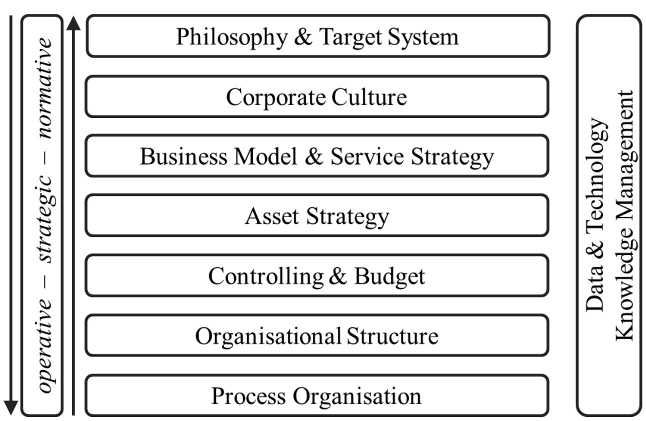

Figure 1 LSM MM categories, modified after [9]

Based on this LSM concept and selected aspects of I4.0, an LSM MM, was developed. MMs can be defined as artefacts with elements that are arranged in an evolutionary scale with measurable transitions from one level to another and which are used for benchmarking, self-assessment and continuous improvement [7, 22, 24, 25]. The main LSM MM categories, spanning from normative to operative management, are represented in Fig. 1 [7]. The category 'Philosophy & Target System' includes all those aspects that provide employees with the basic direction for their behaviour, like a vision, mission statement and the overall maintenance and asset goals.

Table 1 MM categories and corresponding sub-categories

Category	Sub Category
Philosophy & Target System	Corporate Philosophy Vision & Mission; Target System
Corporate Culture	Culture; Employee Motivation; Leadership; Change Management; Communication and Coordination; Digital Competence
Business Model & Service Strategy	Maintenance Services/Stakeholder; Context; Connection/Remote Services Coordination
Asset Strategy	Maintenance Strategy; Life Cycle Management Outsourcing Strategy; Spare Parts Management
Controlling & Budget	Budgeting Process Cost Allocation Controlling System Performance Indicators
Organizational Structure	Structuring; Workshops; Decentralization Autonomous Maintenance; Integration into the Organization; Optimization of the Structure
Process Organization	Process Management; Planning; Process Control; Execution; Weak Pont Analysis; Process Efficiency; Asset Monitoring; Use of Technology in Process Organization
Knowledge Management	Qualification Management Apprenticeship & Trainings Knowledge Coordination
Data & Technology	General IT System; Data Storage/Transfer Data Acquisition; Data Security/Access; Digital Representation; Visualization/Analysis; Assistance Systems/I4.0 Components; Data Integrity; Data Quality

'Corporate Culture' takes a look at aspects around motivation, leadership, change management and communication. The category 'Business Model & Service Strategy' considers new developments and new business models around asset and maintenance management. 'Asset Strategy' encompasses all aspects around maintenance strategy, maintenance prevention, outsourcing and spare parts management. The budgeting and controlling processes are concretized in 'Controlling & Budget'. 'Organizational Structure' focuses on the formal division of job tasks, how they are grouped and coordinated, while 'Process Organization' encompasses planning, information, continuous improvement and weak-point-analysis processes. Planning incorporates internal coordination and scheduling of maintenance tasks. Two categories, 'Data & Technology' and 'Knowledge Management' are treated as further dimensions that affect all maturity categories. The different categories have several sub-categories each, as represented in Tab. 1. [7] Each of these sub-categories includes a few items, or characteristics, which describe the sub-categories in further detail. For each of these items there is one or more interview questions designed to gather the information necessary to describe the organization's maturity. The MM architecture is based on the structure of the capability maturity model integration (CMMI), with its maturity levels from Incomplete to Optimizing [7, 26, 27]. However, it can be characterized as a hybrid MM, as it contains both characteristics of progression- (scaling of characteristics) and capability MMs. Furthermore, it can be described as a prescriptive MM, as it is used as the basis for organizational improvement [7, 24, 28]. Fig. 2 schematically depicts the logic behind the process of finding the maturity of the organization under investigation.

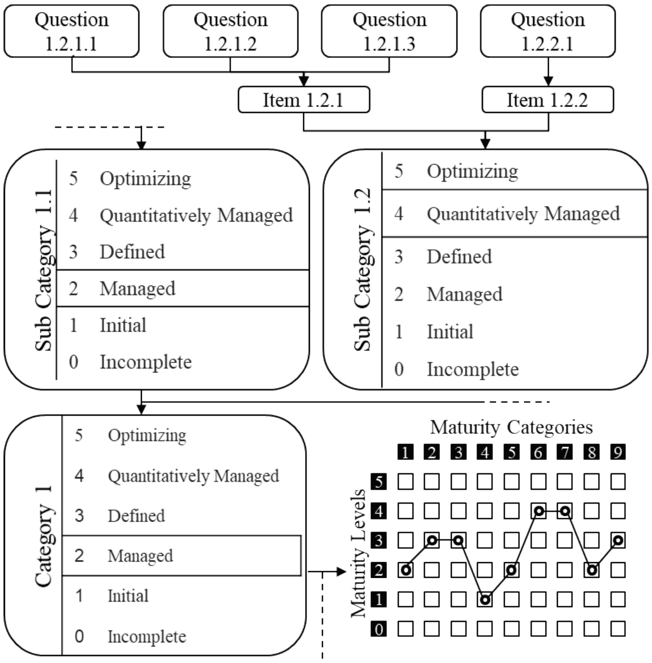

Figure 2 MM logic

As visualized, the questions and their corresponding items lead to the determination of the maturities in the sub-categories while the least mature sub-category defines the maturity of the corresponding category.

3 METHODOLOGY

This paper is set up as validation of the LSM MM with three different use cases. To ensure a scientifically founded methodology, the qualitative case study design after YIN was used. YIN proposed a 5-step model to perform such a study. The phases are as follows: Design, Prepare, Collect, Analyse, and Share the results [29]. Figure 3 shows the individual phases and their interactions with each other.

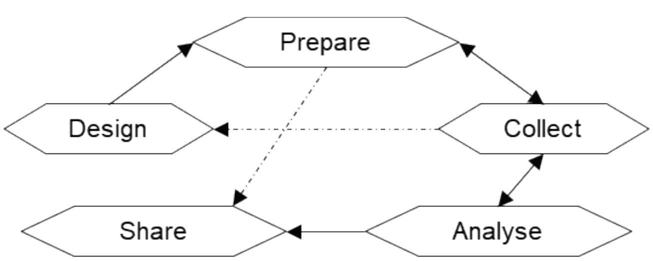

Figure 3 Iterative case study research process, modified after [29]

Case studies are answering research questions in the form of ‘how’ and ‘why’ and focus on modern problems or events. This is only possible if a few crucial components of this research design are considered. The underlying case study’s question, which was stated in section 1 ‘Introduction’, is the essential part with which we begin. The defined research question may not consider all necessary aspects of the case in sufficient detail; therefore, it may be necessary to provide a more precise research question, which can be achieved by introducing propositions. Propositions support the conducting of a case study, by consciously looking at different aspects of the case, in order to avoid misinterpretations through first results.

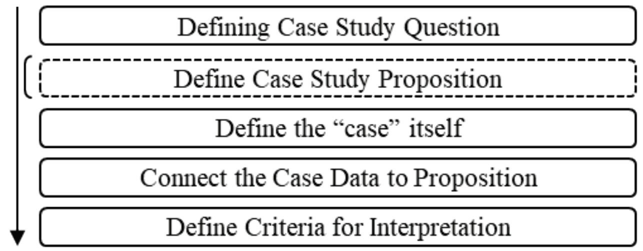

Figure 4 Essential case study design elements; modified after [29]

Nevertheless, it is also possible that a case study is not designed with the definition of propositions. Instead, it can be designed to serve a specific purpose, for example, validate a concept or method with several different cases, and also has to clarify the parameters or criteria of success, by which the success or failure of scientific work should be evaluated. The third phase is to define the ‘case’, which can vary in scope, e.g. small groups, programmes, and entire organisations. By specifying the target of observation, boundaries have to be set. These boundaries can be temporal, spatial or even more detailed, for example, a specific industry sector or size of companies, or even only projects during a certain time. ‘Linking data to the proposition’ is the fourth element which is concerned with analytic techniques as ‘explanation building’, ‘logic models’ or ‘pattern matching’. The final step of the case study design phase is to define criteria of how to interpret the different findings. [29] Fig, 4 illustrates the detailed sequence of the design phase (Fig. 3), which was used as a guideline for this paper.

In the following chapter, the project data are defined, limitations are highlighted, and the structure of the analyses is represented.

4 PROJECT DATA

Based on the case study design research process, the performed assessments of three different projects have been analysed. The assessed company sites are located in Austria and represent production facilities from international companies. These assessments were chosen due to different production types, degree of a concatenation of production, size and structure of the organisations themselves. Due to compliance, the names of the companies were changed to Company A, B and C. For a better understanding of the companies, the different characteristics of each company will be highlighted. Company A is the largest company with about 1400 employees at the production site, followed by Company C and B with 600 and 480 employees respectively. The production types are classified into three different groups after Woodward [30]. The complexity of the production facilities starts from low technical complexity in group 1 up to high technical complexity in group 3. Company A corresponds to group 1 (small batch & unit production), company B can be classified as group 3 member (continuous process production), and company C is part of group 2 (large batch & mass production). As it is seen, due to the different types and complexity of production systems, the companies represent a broad spectrum of the producing industries, and therefore these projects were chosen to prove the generic applicability of the new LSM MM.

Each project intended an increase in efficiency and or effectivity of the maintenance department. Semi-structured interviews were performed with 125 employees, distributed among A, B and C, to generate a comprehensive view of the departments. Employees from all hierarchical levels were questioned. In order not to go beyond the scope of this publication, the following breakdown of the different levels only represents the complete distribution from all interviews. As it is seen in Fig. 5, the main focus of the interviews was on the operative level, to get a deep insight into the working behaviour and methods of each company, followed by interviews with the lower and middle management level which represent 43% of the employees interviewed. The focus of the project with company A was a Total Productive Maintenance (TPM) implementation and first steps towards a digitized maintenance organization. The project with company B had a special focus on communication within the company, especially communication between the functional units of production and maintenance. The third project additionally included basic assessment of production, planning & control and quality assurance. Items around the new category 'Business Model & Service Strategy' were not part of these assessments; therefore, a further discussion of this category is out of scope. Out of the interviews, it was possible to identify the status quo of each maintenance department with the already existing maintenance maturity model modified after Schroeder [5]. In general, the maturities of companies A and B can be described as very similar, while company C has a usually higher maturity in the different categories.

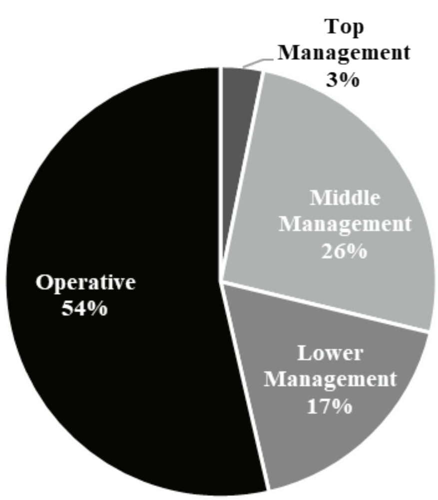

Figure 5 organisational breakdown by organisational hierarchy

The MM structure used in the different projects was slightly different in each case, which emphasises the need for the new, holistic and standardised LSM MM, which was proposed by Schmiedbauer et al. [7].

5 RESULTS

The different organisational setup leads to varying maturity levels for each one of the companies. In order to gain a better understanding of the structure and operation of these enterprises, the following three sections will explain each asset organisation in detail.

5.1 Company A

Company A represents the small-batch & unit production type. As it is seen in Figure 6, Company A, as well as company B and C, had the same level of 'Philosophy & Target System' (Level 2), which, in the case of company A, was attributable to the lack of understanding of the added-value generated by the maintenance department in terms of holistic asset management. A consistent target system was partially implemented, which resulted in varying control options for the different maintenance processes. The missing vision for the maintenance department, which in general should be derived from the company's vision, was the potential to enhance focus and understanding of maintenance as a value provider. On the other side, the higher maturity in 'Organisational Structure' was achieved due to the object-orientation of the maintenance organisation. The object-oriented contact persons of this level correlate directly with level three in 'Knowledge Management', where object-oriented professional development courses are a prerequisite. A closer look at the 'Corporate Culture' showed high potential in creating a structured communication format between shop-floor and management level. The affiliation of the employees with the company was identified as an enabler for the new communication channels.

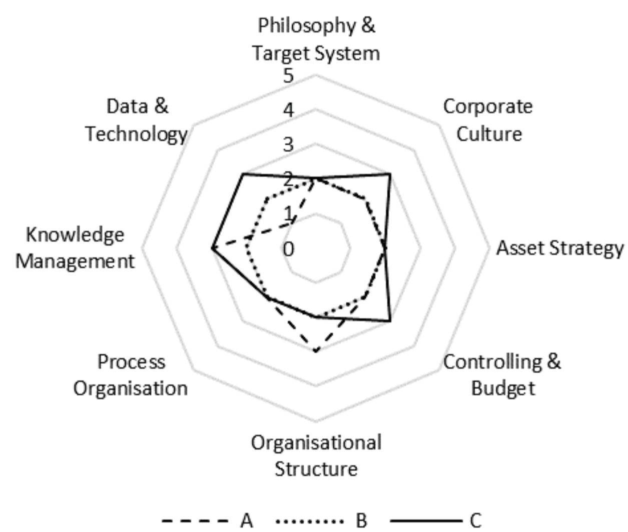

Figure 6 Company maturities in the new LSM MM

The 'Asset Strategy' category was rated with maturity level 2 of 5. This was based mainly on the predominating preventive maintenance strategy, a spare parts warehouse that was complete regarding the inventory, but spread over the whole production site, as well as a not completely defined outsourcing process. Lastly, the category 'Data & Technology' is explained. Company A had the lowest maturity of the three companies regarding data and technology application and standards. The company had no defined strategy regarding data management, which contains defined processes about data storage, handling, pre-processing, and so forth. There were several intersections between the different data systems (SCADA; ERP); therefore, the maturity in the category 'Data & Technology' was 1. With ongoing automation and digitalization, the authors anticipate a high potential for improvement in this category.

5.2 Company B

The case of company B indicates that a high degree of automation in production processes does not have to correlate with high maturity of asset management. Throughout all categories, only a level 2 maturity was reached. Starting from 'Philosophy & Target System', the total asset and maintenance management was only seen as a necessary cost factor, not as a strategic function. The interviews and their unsystematic employee surveys showed that a high number of the workers were unsatisfied, which resulted in a rising fluctuation in this company when compared to the past. Besides, there was no systematic change management. However, a basic but non-transparent bonus scheme had been already implemented. As part of the category 'Asset Strategy', spare parts management software was already implemented, processes for spare parts were well-defined. Nonetheless, there were still unofficial storage sites in some areas. For maintenance prevention, basic processes were defined; however, maintenance was not optimally integrated into the procurement processes. As expected in the highly automated environment of company B, there was a strong focus on preventive maintenance. In some cases, condition monitoring was possible, but usually not used due to a lacking qualification of employees. Maintenance strategies were mainly chosen based on the experience of the management and not by using a systematic approach. In outsourcing, long-term relationships with other companies were established and seen as a strategic factor, but there was a complete lack of a formal outsourcing process. In 'Controlling & Budget' there was a strong focus on cost-oriented performance indicators. Aside from cost-oriented Key Performance Indicators (KPIs), the overall equipment effectiveness (OEE) was used, and there were a number of environmental KPIs, mainly due to compliance reasons. The budgeting process was well-defined, maintenance costs budgeted at the object level and budget deviations analyzed. The 'Organisational Structure' was strictly function oriented, first steps towards autonomous maintenance were taken. The 'Process Organisation' was characterized by non-digital ways of communication and basic capacity planning. There was no knowledge management system implemented; technical training was however available for the employees. Data security protocols were well established, some standard software used, yet many interfaces were problematic, which resulted in, for example, the necessity to export data from SAP and other systems and calculate KPIs in Excel.

5.3 Company C

Of the three cases described, company C has the overall highest maturity in the new LSM MM, with category maturities ranging from 2-3. It had a defined mission and vision for the whole production team, including maintenance, even though maintenance is not explicitly mentioned, meaning that the normative base for the target system is defined. The importance of the maintenance organization was recognized by the management and other employees, and maintenance organization optimization projects had already been carried out in the past. The corporate culture could be summarised by the statement brought forward by almost every employee during the interviews, namely, 'that they cannot really complain about their work.' This indicated a high loyalty towards the company as a whole, which was explained by the fact that the production at this site was almost independent of macroeconomic cycles, leading to secure jobs and for the region relatively high salaries. This, however, led to a low change readiness of the workers. Employee motivation was high and regularly surveyed, and a basic bonus scheme was implemented. The main reason for the low scoring in the category 'Asset Strategy' was the spare parts management. About 20% of the spare parts were mapped in SAP, and the spare parts management processes could be best described as semi-formalized. Spare parts are ordered based on the experience of the maintenance managers. Maintenance prevention was formalized; there was, however, improvement potential concerning life-cycle orientation. In this project, the maintenance strategies were dominated by reactive maintenance. Furthermore, a basic criticality assessment of different assets had already been carried out once, and maintenance strategies were defined for each asset. The company had an implemented controlling system, including a three-level Balanced Scorecard (BSC). Mostly at the shop-floor level, the performance indicator system was intermittent, some KPIs were available for production, but none for the maintenance workers. The whole KPI system was still very new, and deviations of KPIs not always analyzed and measures rarely derived. There was a well-implemented, static budgeting process and costs were allocated at the asset level and all necessary cost categories defined. The organizational structure could be described as very conservative; a strong functional job categorization and practically no autonomous maintenance was present. 'Process Organisation' was characterized by first attempts towards a digital maintenance ordering system. Usually, maintenance times were first recorded on paper and only entered into the system at the end of the week, and there was no structured weak point analysis. There was no structured knowledge management; however, a detailed qualification matrix and a comprehensive training program were available. Most processes around data were well defined; there were regular data quality checks and a responsible data manager. Parallel software solutions were in use, for example production planning in SAP and in Excel, which compromised the quality of the data and the basis for KPIs.

6 DISCUSSION AND OUTLOOK

Ever-increasing complexity and volatility and the developments around I4.0 urge companies to use holistic thinking with respect to asset management. Maintenance departments have the potential to increase their effectiveness and efficiency. To reach higher efficiency and effectivity, the LSM philosophy and the LSM MM were developed. At the beginning of this paper, an introduction on the terms of I4.0, asset and maintenance management as well as in overview of the LSM philosophy and the LSM MM was given. It was followed by the methodological approach used as a basis for this scientific work. To answer the research question: 'Is the new LSM MM generic applicable?', three different reorganization projects were considered and analysed. These companies showed characteristics of different production type classifications (small batch-, continuous and mass production), different organizational structures, and varying employee number in the maintenance and production departments. Resulting from the transfer of the company-specific data into the new LSM MM, it can be stated that company A and B have a similar, and company C a higher overall maturity. The authors have proven the generic applicability of the LSM MM. Next steps for further research are the application of the LSM MM in upcoming reorganization project and a more intensive investigation of the category 'Business & Service Strategy'. Limitations of this work are that only the data from Austrian companies was analyzed and the category 'Business & Service Strategy' has not been applied.

Notice

The paper will be presented at MOTSP 2020 – International Conference Management of Technology – Step to Sustainable Production, which will take place from 30th September – 2nd October 2020 in Bol, island Brač (Croatia). The paper will not be published anywhere else.

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Preliminary communication

Transformation of Cognitive Assistance Systems into Augmented Reality

Matthias Eder*, Atacan Ketenci, Christian Ramsauer

Abstract: The field of Augmented Reality (AR) has received increasing attention in recent years, as AR can be applied to a wide range of problems. The use of AR offers great potential, especially in the industrial sector. Among many applications in this area, one promising application is the augmentation of cognitive assistance systems. Much research has already been done on the development of augmented support systems but it is still lacking on how to transform existing assistance systems into an AR application. This paper focuses on this transformation and presents a process model that intends to support the migration or digitalization of existing support systems into an AR application. An experimental study validates the proposed approach and derives recommendations for action.

Keywords: AR; Augmented Reality; Cognitive Assistance Systems; Support Systems; Worker guidance systems

1 INTRODUCTION

The support of employees has become increasingly important in production operations in recent years. Due to the increasing number of possible product variants, the complexity in production has steadily increased [1]. This increasing complexity represents an additional challenge for those employees who have to assemble this range of variants [2]. In order to handle this challenge, different assistance systems are used, which support the worker during the assembly process [3].

Due to the digitalization of industrial processes, such assistance systems have become more and more relevant in recent years and have thus become an often discussed research topic in the context of the fourth industrial revolution and its challenges [3]. The topic of worker assistance is also becoming increasingly important due to the demographic change and the resulting ageing society in industrial nations [4]. As one category of assistance systems, cognitive assistance systems focus on supporting the employee on the perception and decision level and thus do not aim on relieving the physical strain on a worker [5].

With the ongoing improvements of technologies and the accelerated digitalization of industrial environments, new opportunities for companies to support their employees cognitively are constantly emerging. One of these possibilities is the use of Augmented Reality for information preparation, which has already been validated in numerous studies [6, 7, 8]. However, if companies decide to introduce an augmented assistance system in their production environment, they have to overcome the challenge of transformation. In many cases, companies already have work instructions that guide employees through the production. However, these instructions are often paper-based or, at best, digitally work processes that are displayed on screens. The migration and digitalization of the existing work instructions into an AR system is one of the challenges that must be overcome.

Research still lacks of approaches on how to transform an assistance system which consists of no or basic technology into an AR based assistance system. This paper aims to fill this gap and to present a process model on how to port an existing system into an AR system. An experimental study will validate and substantiate the proposed approach.

The structure of this work is as follows: First, existing literature and related research topics are reviewed. The focus is placed on assistance systems and their categorization, augmented reality for information support and the differences on migration and digitalization of assistance systems. Chapter 3 then presents and discusses the proposed process model for transforming a cognitive assistance system. In Chapter 4, research environment and the concept for the experimental study are presented, before discussing the implementation of the system using the proposed process model.

2 RELATED RESEARCH

This section focuses on summarizing the basics of and existing literature in this research field. First, the categorization of assistance systems is presented. Then related research on augmented reality in production processes is presented and principles for migrating and digitizing systems are covered.

2.1 Assistance Systems

Assistance systems support people preventively and operatively, adapted to their individual needs and specific activities [9]. This represents a promising approach in order to be able to fulfil job requirements for a longer time period. Additionally, they also enable the participation of aging or physically restricted persons in all areas of life [10]. In terms of digitalization, they represent a design principle, which is characterized by the term Industry 4.0 [11]. By using different technologies and adapting them to the individual employee, they contribute a significant added value to digitalization.

In order to understand the variety of assistance systems, a categorization has to be used that distinguishes different systems which assist the worker during the production process. In [12], Sanders presents the basic principles of the information handling process which is followed by the worker when fulfilling a certain task. He categorizes this process into four main steps:

- Discover: Acquiring information from the environment using the human senses,
- Recognize: Receiving the information and perceiving the contents,
- Decision: Using the perceived information to make decisions,
- Act: Executing the decision made by motor coordination.

Stockinger [13] uses the four main steps of a worker's information handling process as basis for the categorization of assistance systems. By assigning them to one of the steps through identification of their primary purpose, they can also be assigned to one of the types presented from Reinhart [14]. According to Reinhart, three types of assistance systems can be identified and used for classification: perceptual assistance, decision assistance and physical assistance. While physical assistance aims at reducing the physical strain on an employee, perception and decision assistance is concerned with the cognitive support of employees [15]. This is also referred to as a cognitive assistance system. Fig. 1 gives a visual overview of the information handling process and the classification of assistance systems.

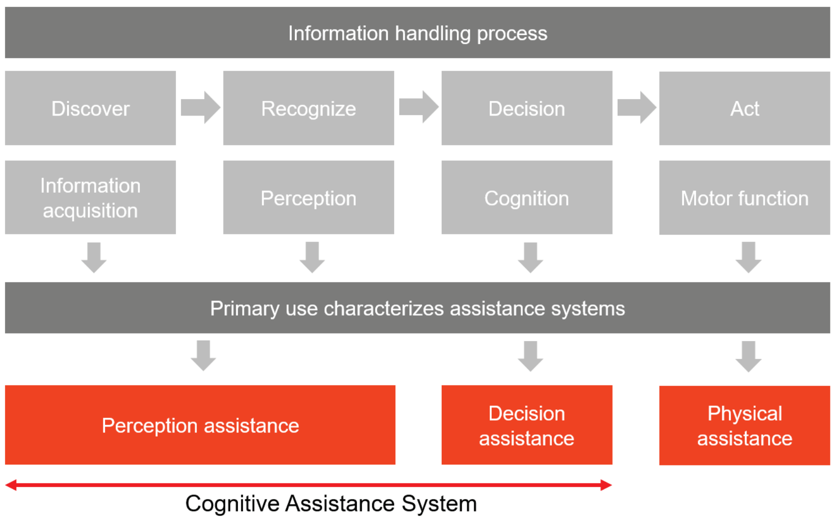

Figure 1 The classification of assistance systems according to Stockinger [13], based on the information handling process of Sanders [12] and the classification of Reinhart [14]

This paper focuses on cognitive assistance systems which are in terms of worker support also called worker guidance systems. Worker guidance systems are defined as cognitive assistance systems that are integrated into the work environment and provide work-related information [16]. This information is provided in a context-related way and, if possible, without additional effort for the employees. Such systems are used in production for various tasks such as assembly of parts or maintenance of machinery. The equipment used to guide the worker through his tasks can be different. Starting from paper-based instructions up to digital instructions on the screen or instructions embedded in the environment, using AR [17].

2.2 Augmented Reality for Worker Guidance

Due to the wide range of possible applications of AR in industrial environments, augmented reality has received growing attention in the research community in the recent years.

One of the possible applications which are researched in industry is the use of AR in the guidance of workers through their work tasks, by embedding the instructions together with virtual objects into the field of sight of the employee [18]. The advantage of AR compared to other forms of work instructions is that it makes it easier for the employee to obtain real time targeted situation-specific information which is directly projected into the working area of the employee, allowing them to see the desired information in the correct place of the workstation [19]. Various studies have already proven an improvement of effectiveness or quality when using AR assistance systems compared to traditional worker guidance systems [6, 7, 8].

When integrating an AR worker guidance system, various technologies can be used. The most common technologies are head mounted displays (HMD), in-situ projection, and handheld devices [20]. Typically, each technology has its strengths and weaknesses which need to be examined when deciding on the best fit for a desired application. HMDs (e.g. Google Glass or Microsoft HoloLens) offer hands-free work and enable good computational performance, but they are also often heavy and not usable over a longer period of time. The in-situ projection has the advantage that no device has to be worn by the worker and the computational performance is open for practically no limit. However, such projections are often hard to setup and can only be used at a specific location. Handheld devices, such as smartphones and tablets, get rid of the disadvantages of the technologies above, but are restricted in terms of hands-free operation.

To evaluate AR applications, studies have distinguished three types of measurements: effectiveness evaluation, usability evaluation and quality evaluation [21]. For these types of evaluation there is a huge diversity in the used methods to assess an AR application and thus various factors that influence the evaluation of a system are still unknown [22]. This leads to different results in studies, depending on the level of complexity of the assembled product, the user interaction methods and the rendering of the instructions that are evaluated. Although various methods on evaluating an AR guidance system exist, the results of the studies cannot be taken as a baseline for comparison. Moreover, when integrating an AR guidance system, the evaluation has to be done individually and cannot be directly assumed by the results of previous studies. By comparing these studies, one can only select the best suited evaluation methods in terms of used hardware and field of application. After selection of the desired methods, the evaluation can be done by comparing the previous worker guidance system with the new system. Evaluation methods for AR systems can be found in various studies such as [22, 23].

2.3 System Transformation

Migration of systems has been a major challenge since the early steps of software development [24]. The task of developing systems in such a way that they are easily extendable, maintainable and changeable is already a focus of various software development methodologies and there is also a separate area of software maintenance that deals with this topic [25, 26]. By definition, migration refers to the transfer of a software system to another target environment. Migrations are purely technical transformations with a clear definition of requirements [27]. Various workflow processes are known for migrating a technical system which is based on software. However, in industry it often occurs that a system which is currently using basic or non-technical solutions should be digitized. This challenge is discussed in various research fields concerning the digitalization process such as [28, 29], but the approach of the projects strongly depends on the object to be digitized and can thus not be generalized. To the knowledge of the authors, there is no such model for digitizing non-technical work instructions into AR. There are several reasons why an existing system should be transformed. The main drivers to migrate or digitize a system are to increase flexibility, efficiency, effectiveness and thus to gain a cost advantage against competitors [30]. Concerning software systems, the need for migration can arise due to the replacement or update of hardware, system software (e.g. operating systems), architecture (e.g. change of programming design for better feature integration or change of programming languages), or because of better features in new systems [27]. Both the digitalization of a process and the process for migrating software are closely related, as presented in the following sections. Therefore, a typical software migration process, as well as a process for digitalization, show similarities in their process models.

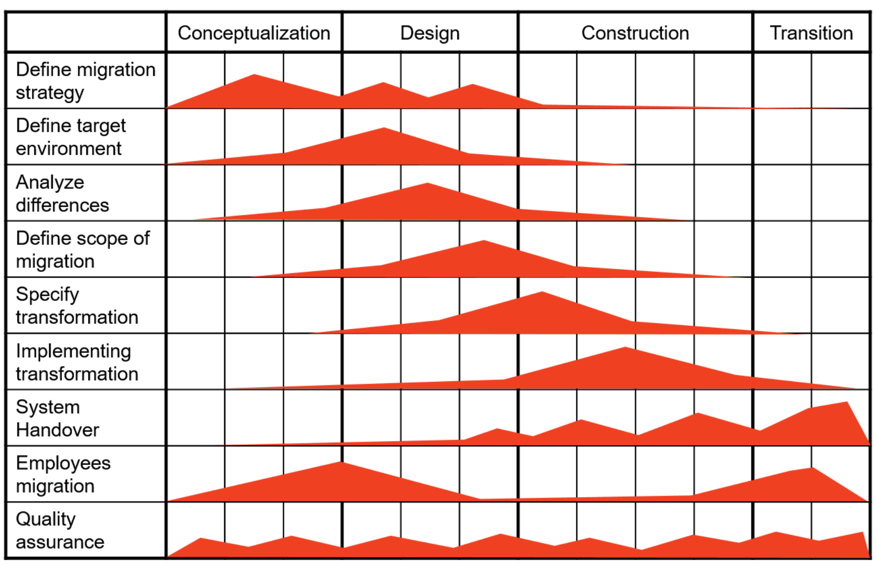

Figure 2 Workflow for the migration of a software system as presented in [27]. Rows indicate the iterative workflow while the columns are different phases during the migration project with different intensities.

2.3.1 Workflow of Software Migration

Reference process models for software migration enable the planned, documented and controlled execution of migration projects [27]. The provision of reference processes is often based on best-practices and enables the targeted development, adaptation and optimization of individual migration processes [31]. Various process models for software migration and their application in practice are presented in [32-34]. These process models follow a common migration workflow which is executed iteratively and with different intensity in the different phases: conceptualization, design, construction and transition. Fig. 2 describes the iterative workflow and the different phases of a typical migration project. The first step is to define the migration strategy, which depends on the design and the quality of the current system. Then, the target environment is to be defined, focusing on hardware, used software, integrated development environment and architecture. Afterwards, the current system is evaluated and differences to the new system are to be set. After setting the scope of the migration project, the desired transformations are specified and implemented. Depending on the selected migration strategy, the handover of the system takes place at once or incrementally. Quality assurance measures for migration ensure that the functional equivalence of the old and target systems is guaranteed throughout the migration process. A more detailed description of the workflow process can be found in [27].

2.3.2 Digitalization Processes

When a cognitive assistance system is not migratable because the current solution has no sufficient technical basis, like for paper-based instructions, the workflow as described in [27] might not be applicable. In this case, the digitalization of the assistance system can be conducted.

When it comes to digitalization of processes or products to solve existing problems or to extend the functionality, one also refers to the term digital transformation [35]. To digitalize a process, the availability of data has to be assured. If non-technical systems are to be digitalized, the analog data first has to be digitized. As a result, a digital transformation for an analog product consists of two different parts: the digitization of the analog data and the digitalization of the product [35-37]. To digitize analog data, a process is proposed by Note [37] which focuses on defining the target environment, selecting and preparing the material for digitization, the actual digitization process, and the delivery of the created collection via a system. During this process, quality assurance is conducted. For the digitalization of the product, a strategy for the digital transformation has to be derived first [38]. The development of the product then follows a typical product development process as described by Cooper in [39]. Cooper describes an improved process model for product development and names seven stages: idea, preliminary assessment, concept, development, testing, trial and launch. In the idea stage, the technological possibilities have to be identified and the idea has to be formulated. In the preliminary assessment, the feasibility and attractiveness of the product are evaluated before a concept is developed in stage III and developed (stage IV). Both testing and trial focus on quality assurance and evaluate the functionality of the product. In the last stage (stage VII), the product is launched and used. [39] gives a more detailed description of the product development process.

3 CONCEPT DESIGN

When it comes to the transformation of cognitive assistance systems into a new technology, such as AR, a process model for the development of the product needs to be prepared. As seen in the previous section, the preferred process model to use depends on the assistance system in use. If no or non-technical worker guidance systems are currently used in production, a digitalization process has to be followed, whereas a migration workflow model could be used to for existing technical solutions. Due to the similarity of both process models presented above, this section presents a unified process model for the transformation of cognitive assistance systems. Furthermore, the focus is placed on the transformation of a worker guidance system into an augmented reality application which supports the worker during his task completion.

3.1 Transformation Process Model for Cognitive Assistance Systems

In this section, a process model for the transformation of cognitive assistance systems into AR is proposed. Therefore, the process models for migrating a technical system [27] and the digitalization process which follows the product development process [39] are combined into one unified process model which ensures a transformability which is independent of the technical characteristics of the existing solution.

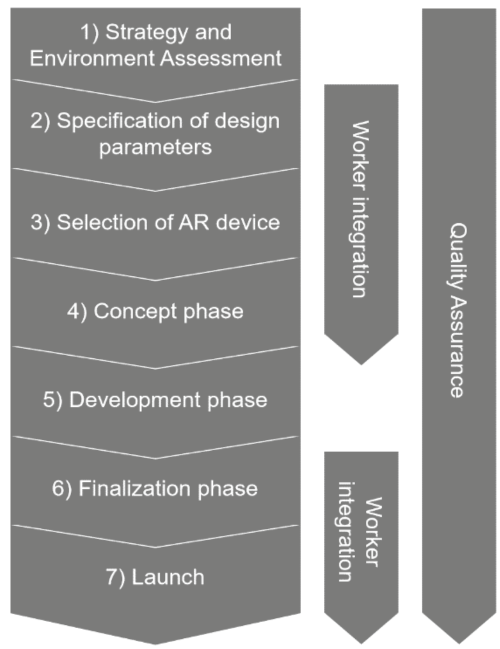

Figure 3 The proposed process model for transforming a cognitive assistance system into AR

Fig. 3 shows the proposed process model for this task. In the beginning, the strategy for the transformation of the cognitive assistance system has to be specified together with the definition of the environment in which the application should be transformed. For the development of a suitable process model, the design fields and parameters of the old and new cognitive assistance system have to be determined. Then, following the requirements for industrial AR applications and analyzing the existing AR technologies, a suitable medium can be selected. In the concept phase, the application is planned based on the preselected parameters before it is developed. At the end of the development phase, a finalization phase is included; it tests the application before launching it in production. The workers who are going to use the worker guidance system should be involved during the specification of the parameters, the concept design, as well as for the final testing before the launch (steps 2-4,6,7).

Besides that, quality assurance should be conducted in all phases to ensure an optimal outcome. In the next sections, the phases of the process model are explained in more detail.

3.2 Strategy and Environment Assessment

The first step is based on the first two phases of the migration workflow, as well as the strategy derivation for the digitalization process. Hence, the desired quality of the new assistance system has to be determined, the budget has to be planned and the decision regarding the transformation mode has to be made: In this phase, it has to be decided how deep the worker who uses the new system should be involved. In principal, workers should be included in phases 2-4 and 6-7 to ensure an optimal outcome. However, the intensity on how much they should be integrated is to be specified firstly. The second part of this phase is to assess the target environment. Therefore, an ergonomic assessment of the work environment should be conducted to identify possible influences on an AR worker guidance system [40]. Possible influences are lighting of the workplace, glare, interactions with other workers/vehicles in the environment and possible safety risks arising from the use of AR devices (for example, due to the restricted field of vision).

3.3 Specification of Design Parameters

The focus in the development of the worker guidance system in this paper is on assembly and therefore assembly-related information, such as parts lists and assembly instructions, and is placed at the center of the consideration. According to Reinhart [14] there are three design fields for worker guidance systems that can be adapted when transforming a cognitive assistance system: Information degree, information design and information device. Information degree focuses on the amount of information which is to be displayed by the system. This design field can be adapted with different parameters such as the definition of the amount of information to be displayed or what type of information to show. Information design focuses on how to present the information to the worker and how it should be displayed. This field focuses on parameters such as the perception of information and the style, mode and intensity of information. The third design field focuses on the information device which is used to assist the worker in their assembly task. This field consists of technical parameters such as the hardware to be used, the communication protocols and the hardware for feedback to the worker. Fig. 4 gives an overview of the design fields and parameters for worker guidance systems. The design parameters can be consciously designed and thus allow the differentiation between different types of worker guidance systems.

When it comes to transforming a cognitive assistance system, the design parameters of the currently used system as well as the new AR system have to be evaluated and determined. Since the assembly-related work information is not fundamentally changed by the transformation of the system, the evaluation of the existing system leads to the determination of the first design field, the level of information. In the next step, the desired information design has to be specified and the desired information device has to be selected. The parameters for defining the information design are strongly related to the selection of the information device. For example, the selection of an AR device can result in restrictions in the embedding of objects in the environment. The selection of a suitable information device depends not only on the selected design parameters, but also on industrial requirements.

Information degree	Information design	Information device
• type of information • amount of information	• perception • mode • style • intensity	• form of transmission • transmission medium • feedback
WHAT	HOW	WITH WHAT

Figure 4 Design fields and design parameters of worker guidance systems according to [14].

3.4 Selection of AR device

When integrating an AR application into an industrial environment, certain requirements have to be met. In [41], Lorenz, Knopp and Klimant present four categories of requirements which have to be met when integrating an AR worker support system in industrial environments: user, technical, environmental and regulative requirements. In terms of the user, the most significant requirements are to provide an overview about the required tools and materials, to present the workflow with the help of images, videos or 3D animations, to record statistical data for future planning and hands-free operation. The user requirements for transforming an existing assistance system also depend on the information degree as described in Section 3.1. The most important technical requirements are a stable data connection and the connectivity to a central data storage system. In terms of environment, it should be usable with a hard hat, safety glasses and should sustain a fall from a 1.2 m of height. Since regulative requirements have to be considered differently due to different dependencies, such as country, industry sector and assembled product, it is not discussed any further in this work. [41] provides a full detailed list of the requirements of AR guidance systems.

By considering the conditions in the given industry sector and the defined requirements for an AR device, a suitable medium into which an existing cognitive assistance system can be transformed can be chosen.

3.5 Concept and Development Phase

In the concept phase the derived specifications and identified parameters are used to create a roadmap for the implementation of the assistance system. Therefore, the scope of the transformation has to be determined and relevant features have to be formulated. Software objects for the system being transformed are to be formulated and their workload has to be estimated. Examples are user interfaces, masks, programs, jobs, files and databases which are necessary for the transformation of the assistance system.

Following the digitalization process, non-technical data, such as paper based instructions, have to be digitized and elaborated.

In the implementation phase, the cognitive assistance system is transformed into an AR application, based on the identified requirements and specified features. During this phase, the developers can follow various processes such as SCRUM or Extreme programming.

3.6 Finalization Phase and Launch

The finalization phase is closely related to the implementation phase. Depending on the software development process, the testing is done continuously. Nevertheless, a final test has to be conducted, including the worker who has to use the system in the assembly line. Their feedback and the release of the system is essential for the completion and success of the project. If employees are not involved enough, there is a risk that the new system will be rejected and thus cannot be used successfully. This phase is related to the handover and employee migration phase in the migration work flow, as well as the test and trial phase in the product development process. When the system is finalized, the product can be launched in production and used in the assembly lines to assist the workers.

3.7 Quality Assurance

Quality assurance measures of the transformation ensure that the functional equivalence of the old and new assistance system is guaranteed. If partially automated transformations are used for conversion, they must be tested in detail. In general, it is recommended to test the transformations on suitable programs, data and masks. The presence of the old system allows the validation of the AR application and ensures the quality during the process.

4 CONCEPT VALIDATION

To validate the proposed unified process model, a project has been carried out in an industry-oriented environment. This section presents the prototype implementation in a learning factory at Graz University of Technology. First, the strategy and environment are assessed. Then, the application is specified and a concept is chosen. At the end, the application is implemented, finalized and launched.

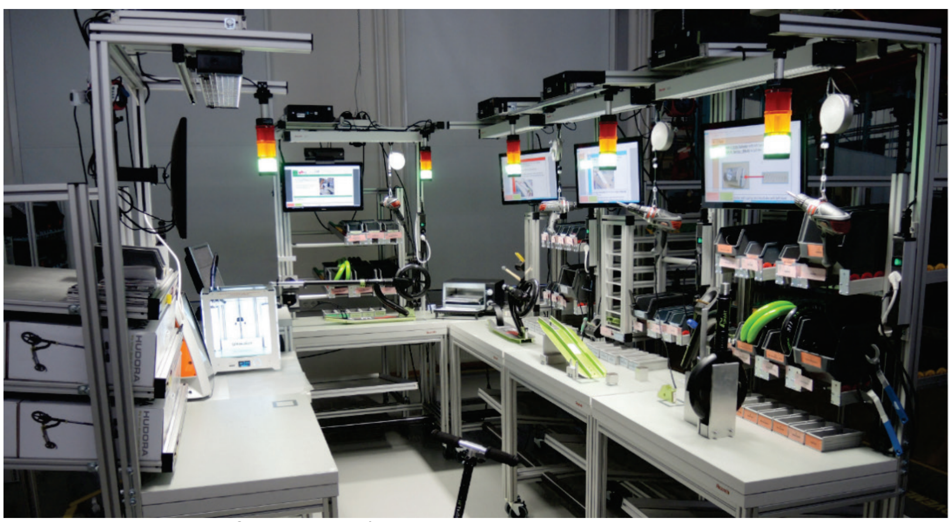

Figure 5 The LEAD Factory at Graz University of technology. It is used to train participants "hands-on" in an industrial setting.

4.1 Strategy Development and Implementation Environment

The start of the project contained the discussion of a suitable strategy which is to be followed throughout the project. Therefore, the goal was set to transform the existing paper-based work instructions into an AR cognitive assistance system. The new system should be low cost and represent a demonstrator which only has to support basic functionality. Since the prospective workers are constantly changing students, it is hard to integrate the same personas throughout the project, but it is still tried to gain feedback from various interest groups, such as the personnel of the institute.

Next, the environment for the implementation is assessed. Therefore, the so-called LEAD factory has been selected as implementation environment since it offers an industrial setting within a teaching environment as it is usually used for training students. The LEAD factory is a learning factory, which represents an industrial assembly line. In this environment, participants get to know industrial processes and optimization methods by directly applying them in the learning factory. During workshops, participants assemble a scooter on five different workstations. Each work station is equipped with a paper-based assembly instruction, whereas in the scope of this project, the instructions at one specific workstation will be transformed. For this project, workstation 1 has been selected. Fig. 5 shows the assembly line of the learning factory. The working process starts at workstation 1 (right) and follows a U-shape through the assembly line to workstation 5 (left).

4.2 Design and Concept Phase

In the next phase, the existing cognitive assistance system design fields are evaluated and the target application, including the selection of the hardware is conducted. The information degree on the paper-based instruction consisted of step by step instructions for which part to assemble and an image showing details on the assembled product. This information is kept as well as the design of the instruction set is defined to stay the same. No embedded 3D objects were integrated as the prototype should only support basic functionality. The digitization of the paper based instructions did not pose a problem, as they were already available in digital form.

Google Glass is selected as information device since it enables assembly using both hands and offers the required hardware to project step by step instructions and images into the field of sight of the worker.

The concept of the application is planned to integrate a server which provides assembly information and communicates with the glasses via Wi-Fi. This way, Google Glass can retrieve the necessary assembly information and can send the progress status via the AR server back to the production system. This allows a real time monitoring of the assembled product and enhances the maintenance of assembly instructions as they can be changed directly on the server. For the control through the instruction steps, a smart watch is connected via Bluetooth to the glasses and waits for the worker input. Hence, the worker does not have to touch their face all the time to start and switch instruction steps, but can control it in the immediate vicinity of his hands. Fig. 6 shows the rough concept for the implementation.

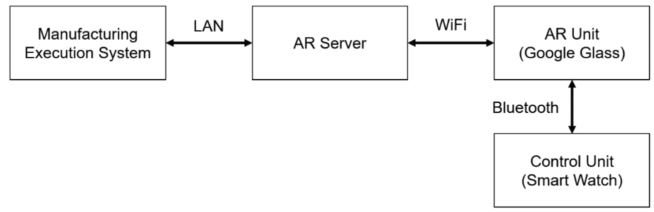

Figure 6 Implementation concept for an AR cognitive assistance system.

4.3 Development and Finalization Phase

Having defined the concept, the prototype is developed and tested. Therefore, the communication interface, the user interface and the control interface are implemented according to the defined concept. When the basic functionalities were implemented, the assistance system was tested with selected personas and their feedback was integrated in several loops.

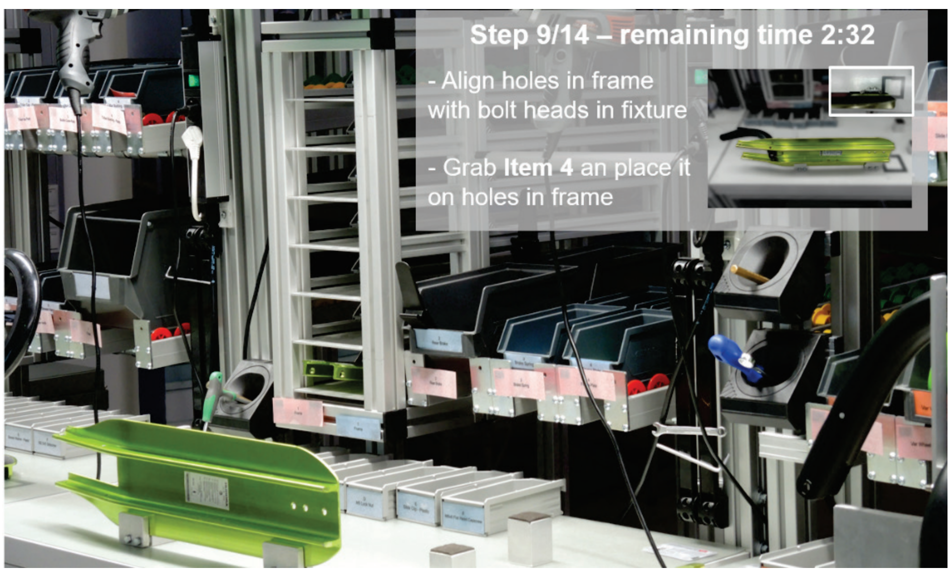

Figure 7 Developed prototype of a cognitive assistance system.

The final product was then released and integrated into the workshop concept of the LEAD factory. A view through the prototype is shown in Fig. 7. The image shows the workplace as perceived by the worker. In the top right corner, an instruction view is projected, including the assembly information and images from the transformed paper based instructions. Additionally, the remaining time for the assembly is projected as well, as this information is available from the Manufacturing Execution System.

The control unit (smart watch) of the prototype consists of three main buttons: The "start" button to initiate the assembly instruction and the "next" and "back" buttons to control the sequence of the assembly instructions.

5 CONCLUSION

In this paper a unified process model for the transformation of a cognitive assistance system has been proposed. Therefore, a migration workflow and digitalization process have been combined and adapted to the needs of a worker guidance system. By transforming an existing paper-based cognitive assistance system into an AR system, the process model was validated in an industry-oriented environment, the LEAD Factory.

The developed process model represents a guideline for the transformation of a system, which can be used as a basis for the implementation of such a project. Nevertheless, the model still offers potential for improvement, as not all steps have been defined in detail. In the future, it is planned to specify the steps more precisely; for example, to better define the selection of a suitable AR device. Furthermore, it can also be checked whether the presented model can be adapted for the transformation of other AR use cases. In terms of the prototype implementation, additional studies can be conducted, such as the quantitative comparison of the old assistance system to the new one or conducting tests in real industrial companies.

Notice

The paper will be presented at MOTSP 2020 – International Conference Management of Technology – Step to Sustainable Production, which will take place from 30th September – 2nd October 2020 in Bol, island Brač (Croatia). The paper will not be published anywhere else.

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Preliminary communication

Utilization of Data Center Waste Heat in Northern Ostrobothnia

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Abstract: Data center industry is growing rapidly due to the expanding internet traffic and the upcoming IoT revolution. Data centers consume vast amounts of energy globally and are also a significant source of greenhouse gas emissions. There is a need to improve energy efficiency and sustainability of data center operations. The energy consumed by data centers is mostly converted to heat and this study focuses on utilizing that waste heat according to the principles of circular economy in the context of Northern Ostrobothnia, Finland. The overall regional business potential of data center waste heat utilization is evaluated and the best options of utilizing waste heat in case data center are sought. The study found that the most viable option would be utilizing waste heat locally to heat facilities or in industrial processes. Another potential option is to connect data center into a district heating system where waste heat can be fed.

Keywords: by-product utilization; circular economy; data center; sustainability; waste heat

1 INTRODUCTION

As the data center industry is growing rapidly due to the expanding internet traffic and the upcoming IoT (Internet of Things) revolution, data center technology must be prepared to become more dynamic and scalable. These changes in the industry are forcing data center energy efficiency to become increasingly more important. The total global electricity consumption of data centers was estimated 198 TW·h in 2018 [1] and the greenhouse gas emissions of ICT sector including data centers have grown to match 2% of the total global emissions and data centers have the sector's fastest growing carbon footprint [2]. The energy used to run a data center mostly converts to heat. Only recently this heat is becoming utilized by mostly large commercial data center companies. The practice is quickly catching on.

Finland has enormous growth opportunities for the data center industry. The cold climate, world-class energy infrastructure and skilled workforce give Finland an advantage as a location for future data center investments. [3] According to an estimate by Boston Consulting Group, a data center investment of EUR 400 million could generate an economic impact of EUR 1 billion and create over 4500 jobs [4]. At this moment individual Finnish companies involved in the data center industry are too small to compete against multinational corporations. Thus, it would be wise to increase cooperation and to create efficient value chains and business ecosystems that involve multiple actors from building, energy production, to the digital industry itself. In the case of Northern Ostrobothnia, the same realities and possibilities are present. This study aims to answer the following research questions (Fig. 1):

- RQ1: What factors affect waste heat utilization in data centers?
- RQ2: What are the location specific factors that affect the data center industry?
- RQ3: How to best utilize waste heat produced by data centers in Northern Ostrobothnia?

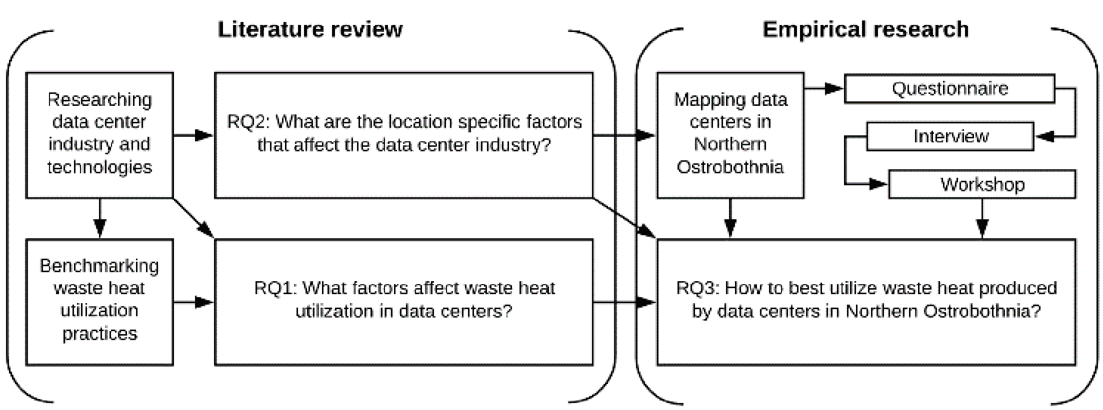

Figure 1 Research process

2 MATERIALS AND METHODS

The study on waste heat utilization from data centers located in Northern Ostrobothnia began by reviewing articles related to data center solutions and technologies and benchmarking potential waste heat utilization practices as well as studying different relevant factors that need to be taken into account in the data center industry, for example, the effects of location on data center energy efficiency referred in this article as location specific factors.

The data collection included a questionnaire, an interview and a workshop session. The research focused on data centers in the private sector that provide commercial services. After mapping the data centers in Northern Ostrobothnia, their cases were studied, and a questionnaire sent. One interview was conducted with a party responsible for planning to build a data center in the Northern Ostrobothnia region. Lastly a workshop session was organized for data center entrepreneurs, researchers and other industry experts. All companies and related parties will remain anonymous in this article. The research process is illustrated in Fig. 1.

3 LITERATURE REVIEW

In order to pinpoint the best suitable technologies for waste heat utilization in data centers, it is important to take into account the relevant factors that possibly affect the viable technologies. These factors will set the criteria for the technologies that can be used in the specific cases and will make it easier to discard unviable solutions. The factors reviewed in this study include geographical environment, information and energy infrastructure, political and social stability and availability of suitable and skilled workforce.

3.1 Data Center Energy Efficiency

Data center technology includes electricity, cooling, IT-tech and lighting. Most of the energy consumed by electrical and IT-systems transforms into heat. The cooling systems can in some cases use up to half of the electricity used in data centers, and therefore they have the largest potential in saving energy. Most of the electricity is usually used by the servers and there is little that can be done to lower that usage. The servers and the cooling systems together are responsible for using over 60% of all the energy consumed by the data center and other systems such as lighting, UPS-system (uninterrupted power supply), ventilation and other non-productive elements are responsible for the remaining energy consumption. Fig. 2 illustrates power allocation in a typical data center [5].

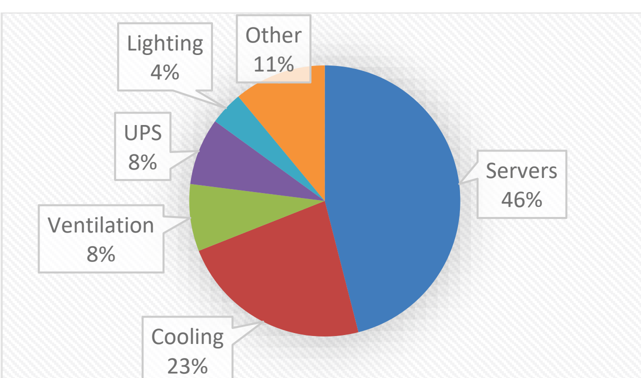

Figure 2 Power allocation in a typical data center [5]

3.2 Data Center Cooling

A substantial amount of heat is produced in the server rooms of data centers. This heat needs to be directed out of the facilities as the optimal temperature of air in the server rooms needs to be in the range of 18–27 °C [6]. To regulate the temperature in the server room of a data center different types of cooling systems can be applied. The cooling systems are normally designed individually for each data center.

Servers are typically placed in racks in a manner that leave hot and cold aisles in between the servers. This allows cooling air to flow to the front of the server and exit as heat from the back of the rack. It is important that the cold and hot aisles are insulated so that waste heat and the cooling air do not mix. The heat energy is then directed out of the server room and can be used in waste heat applications. Data center cooling solutions are various and most often case specific. The most common solutions use both free cooling and mechanical refrigeration, as using only mechanical cooling is less energy efficient. [7]

Free cooling solutions typically use the cooling capacity of outside air, water from a natural water source or ground to cool water to be used in cooling of the server racks. The possibility of using free cooling depends heavily on location specific factors such as geography and climate. In cases where free cooling is not enough, mechanical refrigeration can be added to provide the additional cooling energy. Other potential cooling methods for data centers include liquid cooling such as sorption cooling and district cooling. Sorption cooling can utilize waste heat from the servers and is thus a highly potential solution for data centers to use. [8] District cooling is an emerging technology that uses the same technology as district heating. The cooling energy can be produced by heat pumps or by utilizing a natural source of cool water such as a sea or a lake.

3.3 Location Specific Factors

The demand for data centers is increasing exponentially in the EU and the continuous growth is dependent on the digitalization of Europe. It must be taken in to account, that a data center situated in Finland does not only serve Finnish clients, but the entire European market. In principle, data centers are not dependent on location and can be built anywhere. For optimal operation it is still reasonable to take the geographic and environmental factors into account when choosing a location. Different factors related to the location of data centers were studied in a research conducted by Cushman & Wakefield in 2016 [9]. The most impactful factors are shown weighted in Tab. 1.

These factors can be divided into four categories: geography, information infrastructure, energy and stability.

3.3.1 Geography

When choosing a location for a data center, geographical location is a substantive factor. For the servers in the data center to work continuously, factors such as seismology, possible floods and other natural disasters as well as climate factors need to be taken into account. For example, a northern, colder climate allows cost-efficient cooling mechanisms such as air cooling or district cooling. The risk of natural disasters is weighted as the most important risk to take into account when choosing a data center location [9].

Table 1 Factors likely to affect the successful operation of data center [9]

Criteria	Weighting, %
Energy costs	8.97
Internet bandwidth (Mbit/s)	11.54
Ease of doing business (World Bank Rating)	11.54
Corporate tax	6.41
Political stability	12.82
Sustainability (% energy from alternatives)	8.97
Natural disasters	15.38
Energy security	12.18
GDP per capita	5.77
Water availability	6.41

Earthquakes in Finland are relatively weak ranging between 0–4 in magnitude [10] and according to a report by Cushman & Wakefield [9], Finland is the fifth best in category "World risk assessment vulnerability and coping capacity (natural disaster / economic & political challenges in urban areas)". Northern Ostrobothnia is situated between continental and oceanic climates in the subarctic zone. This climate allows for cold air to be used in data center cooling. The utilization of district cooling in Oulu has also been studied, but the shallowness of the Bothnian Bay results in high temperatures of water and thus the area lacks a year-round source of cold water. [11]

3.3.2 Information Infrastructure

Naturally data centers ought to be located in areas with good network infrastructure such as good internet connections with secure data cables and know-how. According to Mena et al. [12], the key factors when evaluating a site's network infrastructure are network capacity, redundancy and network reliability. It is important for a data center to secure the data in their servers from malware and spying. In many countries legislation allows mass surveillance of the network which hurt the reliability of commercial data centers. In Finland, such legislation has not yet been implemented and its regulatory environment remains superior to its competitors. The country does benefit from world-class network infrastructure. [3]

In 2016 a submarine communications cable was built connecting Finland with mainland Europe [13]. In addition, plans have been made to build a cable from Asia through the Northeast Passage to Finland and further to mainland Europe [14]. With these infrastructure improvements Finland has a tremendous opportunity to become the "Switzerland" of data centers.

3.3.3 Energy

The total global electricity consumption of data centers was estimated 198 TW·h in 2018 [1] and the energy demand of data center operations has been growing steadily. Thus an uninterrupted energy supply and a working and reliable grid is essential for the stability of a data center. Ideally, a data center should receive power from two different grids, and more than one commercial utility provider ought to be near the site. Backup power can be provided using generators to avoid server downtime. Northern Ostrobothnia and Finland in general have the advantage of having state of the art energy infrastructure and technology level. The completion of the nuclear power plants of Olkiluoto 3 and Hanhikivi 1 will further secure energy independence and thus better the Finland position as a location for data centers.

3.3.4 Stability

In addition to a mature network and energy infrastructure, a stable political and social environment is also important for data centers. According to Benáček et al. [15], countries that have transparent and efficient institutions are more likely to attract foreign investors and have more predictability in their regulations. A secure political situation guarantees that the data center operations and the data hosted in the data center are safe and secured. Political stability was listed as the second most important factor in choosing a data center location. In 2016, Finland ranked 9th in the world on political stability in the Data Centre Risk Index of Cushman & Wakefield [9].

3.4 Utilization of Waste Heat

Data center waste heat is energy that leaves the data center as cooling water, air or condensation heat via cooling system. Currently most data centers do not utilize their waste heat in any way. The turn towards green energy production and the EU targets [16] of having 32% of energy being produced by renewables by 2030 and improving energy efficiency by 32.5% by 2030, has encouraged to find solutions for the reuse of data center waste heat. In the case of Finland, over 37% of industrial waste heat is simply released into the environment. This accounts for about 54 TW·h of heat energy. [17] Industrial waste heat can be used in a wide range of applications such as the heating of nearby facilities, controlling the temperature of greenhouses and aquaculture facilities, drying biomasses as well as district heating. Data center waste heat is well suitable for district heating purposes because of its stable and steady supply flow. However, the waste heat from data centers is of low temperature, typically between 25–60 °C, too low to be used in traditional thermodynamic processes. The temperatures used in district heating are between 70–110 °C, depending on the season. Heat pumps can be used to increase the temperature of waste heat but require substantial investment and thus, long-term prospects and an economic incentive.

3.4.1 Heating

The most direct and straightforward way of utilizing data center waste heat is heating. The waste heat can be directed to heat the data center itself, or other facilities in the proximity of the data center. As mentioned before, majority of data center waste heat is too low-grade to be used in district heating directly. Heat pumps are commonly used technology in the industrial sector and are suitable for raising the temperature of low-grade heat in industrial processes. Heat pumps can also be connected in parallel to achieve more power. Investing in a heat pump is profitable, when the difference in the price of heat generated, and the energy used by the heat pump, is of benefit to the investor and the payback period is short. Heat pump expenses vary and are assessed case-by-case.

A study was conducted by Kupiainen [18] in which two different cooling options were compared for a data center in the Futura building in Jyväskylä, Finland. The results showed that applying a heat pump with free cooling could potentially provide lifetime savings of €280,000 in 20 years when compared to applying free cooling and a refrigeration machine.

3.4.2 District Heating

District heating is a common technology in the Northern Hemisphere. District heating systems can distribute heat from a centralized location to residential and commercial heating requirements. Steam or hot water can be piped underground to individual buildings where it is used for heating, hot water consumption or air conditioning. District heat can be produced in several ways such as burning fossil fuels, biomass, geothermal heating, heat pumps, solar and nuclear power. As reported by Andrews et al. [19] district heating produced in combined heat and power plants (CHP) have one of the lowest carbon footprints. Such systems are exceptionally common in Finland and Sweden. As mentioned before, currently the temperatures used in district heating are between 70–80 °C in the summer season, and 100–115 °C in the winter season respectively. As the building industry is striving to find solutions to more insulated housing and new 4th generation district heating technologies are developed, these temperatures used may see a steady drop, which could allow feeding lower quality heat into the district heating network. Data center waste heat could be used in preheating feedwater of a power plant as suggested by Marcinichen et al. [20] This type of utilization can save fuel in the power plant as the operation time of a feedwater preheater can be cut down.

3.4.3 Electricity Production

Electricity can be produced using the waste heat from data centers. At this moment the most promising solutions are mostly based on the Organic Rankine Cycle (ORC). The Organic Rankine Cycle is similar to the Rankine cycle-based systems commonly used in steam turbine systems, but instead of water, uses an organic, high molecular mass fluid with a liquid to vapor phase change, occurring at a lower temperature than water. This allows ORC-technology to use waste heat as power. The technology works best provided with constant heat of over 100 °C but can be used in lower temperatures as well. Several ORC power plants have been installed in the MW range, but according to Tocci et al. [21] the commercialization of ORC power plants in the kW range have not reached a high level of maturity mainly because of economic reasons as well as lack of awareness. Ebrahimi et al. [22] studied implementing an ORC-system in a data center for the reuse of waste heat and estimated a payback period between 4–8 years in data center environments.

3.4.4 Cooling

Waste heat can be also used in cooling using sorption cooling technologies. Sorption technologies use a source of heat to produce cold. This characteristic makes sorption-based cooling technologies useful in waste heat reuse. The term sorption cooling technologies is used to describe both absorption and adsorption cooling. Absorption cooling system is the more common of the two. It is similar to vapor compression cycles but instead of compressing refrigerant vapor, it dissolves this vapor into liquid that is then pumped into a higher pressure and then uses the heat input to evaporate the refrigerant vapor out of the solution. Absorption cooling is specifically economical when the temperature of the waste heat is between 90–160 °C [23].

The adsorption process is similar, but instead of a liquid, the working fluid adsorbs into the surface of a solid. In comparison with liquid absorption systems, adsorption systems present the advantage of being able to be powered by a large range of heat sources. Adsorption processes can run in relatively low temperatures starting from 50 °C and are thus suitable for data center waste heat solutions [24].

3.4.5 Industrial Processes

Numerous industrial processes can use waste heat as an energy source, depending on the quality and temperature of the waste heat and the process itself. Low grade waste heat is commonly used to heat facilities, dry biomasses or in district heating. Low grade waste heat is best used on-site, as it is most energy efficient and investing in a larger network is often not cost effective and the storage of heat energy problematic. In the case of data center waste heat, the drying of biomasses is one potential application. Drying usually takes place in temperatures ranging from 25–60 °C, well in the range of data center waste heat. Using data center waste heat in drying can be challenging due to logistical reasons. Drying biomasses near the place they are obtained is more cost effective, whereas data centers are mostly located in the cities. Another promising application of waste heat are greenhouses. The temperature in greenhouses is kept around 25 °C. A data center provides a constant flow of low grade waste heat and can thus allow a greenhouse to function year-round. Similarly, fish farms using indoor recirculating aquaculture systems, can use data center waste heat to control water temperatures.

3.4.6 Carbon Footprint

Data centers are major consumers of energy. A large share of energy is consumed by the servers themselves and the cooling systems. According to Bouley [25], the emissions caused by a data center mainly depend on three factors, the location of the data center, the IT load and electrical efficiency. The energy production method also plays a role. If hydro or nuclear power is available, emissions are naturally lower compared to fossil fuel driven energy production. When estimating the carbon footprint of a data center one must account the emissions caused by the building "shell" itself, and the embedded carbon in it. Data center facilities themselves are relatively simple by design. Bouley estimates that in a data center of 1 MW electrical power and 530 m^2 there is 128.3 tons of CO_2 embedded. Carbon emissions, when recovering waste heat for district heating purposes depend on the fuel used and the technical demands of the district heating network itself. Marcinichen et al. [20] have suggested that utilizing data center waste heat in a nearby power plant could increase the energy efficiency of the power plant by up to 2.2% as well as cut CO_2 emissions. Data center waste heat can in theory replace some of the fuel used in heat production, and thus lower the carbon emissions. This applies specifically to heat power plants. In the case of CHP plants, the replacement is more complicated, as the replaced heat would also be taken away from electricity production and thus it possibly would not be economically attractive for energy producers.

4 DATA CENTERS OF NORTHERN OSTROBOTHNIA

One of the central goals of this study was to investigate the data centers of Northern Ostrobothnia. Defining a data center can be challenging as any space with a server and a hard drive can be defined as a data center. In this study the focus was limited to commercial data centers. When mapping the data centers in Northern Ostrobothnia, it was found that most were concentrated to the metropolitan area of Oulu. This is not surprising, as most data centers are located in urban areas with good IT and energy infrastructure as well as available skilled workforce. As the recovery of waste heat from data centers is a relatively new phenomenon, it is not surprising that only fraction of waste heat from data centers in Finland is recovered. Such was the case in Northern Ostrobothnia as well. As the data centers mapped were of relatively small size, mostly server rooms that rented their facilities, none of them had plans to recover waste heat. The studied data centers are heated by district heating from a local producer. No large data centers have yet been built in Northern Ostrobothnia.

5 RESULTS AND DISCUSSION

When researching potential data center waste heat utilization solutions in Northern Ostrobothnia, it was discovered that the most viable option would be to use the heat energy to heat the data center facilities themselves, or possible physically adjacent facilities. This type of solution could allow year-round greenhouses, indoor fish farms, offices and residential buildings. To connect the waste heat source into a district heating system is challenging and not cost-effective, due to the low price of CHP produced district heat, as well as the technical specifications of the network itself. With implementing two-way heat networks, the profitability could rise, as heat could be bought and sold between the provider and the receiver, though turning an existing district heating network in to a two-way network requires investments and technical changes. Two-way network solutions are more simply implemented in newly built sites.

The use of data center waste heat for cooling solutions was researched as well. In the case of Northern Ostrobothnia, using outdoor air or free cooling was the most viable approach as the outdoor temperatures are relatively low throughout the year. In addition, investing in sorption systems would require an additional investment in a heat pump to raise the temperature of waste heat. The low efficiency of these systems lowers profitability as well.

Electricity production with ORC-technology using waste heat is a technically viable alternative. However, in Northern Ostrobothnia the low price of electricity makes the solution lose its cost-effectiveness. The waste heat recovered would need to be practically free for the investment to be profitable. Thus, with the current electricity prices the payback times are too long.

All in all, the data center industry is exponentially growing, and the Northern Ostrobothnia has excellent potential to be a key player on the field in Finland. It would take more awareness and cohesion from different parties involved in the business in private and public sectors. It is important to look outside the box to whether different actors in the fields related could provide valuable new insights regarding the data center itself and its relation and integration with industrial and urban environments. As technology advances and the price of energy rises, waste heat recovery solutions that were earlier unprofitable could become cost-effective. The two-way district heat network could encourage producing energy locally in smaller communities.

The construction of the Northeast Passage submarine communications cable will naturally attract more data center building projects in Finland. Thus, it is important for Finland to keep data centers in a prioritized position and to attract investments that will increase the know-how and boost innovation not only in data center design, construction and maintenance but in energy, ICT and other adjacent sectors as well.

When it comes to data centers, Finland and Northern Ostrobothnia need a clear vision and plan to advance the data center industry. Giving up a certain type of pragmatism and having a more open approach could give a boost to the overall economy. Energy efficiency and possibilities for industrial symbioses and other circular economy solutions should be researched early on in data center planning processes.

Notice

The paper will be presented at MOTSP 2020 – International Conference Management of Technology – Step to Sustainable Production, which will take place from 30th September – 2nd October 2020 in Bol, island Brač (Croatia). The paper will not be published anywhere else.

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Preliminary communication

Sustainable Transport Indicators in the Context of Introducing of Electric Passenger Cars

Stevan Kjosevski*, Atanas Kochov, Darko Danev, Aleksandar Kostikj

Abstract: Sustainable development and sustainable transport are becoming of higher and higher importance. A scientific approach to sustainable development analysis means, first of all, identification of relevant indicators. Based on literature review and regional professionals' view, a total of 90 indicators have been chosen. They have been structured in five hierarchic levels. A total of five personal transport means alternatives have been analyzed in the research. The AHP method of analysis has been employed in which 75 professionals from the Western Balkan countries have filled appropriate questionnaire. The research presents their opinion about the capacity of each of the alternatives to contribute to the sustainable transport in the region, but also puts a light on perception of the professionals on importance of chosen indicators. The results of this research could be used for further research and could also help to decision making levels regarding sustainable transport and sustainable development.

Keywords: electric; indicators; sustainability; transport; vehicle

1 INTRODUCTION

Transport represents one of the biggest sectors of the global economy. It has strong impact on the three main pillars of sustainable development: Economy, Society and Environment.

Road transport is dominant part of the earth's transport. That is especially a fact when considering passenger transport in urban and extra urban areas.

Innovations and technology development lead to new transport means which are more acceptable in light of sustainable transport and development. The possibility of wider exploit of electricity for propulsion of road vehicles is an example of it. In parallel, plug-in hybrid and hybrid vehicles take their part on the market. Improvement and introducing other alternative fuel solutions should be added as well.

When, on different levels, decision about choice of transport means has to be taken, it will happen in complexity of a number of opposite aspects. That is especially the case when those decisions are policy related and therefore need to be in line with sustainable development principles.

In the last several decades the science has developed more methods which could help or substitute intuitive approach when taking decisions in such multi factorial conditions.

2 SUSTAINABLE DEVELOPMENT

Sustainable development attracts many institutions and authors to contribute to that process [1-3, 22]. Most of them consider that it should rely on the triple basis (three pillars) of the sustainability: Economy, Society, and Environment as shown in Fig. 1 [2].

United Nations pay special attention on global sustainable development mainly expressed by the Program for Sustainable Development which defines its 17 goals as shown in Fig. 2 [1].

Significant number of those goals are function of establishing sustainable transport [4-8]. Fig. 3 shows UN view of that correlation [4].

In order to drive transport towards its sustainability a number of issues need to be addressed [22]. All those aspects are not from the same nature, and not all of them are measurable, especially not in the same units. Also, not everyone has the same point of view and therefore uses different metrics on the same issue.

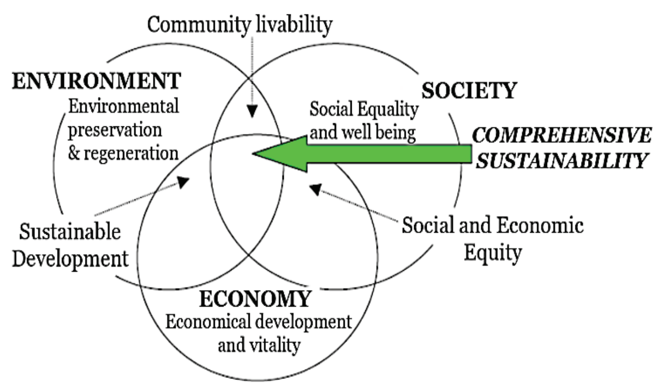

Figure 1 Sustainable development basis as defined on Ontario Round Table on Environment and Economy, 1991 [1]

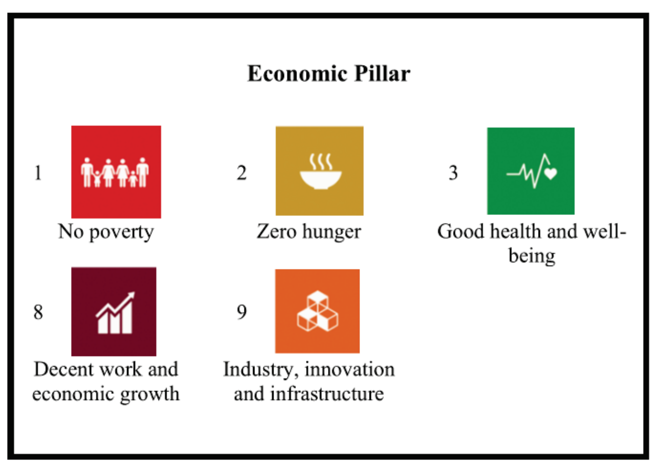

Figure 2 United Nations Sustainable Development Goals

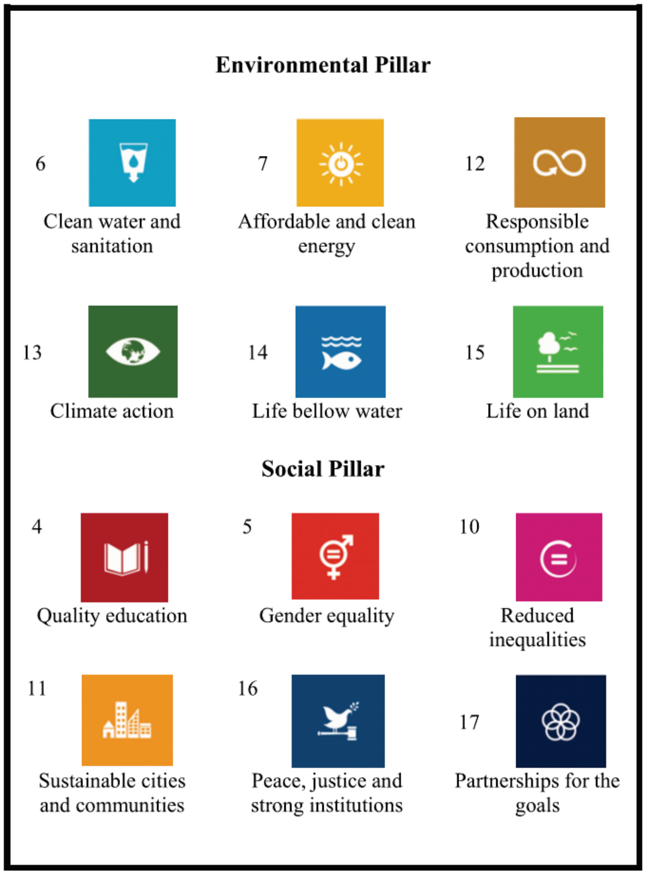

Figure 2 United Nations Sustainable Development Goals (continuation)

In the efforts to contribute to the sustainable development each decision needs to be made not only focused on specific interest, but in the context of sustainable development goals as much as possible. That should be especially the case when those decisions are related to the policy making. To do so, the process of decision making should be scientifically based.

Decision making methodologies cover important part of contemporary science [9-11].

Basically, decision making process is choosing one alternative from wider group, in systematic and logical manner. Main steps of such process are as follows: defining the problem in the core of decision making process; identifying the criteria; defining the alternatives; weighting each of the criteria; applying the criteria on each of the alternatives; applying rules for decision making; estimating the alternatives according to the criteria and identifying the best alternative.

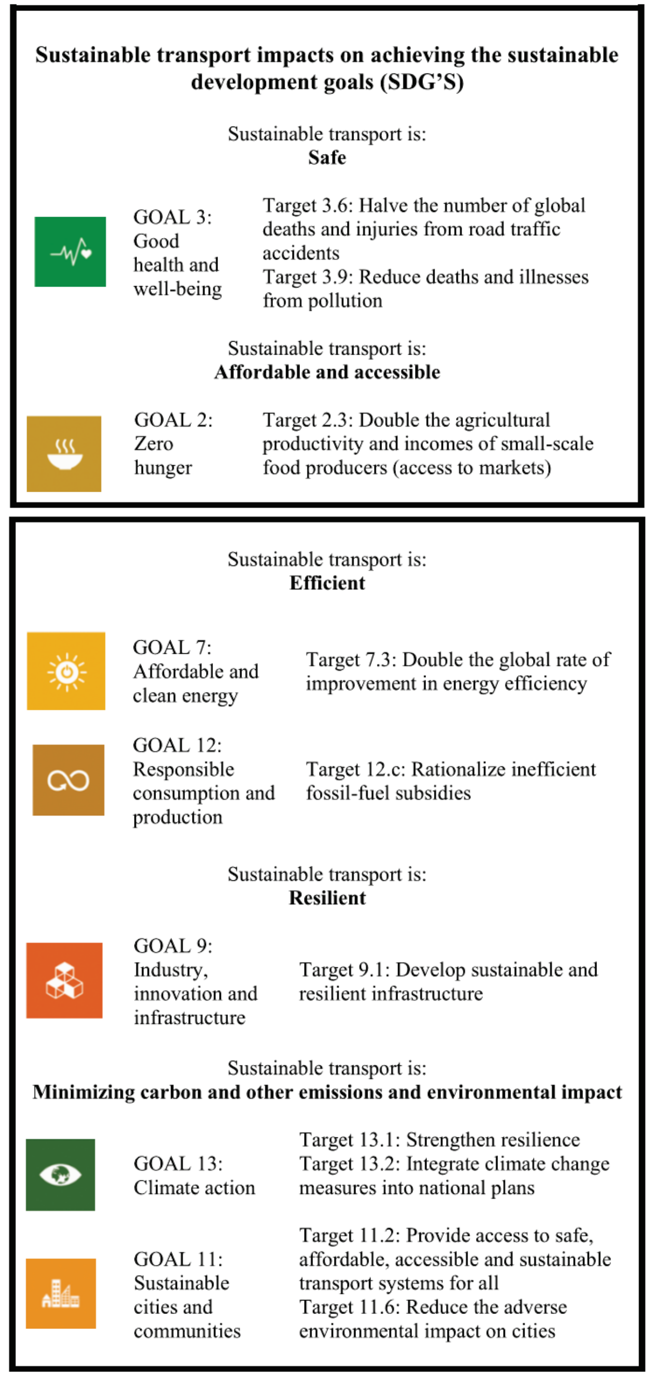

Figure 3 Mobilizing Sustainable Transport for Development; United Nations; 2016

3 DEFINING THE PROBLEM AND RESEARCH APPROACH

The wider research objective has been to clarify which alternatives of cars have most capacity of contribution to the sustainable transport and development, especially in the region of Western Balkan. The scientific approach to that objective included structuring and addressing most of the significant issues of sustainable transport. The almost unlimited area had to be analyzed by the tools of system engineering. In that respect, some general issues like fossil fuels availability, environmental aspects of electric energy production, energy and ecological aspects of production of different types of cars, their recyclability, and similar, have been taken out of the view. Also, the well-known fact that driving behavior can influence transport sustainability [23] has been considered constant, that is, it has not been identified as an indicator in this research.

The specific focus of the research described in this paper has been on identifying the most common indicators of sustainable transport, then perform scientifically based comparison on their importance in the context of described goal in similar developing countries, and earn experience which could be of help when there is decision making on different levels.

3.1 Choosing of Research Methodology

The literature [12], and the local experience point to the AHP methodology as a promising tool.
Besides choosing the alternative transport means, a rational choice of relevant indicators appeared to be one of the crucial factors for its efficiency and the quality of the results.

The variety of nature between the indicators, the way of their expression and possibilities of quantification, plus the different availability of data makes their choosing and processing quite complex. In some cases, the indicators could be well known quantities with measurable indexes of importance. Emission of gases and PM are an example, as well the car price and performances. On other hand, there are a number of indicators with complex nature, very hard to measure their indexes of influence, and in the same time with very different nature. The AHP research methodology in such cases employs view of experts through well-organized interview process.

3.2 Identifying Indicators

A number of literature sources deal with indicators related to sustainable transport [13-22]. Minimum number of indicators mentioned is eight, and maximum 87. Most of them fall in the standard pillars – economy, society, environment – but there are other areas as institutional, and so on. When talking about indicators related to electric vehicles, the number of literature sources is quite limited.

Having in mind the complexity of the area of sustainable transport, a rational choosing of the indicators with capacity to illustrate its relevant aspects presents one of the main issues [22].

In order to provide useable contribution to the area, this research has taken into account almost all available literature sources, and keeping a wide view, a list of 90 indicators has been defined to start the research with. This process has been supported by views of respectable experts interviewed.

All indicators are grouped in five hierarchy levels. The first level consists of the main pillars, in this case: economy, society, environment, good governance and planning and culture. Tab. 1 shows all indicators with their level in the hierarchy.

Table 1 Indicators with their hierarchy level

	Hierarchy level indicator
1. Economic	**2. Transport Demand and Intensity** 3. Volume of transport relative to GDP **3. Vehicle prices relative to GDP** 4. Average registered car value (vs GDP) 4. Vehicles per 1000 population **4. Newly registered cars** 5. New cars price 5. Used cars price **3. Volume of transport (passenger-km)** 4. Public **4. Personal** 5. Taxi 5. Private car **3. Transport performances** 4. Range 4. Dynamic performances
	2. Infrastructure 3. Local road length per capita 3. Density local road infrastructure (km-km^2) **3. Parking spaces** **4. Public parking spaces** 5. With electric charging facility 5. Without electric charging facility **4. Residential parking spaces** 5. With electric charging facility 5. Without electric charging facility
	2. Transport Costs and Prices **3. Expenses for vehicles usage** 4. Environmental taxes 4. Expenditures/taxes on roads, parking, etc. **3. Motor vehicle fuel prices and taxes** 4. Fuel/electricity prices 4. Fuel/electricity tax rates **3. Capital maintenance costs** 4. Capital maintenance cost/new vehicle price ratio 4. Frequency of capital maintenance cost
1. Social	**2. Accessibility and Mobility** **3. Personal mobility (daily or annual person-km and trips by income group)** 4. Average passenger journey time 4. Average passenger journey length 4. No. of journeys 4. Total time spent in traffic 3. Volume of passengers 3. Adaptability for people with disabilities (possibility for control by people with disabilities)
	2. Affordability 3. Private car ownership 3. Average household expenditure 3. Share of transport cost from total household expenditure
	2. Safety and Health **3. Cases of chronic respiratory diseases, cancer, headaches. Respiratory restricted activity days and premature deaths due to motor vehicle** 4. Exposure to particulate matter (PM), nitrogen dioxide (NO2), carbon monoxide (CO); 4. Respiratory diseases due to vehicular pollutants (affected per 1000 population) **3. Population exposed to and annoyed by traffic noise, by noise category and by mode associated with health and other effects.** 4. Traffic noise levels 4. Hearing impairment due to traffic noise
1. Environ-mental	**2. Car Emissions** **3. Particulates emissions** 4. Particulates (mass) 4. Particulates (number) 3. NOx emissions 3. CO emission

	2. Technology Level **3. Proportion of vehicle fleet meeting certain air emission standards** 4. Euro 5 or higher 4. Euro 4 or lower 4. Electric or Plug-In Hybrid 3. Average age of vehicle fleet
	2. Impacts on Environmental Resources **3. Habitat and ecosystem disruption** 4. Climate Change 4. Damage to ecosystems 3. Energy efficiency **3. Renewables** 4. Use of renewable energy sources in current fleet 4. Use of renewable energy sources in first registered vehicles **3. Transport energy consumption per capita** 4. Use of non-renewable resources and energy 4. Use of renewable resources and energy
1. Good Governance and Planning	**2. Measures to Improve Transport Sustainability** 3. R&D expenditure on "eco vehicles" and clean transport fuels 3. Total expenditure on pollution prevention and clean-up
	2. Strategic plan for reduction of transport impact on the environment and population health 3. Implementation of measures to reduce transport impact in regard to municipality strategic documents 3. Strategic planning of public transport with electric vehicles
1. Cultural	

Remarks:
- The number in front of the indicator shows its hierarchy level.
- The first column contains only the indicators on first hierarchy level.
- The second column shows indicators on second, third, fourth and fifth level (where such exists).
- Indicators having sub indicators on lower level are **bold**.

The indicator "Cultural" is quite new in terms of mentioning and has very broad meaning. It is still needed to get further clarification and subdivision. Therefore, in this research it is put on hierarchic level 1 without further expansion. The aim was to obtain "the first view" of interviewed professionals as starting information for potential future focus on that aspect.

3.3 Selection of Alternatives

Based on the market development, the following alternatives of vehicles have been chosen: A1 - electric; A2 - plug-in hybrid; A3 – hybrid; A4 – car with ICE with alternative fuel (gas or similar); A5 – car with petrol ICE, and A6 – car with diesel ICE.

3.4 Research Activities, Processing, Analysis and Presentation of the Results

In all cases where quantitative data were available, indicators have been compared (in pairs) based on them. For the rest of the indicators, the AHP method has been employed by filling of previously prepared questionnaires by experts in the area under research. All Western Balkan countries have been covered in the process.

Tab. 2 shows the structure of the experts interviewed by the countries they live and work.

Table 2 Structure of the experts interviewed by countries

Country	MK	RS	BIH	ME	AL	XK	WB
Participant number	31	9	9	6	10	8	73

Tab. 3 shows the structure of the experts by the area of their profession.

Table 3 Professional structure of the experts

	Academic	Business	Governmental and non-governmental	Total
Western Balkan	29	27	17	73

4 RESULTS

Being processed by professional software for AHP methodology, results offer a variety of possibilities for analysis and presentation. This has been used for analysis of the sensitivity of results depending on the country, professional profiles, and number of different aspects. Finally, the consistence of different indicators influence shows their relevance to the subject analyzed.

With high number of indicators and used hierarchy research methodology (AHP) a very rich list of results has been achieved. In this paper, only the results gathered on first hierarchic level will be presented and discussed.

Fig. 4 shows influence of different indicator groups on first hierarchic level for Western Balkan and separate countries.

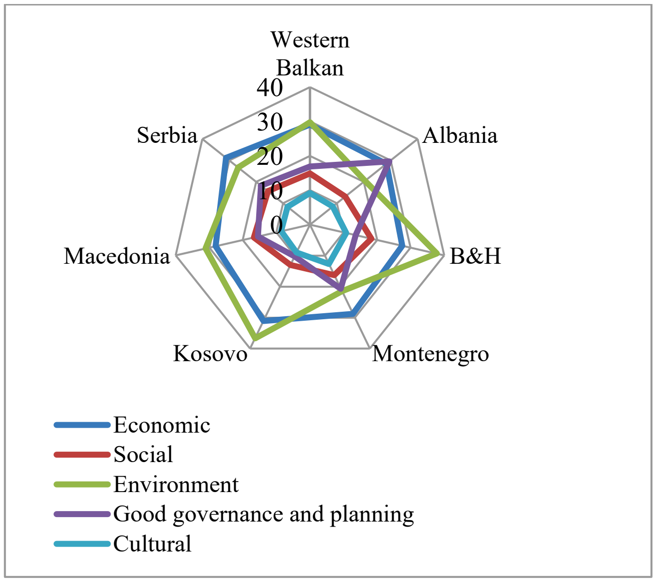

Figure 4 Influence of different indicator groups on the first hierarchic level for Western Balkan and separate countries.

Fig. 5 shows influence of different indicator groups on the first hierarchic level for Western Balkan and different expert profiles.

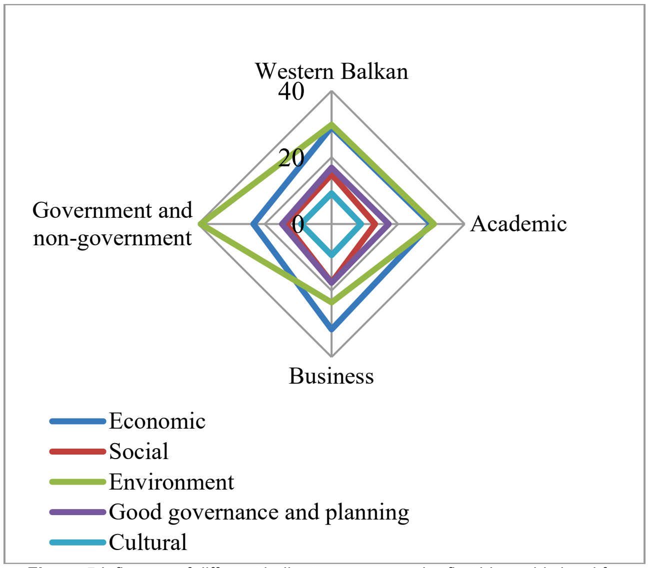

Figure 5 Influence of different indicator groups on the first hierarchic level for Western Balkan and different expert profiles

Fig. 6 shows the results of different alternative vehicles in the context of their capacity to contribute to sustainable development for whole Western Balkan and separate countries.

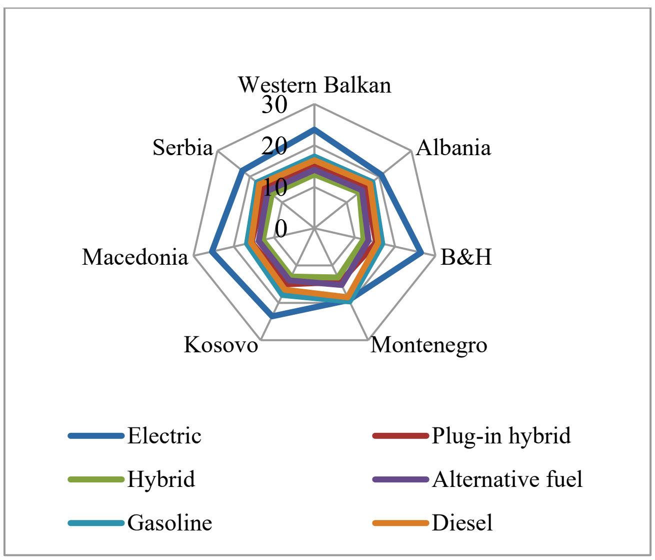

Figure 6 Capacity of different alternative vehicles to contribute to sustainable development

Fig. 7 shows the results of different alternative vehicles in the context of their capacity to contribute to sustainable development based on results of interviews of different profiles of experts.

There are general conclusions to be drawn, which are valid for each country and each group of professionals.

First, it is obvious that the relatively new group of indicators "Cultural" scores very low importance (Fig. 4 and Fig. 5) and so far, it could be neglected, while some of its aspects (indicators) could be moved in other pillars (like "social").

Due to the fact that Social, and Good Governance and Planning pillars generally score similar results (Fig. 4 and Fig. 5), another simplification in further analyses could include mixing parts of their sub indicators.

On the other hand, in Good Governance and Planning, fairly new group of indicators make some differences in different countries. It is superior, together with economy indicators for Albania (Fig. 4), and is second best, together with ecological group of indicators for Montenegro (Fig. 4). Therefore, further research focusing on these aspects might be helpful.

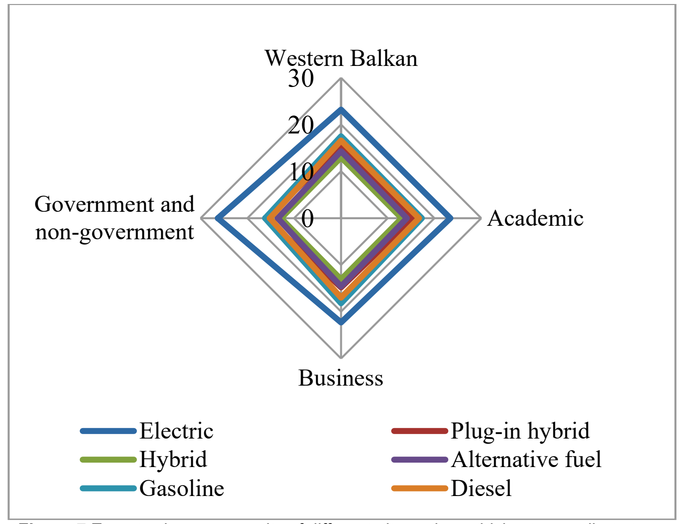

Figure 7 Experts view on capacity of different alternative vehicles to contribute to sustainable development

Analysis of the results in Fig. 4 in general shows that experts from all countries consider economic and environmental indicators superior. Still, there are more details to be taken into consideration from these results. While the economic group of indicators has high scores in all countries, the environmental group shows interesting differences between them.

Countries with heavy environmental problems consider ecology more important than economy and those with minor ecology problems emphasize importance of the economy. Bosnia and Herzegovina, Kosovo and North Macedonia consider the environmental group of indicators as most important, while the same group has much lower importance for Albania and Montenegro.

The correlation of these results with well-known pollution statistics separate Western Balkan countries. Bosnia and Herzegovina, Kosovo and North Macedonia especially in their biggest cities suffer heavily of pollution problems. On other hand, Montenegro and Albania are the only analyzed countries with exit to the sea which obviously has an influence on reducing the pollution. Those differences have clear correlation with the results achieved by this research (Fig. 4).

In the eyes of the experts another picture is drawn (Fig. 5). In comparison to the academic profiles who consider economy and ecology equally important, business professionals prefer economy indicators, and those working in governmental and non-governmental institutions consider ecology aspects more important than those belonging to the economy pillar.

Fig. 6 and Fig. 7 show the results regarding the vehicle alternatives in terms of their capacity to contribute to the sustainable transport and development as a whole. Since this paper is focused on explaining the indicators, and not the alternatives, Fig. 6 and Fig. 7 should be considered informative only.

5 CONCLUSION

In similar countries, as the countries of Western Balkan are, the results of the research show high consistency. That has been proven by the used research method (AHP).

Having in mind the results of the research and the goals of sustainable development, it is obvious that in order to make decisions in the area of transport which have most promising results in the context of sustainable development, there is a need of wider approach both regionally and professionally.

Also, if some decisions have to be made in narrow area (personal, family, company, urban, extra urban), it is normal to expect that not all indicators would be taken into consideration. These decisions could not be considered as fully oriented towards sustainable transport and development.

Therefore, it is up to the people who work on the level of policy-making to take appropriate decisions which will create conditions that will turn the transport towards the direction of sustainable development. That means those decisions will steer other people who have more narrow interest in the end to take decisions generally in line with the process of sustainable development. Most of these tools lie in the economic pillar of indicators.

In all cases of decision making, there is a possibility to define much shorter list of indicators than the ones used in the actual research, and still achieve reliable results in the process of decision making.

Notice

The paper will be presented at MOTSP 2020 – International Conference Management of Technology – Step to Sustainable Production, which will take place from 30th September – 2nd October 2020 in Bol, island Brač (Croatia). The paper will not be published anywhere else.

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Benefits from Implementing the EPLOS System in Logistics Companies

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Abstract: Logistics companies are currently differently using IT tools to assist the planning of their operational activity. The functionalities of tools are also different. The paper presents the results of a research on the use of automated solutions to obtain the data necessary for logistics processes planning. It also presents a review of IT solutions used by TSL (transport, shipping, logistics) companies and the functionality of these tools. This allowed for the assessment of the potential of the EPLOS system to be used in TSL companies, as well as the benefits of implementing this system. In the paper, the selected results of a survey made in companies about the crucial data needed for efficient operating were presented. The summary indicates the main features that software should have in the era of the Industry 4.0 revolution.

Keywords: Big Data Analysis; EPLOS; Industry 4.0; IT for logistic; Logistic 4.0

1 INTRODUCTION

Managing logistics processes in today's dynamic economic conditions is very complicated. Depending on the area of actions and the decisions taken, it is necessary to take into account many factors and the specific operating conditions of a system. In the era of the dynamically changing demand, as well as high uncertainty as to the possibility of implementing processes, it is necessary to properly support decision-making processes by using intelligent computer tools and data banks. This applies to the entire industry, i.e. carriers, logistics operators, forwarders, or production plants.

A lot of research is available in literature for the needs of the logistics processes analysis [1-4] and for the purpose of collecting data [5-8]. These tools are often simplified, and the results are subject to a significant error or require a large number of diverse data. In this context, on the one hand, process decision-makers must have appropriate methods and, on the other hand, a proper data bank, which should be dynamically supplemented by contractors and potential contractors. Contemporary technological solutions and the industrial revolution based on the Internet of Things (IoT) or Internet of Vehicle (IoV), as well as the increasingly developed blockchain technologies, big data analysis, and Artificial Intelligence (AI) give the possibility to combine advanced methods with the appropriate data bank, and thus allow an effective support of enterprises in their current operations.

The European Portal of Logistics Services (EPLOS) is a tool based on the latest technological solutions and it is intended to reach a broad audience. It is a portal of logistics services aimed at supporting enterprises' activities in the scope of planning logistics processes by providing reliable data on the logistics infrastructure and services provided by other entities.

Based on the results of the logistics service market research presented in the PwC report [9], it should be pointed out that transport will be shaped by five main factors. One of them is the constantly growing demand for transport, with the reorganization of transport resulting from the mobility package. An important element are driver shortages, which are estimated at 200,000 in 2020 in Poland. This will require appropriate resource management, because the problem is no longer the shortage of devices and their cost, but the difficulty in filling the workplace [10]. In the context of this paper, the PwC report touches on digitization, which includes an increase in process automation, including the Internet of things, as well as the industrialization and development of e.g. autonomous vehicles.

This paper presents the EPLOS system in the background of solutions used in logistics companies. The main areas to support decision-makers and the conditions and benefits of its application were indicated. The paper is divided into five parts: Introduction to the topic and its area, A general overview of IT (Information Technology) systems supporting operations in the TSL (Transport, shipping and logistics) industry and the benefits of their use, Characteristics of digital data warehouses as a source of data necessary for the functioning of entities in the logistics industry, Description of the EPLOS system as a response to the needs of companies in the logistics sector resulting from market research. The paper ends with a summary and conclusions from the conducted considerations, systematizing, and directing reflections in the field of modern technologies and support of logistics processes. The paper promotes the sharing and exchange of data in logistics systems and indicates this potential.

2 IT SYSTEMS AS SUPPORT FOR OPERATIONS IN THE TSL INDUSTRY

The on-demand economy requires the adaptation of products to customer expectations. The demand for such services, along with the development of technology, is constantly growing and it requires a response from service providers and producers. The logistics, shipping, and transport sector must also adapt to this state of affairs. IT systems have been operating for many years to support the operational activities of enterprises such as ERP (Enterprise Resource Planning), WMS (Warehouse Management system), and TMS (Transport Management System).

Changes in the market have also resulted in the need for greater integration between enterprises in supply chains, and thus in an improved information flow, which is why SCM (Supply Chain Management) systems have been used more and more often in the previous 20 years [11, 12]. The scope of the systems is presented graphically in Fig. 1.

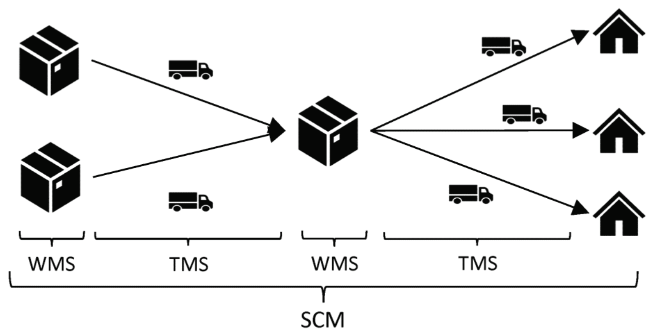

Figure 1 Graphic presentation of the areas of the functioning of management systems in logistics

In transport and forwarding, TMS systems provide the primary support. These are the systems supporting the implementation of transport services through planning and control. They have modules for contractor management, fleet management, order acceptance, route planning, including the optimization of transport performance. TMS supports scheduling, allocation of resources to tasks, and monitoring of transport status. The use of such is dictated by a large number of notifications and resources that must be managed in dynamically changing conditions. These systems allow you to make quick reactions, e.g., in the event of transport complications, cargo problems, or in the buying and planning of orders.

Classic solutions covering the above-mentioned functions are currently not sufficient. Software suppliers are required to be intelligent and intelligently support transport operations. From the beginning of the implementation of such systems and with technological development, but also with the increase in the requirements of customers, their evolution has been taking place. From the classic database approach, TMS is being transformed into a dynamic decision support system, containing many additional modules integrating various areas of transport activity, including economic, legal or ecological [12] activities. Additionally, as the authors indicate [12], in the era of currently prevailing trends, TMS systems are being developed with modules for globally organizing multimodal and intermodal transport.

It is impossible to function effectively without the support of such applications. The new range of functions in TMS requires collecting large amounts of data from various sources. Currently, it is necessary to process large amounts of data, but unfortunately, they are often fragmentary and incomplete, and there are no tools that guarantee the completeness and timeliness of data, especially when they are dispersed in the network. Often, these data are manually searched, entered into the system, and must be manually updated. This is associated with a high risk of error, but also a lot of work.

The term Industry 4.0 is used to refer to the technological developments that occur. The term includes the development and integration of information technologies enabling effective implementation of manufacturing and service processes. It is based on intelligent digital technologies creating cyber-physical systems. This requires adequate communication infrastructure, including data collection, processing, and analysis systems. The term Logistics 4.0 is also associated with this term [13].

Logistics 4.0 is connected with the relationship of services with intelligent tools supporting the activities of employees. This is to prevent uncontrolled situations that may arise and to avoid human errors. It allows for more efficient and faster implementation of individual processes. Therefore, it does not replace human work, but is intended to support its performance and provide the data and analysis to make the right decisions. Including systems in the offered products that take over one part of human work allows you to implement the issue of Smart Logistics. Such activities enable the transferring of the burden to the performance of a more complicated task by man and repetitive, tedious, and often time-consuming activities of intelligent automatic programs. The systems built based on this principle can be used in various areas in logistics, e.g., storage, resource management, vehicle route planning [14]. As it has already been mentioned, effective transport planning requires access to large amounts of data, which often have to be obtained manually. The answer to such needs are "intelligent systems" and infrastructure supporting the flow and collection of information such as the Internet of Things (IoT), Internet of Vehicles (IoV), Internet of Infrastructure (IoI) [15, 16]. Automatic collection and processing of the obtained information, along with the integration with various systems of subcontractors allow for faster and better logistics services.

Planners using information systems integrated with the Internet and other information exchange systems expect fast and accurate analyses regarding the selection of transport offers and the assignment of tasks to vehicles in a way that maximizes the company's revenues, while also keeping in mind sustainable management. Significant support is the equipment of the TMS system with the so-called matching systems that match the enterprise's resources to transport orders [17]. Such mechanisms have been considered for several decades, but only the current state of technology and the possibility of a rapid exchange of information allow their effective application. They allow the analysis of which transport orders to choose for implementation in order to achieve the best possible operational efficiency of the transport company, taking into account customer satisfaction.

3 DATA WAREHOUSE AND DATA ANALYSIS AS A SOURCE OF INFORMATION FOR ENTITIES IN THE TSL INDUSTRY

Data in logistics is extremely important for the quality of services rendered. Many factors are responsible for making the right decisions and implementing the process, which must be analysed to predict market changes correctly, manage available means of transport, use available infrastructure, and ensure adequate process reliability. In this approach, in the context of the Logistics 4.0 and Smart Logistics paradigm, it is necessary to collect a huge amount of data from many sources. This is related to the issue of Big Data Analysis. This concept, in turn, is associated with data collection and terms such as Data Mining and Data Warehouse. These are the typical terms for the ongoing technological revolution and are also used in logistics. Schematically, this issue in the context of logistics is shown in Fig. 2.

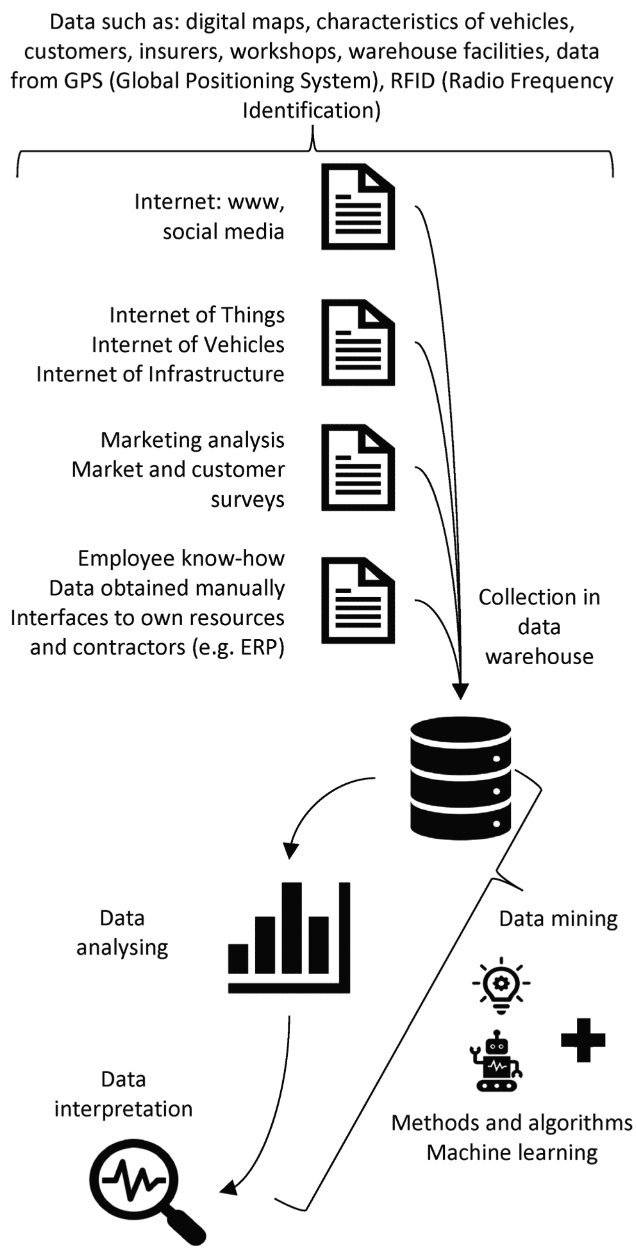

Figure 2 Big Data Analysis in the TSL area

Big Data, as the name suggests, is a collection of a large amount of stored information. It is defined by the 3V features: volume, velocity, and variety. Laney introduced such characteristics [18]. Additionally, it can be extended with features such as veracity, value, variability. Generally, it can be said that big data is a collection of a large amount of data, of great diversity, generated and processed at a fast pace, with a certain trust in their correctness, with a specific value for their owner, as well as with a specific use [19, 20].

The analysis of data sets that are useful in logistics is a popular topic of scientific research, which is indicated by review works, e.g. [21, 22]. This can be referred to as Supply Chain Analytics (SCA). As shown in Fig. 2, many systems, objects, and distributed information sets can be identified as data sources in the area of logistics. Some of this data can be obtained manually, and some automatically using interfaces. The data comes from their own resources, from individual sensors and receivers, e.g., GPS (Global Positioning System), RFID (Radio Frequency Identification), mobile phones, surveys, and customer satisfaction surveys, order history, etc. In Logistics 4.0, IoT, IoV, IoI is a particularly important data source. This data is cleaned and goes to the Data Warehouse, which is an analytical centre collecting data from various sources. It is only from these data that the useful ones are selected, then they are analysed and interpreted - these elements combine into the so-called Data Mining. However, this is not yet SCA, as it needs to be additionally supported by artificial intelligence - machine learning.

The use of the Big Data Analysis in logistics is important for supporting decision making. Investments in new rolling stock, warehouse facilities and concluding contracts are strategic decisions that decide about the company's profitability in the long-term, any changes in the already made decisions are costly and difficult to implement [23]. Therefore, appropriate information resources, along with their analysis and interpretation, are key. These can be various data, e.g. regarding the demand for materials, transport demand, technical or operational data of equipment and infrastructure [24-26]. It is no different when making operational decisions. Of course, their susceptibility to change is much higher, and individual errors do not significantly affect the efficiency of the enterprise, but it is the small decisions that, if accurate, decide on the company's results [27].

4 EPLOS AS AN SCA SYSTEM AND LOGISTIC PROCESS MANAGEMENT SUPPORT - POTENTIAL BENEFITS

The EPLOS portal can be described as an SCA (Supply Chain Analytics) tool. It is a tool in which data on the entities on the logistics market, as well as infrastructure, is contained. These data will be collected automatically by using interfaces to the WMS, TMS, ERP systems of enterprises (to the extent in which they agree), as well as entered and supplemented by entities. Users will have access to a wide range of data under the data warehouse. Additionally, the EPLOS system will support them in the analysis of these data and their interpretation, e.g. in the case of the route selection and order for vehicles. The implementation of these functions will be based on the built-in artificial intelligence algorithms.

This system is aimed at supporting the entities and companies operating in the area of the TSL sector. Therefore, it was necessary to analyse the needs of these entities. For the above-mentioned reason, the significance of logistics information was identified by using the survey method, as well as an assessment of the present method of data obtaining. Transport, service, production and trade enterprises took part in the survey. Their needs in terms of online information infrastructure, warehouses, logistics centres, and other service facilities needed in the performance of transport were examined. In total, 519 entities were surveyed, of which 28.71% are logistics service providers, 43.74% are carriers, i.e., the main recipients of the EPLOS system.

The research results clearly show that despite significant technological progress, including in the field of Big Data, most data are collected manually in transport companies. This applies to smaller enterprises with several dozen employees as well as large transport companies. Among the surveyed entities, over 70% of the data is collected manually from various sources, including the legal acts, information on the functioning of logistics centres and transhipment points, or transport infrastructure. The percentage share of data collection is shown in Fig. 3.

Manual data acquisition is inefficient and very labour-intensive. The time saved can be used for other activities or it can simply reduce the number of employees needed. Thus, the EPLOS system would be an ideal tool to support operations in the TSL industry by collecting and sharing the necessary data.

The analysis of needs indicated that the information on traffic restrictions, road tolls, and services or actual traffic is crucial for the functioning of enterprises. Among the examined entities, the following were considered the key or essential data:

- traffic restrictions (87.5%),
- traffic intensity (86.5%),
- infrastructure parameters (85.2%),
- charges for access to infrastructure (84.8%),
- infrastructure services (81.7%),

As it should be noted in the case of the TSL sector, infrastructure information is of great importance. With this in mind, the EPLOS system will implement a database containing consistent information and be updated on the road and rail infrastructure on an ongoing basis. The answer to this problem is the use of supported map solutions and their supplementation with the available data from external sources. It was assumed that the EPLOS databases would include road digital maps provided by one of the market leading companies and RailMap railway digital maps offered by OLTIS (the company that is the contractor of the EPLOS project).

Additionally, in the scope of services provided as part of the transport infrastructure for the examined participants of the TSL market, the most important one is information about concentrated parking lots, gas stations, and car washes. The distribution of the validity of these data is shown in Fig. 4. The data regarding these places and services has been included in the EPLOS system to better respond to the needs of potential customers. More complex information about the database used in EPLOS can be found in [28, 29].

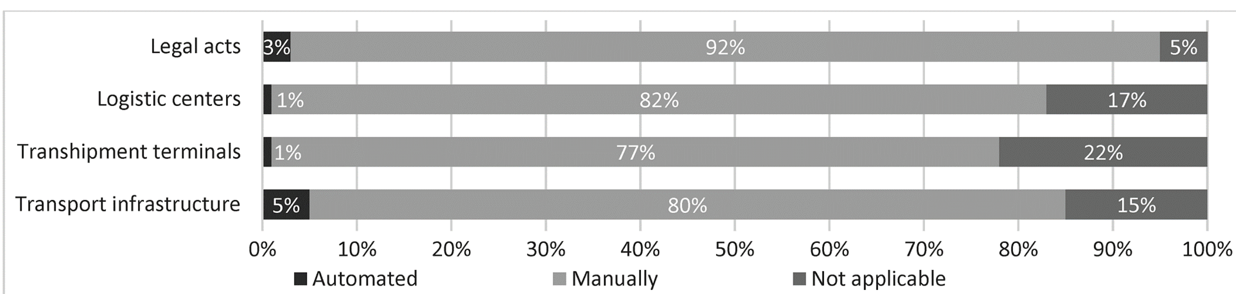

Figure 3 Share of the data collection method in the surveyed entities in TSL

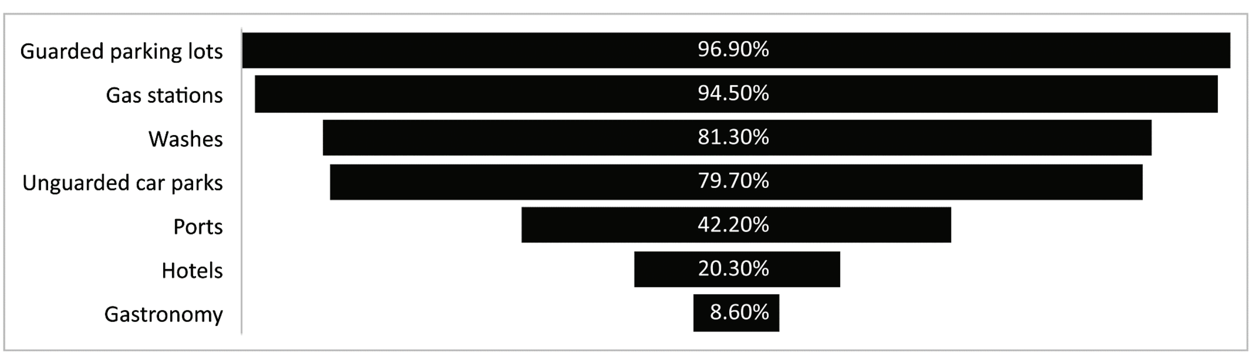

Figure 4 Data identified as key in the scope of additional services by companies from the TSL sector

This system is developed for the specific needs of companies in the TSL industry. Participation in the venture brings many benefits for all participants. In addition to obtaining access to the current data on digital maps and infrastructure, users will share the data enabling the better and faster implementation of processes. These data may relate to basic characteristics such as opening hours, available rolling stock, and number of places in the warehouse, but they also may include more sensitive ones. The more data, the more effectively the system will support the activities of cooperating entities.

Basically, the functioning of the system depends on the participation of its users in its creation. Updating data and taking care of their completeness will ensure the full functionality. The chart in Fig. 5 shows the data that enterprises are willing to share within the system. The analysis demonstrates great caution regarding the exchange and sharing of data. Therefore, it will be necessary to encourage entities and show them the benefits that will result in their achievements.

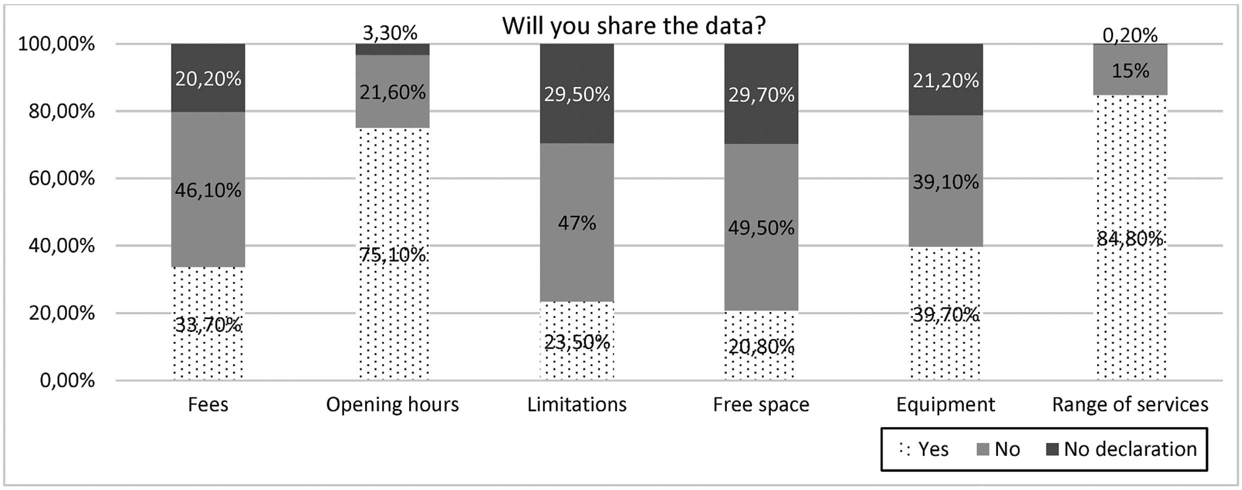

Figure 5 Declaration of data sharing within the EPLOS system

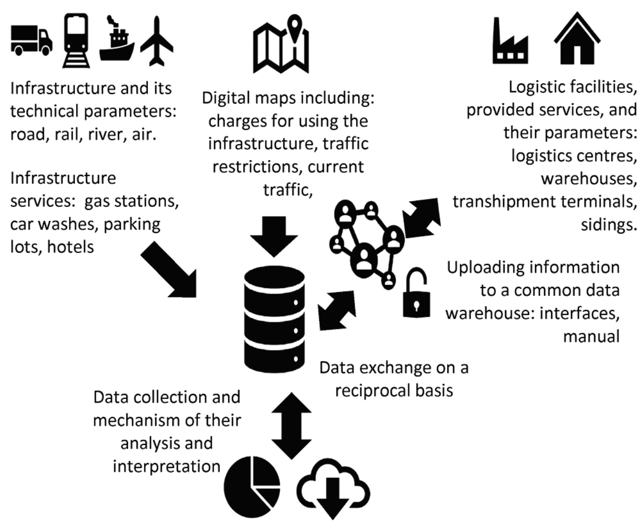

Figure 6 Elements of the EPLOS system

The main benefit of implementing the EPLOS system for logistics companies is the access to regularly updated data on the transport network and business partners. Logistics companies will be able to use the EPLOS databases in a fully automated manner through interfaces. The scope of available data will suit their needs resulting from making decisions in the field of moving goods. They will include data enabling the determination and comparison of options for moving goods, taking into account different types of transport and transshipment terminals. Thanks to the information provided by EPLOS, it will be possible to compare these variants automatically, both for the estimated transport time as well as transport costs. For logistics companies, the EPLOS system will, therefore, expand the functionality of mapping solutions dedicated to truck transport with analogous solutions for rail, air, or inland transport, as well as the information on logistics facilities that is continuously updated. The main functionalities and elements that this system will have are schematically shown in Fig. 6.

Additionally, logistics companies will be able to access reliable and centralized information about potential business partners, as well as compare their offers with the offers of companies with which they currently cooperate. Thus, EPLOS should contribute to improving the competitiveness of logistics service providers, as well as, as a consequence, the competitiveness of logistics companies themselves. This will bring results in the time saved, the better use of resources of individual enterprises, and establishing new contacts. Of course, this will translate into financial savings, social and environmental effects. Therefore, it is a tool that will activate enterprises to share data, enhance integration between entities, and this will be an impulse and a tool for easier creation of supply chains and logistics networks, ensuring data quality and the ability to flow information. The implementation of the EPLOS system in the enterprise is the entrance to a higher level of organization in the context of the Logistics 4.0 paradigm, including the concept of Lean and Agile Management.

The vast potential of using the EPLOS system by logistics companies that implement IT solutions in the field of transport management should also be noted. Namely, these companies will be able to pre-supply local TMS databases with information about their business partners obtained from the EPLOS system. More importantly, thanks to the use of the EPLOS system, this information will be updated regularly. It allows for substantial savings for logistics companies resulting from a significant reduction of the manual acquisition of a lot of data. Thus, enterprises will be able to engage employees for other operational activities and thus achieve additional revenues. At the same time, enterprises will obtain a guarantee of correctness and timeliness of data, as well as become more competitive on the market.

5 CONCLUSIONS

The dynamics of market changes, customer needs, and the strategy of operation forces entities in the TSL sector to adapt to prevailing trends. The Industry 4.0 paradigm and the related Logistics 4.0, as well as the possibilities of using the Internet of Things, allow companies to implement new solutions that respond to current market needs. Nowadays, it is access to data and the ability to analyse and interpret it, which is particularly valuable and, at the same time, necessary for the effective provision of services. Data obtained independently without coordination are often dispersed, their usefulness is disputable, and the labour consumption of obtaining is high.

As the authors indicate [12], systems supporting the operation of logistics enterprises must meet a number of requirements. The main ones include: increasing interoperability - facilitating document exchange, data flow, interfaces for data exchange; providing a tool that will provide certain data along with their analysis and interpretation - this will enable the development of various scenarios and thus increase the resistance to interference and downtime; better process planning and control - implementation of more sophisticated algorithms supporting decision making, resulting in higher efficiency, punctuality and the reliability of processes. Moreover, the system must meet a number of technological requirements such as the ease of use, low cost of use, flexibility, the ability to adapt to individual needs.

The EPLOS system is, therefore, the answer to today's challenges and support in the acquisition and use of data. It will provide entities with data concentrated in one place, easily accessible, current, and standardized. Furthermore, it will enable the use of implemented tools for their interpretation. The success of the venture, however, depends on the way companies think and whether they want to integrate and exchange data.

On the one hand, the EPLOS system must be a tool containing the basic data and the data on the services of other entities. On the other hand, this tool must encourage the exchange of data and promote those who are willing to share data. Only such an approach guarantees the success and usability of this system and, at the same time, a response to the challenges posed by today's market.

Acknowledgements

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Notice

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Preliminary communication

Route Planning with Dynamic Information from the EPLOS System

Michal Kłodawski*, Marianna Jacyna, Rostislav Vasek, Piotr Klimek, Roland Jachimowski, Emilian Szczepański, Konrad Lewczuk

Abstract: The paper presents the problem of distribution route planning with dynamic information about sudden customers' needs. Particular attention was paid to dynamic vehicle route planning and its influence on the distance covered by a distribution vehicle. In the article, authors assume that the quick information about customers' sudden needs is transferred from the EPLOS tool data base. Authors analyze the available literature on transport route optimization and propose a solution to the problem of distribution among customers with sudden needs. In order to present the impact of quick information influence on the distribution route minimization, a simulation model of the vehicle routing problem was generated in the FlexSim environment.

Keywords: EPLOS; FlexSim; route minimization; route planning; VRP

1 INTRODUCTION

Transport is one of the key sectors of the economy in every country. Its importance for the movement of people and material goods seems to be indisputable.

Thus, the efficiency of the implementation of transport processes directly affects the duration of this process and its cost. This cost then also influences the prices of transported material goods.

In addition to the cost aspect, effective freight transport planning is key to satisfying the needs of the recipients of goods in a satisfactory manner in the shortest possible time and at the lowest possible price. Transport planning is not only organizing the right means of transport within a certain period, but also the proper organization of several processes accompanying the physical movement of goods. An example of such activities may be the planning of the route of cargo transport. Difficulties in the planning of the transport route should be seen mainly from the point of view of the lack of reliable information about the current conditions on the transport route (traffic jams, road sections, etc.) [1-3].

In addition to transport route planning, the performance of operational activities related to goods unloading can pose some problems. An example of this type of problems may be the availability of appropriate handling equipment enabling the unloading of vehicles at the recipient's end. Hence, both the knowledge of road conditions and the ability of shippers / recipients to load / unload goods can directly affect the efficiency of the implementation of the cargo transport process [4-6].

These situations most often make it difficult to plan full truck loads, where the goods from one supplier are delivered directly to one recipient. Delays on the transport route and difficulties in unloading vehicles at the advised time are typical problems that transport planners, dispatchers and forwarders must face every day.

The problems mentioned above increase in the case of goods delivered by a single vehicle from one / many senders to many recipients. In this situation, we are dealing with distribution, which is most often defined as the process of making products and services available to the recipients located in places other than service providers or production plants.

Therefore, fast and reliable information is crucial for proper transport planning. Unfortunately, the transfer of quick information faces many problems. Therefore, this article addresses the issue of access to quick information on customers' needs and its impact on distribution costs related to the length of vehicle routes. The article considers the vehicle routing problem with the dynamic information of the customers' needs. Such dynamic information can be downloaded from the EPLOS software (European Portal of Logistics Services) which is manufactured by the Warsaw University of Technology together with the CID International within the European Eureka Program.

2 VEHICLE ROUTING PROBLEM WITH DYNAMIC INFORMATION

The difficulties in cargo distribution planning result mainly from the many aspects that must be considered at the planning stage. These include, for example: limited load capacity of vehicles and their availability in time, time windows for the picking up and delivery of goods, many vehicles distributing cargo at the same time, variable traffic conditions, asymmetry of transport costs, etc. [1]. In literature, such a problem is called the Vehicle Routing Problem (VRP). This problem is development (by the above-mentioned aspects such as load capacity, vehicle availability), one of the oldest optimization problems on networks, called the Traveling Salesman Problem (TSP), which consists of a salesman visiting each of the selected towns exactly once and returning to the town from which the journey began. The travel costs between each pair of locations are known [7, 8].

A traveling salesman should be planned in such a way that he can visit each place exactly once and the total cost of travel is as low as possible [7].

There are many different variations of the vehicle routing problem addressing the aspects of the reality mentioned above. Among the most common are the Capacitated VRP (CVRP), where each customer has a demand for a good and vehicles have a finite capacity; the VRP with Time Windows (VRPTW), where each customer must be visited during a specific timeframe; the VRP with the Pick-up and Delivery (PDP), where goods have to be picked-up and delivered in specific amounts at the vertices; and the Heterogeneous Fleet VRP (HVRP), where vehicles have different capacities.

In the era of a rapidly growing market economy, minimizing the costs of operating an enterprise is no longer the only indicator of its success in competition with the competitors. Very important is also the level of customer service, which depends on on-time deliveries and the ability to respond to sudden customer needs.

In the case of distribution, this issue is addressed by the dynamic vehicle routing problem (DyVRP), where the previously set route can be changed according to a sudden request for transport. That is why it is possible to quickly reshuffle the vehicle's route to minimize the unnecessary distance.

The DyVRP is not a new issue. For many years, scientists have been developing more and more new methods for solving the issue. The first publications dealing with the issue of DyVRP appeared as early the 1970s [9]. This publication concerned passenger transport, where passengers expressed their desire to travel without prior notice. This type of phenomenon is the most common example of dynamism in the DyVRP. This also applies to the transport of goods, where the demand for transport is already reported during the implementation of the vehicle's route. This aspect has been undertaken over the years by many scientists, including, [1, 10-14]. An element of such an emergency call may also be the performance of a service [1, 15-18]. Another source of dynamism in the vehicle routing problem is the time of carrying out loading operations at shippers / recipients of cargo and the time of travel between successive loading / unloading points [1][19][20][21]. Some research also takes into account the possibility that the vehicle can simply break down during the route performance [22-24].

Since DyVRP belongs to the class of NP-hard problems (the optimum solution cannot be found in the acceptable time), its solution requires the use of heuristic algorithms such as: genetic, ant colony, particle swarm optimization, greedy, local search, simulated annealing, or Tabu Search. Additionally, agent programming, dynamic programming and simulation techniques are used to solve these types of problems [21, 25-34].

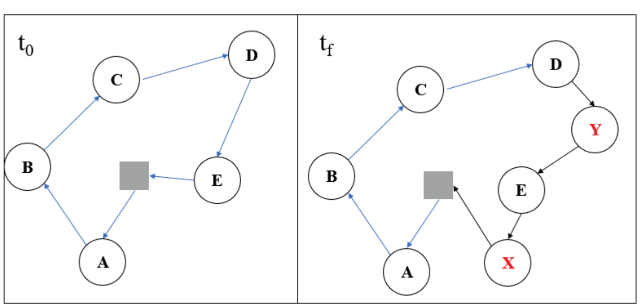

Figure 1 Example of a dynamic VRP

Schematically, the idea of the DyVRP is presented in Fig. 1. The first route designated in t_0 moment is contained of the points ABCDE. Suddenly in the moment t_f, the route is extended by the points X and Y. Because of that, the vehicle does not go from D to E, but in the meantime serves Y. Then after point E, the vehicle visits X before it comes back to the base.

The optimization criterion for a DyVRP is usually the length of the route and the time it takes to complete it. However, other optimization criteria for this problem are e.g. customers' service level, number of requests served, transport provider capacity. The need to respond to dynamic customer requests also introduces the concept of response time: the customer can ask for service as soon as possible; in such cases, the main goal may be to minimize the delay between the arrival of the request and its handling.

3 IT SYSTEMS SUPPORTING VEHICLE ROUTING WITH DYNAMIC INFORMATION

Decision-making regarding the vehicle route must be done online, which can often be a compromise between the response time and the quality of the decision to fulfill that request. The longer the time it takes to find a solution for an emergency request, the less likely it is that a high level of response to that request will be met. Thus, ensuring a high level of customer service while responding quickly to his needs requires very quick access to information about his request. Quick access to logistics information requires the cooperation of both transport organizers and clients on transport services. Such cooperation is possible only thanks to the use of IT systems that connect logistics market participants.

An example of such a tool is the EPLOS (European Portal of Logistics Service) program, which provides access to customer data in real time, including the status of their demand for a given product. This program can be interfaced to the TMS (transport management system) tool of carriers and freight forwarders, as well as to the ERP (Enterprise Resource Planning) tool of customers. Thanks to that connection, the customer who cancels the delivery when the vehicle is already on the road has the option of informing the transport dispatcher about it. With the use of the tools for the planning of transport routes, the dispatcher can efficiently re-route the vehicle. The route planning tools must cooperate with the ITS (Inteligent Transport Systems) systems based on a combination of geolocation technologies with precise geographical location and increasingly more advanced equipment and software for data processing. The DyVRP mentioned above is usually implemented in the Advanced Fleet Management Systems (AFMS) tools used to manage a fleet of vehicle [25, 35]. Thanks to this class of systems, it is possible to analyze and respond to customer requests ad hoc. The very important advantage of this type of systems is the possibility of route optimization or another parameter being the goal of real-time optimization. Nevertheless, these types of systems only allow cooperation with regular customers in a normally defined transport network that includes both the carrier and customers.

In the case of more complex transport systems, the use of these tools can be troublesome due to the lack of access to quick information about the need to handle a sudden customer request. An example of this type of distribution systems will be the systems on a macro scale, where the carrier carrying out certain courses with loads is not aware of any customers who are outside its database and who could be served by this carrier.

Therefore, it is necessary to use the EPLOS system, which is a kind of a logistics database about the participants of the logistics market, both the customers interested in transport or some other logistics services as well as enterprises providing broadly understood logistics services. EPLOS is a system that gives the opportunity to share data on logistics services and gives access to this data to all users at the same time. Due to EPLOS, logistics market participants such as logistics operators, carriers and freight forwarders, who are currently downloading information about their destinations and contractors primarily from the online environment, can now access the quick information.

4 CALCULATION EXAMPLE

The information about the emerging demand for transport mentioned in the previous chapter is extremely important from the point of view of the minimization of costs associated with e.g. the loads distribution. Usually, a distribution vehicle obtains route information some time before the start of the route (the route is pre-planned by the planner). However, it may turn out that immediately after the start of the route, there is sudden information about the need to prioritize one of the recipients of cargo because of his change in the date of the delivery of cargo. Therefore, it is necessary to quickly re-plan the route.

The aim of this example is to show how the quick information about the sudden customer request transferred from the EPLOS to the carrier's TMS tool can influence the distance covered by the vehicle. It is assumed that the carrier's TMS tool has the routes optimization module. Because we don't have access to the carrier's TMS tool, we used the FlexSim simulation software to prepare the model of the Vehicle Routing Problem with dynamic information of the customer's needs. Therefore, in this case, FlexSim is just a software which allows the preparation of the VRP example and is not connected neither to the EPLOS nor to the carrier's TMS tool. The calculation example presented below allows determination of the impact of access to logistics information on the distances covered by distribution vehicles.

Examples of the use of FlexSim can be found in [36]. For the purpose of the study, a simulation model consisting of 6 customers was built. A fragment of this model is shown in Fig. 2. The numbers from 1 to 6 indicate the subsequent route points of the distribution vehicles.

It was assumed that the distribution route always starts and ends at point 1. Moreover, it was assumed that right after the route starts, the driver can receive sudden information, that some recipients must be served as the first or last in the vehicle route. Such situations can appear when recipients change their original time windows for the delivery.

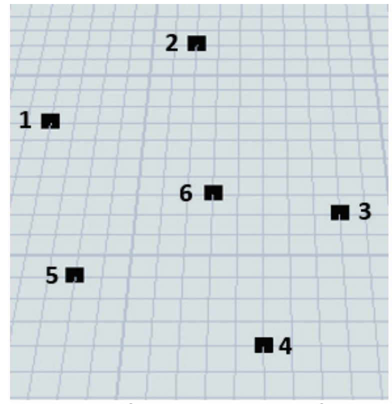

Figure 2 Simulation model in FlexSim

Using the FlexSim optimization module, the optimal vehicle route was determined for situations where there are no sudden customer's needs causing disruptions in the transport route. Searching for the minimum value via the heuristic algorithm implemented in FlexSim is shown in the Fig. 3.

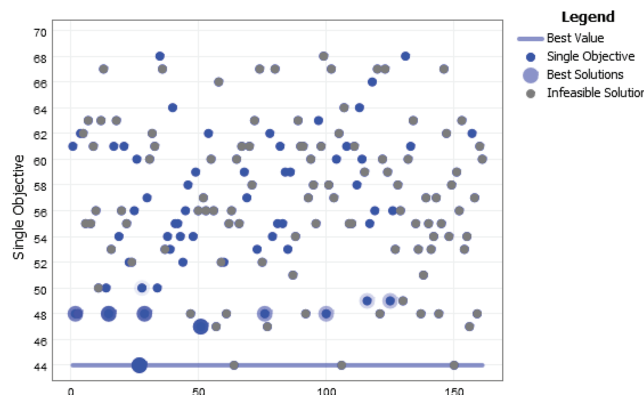

Figure 3 Solution space

As a result, an optimal solution was obtained, according to the points shown in Fig. 2. The points from Fig. 2 were visited by the vehicle in the following order: 1-5-4-3-6-2-1. The obtained route was schematically presented in Fig. 4. The length of the route in this case was 44,51 units.

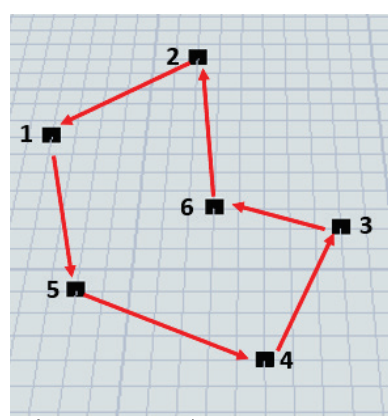

Figure 4 Calculation solution for the route planned in advance

Consequently, various scenarios were analyzed assuming that individual points must be served as soon as the vehicle route begins or after the remaining points have been serviced (the driver receives information that the given point must be served as soon as possible or as the last one). The results of the calculations carried out are summarized in Tab. 1.

Table 1 Route optimization results

Point number with a sudden need (notification)/notification type		Service point order							Route length (units)
2	Service after the start of the route	1	2	6	3	4	5	1	44.51
	Service at the end of the route	1	5	4	3	6	2	1	44.51
3	Service after the start of the route	1	3	4	5	6	2	1	50.57
	Service at the end of the route	1	2	6	5	4	3	1	50.56
4	Service after the start of the route	1	4	5	6	3	2	1	52.77
	Service at the end of the route	1	2	3	6	5	4	1	52.77
5	Service after the start of the route	1	5	4	6	3	2	1	47.68
	Service at the end of the route	1	2	6	3	4	5	1	44.51
6	Service after the start of the route	1	6	5	4	3	2	1	48.24
	Service at the end of the route	1	2	3	4	5	6	1	48.23

"Service after the start of the route" indicates that the driver receives information that the given point must be served right after the service of point 1.

"Service at the end of the route" indicates that the driver receives information after he begins with the route that the given point must be served as the last one.

The results presented in Tab. 1 clearly indicate that the sudden notification of transport demand affects the extension of the previously planned route of the vehicle. In the analyzed case, only the need for service after the start of the route and at the end of the route of point 2 did not cause the extension of the route presented in Fig. 5. Similar results were obtained for point 5, which reported a need for its service at the end of the route. In other cases, the vehicle route was extended.

5 CONCLUSIONS

The problem of vehicle routing with dynamic information presented in the article is an important issue for minimizing the costs of transport as well as for maximizing the level of customer service. As emphasized in the article, planning the minimum route for freight transportation considering sudden notifications (need for transport) is not possible without access to quick information. This quick information can be transferred only with the use of IT systems that connect the customer with the carrier. The direct connection between customer and carrier is not always possible, which is why it is necessary to use tools such as EPLOS, which is a database that can connect the users of the logistics market (logistics market users can obtain information about each other, including the information of a sudden transport need). Such access to quick information about a sudden customer's need will allow, on the one hand, a quick response to the notification (ensuring a high level of customer service), and on the other hand, it will reserve more time to plan the route to minimize it.

The routing results presented with the use of FlexSim, which is just an environment for the preparation of the vehicle routing example, show that quick information positively influence the vehicles' routes and, in the end, also the transport costs.

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Notice

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Preliminary communication

Electromobility and Its Effects on Automotive Workshops

Helmut Ropin*, Robert Supan

Abstract: Due to stricter CO_2 emission limits, new competitors and imminent driving bans, electromobility has registered high growth rates in Austria. The rising number of electric vehicles not only has an impact on automobile production and its suppliers, but also on the after-sales business with the focus on the repair market. In order to meet these requirements, automotive workshops have to redesign and realign their organizational structures and they have to compensate their decreasing service-revenues. Electromobility requires additional qualification and training of employees and the expansion of technical equipment. Small workshops especially are facing this challenge. In order to obtain an answer to the current status of service companies, a qualitative study was carried out and the status was determined based on expert interviews. Recommendations for action can be derived as a result and it can be shown that there is a big difference between the independent and authorised workshops.

Keywords: after-sales business; automotive after-sales; automotive workshops; electromobility

1 INTRODUCTION

The worldwide rethinking of drive concepts in the automotive industry is not only leading to a change in manufacturers and the supply industry, but also car service companies, the spare parts business, workshop service and business models must be adapted to these effects [1]. According to Fraunhofer IOA [2], in Germany, 100,000 jobs will be at risk by 2030 as a result of electromobility, compared to only 25,000 newly created jobs. The biggest driver for this change is currently the CO_2 emission limit value, which actually stands at 95 g CO_2/km as a fleet value for new vehicles [3]. In view of historical developments, automobiles have become more and more complex on a technical scale in the recent decades and maintenance has become more expensive as a result. With the entry of electromobility, complexity is now being reduced again and this means that car workshops will feel a profound impact on value creation. For example, the classic oil change, the replacement of timing belts and clutches will no longer be necessary. However, the combined use of a conventional and electric drive train leads to new challenges in workshop processes [3]. This paper gives an overview of the common drive concepts and the after-sales business in the automotive industry. Furthermore, the effects of electromobility on Austrian car service companies are elaborated in detail and are verified by a qualitative study. The results show the necessary changes in occupational safety, human resources, workshop processes and investments. Additionally, recommendations for Austrian motor vehicle service companies are derived. The empirical investigation in this paper is based on a qualitative study by using guided interviews. This form offers a flexible application and the openness of the approach can generate previously unknown information [4].

2 ELECTRIFIED DRIVE CONCEPTS

The rising growth rates in worldwide sales of electric vehicles show a continuous trend towards diversification in drive concepts. In 2019, the worldwide stock of electric vehicles was around 7.9 million, growing by more than 2.2 million compared to the previous year [5]. Measured against the total vehicle population of around 1.13 billion vehicles excluding commercial vehicles, this corresponds to a share of around 0.7% [6]. A historical review at the beginning of the 20th century shows that 38% of automobiles in the USA were already being driven electrically at that time [7]. The first hybrid vehicle in the world was the Lohner-Porsche from 1900, which achieved an electric range of 50 km and a speed of 50 km/h with its 410 kg battery. The belief in electromobility lasted until 1912, when the electric starter for internal combustion engines was invented and thus the electric car lost massively in importance. However, the electrification of the powertrain continued to occupy automobile manufacturers - the final breakthrough, however, came in 2006 with the Roadster model from Tesla, which could drive several hundred kilometres and marked the beginning of a new era in electromobility [8]. In addition to the familiar combustion engines, today's drive concepts often offer purely electric drives as well as various combinations of combustion engine and electric motor, the so-called hybrids. Additionally, there are also Range Extended Vehicles, which drive purely electrically, but have a combustion engine on board to extend the range [9, 10].

2.1 Battery Electric Vehicle (BEV)

These vehicles have one or more electric motors, power electronics and a traction battery. A combustion engine is not used. The main advantage of the BEV is the high efficiency of the components, which is between 87 and 98%. Three-phase motors are almost exclusively used, since they have a very high efficiency [11, 12].

2.2 Hybrid Electric Vehicle (HEV)

A HEV has two different energy converters and accumulators, whereby the energy converters can convert mechanical energy directly into propulsion, or charge the generated electrical energy into the energy accumulator. The primary goal of this concept is to increase the range of the vehicle. Disadvantages include the loss of installation space and the more complex design. HEVs are classified according to the so-called degree of hybridization [9]. A distinction is made here between Microhybrid, Mildhybrid, Fullhybrid and Plug-In Hybrid Electric Vehicle (PHEV).

2.3 Range Extended Electric Vehicle (REEV)

REEV is powered exclusively by an electric motor and the battery is charged either by an external charging point or by an internal combustion engine which acts as a generator and recharges the traction battery as required. The internal combustion engine can be operated in its optimum working range, although the efficiency of the overall system is lower. This is called a serial hybrid drive [3].

2.4 Fuel Cell Vehicle (FCV)

Similar to the REEV, the Fuel Cell Vehicle also uses only the electric motor for propulsion. Here, however, the fuel cell with a hydrogen tank is used, which drives the electric motor directly or can charge the traction battery [13].

The following figure shows a summary of all forms of powertrain electrification.

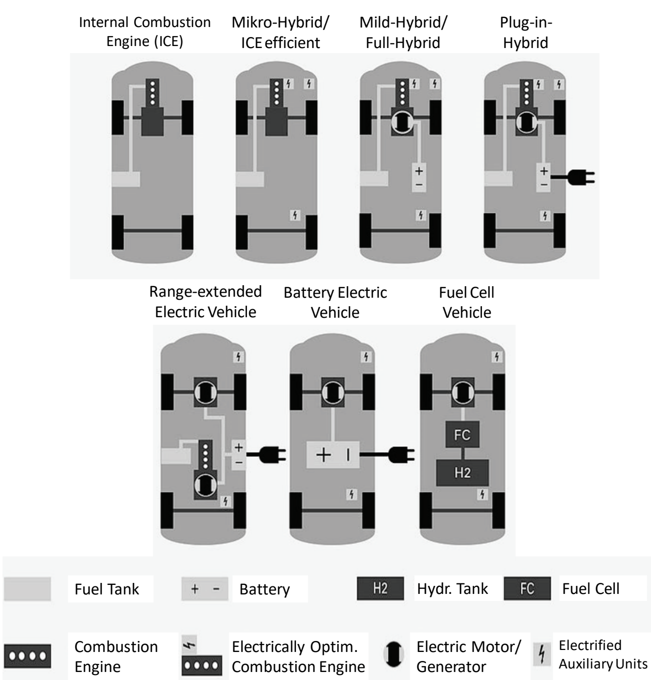

Figure 1 Characteristics of the electrification of the drive train [14]

3 AFTER SALES IN THE AUTOMOTIVE INDUSTRY

The automotive industry in Austria has around 370,000 employees in total and, with 14.1 billion euros in foreign sales, it is the second most important export sector. In addition to the production of motor vehicles, this also includes marketing, maintenance and disposal [15, 16]. The term Maintenance is often used as an overall definition of after-sales service, which can include various services after the purchase of products [17]. In the automotive industry, after-sales begins as soon as the sale of a vehicle is completed. The after-sales market is basically divided into parts business and service and repair business [18]. Fig. 2 shows the various stages of the value chain and the market participants:

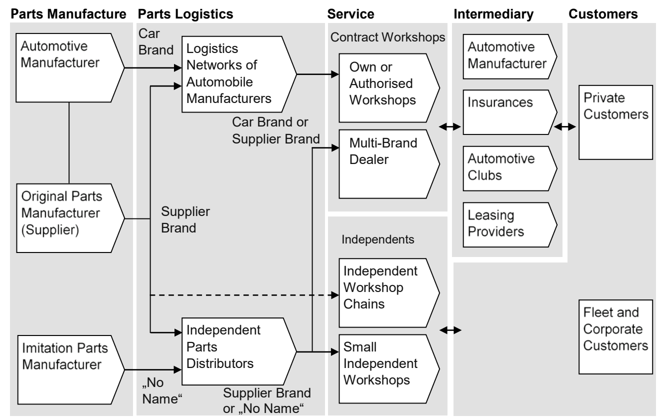

Figure 2 Value chain and market participants in the automotive after-sales [19]

In parts manufacture, the original equipment manufacturers supply their products with the appropriate logo either to car manufacturers or to independent parts distributors. It is also possible for parts manufacturers to supply parts directly to the workshop chains. Imitation parts are brought onto the market via independent parts dealers. In the second stage of parts logistics, the logistics networks of the automobile manufacturers and independent parts dealers operate, and they primarily supply independent workshops. The third stage comprises the actual service business, whereby a distinction is made here between the contract-based and independent vehicle service operations. The fourth level comprises intermediaries who mediate between the customers and car repair shops in order to push through low prices [19]. The after-sales business has a relatively low share of 11% of total sales in the automotive industry, but it is one of the most profitable sectors with 38% profit. By comparison, new car sales have a 41% share of sales with only 4% profit. One of the most profitable sectors is financial services with a 42% profit [20]. The after-sales business is an important economic factor for the original equipment manufacturer (OEM) and the independent aftermarket (IAM). Finally, price-conscious customers often find a better offer for services and switch to them after the guarantee period.

In Austria, approximately 12,800 companies are operating in the automotive sector. 5,400 of them are car repair shops and they generate a turnover of 4.8 billion euros [21]. The car repair shops can be assigned to the service and repair market, which is primarily divided into two groups [22]:

- Independent workshops: The focus is usually on the maintenance and repair of older vehicles and these are not dependent on manufacturers and can move freely on

the market. Another form are workshop chains that are identical nationwide.
- Authorised workshops: These companies are contractually bound to one or more car manufacturers and are often active in the new and used car trade. In addition to these sales partners, there are also OEM-owned branches that the car manufacturer maintains.

The brand-linked service companies are often confronted with the fact that vehicle owners switch to independent repairers for cost reasons after the vehicles have been in service for more than six years and thus lose important sales [23]. According to Dispan, the service business of the future will be characterized by five trends [22]:
- Longer maintenance intervals and higher vehicle quality lead to lower market volume in the service business.
- The higher inventory of older vehicles leads to a higher work volume.
- Flexibility, price, support and convenience are becoming more and more important to customers.
- Technological change in the form of electromobility and digitalization are relevant for service operations.
- Due to the intensified competitive situation, cut-throat competition is emerging.

4 IMPACT OF ELECTROMOBILITY ON AUTOMOTIVE WORKSHOPS

The amount of electrified vehicles is steadily rising in Austria. The number of new registrations of BEV rose by 37% from 2018 to 2019, while the number of vehicle registrations in Austria fell by 2.8% in the same period [24, 25]. The high increases will not only change the upstream processes of vehicle production, but also all subsequent value-adding processes, the downstream, will have to adapt to future conditions [26]. In this context, automotive workshops are already under high cost and sales pressure. Increasingly sophisticated developments and production methods are making repair cycles longer, which reduces the need for spare parts [27]. In the following section, the effects of electromobility on the different areas and processes of an automotive workshop are presented.

4.1 Work Safety and Qualification of Employees

Hybrids and Battery Electric Vehicles are operating with voltages of up to 800 V [28]. These can cause serious injuries, such as ventricular fibrillation or burns, if operated improperly. To minimize these risks when working on electric vehicles, proper protective equipment, such as insulated tools or safety gloves, must be provided. High-voltage technology thus distinguishes the service of electrified vehicles from those with a conventional drive concept. To be able to work on electrified vehicles with high-voltage technology, it is necessary to train and raise awareness among employees. The qualification is divided into three levels HV-1, HV-2 and HV-3 (HV = High Voltage). HV-1 covers all non-electronic activities. HV-2 includes all activities of HV-1 and additionally, the voltage isolation, the determination of the absence of voltage, when work on the high voltage system can be carried out. The third level HV-3 is based on HV-2. This authorises the employee to work on vehicles that are not HV-intrinsically safe and on high-voltage energy storage systems [29, 30].

4.2 Technical Equipment

To meet the requirements of high-voltage systems, investments must be made in the technical equipment [31]. The study of the State Agency for Electromobility and Fuel Cell Technology Baden-Württemberg "Development of Employment in After Sales" developed two concepts for the investments for car service companies in Germany. The basic variant focuses on one workplace which carries out maintenance and repair work, and the costs for this are 10,100 €. The second concept comprises a competence centre consisting of four workplaces, equipped with the necessary technical equipment for electromobility. The costs for the competence centre are 48.060 € [32].

4.3 Effects on the Workshop Process

Workshop processes are often standardized in successful companies. This minimizes uncoordinated processes, time losses and increases the added value [33]. Services for electric vehicles are also changing the structure of classic workshop processes. For example, a specifically trained specialist must be scheduled in the appointment preparation process. New types of complaints and claims must be taken into account, such as the charging or range of the vehicle. The new drive concept also fundamentally changes the service and repair activities [32].

4.4 Changes in Repair and Maintenance Services

The specific characteristics of vehicles with electrified drive trains are changing the economic considerations of maintenance and repair. Vehicles have certain components and fluids that require regular maintenance. The intervals are determined by the OEM. However, vehicles with combustion engines have components that require much more maintenance [34]. The following table compares the various drive concepts regarding the maintenance and repair measures.

Table 1 Maintenance and repair of various drive concepts [32]

	ICE	Hybrid	REEV	BEV
Oil change	✓	✓	✓	-
Exchange coolant	✓	✓	✓	-
Exchange spark plug	✓	✓	✓	-
Exchange fuel filter	✓	✓	✓	-
Exchange brake fluid	✓	✓	✓	✓
Check power electronics	-	✓	✓	✓
Additional coolant	-	✓	✓	✓
Brake system	✓	reduced	reduced	reduced
Exhaust system	✓	reduced	reduced	reduced
Clutch	✓	reduced	-	-

As shown in Tab. 1, the maintenance and repair effort of the electric vehicle is significantly lower compared to the ICE. In contrast, the operation of a hybrid vehicle is associated with a higher effort.

4.5 Turnover and Employment

As shown in Tab. 1, electrified vehicle concepts require considerably less maintenance and repair work. The Deloitte study "The Future of Automotive Sales & Aftersales" concludes that an after-sales business could be threatened with a 55% decline in sales by 2035. As a scenario, Deloitte assumed that 40% of all new car sales in 2035 will have an alternative drive concept (BEV, Hybrid, FCV). If only the area of maintenance and service is considered, a decline of 84% is assumed [35].

5 RESEARCH METHODOLOGY

In order to investigate the current status regarding the effects of electromobility and the future development of Austrian car service companies and to compare it with the current state of literature, this paper is based on a qualitative research method. The following research questions are examined on the basis of the empirical study:

1) Which requirements and challenges will be faced by skilled workers and their companies as electromobility moves forward?
2) What investments do car service companies have to make in order to service and repair electrified vehicles?
3) Are the changes in the workshop process a relevant problem?
4) How large will the decline in sales and workload be if electromobility continues to grow at such high rates?

5.1 Guideline Interviews

An empirical study based on a quantitative method using semi-standardised guideline interviews was selected as the research methodology. Compared to the quantitative approach, this methodology offers a much more open and flexible approach to data collection. It is possible to understand and interpret correlations. The often spoken words such as interviews, texts, written documents and observed behaviour are examined with the aim of deriving theoretical statements from the collected data [36]. Guided interviews are standardised and the same one is used for each interview to allow comparability. The interview is structured, although the order of the questions may vary. Additional questions can be asked. The personal interview was chosen as a variant of the communication form [37]. The interview guidelines were designed in an iterative process, whereby the research questions mentioned above served as a basis and three blocks of questions were derived: general questions (n = 3), specific questions (n = 7), basic data query (n = 7).

5.2 Expert Selection and Participant Structure

The selection of experts or the appropriate group of persons has a significant influence on the success of the data collection. The experts selected for the work in this study are persons in the leading positions in the service sector of automotive workshops. In the final analysis, company owners, plant managers and workshop managers were interviewed. The survey of test persons was always conducted on site and it included ten companies with ten participants. The participant structure shows that the number of employees in workshop operations is between 2 and 70 persons and thus represents a good cross-section. Both the independent workshops and authorised workshops of various manufacturers were surveyed.

6 RESULTS

In the following section, the results of the qualitative study are presented and are aggregated in four categories.

- Work safety and qualification of employees,
- Experience and future of drive concepts,
- Workshop process and effects on turnover and workload,
- Investments.

6.1 Work safety and qualification of employees

In practice, the experts consider the newly emerging sources of danger to be especially problematic. The high voltages of high-voltage components can be life-threatening if handled incorrectly. It is therefore necessary to raise the employees' awareness of this issue. Furthermore, not all employees are yet willing to accept electromobility. However, the problem of acceptance is not only based on electromobility, but also on the general change that the profession of a car technician is subject to. Work on electronic components is constantly increasing. Only two out of ten experts were able to ascertain a high level of willingness for further training in the field of electromobility in their companies.

6.2 Experience and the Future of Drive Concepts

The majority of experts have already gained experience with electric vehicles. 40% have already considered the purchase of an electric vehicle, but none of them has realized this plan yet, mainly due to the price and range. 70% of the experts assume that petrol or diesel vehicles will continue to lead the registration statistics in the next 5-10 years. However, diesel will lose market share. There is disagreement about hybrid technology. 30% of the experts are convinced that the hybrid will be at the top of the list of new registrations due to its benefits of private use for company vehicles and fleet consumption. In contrast, companies with a high number of sales of BEV and hybrids have experienced that the hybrid is less in demand than the BEV. Other drive concepts were not considered as relevant for the next years. One expert sees electromobility only as an interim solution to meet the fleet consumption of the European Union. Moreover, 80% of the respondents do not consider electromobility to be relevant in the next five years for automotive workshops, especially in the rural areas. Although the experts expect that the percentage of BEV and hybrid vehicles will increase, hybrids will be able to compensate for the losses of BEV.

6.3 Workshop Process and the Effects on Turnover and Workload

80% of the companies have already gained experience with electromobility. The provided services ranged from service work to repairs on the electric engine and battery. The effects on the workshop process mentioned in 4.3 could be partially verified. Electromobility has no noticeable influence on regular service and maintenance work. Only the sub-process of vehicle return changes, as the workshops return the vehicles to the customer charged. However, repairs of electrified vehicles are seen as problematic. For example, areas around the vehicle being repaired must be cordoned off and batteries can only be opened and repaired in a separate room. The problem of accident vehicles has also been explained, separate quarantine areas outside are necessary and a HV-2 or HV-3 trained person must first check the vehicle and clarify how to proceed further. The disposal process also differs. External service providers must be requested to dispose battery components, as there is an increased risk of fire.

Although it could be verified that the service process will not undergo any relevant changes as a result of electromobility, this does not apply to the workload and volume of sales. A hypothetical example was created in which a quarter of all vehicles in Austria are purely electrically powered. Based on this scenario, the question was which of the regularly occurring service and maintenance work would be most difficult to compensate for. The regular oil and filter change were named first by all the experts. Although the turnover generated with the vehicle's operating resources is relatively low, the profit margin is very high. The exhaust- and brake system were also mentioned by the majority of the experts. The lower service costs are also a decisive factor, see below Tab. 2 on different service costs based on the information provided by one company.

Table 2 Comparison service costs for BEV and ICE

	Service costs 3 years (€)	Service costs 4 years (€)
ICE	1500	1900
BEV	600	800
Sales decline	900	1100

The data from Tab. 2 shows that in this company, the turnover for a battery electric vehicle service is between 300 and 275 € lower. The expert summed up the topic with the words "In the case of the electric vehicle, components are checked and in the case of the combustion engine, they are replaced". Furthermore, 40% of the experts estimated a decrease in the workload and sales volume at about 20-25%, while 30% believe that electromobility will only have a minor impact on the workload and sales volume. New services, such as battery repair, will compensate for any reductions due to oil changes that are no longer required. Legislation and OEMs were also mentioned. It is assumed that additional regular services will be implemented for BEV. The remaining 30% of the experts abstained or estimated the decrease to be around 10-15%.

6.4 Investments

This area of investigation is intended to provide information on various investments. The following figure provides an overview of the investments made. The independent automotive workshops are provided with a frame.

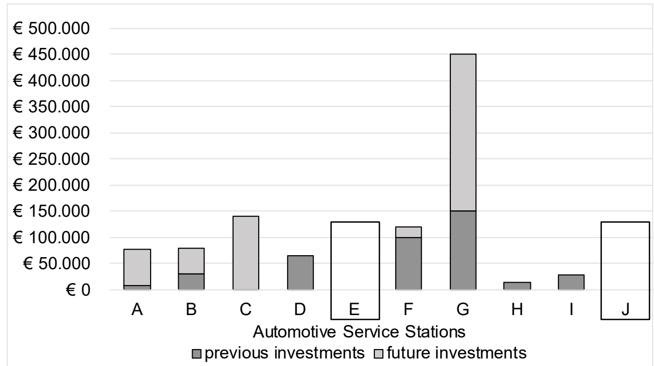

Figure 3 Previous investments and future investments

As shown in Fig. 3, independent automotive workshops have neither made nor plan to make any investments in the future, while all the authorised workshops that were surveyed have already invested in electromobility. The investment volume starts at 15,000 € and ends at 450,000 €. This large difference can partly be attributed to the size of workshops or because construction measures have been taken. The largest investment volume is made by the largest company and the high amount can be explained by the high costs of the quick charging stations. Approximately 160,000-200,000 € are spent on them. Other reasons can also be attributed to the respective contract partner. Depending on the OEM, different regulations apply to the workshops. The prices for special tools or training can also differ. If no construction measures are taken, charging stations and tools are the largest items, followed by trainings. In general, the investments of authorised workshops strongly depend on the requirements of the car manufacturer.

7 KEY RESULTS

At the beginning of this paper, it was stated that the automotive industry is facing an increasing change due to the new mobility requirements of the society, digitalization and stricter CO_2 emission limits. Without electrified vehicles, CO_2 emission limits cannot be fulfilled. After conducting expert interviews, it became clear that in practice, electromobility will have different effects on automotive workshops. At present, electromobility has no relevant impact on independent workshops. For authorized workshops, the contractual partners, i.e. the car manufacturers, set the course. All the authorized workshops that were surveyed have already had experience with electrified vehicles. The issue of work safety is particularly noteworthy. Due to the invisible danger of high voltages, it is particularly important to raise awareness among employees. It was also found that electromobility, depending on whether service or repair work is to be carried out, requires high investments, which are difficult to handle, especially for smaller companies. Regarding the workshop process, a distinction must be made between service and repair work. Although the service work on a BEV has no relevant effect on the workshop process, repair work, especially on damaged vehicles, is a problem. Here, workshops have not yet been able to gain sufficient experience. If electromobility becomes widely accepted, the majority of experts estimate that there will be a significant decline in the workload and sales volumes. This also coincides with the studies described in this paper. However, the majority of experts also consider that electromobility will be irrelevant for automotive workshop companies in the next five years. The empirical study shows that electromobility will ultimately have a major impact on automotive workshops. However, one factor is decisive here, namely the market penetration of electric vehicles.

8 RECOMMENDATION FOR ACTION

In order to be able to give recommendations for the action of automotive workshops concerning electromobility, it is important to distinguish between independent and authorised workshops, as they address different customer groups and authorised workshops are tied to manufacturers' requirements.

In the authors' view, independent workshops do not have to invest heavily in electromobility in the next five years. However, it is important not to ignore electromobility and to closely follow market changes and growth. Moreover, electromobility should be taken into account if construction measures are planned. The research results from the scientific work and the empirical study show that independent workshops are very rarely servicing and repairing new cars and that this business is responsible for the authorised workshops. Since electric and hybrid vehicles are still a niche market, the percentage of used vehicles on the market with electrified drive concepts is low, and so is customer demand. High investments for structural and mechanical adaptation (e.g. a separate room for battery repair, extra wide lifting platforms) make independent workshops still hesitant. In order not to overlook the right time, it is advisable on the one hand, and operationally, to carry out an ongoing screening of the publicly available registration statistics and the private used car market; with always the same consistent query on the hybrid and BEV on the same used car portals. Should the figures move up significantly, a business decision on the "entry" into the electrical repair market should be made regarding the necessary investments. On the other hand, and also strategically, the CO_2 emission limit set by the EU can also be observed, as this is an indicator of the extent to which car manufacturers must adapt to avoid penalties.

Authorised workshops are affected by electromobility earlier than independent workshops, as almost all car manufacturers offer hybrids and BEVs. In general, authorised workshops are very much dependent on the decisions of their respective car manufacturers. Workshop design or required personnel and tools are only a few examples of the different specifications. Accordingly, electromobility is largely determined by the OEM. However, in order to accelerate the amortization of the investments made in electromobility, it is beneficial to keep an eye on the new mobility concepts. For example, newly emerging Car-Sharing platforms offer the possibility of receiving service and repair orders for the vehicle fleet, and such platforms often have a comparatively high share of BEV.

Notice

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Preliminary communication

An Integrated EPLOS Database as a Tool Supporting TSL Companies

Mariusz Wasiak*, Michał Kłodawski, Konrad Lewczuk, Piotr Klimek, Emilian Szczepański

Abstract: The paper presents the conceptual design of a database for the European Portal of Logistics Services (EPLOS) and its application. The database contains the data on logistics companies, the infrastructure for road, railway, inland, and air transport, as well as the data on the nodal elements of logistics infrastructure (warehouse facilities, seaports, transhipment terminals). Complete and verified information is the fundamental condition for rational decisions about the realization of logistics processes on a meso- and macroeconomic scale. Authors present the relations in the making of the EPLOS database, its assumed scope, and the potential benefits for the TSL market from accessing the EPLOS database.

Keywords: EPLOS; European Portal of Logistics Services; integrated database; logistic data; parameters of a transport network

1 INTRODUCTION

Logistics services require many complex decision-making processes to be efficient and reliable. This is especially true for the configuration of long-distance freight transport and global logistics chains. Logistics processes use extensive and dispersed information for functioning. When valid and complete operational data are difficult to access, there can be a reason for an irrational logistics service. This problem is particularly acute for small and medium companies which do not invest in the decision support and data gathering systems tailored to their needs. Practice and research show that the bodies of this type dig for logistics information completely or partly manually, and that they use established contacts with no broad view on the market. This made a niche for a new IT system which would gather all or almost all information required for the bodies on the TSL market. The key element of this system is an integrated relational database.

The purpose of this paper is to discuss the concept of an integrated EPLOS database meeting the need for information on logistic entities and facilities, as well as their servicing potential and technical infrastructure availability, reported by the TSL market participants. The paper also describes the process of data gathering from functioning databases and other sources which feed the EPLOS system database.

The European Portal of Logistics Services (EPLOS) is developed under the EUREKA program by the National Centre for Research and Development (Poland). It is a comprehensive IT tool that supports the participants of the TSL market with access to verified information about the logistics infrastructure and services in the area of their operation. EPLOS users are not only the consumers of information, but also the source of information for other clients. This is done to reduce the time-consuming manual search and verification of operational data and to guarantee quick access to the reliable information uploaded in real time. This tool will be crucial for the planning of logistics and business processes, and it will help multi-organizational supply chains in the combining of different businesses in different countries.

2 DATABASE DEVELOPMENT SOLUTIONS FOR LOGISTICS-RELATED APPLICATIONS

The problem of designing a database for the European Portal of Logistics Services is similar to those presented in the studies [1-9]. It can be decomposed to two elements:

- database architecture (software development),
- EPLOS application (structure of business data).

Considering the following aspects of software engineering, database architecture designing requires the following [10-18]:

- a database model specified as a set of rules describing the structure of data in a database and a set of operations performed on data to process them as required. Typical database models are hierarchical, relational, network, object, and semantic. Particular types of models have advantages and disadvantages from the EPLOS point of view, but relational database is the first choice. The basic characteristic of a relational structure is that relationships between records are represented only by data values. Operational data are stored in tables interrelated by mathematical relations. The access to data is quick and the specific knowledge on database structure is not necessary to find specific information.
- a database schema presented as a graphical mapping of the database model (e.g. groups of tables, tables, headers of columns and relations),
- a database management system, a tool enabling developers to prepare the database for a specific system and to manage the entered data (adding and removing records, editing, modifying, sorting and other) [19, 20],
- algorithms and methods to maintain a high quality of the data described as a set of rules allowing to keep the consistency, accuracy, timeliness and correctness of the data and the database itself, as well as ensuring high effectiveness of its operation [20],
- a database structure given by the arrays of uniform data and the connections between these arrays made by mutual relations: one to one (one element from the array can be combined exactly with one element from the

other array), one to many (one element from one array can be combined with many elements from the other array) or many to many (many elements from one array can be combined with many elements from the second array),
- database implementation and development with the IT tools based on the selected solutions from the above-mentioned [21].

The programming work on the implementation of a database and the tools for database management are not discussed in this paper. Authors focus on database structure conceptualization and the references to the external data sources feeding EPLOS.

3 REQUIRED FUNCTIONALITIES OF AN INTEGRATED EPLOS DATABASE

A dedicated survey was designed and carried out to recognize the scope, form and relevance of the information required by different logistics businesses. The survey was also designed to recognize how the analysed companies obtain information and what their expectations in that matter are. The target group of EPLOS users is mainly composed of transport, forwarding, transhipment and warehousing companies using the means of transport with a total weight exceeding 3.5 t. The group also contains the representatives of service, production, and trade companies which are the points of origin or of dropping the goods.

The survey helped identify the types and economic size of the analysed bodies, their needs and the scope of the provided services. The respondents were examined for the timeliness and completeness of the information on transport infrastructure and different services related to this infrastructure, warehousing services, logistics centres and the transhipment terminals that they use.

The selection criteria for enterprises were defined through the expert method. Selection was based on the knowledge and experience of academics engaged in research on logistics matters and representatives of international enterprises supplying different classes of IT systems to logistics companies. Contact details of companies participating in the survey were gathered from their business websites and commercial databases. It should be noted that the highest percentage of responses was from the companies cooperating with the EPLOS project leader – the OLTIS company. Additionally, in view of the difficulties with obtaining representative samples of companies that are similar in terms of their economic size or scope of activity, it was decided that all completed surveys will be used for further research.

In total, 519 companies took part in the survey. The largest group were those employing 10 to 19 people (30.1% of surveyed companies) and 20 to 49 people (27.4% of surveyed companies). A group of respondents included: providers of logistics services (28.71%), transport companies (43.74%), infrastructure operators (3.66%), development companies (2.89%), manufacturing companies (9.25%), trading companies (7.32%), service companies (2.7 %), and media representatives (1.54%).

The survey focused on the significance of the specific types of data for logistics companies. The following categories of data were subjected to importance evaluation:
- various types of information about the technical infrastructure of transport,
- various types of information about transhipment terminals,
- various types of information about warehouse facilities,
- parameters of the technical transport infrastructure,
- the servicing potential of facilities providing auxiliary logistics services.

The results of the survey, categorized by the types of services, are summarized in Tabs. 1 - 5.

Table 1 Relevance of logistics infrastructure data for the participants of the TSL market by the type of services they provide

Infrastructure parameter type	Types of services offered by the company							
	In total (n = 276)	Road transport (n = 210)	Rail transport (n = 26)	Sea transport (n = 21)	ADR transport (n = 57)	ATP transport (n = 21)	Forwarding (n = 107)	Warehousing (n = 30)
	Parameter importance in percentage							
Parameters	85.2	98.8	93.1	83.3	98.4	100.0	94.4	84.5
Services	81.7	97.9	69.0	80.0	95.2	100.0	92.9	83.1
Fees	84.8	98.8	89.7	86.7	98.4	100.0	96.4	85.9
Traffic restrictions	87.5	100.0	100.0	100.0	100.0	100.0	99.0	91.5
Traffic volume	86.5	98.3	89.7	90.0	95.2	95.7	97.0	88.7

Table 2 Relevance of transhipment terminal data for the participants of the TSL market by the type of services they provide

Terminal parameter type	Types of services offered by the company							
	In total (n = 276)	Road transport (n = 210)	Rail transport (n = 26)	Sea transport (n = 21)	ADR transport (n = 57)	ATP transport (n = 21)	Forwarding (n = 107)	Warehousing (n = 30)
	Parameter importance in percentage							
Owner	73.4	63.3	96.6	100.0	77.8	73.9	89.8	80.3
Type	73.4	65.0	96.6	100.0	73.0	65.2	90.4	83.1
Equipment	66.3	55.4	96.6	100.0	61.9	56.5	83.2	80.3
Scope of services	68.8	53.8	93.1	100.0	60.3	56.5	90.9	85.9
Operational capability	75.7	72.1	89.7	96.7	77.8	73.9	91.9	84.5
Restrictions on access	81.1	82.5	96.6	100.0	88.9	78.3	96.4	84.5

Since the European Portal of Logistics Services is a tool dedicated to the companies from the TSL sector mainly engaged in transport and forwarding, the obtained results show that the EPLOS database should contain information on:

- charges for using the infrastructure,
- traffic restrictions and the current traffic situation,
- technical parameters of the infrastructure, including speed limits, permissible axle loads on the road, total weight and permissible gross weight limits, restrictions for ADR vehicles, vertical gauge limits, allowable length and gross weight of trains and limitations of the horizontal gauge (for railway lines), navigability classes;
- infrastructure services, including gas stations, car washes, guarded parking lots, unguarded parking lots, ports;
- transhipment terminals, including access restrictions, operating ability and throughput, terminal type, owner, equipment, scope of offered services;
- warehouse facilities, including access restrictions, additional services, owner, scope of offered services, equipment, surface, custom services.

Table 3 Relevance of warehouse facilities data for the participants of the TSL market by the type of services they provide

Warehouse parameter type	Types of services offered by the company							
	In total (n = 276)	Road transport (n = 210)	Rail transport (n = 26)	Sea transport (n = 21)	ADR transport (n = 57)	ATP transport (n = 21)	Forwarding (n = 107)	Warehousing (n = 30)
	Parameter importance in percentage							
Owner	78.0	70.0	72.4	90.0	81.0	87.0	91.9	91.5
Area	50.9	29.6	62.1	70.0	33.3	26.1	62.9	84.5
Equipment	60.3	42.1	72.4	90.0	42.9	39.1	77.2	90.1
Scope of services	65.9	45.8	69.0	93.3	54.0	47.8	90.9	93.0
Additional services	84.0	85.8	62.1	86.7	87.3	95.7	93.9	90.1
Restrictions on access	85.2	86.7	72.4	93.3	93.7	100.0	96.4	94.4

Table 4 Relevance of linear infrastructure data for the participants of the TSL market by the type of services they provide

Linear infrastructure parameter type	Types of services offered by the company							
	In total (n = 276)	Road transport (n = 210)	Rail transport (n = 26)	Sea transport (n = 21)	ADR transport (n = 57)	ATP transport (n = 21)	Forwarding (n = 107)	Warehousing (n = 30)
	Parameter importance in percentage							
Speed limits	87.00	93.30	53.80	61.90	87.70	85.70	86.00	80.00
Limits of axle loads on the road	73.90	78.10	69.20	81.00	75.40	71.40	80.40	80.00
Total weight limits and permissible gross weight	38.80	36.70	65.40	81.00	42.10	28.60	51.40	63.30
Vertical gauge limits	26.10	22.40	76.90	57.10	33.30	23.80	32.70	53.30
Horizontal gauge restrictions	13.40	6.70	76.90	42.90	3.50	0.00	17.80	23.30
Restrictions for ADR vehicles	56.50	61.90	50.00	66.70	77.20	33.30	66.40	76.70
Longitudinal inclination of roads	6.90	5.70	34.60	33.30	0.00	0.00	14.00	20.00
Train length limits	15.60	6.20	76.90	42.90	1.80	0.00	16.80	23.30
Trains' gross mass limits	14.10	5.70	76.90	42.90	1.80	0.00	15.00	23.30
Navigability classes of waterways	2.90	1.40	15.40	14.30	5.30	0.00	4.70	3.30

Table 5 Key or important information about the facilities integrated into the linear transport infrastructure by the type of services they provide

Type of facility integrated into the infrastructure	Types of services offered by the company							
	In total (n = 276)	Road transport (n = 210)	Rail transport (n = 26)	Sea transport (n = 21)	ADR transport (n = 57)	ATP transport (n = 21)	Forwarding (n = 107)	Warehousing (n = 30)
	Parameter importance in percentage							
Gas stations	90.00	94.30	56.30	55.00	96.60	95.20	86.90	78.00
Car washes	76.30	80.60	43.80	45.00	82.80	90.50	77.90	63.40
Unguarded parking lots	76.30	84.10	50.00	55.00	87.90	76.20	73.80	68.30
Guarded parking lots.	93.80	98.20	68.80	85.00	100.00	100.00	93.80	87.80
Ports	41.10	37.00	62.50	45.00	37.90	42.90	49.70	46.30
Hotels	18.10	19.40	12.50	10.00	27.60	14.30	11.00	9.80
Gastronomy	10.00	11.00	0.00	5.00	13.80	0.00	4.80	0.00

4 THE CONCEPT OF THE EPLOS INTEGRATED DATABASE

The EPLOS system created under the EUREKA initiative is a database tool providing information on the transport and logistics infrastructure and other services from logistics companies (by the WebServices) to the business. The target group of EPLOS users are primarily small and medium logistics and transport companies (which only plan the realization of their services), but also production and distribution companies (which not only plan their services, but also design supply networks and supply processes).

Through WebServices, the EPLOS system will provide verified and valid logistics data to interested companies in a form required by their specialized IT systems. This will facilitate and accelerate further processing of this data and will later allow those companies to upload data back to EPLOS. The data from EPLOS can also be used by research units and universities in order to develop and test data processing algorithms supporting the strategic and operational logistics decision-making. In the next stages of development, EPLOS will be extended with data analysis tools and logistics decision supporting. After that, the EPLOS system will gain additional functionalities which will cause a significant increase of data in the system.

The EPLOS database must contain extensive data grouped into different thematic areas. These thematic areas make a complex and differentiated structure, which is why the methods of data gathering, along with the data sources, must also be diversified. Therefore, the EPLOS database is updated with business and technical data from different sources in real time. On one side, it must be connected through interfaces to the external sources of the infrastructural and operational data, and from the other side, to the companies using EPLOS. This is the condition to get a useful and efficient tool offering current and reliable data on the European logistics system.

The EPLOS database is modular. Each of the modules is responsible for different types of information relating to the thematic areas. An integrated EPLOS database is composed of the following sub-databases: database of logistic companies, database of non-intermodal transhipment terminals , database of intermodal transhipment terminals, database of warehouse type logistics facilities, database of the sections of the road network, database of gas stations, database of car washes, database of parking lots, database of the sections of the railway network, database of railway stations, database of loading points, database of inland waterway network sections, database of inland water ports and transhipment quays, database of airports.

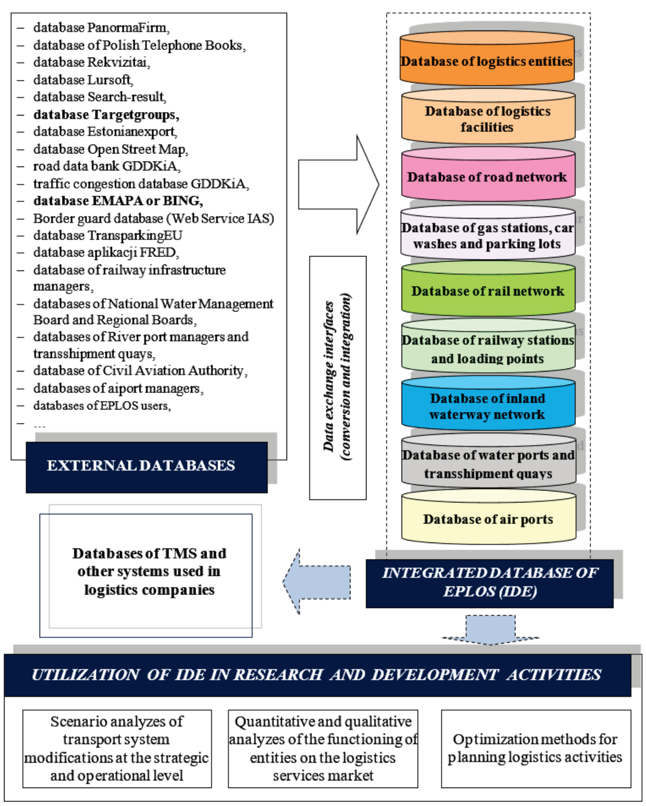

Figure 1 Structure of the database and module integration in EPLOS

The EPLOS system also includes the input and output interface modules, internal interfaces and graphical interfaces. The system is also equipped with a digital map module with its own database combined with other EPLOS databases. Schematically, all elements of an EPLOS integrated database are shown in Fig. 1 (data sources available only in the commercial version of EPLOS are bolded).

Each element of the integrated database is associated with other elements by strict rules. Integration of system components with external databases requires the integration of modules and the conversion of data to the required form. Data is standardized before it is incorporated into the EPLOS system. All data in the EPLOS databases undergoes feedback. This means that the results of data analysis and their use can later supplement the database and be the basis for further research.

The primary goal of the database is to support the operational activities of the companies operating on the logistics services market and other industrial markets that take advantage of transport. The secondary goal is to have a database for studies and analyses at different levels of detail. Depending on the needs, the database can be used for an analysis of the logistics market and its functioning, a simulation of the impact that the modification of the transport network will have on the logistics business, or an assessment of transport and finally, for an analysis of the handling and storage potential that regions can offer to the business.

Universality and comprehensiveness of the database also make it usable in other software packages. It can be built into applications by extending the EPLOS system for financial, analytical and optimization tools.

All databases included in EPLOS are associated with other databases by specific relations. The core database is the one which contains the following information about logistics companies:

- numbers and names of companies,
- parent entity numbers,
- headquarters' addresses and geographical coordinates,
- types of business, areas of activity and scope of services,
- opening days and hours,
- website addresses,
- contact details (e-mail addresses, phone numbers),
- disposed logistics facilities (numbers of nods in the transport/logistics network and the length of owned transport networks).

Accordingly, each logistics entity in the EPLOS database can be defined by specific logistics facilities (e.g. warehouses, transhipment terminals) that are managed by this entity. Databases on facilities contain additional information:

- number of the node in the transport network, its name and geographical coordinates,
- type of the node in the transport network (e.g. intermodal transport terminal),
- transport mode and transport means to be served in,
- opening hours,
- operator data,
- information on the customer service,
- information on the operating station,
- terminal availability (open, contractual),

- scope of performed services,
- available loading devices,
- length of the loading front (m),
- types of cargo handled,
- maximum total weight of transport means (kg),
- maximum length of supported transport means (m),
- daily throughput (transport means/day),
- total storage area (m^2),
- available storage area (m^2),
- pallet storage capacity (PAL),
- available pallet storage capacity (PAL),
- container storage capacity (TEU),
- available container storage capacity (TEU).

Databases for individual transport networks collect information on:

- number and name of the section of the transport network,
- infrastructure manager (number and name from the logistic entity database),
- numbers of the start and end node of the section in the transport network,
- mode of transport,
- category of road / type of railway line / type of waterway,
- types of vehicles allowed for movement,
- road tolls / fees for access to the railway infrastructure,
- traffic directions,
- technical class of the road / class of the railway line / navigability class of the waterway,
- type of road surface / type of railway track,
- number of lanes / tracks in the main direction and in the opposite direction,
- road section length (m),
- speed limit on the road or the maximum speed on the railway / waterway (km/h),
- restrictions on the permissible total weight of transport means (t),
- restrictions on the actual total weight of transport means / gross weight of the train (t),
- hours of tonnage restrictions,
- permissible axle loads of transport means (kN/axle),
- train / ship length (m),
- restrictions on the vertical gauge / permissible height of ships (m),
- restrictions on the horizontal gauge / permissible width of ships (m),
- minimum clearance under bridges over Great Navigable Water (m),
- navigable route width (m),
- transit depth (m),
- traffic restrictions on transport means carrying ADR materials,
- restrictions on transport means due to exhaust emissions,
- longitudinal slope of the road (tenth of percent),
- road technical condition,
- current speeds in the main direction and the opposite direction,
- traffic incidents (description and location of an incident),
- unplanned outages / temporary closures,
- current water level (cm).

More detailed information on the solutions adopted for the EPLOS databases describing road and rail networks, as well as on logistics facilities, are presented in [13, 22, 23].

5 CONCLUSIONS

The effectiveness of logistics processes is conditioned by the access to complete and up-to-date information on the logistics infrastructure, logistics companies and their contractors. This data often come from various sources and in most cases require a manual search and time-consuming processing. The EPLOS project responds to these issues. The outcome of the project is an IT system feeding logistics entities with reliable and actual data obtained from various, but validated sources.

Research on the possibility of an automated data collection and update from the existing sources show that such a collection is now not possible or is significantly limited. This is confirmed by the results of a survey carried out on logistic companies and market representatives. The respondents pointed out that almost all relevant and important logistics information must be gained manually and then also manually entered into their systems. As a consequence, companies engage significant resources in data acquisition and processing and they incur additional costs as a result of the poor-quality data or lack in information.

Limited or closed access to data might significantly limit and delay benefits from any IT solution designed to plan and manage logistics processes in the company. In a worst-case scenario, such implementation can be unjustified or used only partly.

This observation shows that centralized expenditures on the access to logistics and transport infrastructure data is a rational solution. Logistics companies save time and have a guarantee that data are of adequate quality and form. Thus, the users' benefits from the access to the EPLOS databases are indisputable. In some cases, users will be obliged to provide data about their facilities and services to EPLOS. This data can be entered manually or available via interfaces between EPLOS and their internal database. Such an exchange will increase the quality of the entire system.

EPLOS will be very beneficial for companies implementing new IT solutions such as the Transport Management System, Warehouse Management System, Enterprise Resource Planning or specialized Supply Chain Management Systems, Distribution Resource Planning or Advanced Planning Systems. They will be able to feed their databases with information about market participants and their actual or potential partners. This information will be regularly updated by EPLOS.

The big advantage of the EPLOS system is the up-to-date information on transport network parameters, loading points and costs of their use. Such data is necessary for the planning of transport processes, especially over long distances and when using multiple modes of transport. Inquiries to the EPLOS system may relate to the variants of transport routes for a given mode of transport or for a specific type of load/material.

To summarize, constantly updated EPLOS databases can be crucial for logistics companies to make transport, storage and handling more effective and faster. It consequently leads to economic benefits. There is a high potential for developing EPLOS by adding decision supporting models which cover various areas of material flow management and supply chain configuration to the system (see [24-29]). The EPLOS system can be a significant support for macroeconomic traffic models, such as [30-32].

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Notice

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Preliminary communication

Qualitative Acceptance Model of Augmented Reality from the Perspective of Personalists

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Abstract: Smart devices and the corresponding new technologies have established themselves within our society. Since the release of the smartphone game Pokémon Go, the field of augmented reality (AR) - the enrichment of reality with information, realized by smart devices such as tablets, data glasses or smartphones - has been experiencing an upswing. Additionally, the industry is starting to integrate AR applications to increase efficiency. In this respect, HR managers play a key role in the implementation of such technology. They maintain direct contact with employees, have an overview of the entire company and thus are often responsible for change processes. The paper analyses the potential of AR within a company from a personalist's point of view and discusses critical factors both in theory and practice. The paper validates the technological possibilities and shows results from a qualitative analysis from focus group discussions. The qualitative acceptance model displays factors influencing the implementation of AR.

Keywords: acceptance model; Augmented Reality (AR); human resources; process optimization; Technology Acceptance Model (TAM)

1 INTRODUCTION

We live in the age of digital transformation - not only companies are changing, but also the private sector is changing due to new technical possibilities [1, 2]. Smart devices already play a major role within the society and thus they enable the spread of further technological applications. One technology that uses such hardware is augmented reality (AR) - the enrichment of reality with information, realized by smart devices. Although the technology was used in the first approaches already in the 1960s, the spread of AR applications occurred only in the recent years [3]. Looking at trend analyses, the industry is increasingly implementing AR applications to increase efficiency [4, 5]. The opportunities that AR brings with it offer optimization potential along the entire value chain. By enriching reality with targeted real-time information and the possibility of flexible access to data and systems, new ways of working arise: spatial, temporal and content related [6].

In this respect, HR managers play a key role in the implementation of such technology. They maintain direct contact with employees, have an overview of the entire company and thus are often responsible for change processes [7]. Therefore, when disseminating AR in companies, it is important to consider the perspective and experience of HR managers.

In this context, the question arises as to the importance of AR from the HR perspective, and which factors influence the implementation of the technology. Of particular interest is the question of technology acceptance.

Thus, the paper analyses the potential of AR within a company from a personalist's point of view and discusses critical factors both in theory and practice. The paper validates technological possibilities and shows results of a qualitative analysis from focus group discussions. The thereof developed qualitative acceptance model displays factors influencing the implementation of AR. Based on this, the paper contains recommendations for companies to increase the acceptance of the AR technology.

2 AUGMENTED REALITY

Although a wider audience first got acquainted with AR in the early 2010s, the concept of the technology has existed for much longer [3]. The first rudimentary prototype of a head-mounted AR-device already existed in 1968 [8]. It took further 24 years until the term augmented reality first appeared in literature [9]. In this period, the reality–virtuality continuum was also created, which is a model for defining AR and related technologies that is still relevant to this day [10].

Despite the efforts of the scientific community to bring together the different directions of literature into a unified model [11], the meaning of the terms is still fragmented. This is, among other things, because companies operating in this business field introduce new terms for marketing purposes or redefine the existing ones [12].

Contradicting Milgram/Kishimo [10], we do not differentiate between mixed reality and augmented reality in this paper due to the divergence of delimitations and definitions even among the experts of the field [12]. Since technological aspects are not the core concern of this paper, we simplify the terminology by using augmented reality in a wider sense as an umbrella term for every system that is able to superimpose interactive digital information or objects onto the view of the real environment in real-time.

Speaking from a technical perspective, an AR system consists of a combination of hardware and software [13]. The following components are seen as the minimum requirements for a functioning AR implementation [14]:

- Video capture of the real worldview as the basis for the following augmentation of a scene.
- Tracking of the AR device's position and motion to generate a moving coordinate system of the user's point of view.
- Geometric registration of the surrounding space to correctly position and orient the digital content.
- Rendering of the digital content based on the previous device tracking and geometric registration of the surrounding space.

- Output of a video stream to visualize the result through a display.

The benefits of the technology boil down to three key capabilities [15]:

- Visualization: ability to comprehensibly reveal insights of complex data sets in a context-sensitive manner.
- Instruction: ability to deliver training and coaching in an effective and efficient way by providing on-site, step-by-step, real-time visual guidance.
- Interaction: ability to add new dimensions of interactivity through the use of voice control, gesture recognition, eye-tracking, etc.

A multitude of devices is available for a practical implementation of AR [3]. Depending on the requirements of the planned use scenario, a common smartphone could be sufficient, whereas other situations might require a highly specialized and individualized device such as data-glasses that are integrated into personal protective equipment. The same is true for the corresponding software. While common use-cases are often solvable with the available standard-software, highly individualized use-cases might also require some degree of individual software development.

2.1 Potentials and Challenges for the Industry

AR is not seen as "the new thing" anymore: AR entered the "trough of disillusionment" in the 2018 Version of the Gartner's Hype Cycle and is not included in the 2019 revision anymore, which indicates that the technology has established itself on the market [4, 5]. This statement is also supported by empirical data. A survey from 2018 found an adoption rate of 13% with 42% of the companies stating that they plan to adopt augmented reality in their company by 2021 [16].

The manufacturing industry, especially the automotive sector, is one of the frontrunners of the technology [17] and it uses AR along the whole value chain. From product development to human resources – no area remains unaffected.

A study from 2019 focuses on the status quo of the technology in practice. Out of nearly 150 companies of different sizes in Germany, 46.3% said that they already use augmented reality in their companies. The main areas of application are step-by-step instructions (45%), remote assistance (39%) in particular and knowledge transfer (38%) in general, whereby very specific use cases such as pick-by-vision (22%) or product simulation (32%) were also mentioned [18].

Companies that have managed to successfully integrate AR into their business processes report substantial improvements in terms of productivity and costs [15].

The aforementioned key capabilities will transform into key success factors with further progression of digital transformation. Customers increasingly demand highly customized products, which in turn requires high flexibility of suppliers to be able to fulfil this need [19]. AR can help achieve this goal while ensuring that the company remains competitive through high efficiency.

The arising technical challenges are dependent on the area of application and cannot be generalized. On the one hand, AR implementation in the field of product development will likely require three-dimensional interaction capabilities and a connection to other systems that are used in this context (e.g. CAD-systems). On the other hand, an AR system used for remote assistance might only require simple, widely available hardware such as tablets or smartphones with a Wi-Fi connection, a microphone and a camera, as well as a corresponding (standalone) software that provides the functionality.

Each use case, as well as the environment in which the use case is located, requires an individual set of technical requirements for the AR solution. Therefore, when implementing AR, it is important to define the desired use cases and analyse the application environment in order to make an adequate hardware and software selection.

As with any other major technology changes, there are not only challenges in terms of technology, but also in the areas of culture and organization. AR is no exception [20]. Therefore, a holistic implementation process is indispensable.

2.2 Implementation Process

The use of AR within the industry necessarily entails a change in work processes. Work is reorganized and thus - depending on the area of the AR application - hierarchical structures and decision-making competencies are changed. [21] The latter occurs, for example, when workers in production access ERP systems bidirectionally via AR systems. However, not only the activity in the narrower sense is subject to change, but what also changes are the ways of communication and interaction, as well as the socio-technical system. [22, 23] There is a shift in the core competencies of activities to be performed and controlled. In this context, Bauernhansl 2014 [24] speaks of "augmented operators" along the value chain.

The formulation of an introduction strategy is especially necessary for the implementation of IT-supported solutions, since it defines the goal and framework of the implementation [25]. Additionally, systematic support, particularly in the case of comprehensive changes, is also conducive to successful implementation. In this respect, there are different approaches from theory and practice.

Research shows that the resistance of employees and a lack of change-competence are main reasons for the failure of a change process [26, 27]. Often the awareness for the necessity is missing and thus no acceptance for the new solution - in this case the use of AR - can be achieved. Krüger 2006 therefore recommends involving employees at different hierarchical levels and from different areas of the company right at the start of the change process [28]. The focus is on the keywords job satisfaction and employee retention [29].

It is also important to know the factors that affect the acceptance of the workforce. For the introduction of AR, the following main factors can be derived:

Usability plays a decisive role, especially when new technologies are used. Accordingly, the technical solution should be intuitive, self-explanatory and easy to use [30]. In connection to this, there are requirements concerning the organizational framework. Thus, the availability of **learning opportunities** plays an essential role. These should also be prepared in an understandable way and, in particular, be targeted. Furthermore, the **transparency** of the project and the underlying motivation for the implementation is a critical factor. If this is not given, there is a risk that employees will perceive the use of AR as a monitoring measure and actively work against it as a reaction [31]. **Employability** [32] and the extended decision-making competencies made possible by AR also place demands on management. The nature of participation options and the **support** [32, 33] provided by managers are further critical factors. Here, too, the more successfully these factors are taken into account, the less uncertainty employees feel [21]. All these factors are based on a culture of trust in which employees and management interact at an eye level.

At this point, it should also be mentioned that the use of AR also has medium to long-term effects on the expectations of employees in other areas of the company. For example, the expectation of on-demand training or flexible work opportunities increases [34].

All these areas of influence and fundamental considerations regarding employee satisfaction should be incorporated into the company's human resources strategy [21]. HR therefore becomes a key element of implementation projects in general and thus also with regard to the introduction of AR.

3 HUMAN RESOURCES

The tasks of human resource management are manifold and range from personnel planning, recruitment and onboarding to personnel development and controlling. Additionally, human resources (HR) is the point of contact for employees and managers for all personnel matters [7]. It is therefore obvious that HR managers not only know their colleagues well, but also play a decisive role as a link in change processes [35].

Looking at the approach of Krüger 2006, analysing the initial situation is the starting point of every change process [28]. People who, on the one hand, can grasp the company as an overall system and, on the other, are familiar with the social structures, communication structures and corporate culture are in high demand. This knowledge is necessary in many ways:

- HR helps detect the right change agents throughout the company.
- Formal and informal channels of communication can be supplied regularly and systematically.
- HR usually has a holistic view of the company and can therefore offer unbiased solutions.
- HR can assess the need for further training and provide suitable further training measures.
- The focus is always on the corporate climate and, in connection with this, on employee satisfaction.

In this respect, HR has a huge influence on change processes and should be taken into account when thinking of implementations.

Derived from this initial situation, the views and experiences of personnel managers were collected for the presented AR acceptance model.

4 METHODOLOGY

The qualitative acceptance model developed in this paper is based on the Technology Acceptance Model (TAM) according to Davis 1989 and the further development of TAM 2 according to Venkatesh/Davis in the year 2000 [36]. TAM (2) tries to explain the individual usage behaviour of technologies - especially information systems - by means of different influencing parameters such as experience, relevance or usability.

The core of the model defines the subjectively perceived practicability and usability of a technical solution, which has a direct effect on the readiness for use, which in turn leads to corresponding user behaviour [36]. The basic premise is that employees always strive for solutions that require little implementation effort, but have a high direct positive effect on their own work performance. If this ratio is perceived as sufficient, this increases the intention to use the new technology. This basic behaviour pattern is influenced by various factors, which are again influenced by the subjective perception of employees. According to Venkatesh/Davis 2000, the perceived usefulness is in particular subject to decisive spheres of influence, which are both work-related and socially shaped. Regarding their job, the positive impact of the new technology on their own tasks (job relevance) [36], as well as the quality of the performance achieved by using the technology (output quality) [37], are taken into account. In this respect, it is important that the achieved improvements are also directly related to the use of the technology (result demonstrability) [38, 36].

In assessing the impact of the new technology on the work situation, potential effects on the social work environment are also included. In particular, the effect of the technology on internal reference groups subjectively perceived as important or the protection of one's own internal status should be mentioned in this respect (image) [38, 36]. Thinking about image is accompanied by the human need to adjust one's own actions to the expectations of the environment. Thus, the opinion of people who are subjectively considered important has a greater influence in this respect (subjective norm) [39]. According to Venkatesh/Davis 2000, these subjective norms not only influence the characterization of the image and the perceived usefulness of the new technology, but there is also a direct correlation with the intention to use [36].

In addition to these direct influencing factors, two further spheres of influence were identified in the TAM 2 model, which indirectly influence the acceptance over time via the subjective standards. On the one hand, the experience gained with the technology contributes to acceptance - positive ones will increase, negative ones will decrease (experience) [36]. On the other hand, the personally perceived negative pressure to perform with regard to the use of the technology. The higher the voluntariness, the greater the willingness to use the new technology and to accept it in the future (voluntariness) [40, 38].

Since its development, the model has been validated and confirmed by various authors and is therefore often used as an empirical method.

To develop the qualitative acceptance model presented within this contribution, a three-phase methodological approach was applied. In phase one, the relevant literature was analysed and the content framework of the acceptance model was developed. For this purpose, the crucial factors mentioned in TAM 2 were used and applied to the industrial use of AR.

Phase two comprised qualitative focus groups, which were used to examine the previously developed factors influencing the acceptance of AR from different perspectives relevant to practice. This phase represents the practical validation of the previously derived model. The target group consisted of human resources representatives from the manufacturing industry and industry-related service providers who already had a basic interest in AR.

The latter was ensured by the fact that participation in the focus group was on a voluntary basis. In total, a sample of n = 63 could be reached. In accordance with the main tasks of human resources, the focus group examined the topic "Challenges/success criteria for the introduction of AR in the industry" from three perspectives: the employees, the management (including strategic considerations) and the organization in general. The 63 participants worked out a total of 49 nominations, which could be summarized into 8 clusters of content:

- Training/Learning
- Willingness to use AR
- Employee participation
- Communication
- Data Protection
- Benefit-orientation
- Strategic Value
- Ergonomics.

In phase three, the theoretical and practical findings were combined and a practice-relevant qualitative acceptance model for the use of Augmented Reality was derived.

Results examine the issue of the acceptance of AR technology from a qualitative perspective, which is also a limitation of the research results. The presented results thus form the basis for an in-depth quantitative analysis of the strategic approach to the application of AR.

5 RESULTS

5.1 Augmented Reality Acceptance Model Framework

After an analysis of the relevant literature on the acceptance and introduction of AR in the industry, specific additional influencing factors could be derived in addition to the TAM 2 model. The following Fig. 1 shows the original TAM 2 model extended by the key results of the literature review, which are shown in italics and dashed text boxes.

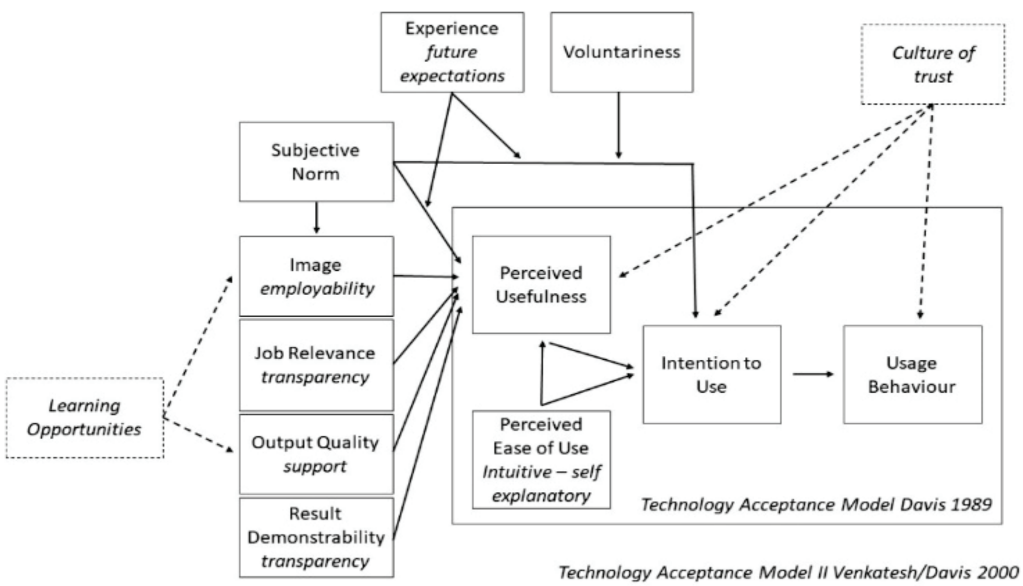

Figure 1 AR Technology Acceptance Model framework

As in TAM 2, there are direct and indirect factors influencing technology acceptance. Comparing the AR specifics, some factors can be assigned to the already existing TAM 2 areas. For example, a transparent handling of the reasons for introducing AR influences the *job relevance*, but is also relevant for the *result demonstrability*. With regard to the *usability of the perceived ease* of use for AR applications, the terms intuitiveness and self-explanatory can be used to describe the process. Furthermore, the outlined experience must be defined more broadly: positive experiences with AR over time lead to corresponding future expectations. Depending on the level of experience with the technology - this can also have an effect from the private sphere. For example, digital natives who have already been involved in

AR applications also tend to have higher expectations regarding professional AR use.

However, the analysis also revealed the need for two new areas. Due to the broad professional use of AR applications, the technology and the associated devices can be predicted to be of similar importance as the PC. It is a new tool that is revolutionizing daily work along the entire value chain. According to this, a broad mass of people is affected by the change. The demand for suitable, targeted **learning and training opportunities** is correspondingly high. With reference to TAM 2, the degree of learning possibilities influences in particular the *output quality*, but also the self-perceived *image* towards other people perceived as subjectively relevant. However, it should be emphasized that the degree of influence depends to a large extent on the choice of the AR hardware device. If smartphones or tablets are used, the impact on the *image* in particular is lesser than if data glasses are used. The fear of making oneself ridiculous because of "looking funny" coupled with the fear of making mistakes play a particularly important role.

The second key area is the existence of a **culture of trust**. Studies show that if employees have the confidence to act on their own responsibility to get support and feedback, the willingness to deal with AR is higher. In this context, a culture of trust describes on the one hand the trust of employees in themselves and the technical solution, and on the other hand, the trust of managers in the decision-making quality of their employees. If the manager in particular does not have this trust, the potential of AR cannot be exploited.

5.2 Qualitative AR acceptance model

In addition to the AR specific acceptance criteria, the aim of the present contribution was to ascertain the practical relevance with regard to the introduction and use of AR.

The importance of different perspectives in change processes can be seen from the theory of change management. In addition to the decision-makers, the employees and the organizational framework play a decisive role.

In this respect, the results of the focus group largely confirm the areas of influence identified so far, but highlight additional factors. These are shown as circles in Figure 2. The shading shows the frequency of discussion and the naming of the areas in the focus group. The darker a field, the more often it was considered important. For better understanding, only those areas that were mentioned particularly frequently (nomination rate more than 10%) were highlighted.

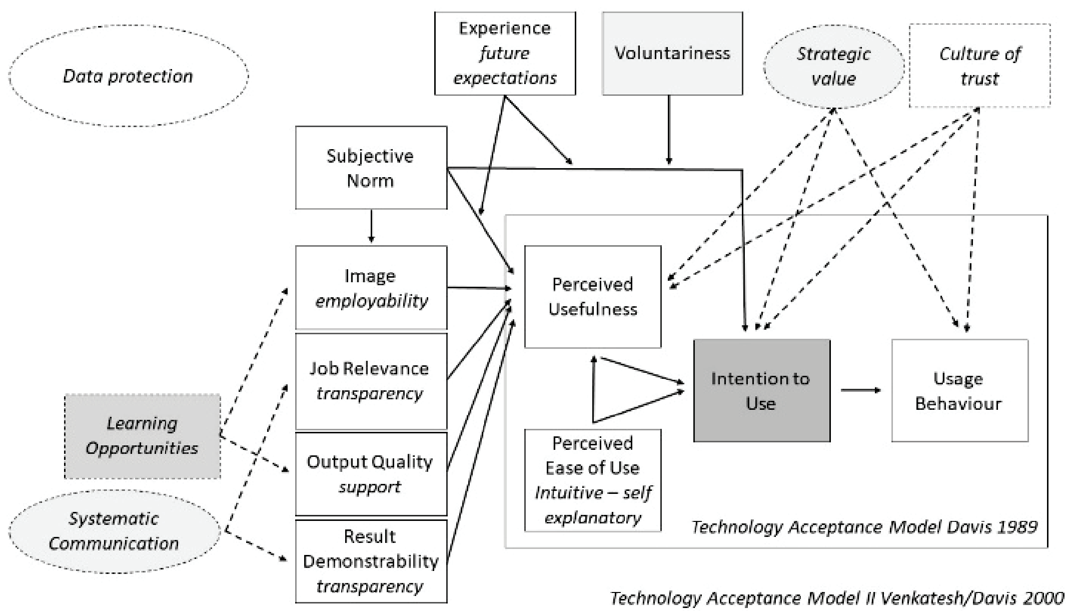

Figure 2 Qualitative Acceptance Model of AR

The willingness of employees can be allocated to the *intention to use* and it was named by the focus group as the most important success criterion for the introduction of AR. Especially from the employees' point of view, but also from a strategic and organizational perspective, willingness generally plays a major role. The focus group thus confirms the existing research in change management, according to which one of the main reasons for the failure of change processes is the resistance of employees.

From the employees' point of view, adequate *learning opportunities* were named as the second most important success criterion. Especially when dealing with data glasses, it is important that employees are given sufficient time for individual preparation with the device. Only when operating safety is ensured, can AR quickly lead to the desired improvements in the company. It is interesting to note that from the point of view of HR, the need for learning is almost exclusively assigned to employees. However, this contradicts the literature, according to which managers should set an example in change processes and also master the technology with regard to AR.

In addition to adequate learning opportunities, *systematic communication* was cited by the experts as a key factor for technology acceptance by employees. Therefore, this factor was newly added to the outlined model. This again reflects the common literature in change management, according to which systematic communication serves to create an awareness of change, but also to ensure a long-term readiness for change through communication over time. The discussion shows, that in the narrower sense, this factor has a direct effect on the areas of job relevance and result demonstrability in order to maintain awareness.

Another new area is the *strategic value* of technology. The greater the impact of the technology on the overall company, the more likely it is to be well-perceived by employees and the greater the willingness to use it. According to the focus group, if the strategic benefit is reinforced by an active role model for managers, this also has a direct positive effect on usage behaviour. With regard to AR, the experts noted a high degree of broad use of the technology, since it represents a new working tool for many areas and can change the work processes there in a positive way.

Another interesting result of the study can be assigned to the area of *voluntariness* in the TAM 2 model. If a company wants to implement AR throughout the company, a high degree of employee participation is of particular importance. In line with the recent change approaches, it is therefore important to give employees at all levels the opportunity to shape the implementation.

The last conspicuous point of discussion concerned *data protection*. Due to the technical possibilities of AR, especially in the area of video processing and tracking, the experts argued for an explicit consideration of this topic. According to the experts, the consideration of data security is decisive for the user safety of the employees and thus for the acceptance of the new technology. Possible fears of employees of being controlled must be considered and dealt with from the beginning of the introduction process.

Table 1 Overview of the results of the focus group

Point of view / Named cluster	Employees	Decision-making/strategy	Organisational framework	Total
Training/Learning	7	1	0	8
Communication	6	0	0	6
Willingness to Use	14	1	2	17
Employee participation	4	1	2	7
Data Protection	2	1	0	3
Benefit-orientation	3	1	1	5
Ergonomics	1	0	0	1
Strategic Value	1	3	2	6
Total	39	8	7	54

To summarize, the following Tab. 1 provides a condensed overview of the results of the focus group discussions in total; 54 factors were worked out by the experts from three perspectives: employees, decision-making/strategy and organization. The factors were assigned to the presented clusters, which results in the number of mentions shown.

6 RECOMMENDATIONS

The contribution was aimed at specifying the generally applicable TAM 2 model explicitly for the technology of Augmented Reality and at incorporating practical experience. This was done in order to show companies the scientifically grounded, and at the same time practice-oriented, recommendations.

First of all, it is important to plan the introduction of AR systematically. An *AR strategy* should therefore examine and evaluate different areas of application and the necessary technical requirements. It is recommended that the selected AR system be used in a company in as many different ways as possible. Additionally, Klumpp et al. recommend that *risk assessment* should be carried out to detect possible disruptive factors during implementation and to assess the probability of these factors occurring and their effects.

According to the strategy, it is important to accompany implementation systematically in accordance with *change management* theories. *Regular transparent communication* and, in line with Krüger, an intensive *participation of employees* play a key role. Active communication channels should be established to avoid isolated and unstructured communication.

The article underlines the importance of employees for the implementation process, according to which it is important, especially with such a comprehensive technology as AR, to respond to the needs of employees. Specifically, for AR, these relate to the user-friendliness of the devices and the achievable positive outcome, among other things. To ensure this, *learning formats* tailored to the individual needs of the employees should be offered. Employees must be able to familiarize themselves with the technology at their own pace and in their comfort zone. It should be noted that, depending on the used AR device, learning can occur on two levels. Not only the use of AR in daily business, but also the operation of the device itself (for example when using data glasses) must be trained.

Finally, it is important to gain the trust of employees on several levels. The involvement and commitment of the *works council* plays an important role here.

7 CONCLUSION

The results of the qualitative analysis of the focus groups confirm the contents of the TAM 2 model on the one hand, but also indicate a need for further research. For example, the model can be used to describe the emergence of technology acceptance in general, but cannot be seen as absolute and conclusive. Depending on the technology and its degree of diffusion in a company, it is necessary to consider further factors in order to achieve a high level of acceptance among employees.

AR can be seen as a far-reaching technology that can be deeply anchored in a company and it does not only affect individual employees. Accordingly, increased attention must be paid to the strategic perspective and overall organizational issues such as data protection. Additionally, AR can not only be used for individual activities, but can also rather be seen as a new work tool. It is therefore necessary to develop an accompanying learning concept that covers the individual needs of employees.

Finally, it should be noted that the study is only a qualitative, practical-focused excerpt, which cannot be automatically generalized. Thus, the results largely reflect the experiences of HR managers from different industries. Further research from the perspective of employees or managers would be recommended in any case.

Notice

The paper will be presented at MOTSP 2020 – International Conference Management of Technology – Step to Sustainable Production, which will take place from 30th September – 2nd October 2020 in Bol, island Brač (Croatia). The paper will not be published anywhere else.

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Preliminary communication

Application of Semi-Analytical Methods in Production Systems Engineering: Serial Lines

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Abstract: Production lines can be designed by an analytical, semi-analytical, or numerical approach. This paper gives a brief introduction to the analytical approach of a single buffer line, the aggregation method, and the analytical approach of a multi-buffer line. An automotive paint shop production system will be used as a figurative example to compare the aggregation method and the recently developed analytical approach for a multi-buffer line. A discussion at the end will show the advantages and disadvantages of the analytical approach.

Keywords: aggregation method; analytical approach; multi-buffer lines

1 INTRODUCTION

Production lines have a big influence on our lives nowadays. Since Henry Ford, they developed rapidly and helped shape the modern economy. The main advantages are an increase in productivity, while at the same time, they lower costs. The result of this constellation is mass production and products with a higher profit. That is the reason why there are various efforts to optimize them. At the early beginnings, the organization was simple as the factories were simple and small. Foremen dominated the shop floors, they decided what would be manufactured and where. The company's growth and products got more sophisticated. The organization of production at the beginning was founded on the experience of foremen. Later on, organization was based on numerical software, whereas today, it is based on big data.

Production lines can be described by various approaches, which can be summarized into analytical, semi-analytical, or numerical. Throughout the decades, since the first manufacturing systems got modelled, up until now, a lot of different subtypes were discovered.

In today's industries, it is convenient to design manufacturing processes [1]. Such an approach allows the operator to decide which machine he can turn off to save energy without losing the required performance [2]. Another benefit is the ability to test various scenarios of investing in new machines while minimizing the risk of investment failures [3]. In the end, the benefits of designing the manufacturing processes can be simulated and presented to the decision-makers in a company in order to ensure a better acceptance toward the Industry 4.0 [4].

An analytical approach of a steady-state series Bernoulli production line with one buffer and two machines was published for the first time in 1962 [5]. For a long time, the problem could not be solved for an arbitrary number of machines and for the buffers with arbitrary capacity because of the complexity to define the transition matrix. The generalized transition matrix was formulated recently [6]. Methods for the evaluation, analysis, and control of the system's continuous random variables were developed by using the analytical approach [7].

The semi-analytical approach can be divided into the aggregation and decomposition methods. The semi-analytical approach dominates because the analytical approach was only developed recently. The aggregation method will be further described. This method has a wide application; it can be used to simulate the setup time of a manufacturing line [8]. One of the main benefits of the aggregation method is the short processor time. This makes it a quick tool in the designing and optimization of a production system.

2 THE ANALYTICAL APPROACH – A SINGLE BUFFER LINE

The Bernoulli line with two machines and one buffer was described by Markov chains in 1962. The sample space of the random variable is 0 and 1. If the machine state is up, the number is 1, if the machine is down, the number is 0.

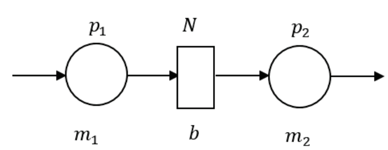

Figure 1 Two-machine Bernoulli production line [9]

The following conventions must be fulfilled [9]:

- blocked before service,
- the first machine is never starved; the last machine is never blocked,
- the status of the machines is determined at the beginning and the state of the buffer at the end of each time slot,
- each machine status is determined independently from the other,
- time-dependent failures.

2.1 State Transition Diagram for a System with One Buffer

Various buffer conditions can be shown in a transition diagram. The transition diagram is built up from circles and arrows. The circles describe the buffer condition and the arrows, called trajectories, show the direction of a possible change of the buffer status. The values of the arrows are called the transition probability and depend on the conditional probability of the machines (machine up or machine down). The system with one buffer has two trajectories at the zero and the end status of the buffer condition. Between them, there are three trajectories from each buffer condition. The characteristics of the machines and the buffer can be shown in a matrix called transition matrix, where the sum of the probabilities in a column must be one.

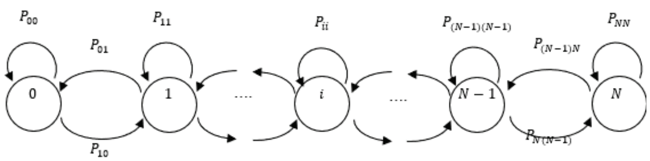

Figure 2 Transition diagram of a two-machine Bernoulli production line [9]

When the transition probability after a time circle $n + 1$is not changing, the whole line reaches the steady-state environment. In such case, the transition matrix can be multiplied with the buffer conditional vector and the result will be the same buffer conditional vector. Following some mathematical operations, it is possible to define each state of the buffer conditional vector.

3 THE AGGREGATION METHOD

This method belongs to the class of semi-analytical solutions. The aggregation method was developed because of the multi-machine and -buffer problems with the transition matrix. Some authors claimed that it is not possible or even necessary to solve these issues [9]. However, this problem was finally solved in 2018 [6].

The aggregation approach has three steps. The first step is the backward aggregation, the second step is the forward aggregation and the third step is the iteration of both aggregations.

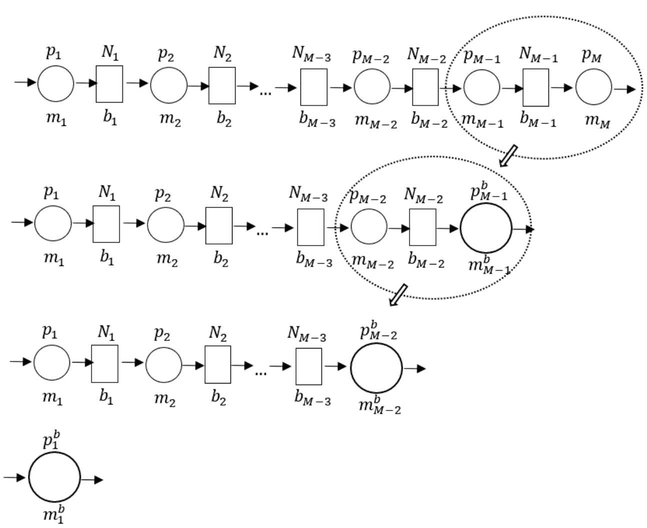

Figure 3 Backward aggregation [9]

The first step starts with the substitutions from the end of the production line. The first substitution consists of the last two machines and the buffer between them. This new composition creates a machine denoted by m_{M-1}^b, where b describes backward aggregation. This aggregated machine represent a two-machine single buffer line. Corresponding to that, the probability of this new machine p_{M-1}^b is calculated by the production rate of this two-machine single buffer line. The next substitution consists of this aggregated machine m_{M-1}^b, machine m_{M-2} and the buffer b_{M-2} which will be denoted as m_{M-2}^b. These substitutions are repeated until the whole line is aggregated into one machine p_1^b. This is the end of the first step.

The forward aggregation starts with the substitution of the first machine m_1, first buffer b_1 and the backward aggregate rest of the line m_2^b into the machine m_2^f. This aggregated machine represents a two-machine single buffer line. Corresponding to that, the probability of this new machine p_2^f can be calculated as the production rate of the two-machine single buffer line. The next substitution consists of this aggregated machine m_2^f, the next buffer b_2 and the backward aggregated rest of the line m_3^b. This combination will be denoted as m_{M-1}^f.

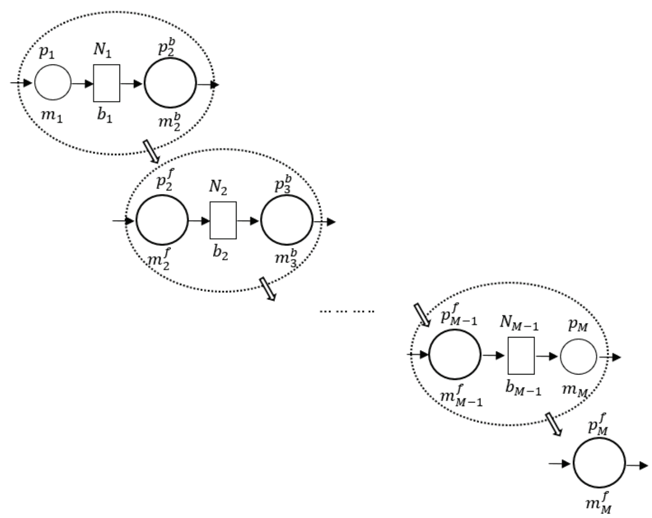

Figure 4 Forward aggregation [9]

Such aggregations will be repeated until the whole line is substituted into a single machine m_M^f which is built up from the last machine, last buffer, and the before aggregated machine.

During the third step, the backward and forward aggregation are repeated by using the results of each cycle. After three or four circles, the results will not change anymore and they can be used to calculate the following parameters: *PR* -Production Rate, *WIP* - Work in Process, *BL* - Blockages and *ST* - Starvations, and the *RT* - Residence time.

PR defines the average number of parts that are produced by the last machine per cycle time.

The *WIP* defines the average number of parts contained in all process buffers.

The *BL* defines the probability of a blocked machine. This case happens when the machine in front of the blocked one is up, the buffer in front of it is full and the machine after the blocked machine did not take an object.

The *ST* parameter defines the probability when a machine is running out of parts. This case happens when the machine is up, but the buffer in front of the machine is empty.

The *RT* residence time can be calculated out of the *WIP* and *PR*. In some literature, it is called flow time or system cycle time.

$$\begin{aligned} PR &= p_1^b = p_M^f \\ PR &= p_{i+1}^b \left[1 - Q\left(p_i^f, p_{i+1}^b, N_i\right)\right] \\ PR &= p_i^f \left[1 - Q\left(p_{i+1}^b, p_i^f, N_i\right)\right] \quad i = 1,..., M-1 \end{aligned} \tag{1}$$

$$WIP = \begin{cases} \dfrac{p_i^f}{p_{i+1}^b - p_i^f \alpha^{N_i}\left(p_i^f, p_{i+1}^b\right)} \left[\dfrac{1-\alpha^{N_i}\left(p_i^f, p_{i+1}^b\right)}{1-\alpha\left(p_i^f, p_{i+1}^b\right)} - N_i \alpha^{N_i}\left(p_i^f, p_{i+1}^b\right) \right] & \text{if } p_i^f \neq p_{i+1}^b \\ \dfrac{N_i\left(N_i+1\right)}{2\left(N_i+1-p_i^f\right)} \quad \text{if } p_i^f = p_{i+1}^b \end{cases} \tag{2}$$

$$BL_i = p_i Q\left(p_{i+1}^b, p_i^f, N_i\right) \quad i = 1,..., M-1 \tag{3}$$

$$ST_i = p_i Q\left(p_{i+1}^b, p_i^f, N_i\right) \quad i = 2,..., M \tag{4}$$

$$RT = \frac{WIP}{PR} \tag{5}$$

4 THE ANALYTICAL APPROACH – MULTI-BUFFER LINE

The multi-machine and -buffer problem was solved recently [6]. The first step is the creation of the transient matrix which is built up form constitutive matrices $P_i(p_i)$ (6). There can be three different types of constitutive matrices. The first matrix, the last matrix and the matrices between the first and the last matrix. For each type, there is a set of four different boundary conditions, which defines the elements $P_{h_1^n h_2^n h_1^{n+1} h_2^{n+1}}$ of these matrices [6]. The number of constitutive matrices is equal to the number of machines in the line. Each matrix has the same structure of elements which depends on the system state of the whole multi-machine line.

Fig. 5 shows an example of the structure of a constitutive matrix with three machines and two buffers.

$$\begin{aligned} \left[P(p_1, p_2, ..., p_M)\right] &= \left[P_1(p_1)\right]\left[P_2(p_2)\right]...\left[P_M(p_M)\right] \\ \left[P(p_1, p_2, ..., p_M)\right] &= \prod_{i=1}^{M}\left[P_i(p_i)\right] \end{aligned} \tag{6}$$

All matrices have the dimension $d \times d$. The number of elements d depends on the number of buffers as shown in the Eq. (7).

$$\begin{aligned} d &= (N_1+1)(N_2+1)(N_3+1)\cdots(N_{M-1}+1) \\ d &= \prod_{i=1}^{M-1}(N_i+1) \end{aligned} \tag{7}$$

The transient matrix is a stochastic matrix where the sum of each column equals one, the maximum eigenvalue equals one and all the elements of the matrix are smaller than one. These properties are crucial in the solution of the eigenvalue problem, which is the next step.

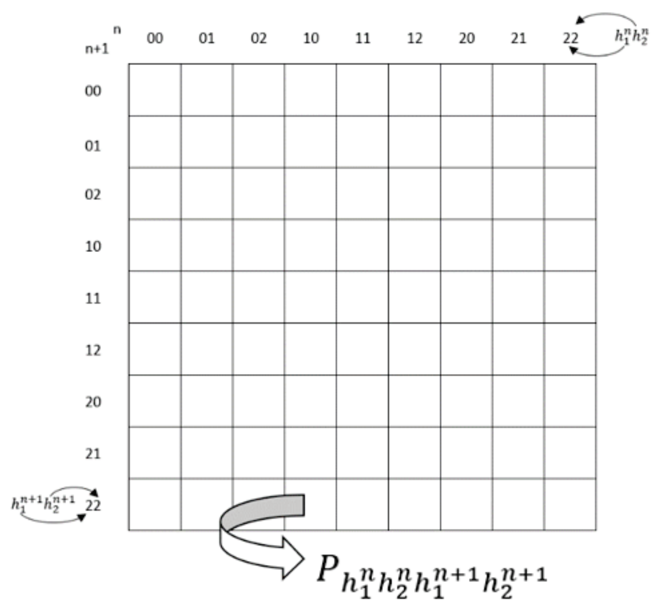

Figure 5 Matrix structure

The solution of the eigenvalue problem depends on the steady-state of the production line. In that case, it can be written as

$$\left(\left[P\right] - \Omega_1\left[I\right]\right)\left\{P_1\right\} = \left\{0\right\} \tag{8}$$

where Ω_1 is the eigenvalue for the steady-state, P_1 is the unknown eigenvector which is built up of probability elements $P_{h_1 h_2 ... h_{M-1}}$. These elements can be used to calculate the following parameters: *PR* - Production Rate, *WIP* - Work in Process, *BL* - Blockages and *ST* - Starvations. Formulas are listed in the paper [6].

5 ILLUSTRATIVE EXAMPLE

The illustrative example will be an automotive paint shop production system [9] with 11 operations. During these operations, the car bodies are cleaned, sealed, painted and finally finessed [9]. Parts are moving on carriers along the operational and accumulator conveyors. The operational conveyor enables the stopping of carriers without stopping the whole line. The initial layout of the automotive paint shop is simplified to ensure the application of the aggregation method and the analytical approach, see Fig. 6.

In this illustrative example, the machine parameters from month 5 will be taken into consideration, Tab. 1. The effect of a closed loop is considered with the factor p_{st}.

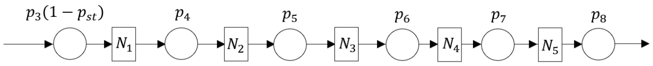

Figure 6 Simplified structural model of a paint shop system

Table 1 Machine probability parameters month 5

$p_3(1-p_{st})$	p_4	p_5	p_6	p_7	p_8
0.8832	0.9587	0.9740	0.9938	0.9675	0.9935

Table 2 Buffer capacities

N_1 (pcs)	N_2 (pcs)	N_3 (pcs)	N_4 (pcs)	N_5 (pcs)
3	4	7	60	5

These input parameters are used for the aggregation method and for the analytical approach.

Table 3 Comparison of the aggregation method with the analytical approach

Parameters	Aggregation	Analytical
PR (pieces/cycle time)	0.88069	0.88125
WIP 1 (pieces)	1.26520	1.26526
WIP 2 (pieces)	1.12095	1.11791
WIP 3 (pieces)	0.92897	0.92819
WIP 4 (pieces)	1.21042	1.23578
WIP 5 (pieces)	0.93144	0.93256
Sum *WIP* (pieces)	5.45698	5.47969
BL 1	0.00251	0.00251
BL 2	0.00014	0.00014
BL 3	0.00000	0.00000
BL 4	0.00000	0.00000
BL 5	0.00000	0.00000
ST 1	0.07788	0.07788
ST 2	0.09331	0.09331
ST 3	0.11311	0.11311
ST 4	0.08681	0.08627
ST 5	0.11281	0.11225
RT (cycle time)	6.19623	6.21807

Tab. 2 shows that the results between the aggregation method and the analytical approach for this figurative example are almost equal. The advantage of the aggregation method is the lower CPU load which makes the calculation much faster than the calculation of the analytical approach. The analytical approach is still necessary to validate the aggregation method.

It can be recommended to first calculate with the faster aggregation method and at the same time to start the analytical calculation, which will take some time, but in the end, the user will know if the first results are good enough or not. The calculation of the aggregation method will take just a second on an average PC. The calculation time for the analytical approach needs approximately 64 h on an average PC.

6 CONCLUSION

The analytical, semi-analytical and numerical approaches in the production system engineering are valuable tools to describe and improve the production. The figurative example shows the importance of a double approach concept to validate the results. The result of the aggregation method alone is not necessarily the best. After the application of the analytical approach, the results get validated.

Further investigation of the analytical approach may result in a speed-up of the calculation time. The numerical approach should be validated in further comparison. Measurements in the industry should be provided to validate all three approaches.

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Notice

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Preliminary communication

Elements of the Fourth Industrial Revolution in the Production of Wood Buildings

Jozef Švajlenka*, Mária Kozlovská

Abstract: We are on the threshold of a technological revolution that fundamentally changes the way we live, work and communicate with each other. To some extent, scale and complexity, this transformation will be as fundamental to humanity as no other technological change in the past. We do not know how it will evolve, but one thing is clear: the response to it must be integrated and comprehensive, involving all stakeholders on a global basis, from the public to the private sector, to the academic community and to civil society. In the context of sustainable and efficient construction, traditional material bases such as wood are becoming increasingly prevalent and implemented in modern design processes and design solutions. The great potential of this building material is achieved due to developments in production as well as the actual construction of timber buildings. Possible ways of production and construction of wooden buildings are diverse. Especially through prefabricated and solid wood products, which are also cross-glued laminated timber products, modern timber construction represents an interesting and sustainable construction technology. The aim of this paper is to define the basic aspects of industrial building industry in the context of new trends and to introduce the possibilities of implementation of elements of industry 4.0 in the field of wood-based construction.

Keywords: efficiency; Industry 4.0; modern methods of construction; sustainability; wood constructions

1 INTRODUCTION

In the world, market volatility is increasing, product life cycle is shortened, product complexity is growing, and global supply chains are increasingly influenced. In Western countries, productivity growth has declined sharply in recent years, at less than 1%, and the share of developing countries in world industrial production has risen sharply to the detriment of developed countries. In this environment, companies strive to become more flexible, cheaper, faster and better responsive to business trends. Industry 4.0 provides solutions and ways for companies to meet these challenges [1]. Human society is on the verge of a technological revolution that fundamentally changes the way it will live, work and communicate with each other. The speed of recent discoveries is unprecedented. Compared to previous industrial revolutions (the first mechanized by steam discovery, the second brought electricity and mass production, the third used electronics and ICT to automate production), the fourth - known as Industry 4.0 - is developing at a much faster pace and affects every area of life. Industry 4.0 is built on two main pillars: digitalization (products, processes, services) and application of so-called exponential technologies that bring rapid growth in productivity and efficiency (ICT, 3D printing, sensoring, robotics, etc.). Continuously improved ICTs enable people, machines, devices, logistics systems and products themselves to communicate and collaborate directly [2, 3]. This close interconnection of modern technologies enables to increase production efficiency [4, 5] by reducing all kinds of waste (costs, time, resources, etc.). However, the expected benefits must continue to take into account the sustainability principle. At the same time, smart and innovative production has to cope with energy, resource or environmental constraints in the context of social and economic impacts. The Industry 4.0 strategy line emerged in Germany in response to a decline in industrial production and productivity in paradoxically developed countries that expect it to increase global competitiveness [6]. This will not be possible without a strong innovation platform, which will bring, in addition to higher economic performance, undisputed benefits for the customer (respect for individual requirements - "Made-for-Me", "Customerization" as well as for the workers themselves, etc.) [7]. Although this modern technology line is directed to the so-called, the intelligent model of production, procurement or use of the product (Smart Factory, Smart Logistic, Smart Buildings, Smart Maintenance, etc.) is conditioned by a number of partial innovations, whether in the field of processes or the products themselves [8]. In the construction industry, one of the fundamental ways of increasing efficiency is the implementation of the Building Information Model (BIM) platform throughout its life cycle [9]. This revolutionary innovation in the management of a digitized building model follows the concept of the "Digital Twin", one of Industry 4.0's core technologies [10]. The intelligent digital information model built in this way significantly supports subsequent "smart" innovations at all stages of the design, procurement or use of the construction. It follows that construction and building technologies are also responding much faster to global challenges in the field of sustainability of energy, resources, environment, but also intelligent design solutions [11] or better customization of provided services in the field of construction supply [12]. Modern technologies and methods in the construction industry are currently marked by the trend of sustainability and increasing productivity by new modern technologies or by innovation of traditional modern methods [13-15]. The term Modern Methods of Construction (MMC) is a common term for building technologies and off-site and innovative on-site technologies. Off-site construction methods use prefabricated elements made off-site and are then transported and assembled on site (prefabricated panel or modular systems, volumetric modules, etc.). On-site construction methods represent traditional construction systems, but in combination with innovative construction methods such as semi-finished construction methods, lost formwork, etc. According to several studies, MMCs are characterized by reduced construction time, greater productivity, better quality, lower costs, less waste, environmental emissions, reduced energy consumption, and higher occupational safety and health. MMCs enhance business efficiency and quality, customer satisfaction, sustainability and predictability of product delivery [16] and enable the management of the product process more effectively to deliver more quality products in less time [17]. Wood-based design solutions are increasingly being used within MMC [18, 19]. The aim of this paper is to define the basic aspects of industrial building industry in the context of new trends and to introduce the possibilities of implementation of elements of industry 4.0 in the field of wood-based construction.

2 DEVELOPMENT OF BUILDINGS BASED ON WOOD

Timber construction is characterized by a supporting structure made mainly of wood and wood-based materials. Wooden buildings can include not only buildings, but also hall buildings, footbridges, bridges, towers and the like. Buildings made of wood and wood-based materials find their greatest application in low-rise construction, usually on four above-ground floors. Structural systems can be divided into log, skeleton and solid slab. By the first half of the 19th century, wooden constructions of residential buildings were built in two basic variants, with log and half-timbered walls. Both of these variants were characterized by demanding carpentry joints. Since the first half of the 19th century, sawn timber and machine-nails were added as joining elements. These technologies have enabled a lightweight skeleton made of boards and planks to be used in addition to log systems and heavy skeletons in the form of framed structures. In terms of implementation technology, this system has gradually evolved into three forms - construction site, panel and cellular. However, cells which exemplify a high degree of prefabrication have limited applications and are particularly suitable for the construction of temporary structures (for example, construction site equipment and the like). Currently, heavy and lightweight skeleton systems in various forms and prefabricated sandwich construction systems are most commonly used [20].

Wooden buildings made of prefabricated panels nowadays occupy the largest share of the wooden buildings market in Europe. There are hundreds of companies that produce panels of different sizes, different material composition and degree of completion. The diversity in panel technology is enormous. Upon detailed examination, however, we find that prefabricated panel timber buildings are based on three basic design principles of panels (wood frame panels, structural insulated panels SIPs, laminated wood panels). The oldest design principle, i.e. a panel with a wooden frame, was patented as early as 1880. This year it celebrated 140 years of its existence. Panel buildings have become world famous right after their inception, and the winning mining of panel technologies across all continents continues for the third century. In the second half of the twentieth century, industrial production of prefabricated wooden buildings developed practically throughout Europe. Modern board construction materials, various types of thermal and acoustic insulation, modern connecting and construction fittings and, of course, building chemistry have been introduced to the market. The original Döcker panel with tapped and glued joints was increasingly replaced by a butt frame in the second half of the 20th century. The rigidity of such a panel is provided by a frame casing with a solid structural board, mostly based on wood. The different manufacturers differ in size of the panels produced, the degree of prefabrication, the degree of typing and the materials used. The basis of the panels, however, remains the wooden frame, which Johann Gerhard Clement Docker used in 1880 for his houses, and thus actually established a new branch of woodworking industry and construction. Currently, 60-65% of the construction is done in the USA. In Germany, Austria and Switzerland it is between 20 and 40% of construction. The largest number of constructions made of wood (including log buildings) is in Norway and it makes 95% of residential construction [21].

3 IMPLEMENTATION OF PREFABRICATION IN THE FIELD OF WOODEN BUILDINGS

The construction of wooden buildings as a division of the construction industry has moved from purely traditional craft on-site production techniques (on-site construction method) to industrial off-site prefabrication (off-site construction method) (Fig. 1, Fig. 2). In today's concept, prefabrication is usually understood as serial production of panel or modular construction. Precisely defined on the basis of literature, however, the term prefabrication refers to the creation of structural elements of a building in a place protected from the effects of the weather. The degree of off-site prefabrication varies, depending on whether only individual components or assembled elements or spatial modules are delivered on site. According to Kolb [22], prefabrication takes place although it is undemanding for all modern construction systems. Factory pre-fabrication gives construction companies the opportunity to make their productivity more efficient (Fig. 3, Fig. 4). At the same time, however, they must meet the requirements of customers, i.e. offer flexible building solutions, forcing them to strike a balance between productivity and flexibility to create more precise quality control. At present, it is irrelevant whether prefabrication is done by machine or by hand. The degree to which the individual elements are prefabricated is not further defined [23].

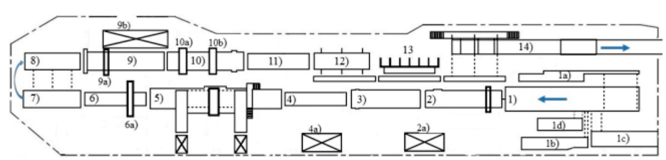

Figure 1 An example of an arrangement of a panel production line [23].

Wooden frame panels assembly line of Swedish company (Fig. 1):

Production line layout: 1) base frame assembly, 1a) horizontal components, 1b) vertical components, 1c) other parts, 1d) mineral wool insulation, 2) assembly of windsheets and installation grid, 2a) supplies for installation grid, 3) nailing installation grid, 4) manual placement of horizontal cladding wood elements, 4a) horizontal cladding stock, 5) nailing horizontal cladding 6) nailing horizontal cladding, 6a) nailing machine, 7) assembling from outside of panel, 8) tipping device 9) placement of vapor barrier and gypsum / wood-fiber boards, 9a) positioning device for boards, 9b) stock boards, 10) fastening and coupling device of gypsum / wood-fiber boards 10a) fixing machine, 10b) CNC router [23].

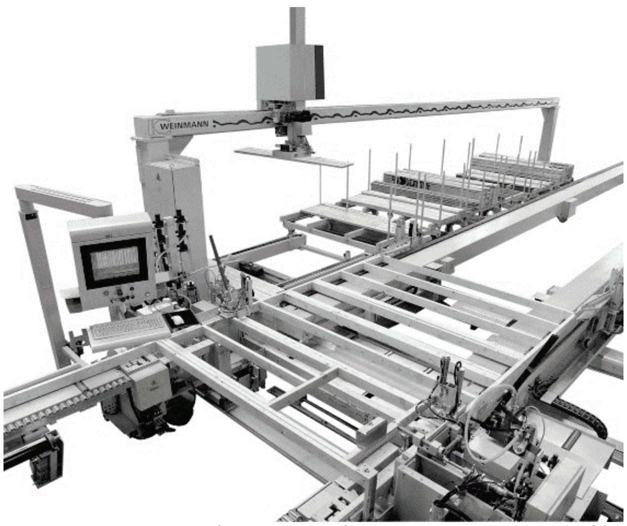

Figure 2 An example of automation prefab wood panel production line [24].

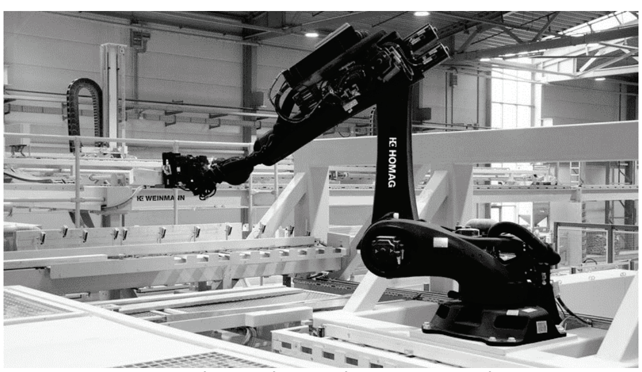

Figure 3 Robots used for manufacturing frame works in prefabricated housing construction [25].

Figure 4 The software modules ensure an end-to-end flow of data and production [25].

In wooden frame constructions, it is common to recognize the prefabrication stages depending on the number of elements assembled as follows:

- Fully assembled on site – on-site construction method,
- Open wall elements – the wooden frame is lined on one side, while the plate element fulfills the reinforcing function – so-called off-site method,
- Closed wall elements – the wooden frame is closed on both sides.

4 CONCLUSION

Like the revolutions that preceded the current trend, the Fourth Industrial Revolution has the potential to increase world income levels and improve the quality of life of populations around the world. New technologies and progress have brought fundamental changes for many countries. These trends and visions are also widely applied in the construction sector. Currently, all directions are focused on solutions that are efficient, sustainable and smart. In the implementation of efficient and sustainable solutions, wood-based industrial construction elements are well implemented as an efficient and environmentally friendly alternative. However, there are still gaps in the implementation of more efficient building practices and principles. In order to improve productivity in the timber sector, it is necessary to analyze and evaluate production and implementation processes in order to find more efficient processes as such. Elements of such analyses have also been described in this paper, which implies that by implementing modern computer-controlled automated production lines, conveyor systems and storage systems and many other aspects already mentioned, the trend of the Fourth Industrial Revolution can be taken.

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Notice

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Preliminary communication

Preliminary Research on Influence of Welding Parameters Strength at Welded Joints in Ribbed Reinforcing Steel

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Abstract: As already known, no proper control or process control parameter which absolutely guarantees a high level quality of joints made by electro-resistive welding has been established so far, especially when all possible parameters are taken into account during the welding process. Due to the process of butt-welding being very short-lived, ensuring quality of the joints is a difficult and under-researched problem. The application of non-destructive testing methods to the control interface joints is also not reliable. Therefore, further research in this area should concentrate on studying the influence of basic welding parameters, and calculating their direct or indirect impact can serve to achieve a high-quality welded joint with for practice sufficient accuracy.

Keywords: intensity and time passage of welding current; pressure force upon sealing; tensile strength of welded joint

1 INTRODUCTION

Obtaining a quality welded joint involves the determination and finding of the optimal relationship between a large number of parameters, which is very difficult, if not impossible to take into account in real production conditions. All of these parameters are interdependent and changing; one parameter can cause the value of several other parameters to change, which makes them very complex to study. In practice, all influential quantities that disturb the stability of the process are not considered, whereas only those with the greatest impact are [2].

Generally, by taking the Z-side welding process we can think of a set to which sets of input sizes (x) and output sizes (y) are connected, Fig. 1.

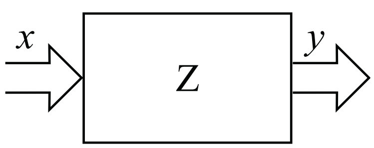

Figure 1 Scheme of welding process as a set of input and output sizes [2]

In this case, the dependence between input sizes (x) and output sizes (y) can be represented analytically, in tables or graphically. If in our considerations we denote the selected size (quality criterion) by (y), and the set of input variables (basic parameters of the welding mode) by (x) then the dependence $y = y(x)$ can be written in the following form:

$$y = f(x_i);\ i = 1, 2, 3, ..., n \tag{1}$$

All analytical expressions, tables or curves that show this dependence are called mathematical models in which time changes of the chosen parameters do not occur; thus, they are called static models described by algebraic expressions [2].

The quality of the welded joint is an integral category and can be discussed in several aspects. Welding result is a quantitative measure that captures the mechanical properties of a welded joint. To determine these characteristics, welds should be tested by non-destructive methods. Testing of welds by such methods is performed on specimens whose shape and dimensions depend on the purpose of the test. This test group includes tests of mechanical properties:

- testing the tensile strength and breaking strength of the welded joint,
- welding joint welding test,
- microscopic examination to determine the geometric characteristics of the weld,
- dynamic testing.

The non-destructive testing group used in concrete steels includes radiographic, ultrasonic and visual testing.

The quality criterion is usually taken to be the breaking tensile force F_M; however, the tensile strength of the welded joint can also be taken. It is also possible to determine the character of the change in tensile strength by measuring the hardness per section of the weld. Due to the limitations of the testing machine, the following quality requirements will be taken into account as a quality criterion in these studies, and according to previous considerations [2]:

- tensile limit of welded joint σ_R (MPa),
- tensile strength of welded joint σ_M (MPa),
- breaking force of welded joint F_M (kN).

2 DEFINING BASIC WELDING PARAMETERS

From the very expression of Joule law, which defines the decisive factors of the thermal phenomenon of butt-welding:

$$Q = \int_0^t I^2(t) \cdot R(t) \mathrm{d}t \tag{2}$$

where: I - current (A); R - electrical resistance (Ω); t - time passage of electric current (s).

It can be concluded that the process of forming a welded joint is decisively influenced by: current (I), time of passage of current through welded pieces (t) and electrical resistance of a part of the secondary circuit between the electrodes (R).

The above expression does not explicitly take into account the pressure force between the welding pieces, which is one of the important factors in the butt-welding process. The mechanism formation of the butt-weld is quite complex, both from thermal and metallurgical aspect, and it is logical to ask under what conditions optimal quality of the joint will be obtained, i.e. what relation should be established between the above and some other welding parameters in order to achieve the desired target. It can be said that in order to obtain a quality welded joint, an optimal relationship should be established between:

- the strength of the welding current and the time it flows through the welded pieces,
- the magnitude of the pressure force between the workpieces and its time change,
- types of materials.

The following parameters should definitely be added: shape of the current wave (heating, cooling) and times of different stages in the welding cycle (intermission, time of pressure setting, etc.). All these parameters are selected on the welding machine, but the quality of the welded joint is also influenced by the properties of the material that we want to weld, such as:

- thickness of welded pieces and their shape,
- condition of contact surfaces on the piece,
- mechanical properties of welded pieces,
- chemical composition of the material,
- electrical resistance of the material,
- thermal conductivity of the material,
- some important physical characteristics of the material being welded,
- metallurgical properties of materials.

Some of the listed properties significantly affect the quality of the joint. However, since it is a matter of securing materials of a certain shape and thickness, attention is focused on controlling the parameters that are set on the welding machine.

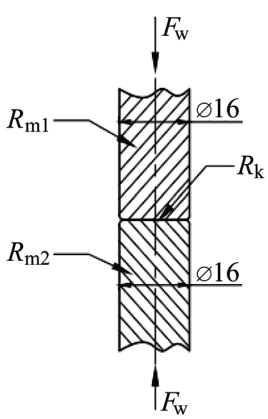

Figure 2 Total resistances for butt welding [2]

The main factors on which the required amount of heat for the formation of a welded joint depends are that the thickness of the welded pieces increases, the current strength also increases, the current time of welding is longer, and the pressure between the electrodes is higher to obtain a quality joint. The process of forming a butt weld is significantly influenced by the condition of the piece through the contact resistances, Fig. 2. The resistor resistance R_C represents the total resistance on the part of the electrical circuit between the workpieces and the sum of the following resistances is shown:

$$R_c = R_{m1} + R_k + R_{m2} \tag{3}$$

where: R_k - contact resistances piece – piece, R_{m1}, R_{m2} - intrinsic resistance of welded specimens.

At the initial moment the contact temperature is the highest because most of the Joules heating is released at the contact between the pieces. However, as the temperature increases, the contact resistance R_k decreases, and the resistance value R_{m1} and R_{m2} increases with increasing temperature, and they now play a greater role. Contact resistance at the point of contact occurs due to inhomogeneity of contact. The metal surface is characterized by greater or lesser roughness, which under microscopic magnification has the shape of a relief. From the cross section of the piece, the roughness is manifested in the form of ridge projections and recesses, Fig. 3.

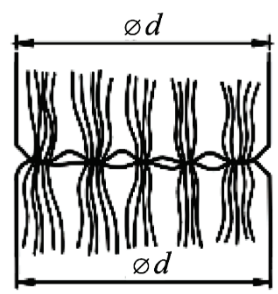

Figure 3 Microscopic image of a piece-by-piece contact surface [2]

Contact is made only on ridged projections. Therefore, the current flows only through the actual contacts in order to obtain a very high concentration of current on that surface, which leads to a large electrical resistance at the points of contact and results in a high spark during welding.

In principle it can be said that contact resistances depend on:

- contact behavior of metals (mechanical properties, electrical and thermal conductivity),
- state of the surface on the piece (oxides, impurities, oil, grease, etc.),
- the force pressure acting on the pieces,
- metal temperatures at the point of contact.

The latest research to determine the effect of surface roughness or method of surface preparation, which influences the size of the contact resistance when welding concrete steels shows the following:

- the speed of volume expansion on welds increases with reducing the surface roughness and increasing the electrical resistance of steel,

- the weld ductility increases with decreasing of the roughness at the contact surface on the welded piece.

3 SELECTION OF CONCRETE STEEL FOR EXPLORATION

A 16 mm diameter ribbed concrete bar with DIN 488 - BSt 420 S. grade was selected for the study. The bars were first rolled and then heat treated. The chemical composition of the bars and the mechanical properties are shown in Tabs. 1 and 2.

Table 1 Chemical composition of bars 16 mm in diameter

No.	C	Si	Mn	P	WITH	Cu	Cr	Sn	Nor
1	0.33	0.24	0.88	0.03	0.04	0.40	0.14	0.02	0.11
2	0.29	0.28	0.90	0.04	0.05	0.45	0.18	0.05	0.18
3	0.30	0.28	0.94	0.03	0.07	0.58	0.14	0.04	0.16
4	0.30	0.32	0.93	0.03	0.05	0.74	0.19	0.04	0.20
5	0.33	0.25	0.85	0.04	0.06	0.51	0.12	0.02	0.09
6	0.33	0.28	0.93	0.04	0.05	0.43	0.17	0.02	0.13
7	0.35	0.24	1.00	0.04	0.05	0.44	0.20	0.03	0.13
8	0.36	0.22	0.94	0.06	0.04	0.56	0.17	0.03	0.11
9	0.28	0.25	0.87	0.04	0.05	0.61	0.14	0.03	0.11

Table 2 Mechanical properties of bars 16 mm in diameter

No.	The batch	Dimension (mm)			Stretching limit MPa	Tensile strength MPa	Elongation %	Flexion	Weight kg/m
		Diameter	Rib height	Width of rib					
1	142914	15,30	1.6	3.4	432	624	25	90	1550
2	228051	15,30	1.6	3.5	441	633	20	90	1550
3	228050	15,30	1.6	3.8	447	643	20.6	90	1560
4	228049	15,30	1.6	3.7	452	657	20	90	1570
5	142835	15,40	1.5	3.5	442	638	19.4	90	1590
6	142834	15,40	1.5	3.5	460	681	21.9	90	1590
7	142833	15,30	1.9	3	456	676	18.8	90	1580
8	142907	15,30	1.7	3	487	732	18.1	90	1560
9	142905	15,40	1.6	3.4	449	655	23.1	90	1590

4 EXPERIMENT PLANNING AND SELECTION OF EXPERIMENT PARAMETERS

After selecting 16 mm diameter steel bars, it was necessary to define a test plan and select parameters according to certain mathematical models. According to [2], a three-factor experiment plan was chosen with two extreme levels for each parameter and at least three repetitions for each combination of parameter levels. Such a three-factor plan of experiments with a mean (zero) level can be shown in coded coordinates in the form of cubes, Fig. 4.

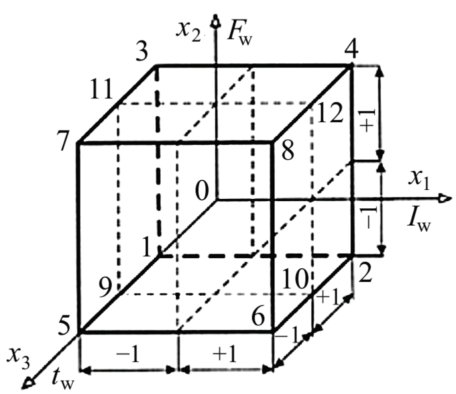

Figure 4 Model of three-factor test plan in coded coordinates x_1, x_2, x_3 [2]

Number of trials in one batch:

$$N = 2^n + n_0 = 2^3 + 4 = 12 \frac{experiments}{samples} \quad (4)$$

where: n = 3 - number of factors (welding parameters); n_0 - number of intermediate level experiments introduced to evaluate the adequacy of the mathematical model obtained.

The values of the parameters selected by the three-factor test plan are given in Tab. 3.

Table 3 Welding parameters selected by three-factor test plan [2]

No.	I_w (A)	F_w (N)	t_w (s)
1	23	150	3
2	28	150	3
3	23	180	3
4	28	180	3
5	23	150	4
6	28	150	4
7	23	180	4
8	28	180	4
9	23	150	3.5
10	28	150	3.5
11	23	180	3.5
12	28	180	3.5

5 TENSILE TEST RESULTS

According to [2], the tensile strength test of the welded specimens was performed according to HRN EN ISO 6892-1:2016 [6] on the UHP40 testing machine located in the FESB laboratory in Split, whose maximum test force is 500 kN. Prior to testing, all welded specimens were inspected visually using a microscope and 30× magnification (Fig. 5 and Fig. 6). The visual appearance of all samples was satisfactory.

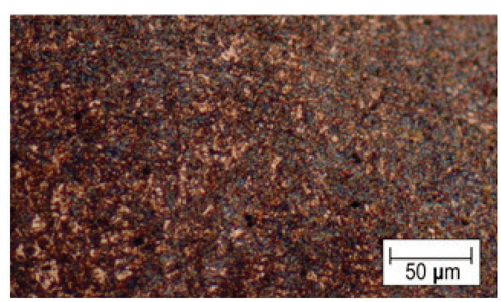

Figure 5 Microstructure of a 16 mm bar edge

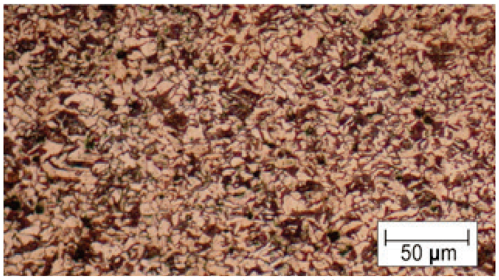

Figure 6 Microstructure of core rod 16 mm in diameter

The minimum and maximum test values obtained were omitted from the analysis, so that in Tab. 4 data for 10 specimens of 16 mm diameter rods are given.

Table 4 Test results for welded bars of 16 mm BSt 420 S steel [2]

Sample number	Rod diameter (mm)	Variable parameters			Tensile strength MPa
		I_w (A)	F_w (N)	t_w (s)	
1.1	15.3	23	150	3	562
1.2	15.3	23	150	3	566
1.3	15.3	23	150	3	555
2.1	15.3	28	150	3	531
2.2	15.3	28	150	3	547
2.3	15.3	28	150	3	556
3.1	15.3	23	180	3	599
3.2	15.3	23	180	3	609
3.3	15.3	23	180	3	617
4.1	15.3	28	180	3	656
4.2	15.3	28	180	3	653
4.3	15.3	28	180	3	620
5.1	15.4	23	150	4	611
5.2	15.4	23	150	4	637
5.3	15.4	23	150	4	633
7.1	15.3	23	180	4	559
7.2	15.3	23	180	4	566
7.3	15.3	23	180	4	573
9.1	15.4	23	150	3.5	631
9.2	15.4	23	150	3.5	635
9.3	15.4	23	150	3.5	604
10.1	15.4	28	150	3.5	593
10.2	15.4	28	150	3.5	509
10.3	15.4	28	150	3.5	511
11.1	15.4	23	180	3.5	630
11.2	15.4	23	180	3.5	643
11.3	15.4	23	180	3.5	630
12.1	15.4	28	180	3.5	603
12.2	15.4	28	180	3.5	616
12.3	15.4	28	180	3.5	595

6 ANALYSIS OF THE TENSILE STRENGTH TEST RESULTS

The processing of the results of the experiments was carried out using the software package "Design Expert". The software itself is an extremely powerful tool and is used both in the analysis of the results obtained and in the design of different experiments using different engineering, statistical methods and optimization of different processes. When using the program itself, it is important to choose one of the models offered and follow on-screen instructions. As the very experiment of this work was already planned by a three-factor test plan according to [2], Design Expert was used here only for the purpose of analyzing the results obtained, verifying the assumptions made in order to obtain optimal welding parameters which will result in the highest tensile strength of welded concrete steels.

A model with categorical factors was used for the analysis because according to [2] we have 3 factors that do not change continuously, so it is important to adjust the model to such factors. The results of the analysis are given in Figs. 7 - 11.

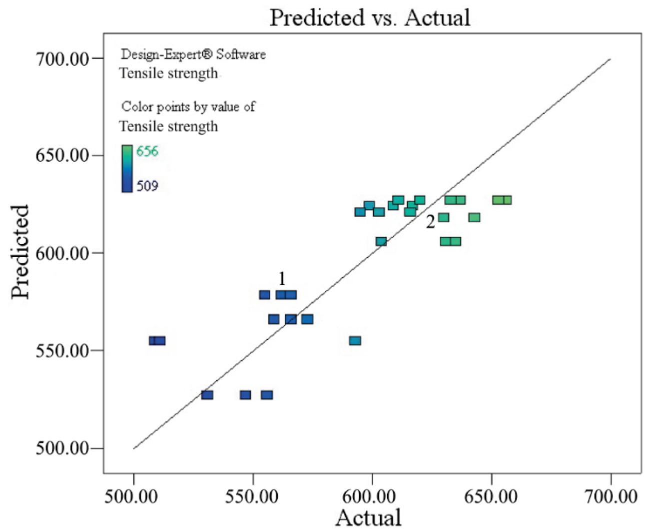

Figure 7 Relationship between obtained and predicted results of tensile strength values (in MPa)

In Fig. 7 the relationship between the actual and predicted tensile strength values according to the experimental results is shown. It is evident that the results do not deviate too much from the predicted ones, which shows us that both the model chosen and the results obtained are significant and further analyses of the obtained results can be carried out.

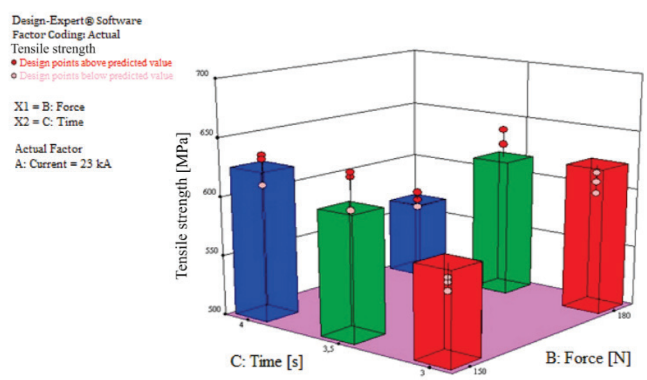

Figure 8 Effect of force and time on tensile strength at a constant current of 23 kA

Other Figs. 8 - 12 show the dependence of the tensile strength on different combinations of the observed welding parameters.

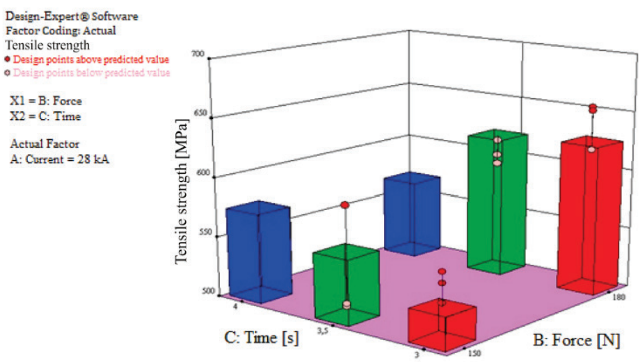

Figure 9 Effect of force and time on tensile strength at constant current of 28 kA

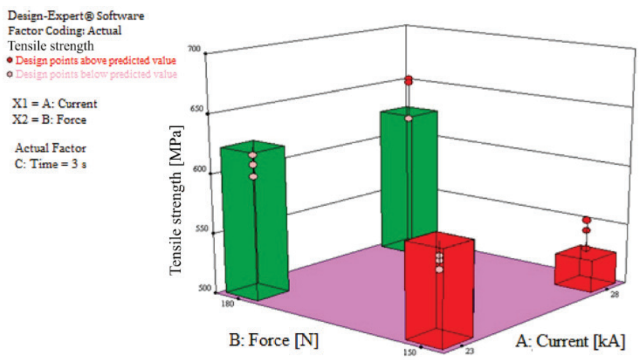

Figure 10 Effect of force and current strength on tensile strength at a constant time of 3 sec

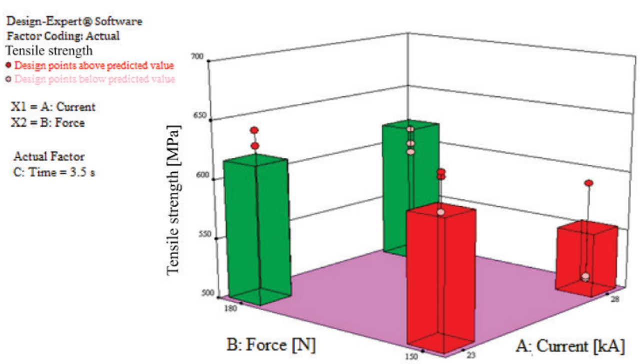

Figure 11 Effect of force and current strength on tensile strength at a constant time of 3.5 sec

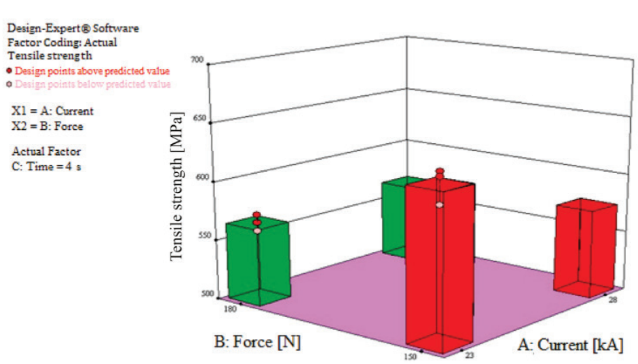

Figure 12 Effect of force and current strength on tensile strength at a constant time of 4 sec

7 EXPERIMENT PLANNING USING THE "DESIGN EXPERT" SOFTWARE PACKAGE

In this section an experiment plan for future research is made. The "Design Expert" software package was used – it offers a wide range of options for optimizing trial planning and processing data after experiments have been conducted, such as type and number of input parameters for a particular problem. This paper addresses the problem with three input parameters – time, force, current – and it selects a central composite test plan as one of the better models within the Design Expert.

After selecting the model of the test plan, it is necessary to enter the min and max values for each individual input parameter: force, time and current. Accepted parameters result the tensile strength as the output parameter. All parameters are entered into the central composite plan and shown in Tab. 5.

Table 5 Min and max values of input parameters [5]

Name	Units	Type	Changes	Std. Dev.	Low	High
Current	kA	Factor	Easy	0	23	28
Time	s	Factor	Easy	0	3	4
Force	N	Factor	Easy	0	150	180
Tensile strength	MPa	Response				

The next step is to design the experiment in such a way that Design Expert itself selects the required number of samples with different input parameters for each sample using the central composite model, Tab. 6.

Table 6 Input parameters of each sample according to the central composite plan [5]

Std	Run	Factor 1 A: Current (kA)	Factor 2 B: time (s)	Factor 3 C: Force (N)
2	1	28	3	150
17	2	25.5	3.5	165
5	3	23	3	180
12	4	25.5	4.3	165
10	5	29.7	3.5	165
15	6	25.5	3.5	165
9	7	21.3	3.5	165
6	8	28	3	180
13	9	25.5	3.5	140
1	10	23	3	150
19	11	25.5	3.5	165
3	12	23	4	150
11	13	25.5	2.7	165
4	14	28	4	150
20	15	25.5	3.5	165
16	16	25.5	3.5	165
7	17	23	4	180
14	18	25.5	3.5	190
18	19	25.5	3.5	165
8	20	28	4	180

The model works in such a way that it always gives two values called the min / max limit for each input parameter; in this way it can be easier to ultimately optimize the process and give a better mathematical description of the problem depending on the input parameters.

Finally, it is necessary to perform experiments on the defaults for each sample and to enter the measured tensile strength results back into Design Expert, which then analyzes the results itself and gives the relevant mathematical polynomials and graphical representations of the tensile strength change depending on the input parameters, i.e. the force, time and current.

8 CONCLUSION BASED ON TENSILE TEST RESULTS

Electro-resistance welding is a specific technological process in which by varying the three parameters (current strength, compressive force and contact time) we obtain different values of the tensile strength on 16 mm concrete steel bar. For this reason, more experiments should be carried out and a universal mathematical model would be obtained which would result in optimal values of all three parameters in order to achieve maximum tensile strength.

Mathematical modeling of the butt welding process enables the prediction of optimal welding modes with respect to the dissipation of the value on a particular qualitative requirement at a constant welding mode, and the order of the welding parameters according to the influence on a particular qualitative request.

The models obtained are valid within the selected range of variation on welding parameters which must not be exceeded. This area can be relatively simple to determine based on existing tables and nomograms for selecting the welding mode, which often require only one combination of welding parameters.

The analysis of the obtained results has shown that the greatest influence on the tensile strength is due to the current strength and the compressive force during the butt-welding. The higher the current and pressure, the higher the tensile strength; however, then the contact time must be very low.

From all the above it is evident that this model is not satisfactory because the current strength and the compressive force are interdependent parameters, i.e. in order to achieve maximum tensile strength, both parameters must either increase or decrease and the contact time is inversely proportional.

In order to carry out the experiment to get a real state of affairs and an adequate mathematical model, immentation is recommended, but in this way, the experiment will be planned from the beginning with the help of the software package "Design Expert", which will ultimately lead to better results, more detailed and faster analysis of the obtained data and relevant mathematical models that can be used in real welding processes.

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Subject review

The Selected Problems of Public Transport Organization Using Mathematical Tools on the Example of Poland

Piotr Gołębiowski*, Jolanta Żak, Piotr Kisielewski

Abstract: Public transport plays an increasingly important role in satisfying the transport needs. Travellers' requirements regarding the quality of services are increasing. In addition to passenger comfort, other parameters are important (timetable and the state of transport infrastructure). Therefore, methods that determine the appropriate organization of public transport for an area should be sought. The purpose of the article is to present the most commonly used optimization methods and tools that have been applied to the chosen problems of organization of public transport mainly in Poland (described in the articles of mainly Polish scientists), but against the background of global research. The article characterizes the functioning of public transport in Poland. The selected problems of public transport functioning, which can be solved by using optimization methods and tools were discussed. The chosen methods that were used to formulate and solve the identified problems were indicated. The effects of this article will form part of the work on the POIR.01.01.01-00-0970/17-00 project "IT system for computer-aided public transport planning" financed by the National Centre for Research and Development.

Keywords: optimization organization of public transport; public transport

1 INTRODUCTION

Every year, public transport plays an increasingly important role in meeting the transport needs of the population. The main factor, which causes a rise in its popularity is an increase of the ecological awareness of potential travellers, which translates into an increased concern for the natural environment. People leave their vehicles at home and choose public transport, which reduces the negative impact of transport on the environment. The second factor that influences the increasing popularity of public transport is its systematically increasing quality. Thanks to the financial resources from the European Union, older vehicles are systematically replaced with newer and more ecological ones, which attracts people.

However, travellers' requirements in shaping the quality of services provided by public transport are increasing [1-8]. In addition to passenger comfort, other parameters are extremely important. They are related to the timetable and the state of transport infrastructure. It is mainly about the frequency of travel, travel time and availability of stops. To meet these requirements, it is necessary to have the right number of vehicles that will be sufficiently capacious and to employ the right number of people who will service these vehicles. This is due to the need to have adequate financial resources for transport service companies. Obtaining the best solution that reconciles the needs of all interested parties will enable the obtaining of an appropriate organization of public transport.

Therefore, methods that will allow to determine the appropriate organization of public transport for a specific area should be sought. This organization should make it possible to meet the needs of all stakeholder groups - mainly passengers, with the minimum costs associated with it by the transport organizer. Moreover, the organization's project should enable the implementation of the concept of sustainable development, i.e. maintaining an appropriate balance between the society, the environment, and economic aspects. The organization of transport can be introduced in various ways – among others, manually or by using specialized tools with an optimization engine.

The purpose of the article is to present the most commonly used optimization methods and tools that have been applied to the chosen problems of the organization of public transport mainly in Poland (described in the articles of mainly Polish scientists), but against the background of global research. The article characterizes the functioning of public transport in Poland. The selected problems of public transport functioning, which can be solved by using the optimization methods and tools were discussed. The chosen methods that were used to formulate and solve the identified problems were indicated. The effects of this article will constitute an element of work on the project POIR.01.01.01-00-0970/17-00 "Computer system for computer aided planning of public transport" financed by the National Centre for Research and Development. The project is implemented by the Faculty of Transport of the Warsaw University of Technology at the request of the DPK System Consulting.

2 FUNCTIONING OF PUBLIC TRANSPORT IN POLAND

The purpose of this chapter is to present problems related to the organization of public transport on the example of Poland, which can be solved by using optimization tools. The content of the chapter additionally presents the specific conditions of the functioning of public transport in Poland.

Public transport (PTZ) can be defined as publicly available regular passenger transport carried out at specific intervals and on a specific communication line, communication lines or a communication network [9]. Therefore, this transport must be equally accessible to all who would like to use it. Moreover, it should be carried out according to a fixed plan, in a repetitive manner at strictly defined or equal intervals [10]. It should be noted that in the statutory definition, a part of the concept of regularity is included later in it. Furthermore, there is a definition of the area for the implementation of public transport, i.e. a communication line or communication network. Hence, this area is defined as a series or set of routes of public roads together with marked communication points where people exchange takes place.

Public transport should operate according to the principles of competitiveness. For this reason, it is necessary to conclude an appropriate contract (Contract for the provision of public transport services [9]) with its organizer. The role of PTZ organizer is played by a local government unit adequate to the range of transport - including commune, district, or province. The tasks of the organizer of public transport include [9] development planning, organization, and management of PTZ. It should also be noted that organized transport should consider the concept of sustainable development. Public transport is carried out by the PTZ operator, who must have the appropriate authorizations to perform it. If the entity does not provide public services, then it may perform transport services after reporting the transport [9].

Public transport should be implemented based on a plan for sustainable development of public transport, which is commonly called a transport plan. It is developed by PTZ organizing units, with the subordinate unit having to include in its document the assumptions of the master unit plan. The transport plan specifies [9]:

- the communication network,
- transport needs assessment and forecasts,
- expected financing of transport services,
- preferences regarding the choice of the means of transport,
- rules for the organization of the transport market,
- the desired standard of transport services,
- expected organization of the passenger information system,
- communication lines served by electric vehicles or vehicles powered by natural gas,
- the location of the natural gas station and electric vehicle charging infrastructure together with the places of connection to the distribution network.

The transport plan should include [9]:

- the spatial development status,
- the socio-economic situation of the area,
- environmental impact of transport,
- the need for a sustainable development of public transport, the needs of disabled persons and persons with reduced mobility, in the field of transport services,
- needs arising from the direction of the state policy in the field of communication lines in inter-voivodship and international passenger transport,
- profitability of communication lines.

Organizing public transport can be considered from two points of view - the transport organizer and the transport operator. Organizing from the first point of view (PTZ organizer) involves, among others [9]:

- the research and analysis of transport needs, considering the needs of disabled persons and persons with reduced mobility,
- taking actions to implement the transport plan or update it,
- ensuring appropriate conditions for the operation of PTZ (in terms of stops, stations, and integrated interchanges - including from the area of the tariff-ticket and information system),
- determining the method of marking the means of transport,
- setting rates for using public transport stops and stations,
- preparing and conducting proceedings leading to the conclusion of a contract for the provision of public transport services and its conclusion,
- setting transport charges and other charges for the service provided by the operator in the field of public transport,
- determining the method of ticket distribution for the service provided by the operator in the field of public transport.

Organizing from a second point of view (PTZ operator) involves, among others (based on [11]):

- delineating the routes of communication lines together with an indication of the stops where people will be exchanged,
- setting terms of riding for individual communication lines,
- determining travel times,
- determining the frequency of running on the communication line,
- setting communication routes (timetables),
- shaping transport tasks for vehicles and drivers,
- the selection of vehicles' types to carry out transport tasks,
- handling and operation of owned vehicles.

3 SELECTED OPTIMIZATION ASPECTS OF THE FUNCTIONING OF PUBLIC TRANSPORT

There are many aspects when optimizing public transport. In the literature written by Polish scientists, several research areas can be distinguished.

The first research area concerns how to deal with problems. Public transport can be considered by using the system theory from two points of view. The first point of view is to consider it as a static system. The state valid at a given moment is then analysed. The second point of view is considering it as a dynamic system. The specific state of the system is then not analysed, but the changes that occur in the system under the influence of time. We are then dealing with a transport process. There are many methods of testing transport processes - including using the process phase network method [12].

The second research area concerns the problem of shaping the transport offer in public transport, which is extremely important. Communication lines should be routed in such a way as to handle the largest possible number of people directly. It is therefore reasonable to study new methods for routing vehicles on the network [13-15].

The third research area concerns mobility. The participation of public transport in providing mobility to city users is also an important aspect [16, 17].

An important optimization problem related to public transport is the search for the best solution in the scope of the interval synchronization of timetables in municipal public transport [18-20]. Therefore, work is being done to ensure that subsequent communication lines depart from a given stop at a specified time interval, rather than in a group. Additionally, work is underway to optimize the timetables and circulation (cycles) of trains in railway transport [21-23]. A proper assignment of train sets [24], and buses to tasks [25] is also sought.

An important research trend related to public transport is also the choice of the means of transport for travel. This can be done by using both one criterion and multiple criteria [26]. Optimization problems in transport also apply to the optimization of depot location in each area [27]. This problem can be combined with the simultaneous determination of the routes of communication lines [28]. A large group of problems concerns the proper flow of passenger information [29].

The occurrence of a problem that can be repaired by using optimization tools should be properly diagnosed. It is possible to use quality science - qualitology [8, 30, 31] or the multi-criteria assessment method [32, 33]. For quality assessment, it is proposed to use time savings, among other methods [34].

To summarize, we have six research areas. Their specification is related to the scope of work on the POIR.01.01.01-00-0070/17-00 project *Computer system for computer aided planning of public transport* financed by the National Centre for Research and Development.

Various IT tools are used to analyse optimization problems. One of the groups are simulation models [35]. They are used, among others for testing the punctuality of public transport buses [36, 37], analysing the operation of selected communication nodes [38, 39], optimizing the number of vehicles serving a given region [40], and individual segments of transport needs [41]. It is also important to organize traffic in such a way that time losses incurred by public transport vehicles are as low as possible [42]. An important application of simulation models is motion modelling by using specialized tools [32]. You can analyse both the current situation [43] and the possibilities of developing the transport system [44, 45]. In simulation models, it is important to properly divide transport tasks [46]. There are many dilemmas associated with traffic modelling and significant mistakes can be made [47].

For the needs of solving problems of public transport organization, IT tools are being built that allow solving optimization problems [48, 49, 50, 51].

The use of mathematical tools for the problem of the functioning of public transport is also related to the scope of work on the POIR.01.01.01-00-0070/17-00 project *Computer system for computer aided planning of public transport*.

4 SELECTED OPTIMIZATION METHODS FOR THE FUNCTIONING OF PUBLIC TRANSPORT DESCRIBED IN THE ENGLISH-LANGUAGE LITERATURE

The main optimization problem related to the subject of the POIR.01.01.01-00-0970/17-00 *IT system for computer-aided public transport planning* is the allocation of vehicles for tasks and the allocation of teams for tasks. The issue of work planning in the context of public transport in literature is classified from the point of view of problems regarding work scheduling. The following issues have been distinguished in the English-language literature [52]:

- Crew Scheduling [53],
- Tour Scheduling [54],
- Shift Scheduling [55],
- Days-Off Scheduling [56],
- Workforce Planning [57],
- Crew Rostering [58],
- Cyclic Roster [59],
- Demand Modelling (Flexible Demand, Task-Based Demand [60], Shift Demand [61]),
- Task Assignment [37, 62],
- Shift Assignment [63],
- Roster Assignment [64],
- Other Classifications.

The above-mentioned problems have been ranked according to their popularity. Popularity should be understood as the number of articles about transport in which a given method was used. Researchers used the following methods to solve them (also ranked from the most popular to the least popular, popularity should be understood the same as above) [52]:

- Integer Programming,
- Constructive Heuristic [65],
- Set Partitioning,
- Set Covering,
- Column Generation,
- Constraint Logic Programming,
- Simple Local Search,
- Network Flow,
- Matching,
- Linear Programming,
- Lagrange Relaxation,
- Queueing Theory,
- Simulation,
- Branch-and-Price,
- Genetic Algorithms,
- Mathematical Programming,
- Simulated Annealing,
- Goal Programming,
- Dynamic Programming,
- Tabu Search,
- Expert Systems,
- Branch-and-Bound,
- Enumeration,
- Other Metaheuristics,
- Branch-and-Cut,
- Iterated Randomised Construction,
- Evolution.

5 SUMMARY AND CONCLUSIONS

The purpose of the article was to present the most commonly used optimization methods and tools that have been applied to the chosen problems of the organization of public transport mainly in Poland (described in the articles of mainly Polish scientists), but against the background of global research. At the end of it, it should be stated that public transport is most often understood as public transport, i.e. subsidized transport services carried out by using buses, trolleybuses, trams, subway, or city railways. There are many problems in this area that can be solved with mathematical modelling tools.

In the area of the functioning of public transport, there are basic areas that can be solved by using optimization methods and tools. The most important aspects are the shaping of the transport offer and the construction of the timetable. Preparing the route of communication lines and tracing vehicles in a network that has a certain size is troublesome and sometimes even impossible for a man who is not assisted by a computer. The use of IT tools equipped with applications that have an optimization engine reduces the possibility of making a mistake and it reduces operating costs.

The problem of assigning lines to service individual stops at intermodal interchanges is also important. Excessive stops may lead to a poor solution being chosen. A large group of problems concerns the planning of the work of vehicles (the allocation of vehicles for tasks) and the work of vehicle service teams (the allocation of human resources to tasks). These two problems have a very large impact on the financial functioning of the employing enterprise. Optimization tools allow you to reduce costs by allocating the least possible number of vehicles and people to handle transport tasks.

Research areas and mathematical tools specification is related to the scope of work on the POIR.01.01.01-00-0070/17-00 project *Computer system for computer aided planning of public transport* financed by the National Centre for Research and Development. We could only show selected methods due to the confidentiality agreement signed with the company with which we implement the project. To summarize – only part of the methods, which were used globally to solve the optimization problems of public transport functioning, were used in Poland. It is therefore reasonable to carry out the work on the project and use these methods to improve the situation in Poland.

The scientific work carried out as part of the POIR.01.01.01-00-0070/17-00 project *Computer system for computer aided planning of public transport* was financed by the National Centre for Research and Development.

Notice

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Subject review

Trends towards IOT in Egypt: Cloud Computing System Implementation in Egypt – Challenges and Benefits

Mai Salah ElDine Mohamed ElSayed

Abstract: This research aims to investigate the benefits of implementing the cloud computing system over the currently used IT system, as well the challenges of applying Cloud computing that companies in Egypt could face. This research applies mixed methods of research. Both qualitative and quantitative methods of research are used in the form of semi-structured interviews and questionnaires, respectively. The semi-structured interview was targeting the supply chain and IT managers of three different companies at Coca Cola Egypt, Nestle Egypt and Carrefour Egypt. A SWOT analysis was conducted to serve as a guide to many companies in Egypt that are willing to implement such a system and can then avoid the weakness points and the threats that they could be faced with during the implementation. The importance of this research adds to the literature by focusing on the application of IOT in Egypt in terms of the implementation of a cloud computing system in Egypt and it analyzes whether it could increase the efficiency of the companies in Egypt.

Keywords: Cloud computing System; IOT; SWOT

1 INTRODUCTION

In the today's global supply chain, companies from different industries face many challenges such as increased selection, competition, uncertainty and information sharing. Many of these challenges can be seen as one of the primary performance setbacks of any company. Faced by ferocious competition and the ever-changing customer demands, organizations need systems capable of adapting and advancing their company through these tough waters.

One of the newest advances or systems to be used on supply chains is Cloud Computing, which supports many activities such as product innovation, strategic material sourcing, outsourced manufacturing, integrated logistics, omni-channel fulfillment, and integrated demand and supply planning. The main idea behind Cloud computing is to consolidate and manage computing resources in central locations, make them available to users anywhere and move maintenance and operational management burdens away from the enterprise to a third party. Nonetheless, despite the benefit of the SCM cloud, companies tend to fear losing their information or having their information leaked to their competitors, which can have a counter negative effect on their market status.

This paper researches the benefits and challenges of applying Cloud computing in companies in Egypt, using Carrefour Egypt, Coca Cola Egypt and Nestle Egypt as samples for data collection. A comparison between the current system used by the industries and the Cloud computing system will be discussed in order to find out the different factors and barriers stopping organization in Egypt from applying the Cloud computing application to manage their business processes and the supply chain process.

In this research, two companies from different sectors and a company whose U.S. inhabiting branch uses the Cloud computing technology to manage their supply chain activities are researched. The research took place two years ago. The three companies are Carrefour Egypt (a retail company), Coca Cola Egypt - an FMCG whose US counterpart applies Cloud Computing, and Nestle Egypt (a FMCG). The research analysis focuses on applied semi-structured interviews with the IT manager and the Supply Chain or Operations Manager of each business. Moreover, fifteen questionnaires were handed out to employees in different departments, to further research the state of the currently applied IT systems, their problems and performance barriers based on usage experiences. The systems were compared to the Cloud computing system, whilst allowing the participants to analyze the system's pros and cons and leaving their professional opinions and suggestions regarding the application of Cloud computing.

2 BACKGROUND

2.1 Trends towards IOT in 2020

The Internet of things (IOT) is changing the industrial and consumer world. Smart Technology is now spreading to every business from healthcare and finance to logistics. Nowadays, any company will fail in achieving its strategic goals as long as it stops innovation. The year 2020 will focus on 4 IOT models; one of them is the Cloud computing system. By the end of 2020, IOT is expecting to increase revenues by 344 B$ and reduce costs by 177 B$. It is also expected that investments on IOT will hit 1.4 trillion dollars by 2021 [1]. IOT plays an important role in making production more efficient, less risky and more profitable through data integration and analyses by using one of the IOT technologies such as the cloud computing system [2].

2.2 Cloud Computing Service Models

Cloud computing growth has taken the attention of various communities such as researchers, students, business, consumer and government organizations. Big data is the main reason for the introduction of Cloud computing. Cloud computing can be defined as a model for enabling convenient, on-demand network access to a shared pool of customizable computing resources, such as networks, servers, storage, applications and services, that can be rapidly edited and released with a minimal management effort or service provider interaction [3, 4]. In other words, a cloud can be considered a collection of hardware, software and other resources that can be accessed over the Internet, and used to assemble a solution on demand at the time of request in order to provide a set of services back to the requester.

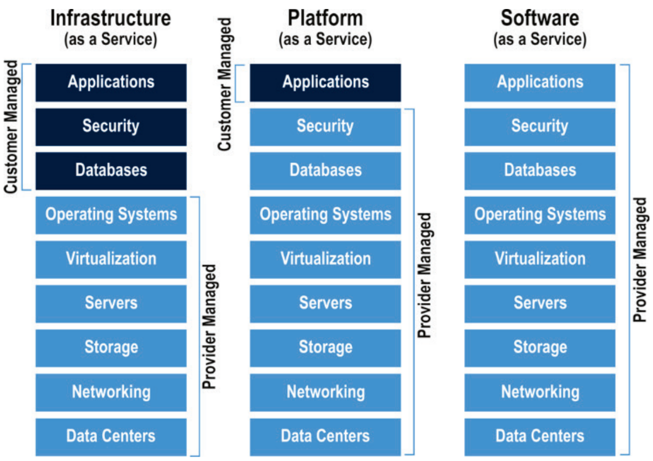

Figure 1 Cloud Computing Service Models [21]

Cloud computing presented a vital shift in the way businesses pay for and access IT services, as well as in creating new opportunities for IT services providers and outsourcing vendors who now have to modify their strategy to take advantage of this new computing exemplar [5]. Cloud computing is a new model of computing that is widely used in today's industry and society [6]. According to the cloud report 2020 [6], Cloud computing is one of the latest computer industry trends. The concept is derived from the idea of an Internet cloud, in which the term "cloud" is traditionally used to represent the Internet or some large networked environment. The idea presented is that client data and applications are stored and accessed somewhere out there [7]. In Cloud computing, resources are located in virtualized and distributed environments geographically interspersed [8]. One definition offered for Cloud computing is the virtualization of resources that maintains and manages itself [8]. Beal (2018) [9] also stated that Cloud computing can be described in an abundance of manners, such as the one that the phrase Cloud computing means a type of Internet-based computing', where different services – such as servers, storage and applications – are delivered to an organization's computers and devices through the Internet. To simplify, Cloud computing can be defined primarily as the use and sharing of applications and resources of a network environment to fulfill work without concern about ownership and management of the network's resources and applications. The cloud computing system consists of three main elements; Infrastructure as a service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). IaaS consists of virtual resources, servers, networks, storage and operating systems offered by the cloud provider. PaaS consists of an operating system and software development kit to be deployed into the cloud infrastructure by using a programming language, library services and support tools provided by the providers. SaaS is an application installed by the provider to be easily accessed by consumer devices through web browsers or a program interface, which avoid wasting the time of installation, running, managing and controlling the application by the consumer as shown in Fig. 1 [20].

2.3 Impact of Cloud Computing on Supply Chain Management in Organizations

The biggest competitive contribution that an IT system can provide is the enabling of collaboration within an organization in itself and with its business partners and customers [10]. Organizations that have joined their systems have increased and improved both the collaboration and economic performance of each partner involved. The use of such suitable technology has helped firms differentiate from competitors by enhancing their relationships with suppliers and customers [11, 12]. Cloud computing as a new technology offers an opportunity to many firms to harness the tools, equipment, and expertise necessary to aid collaborative relationships. It offers a possible solution to some organizations to increase their capacity without huge investments [13]. As such, Cloud computing provides faster implementation times and lower upfront investments in the sense that organizations do not have to spend their resources acquiring infrastructure [14].

Multiple business processes can be managed across businesses by using cloud technology. A growing number of third party logistics providers, or 3PLs, are turning to the Cloud computing technology to successfully support customers, enabling them to see further along both sides of the supply chain [15]. Collaborative relationships are allowing shippers to improve decision making and the costs are spread across users. Cloud computing also offers an opportunity that will enable small organizations to share the same services as larger companies, including the benefits from the ability to transparently interact and manage processes outside the organization, which reduces the cost of ownership for a supply chain collaboration.

2.4 Cloud Computing Pros and Cons

The cloud computing technology has now become a vital part of any business. It has a many advantages, but it also has disadvantages which result from its implementation that can be explained as follows.

2.4.1 Cloud Computing Pros

The biggest advantage of Cloud computing for a company is cost reduction, which is achieved by eliminating the investments of software or servers, saving the licensing fees and eliminating overhead charges such as the cost of data storage and software updates. Moreover, Cloud computing helps in reducing the cost of ownership through the sharing of infrastructure, as it depends on service providers for various low-level management and service levels of their multi-tenant applications, platforms, and infrastructures [16]. Cloud computing also allows for an easy access to data and information, which increases the end users' satisfaction to access their need anytime from anywhere with no cost. Cloud providers have a vital role in backing up data, which could under any circumstances be lost due to technical errors. Finally, Cloud computing is environmentally friendly, because when servers are not used, the infrastructure scales down, thus clearing up resources and consuming less power, i.e. only the resources that are truly needed are consumed by the system [17].

2.4.2 Cloud Computing Cons

Data security is considered as the biggest concern of potential cloud users. This is because the company is forced to provide the consultant with private, sensitive data and information. The cloud service provider has to manage, protect and retain the confidential information; therefore, end users are afraid to give their information to a third party. Another challenge is that the company could lose its expertise, as it would be obliged to outsource the system from another company. Companies using Cloud computing need a reliable Internet service. As the majority of the critical work done by Cloud computing is done on the Internet, if the Internet connection's speed is not reliable, Cloud computing is not a suitable solution for the company. Finally, data transfer bottlenecks are also a drawback of Cloud computing when applications become data-intensive, which will complicate data placement and transport, and as a result, cloud users and cloud providers have to think about the placement at every level of the system if they want to minimize costs [16, 17].

2.5 Cloud Computing Status in Egypt and Its Benefits to SMEs in Egypt

According to the Global Connectivity Index (GCI 2019), Egypt ranked as 58th over 79 countries. Investments on fixed line broadband and mobile broadband increased in 2019, which led to an increase in the demand for downloaded applications and cloud migration. Egypt uses its competitive advantage in its geographical location connecting to numerous cables that interconnect different parts of Europe with the Middle East and Asia. This helped Egypt to rank a high score in terms of Internet downloads speeds, Cloud computing and Internet usage. Egypt also has a good infrastructure in its data center and it has been well prepared since 2019 to grow its Cloud computing industry. Accordingly, it was ascertained the Egypt is classified among the starters that have a growth of GDP, and it finds itself in the fast lane to reach digital and sustainable growth. Consequently, GCI recommends that Egypt should focus on setting up more connectivity with a wider coverage and faster speed. Concerning the four technology enablers, Egypt is ranked below the average in terms of a cloud system as it ranked as 45th compared with the average calculated as 51. This indicates that Egypt is still at the beginning in the IOT and Cloud computing usage [18].

SMEs are defined as enterprises with an established volume of business of less than a hundred million Egyptian pounds, with categories going down to less than one million Egyptian pounds - medium, small, very small and micro finance. Micro, small and medium enterprises (MSME) are considered to be the backbone of domestic and international business. Based on recent research, in Egypt, MSMEs contribute with about 99% of the private organizations. [18] Generally, SMEs are amongst the most vital elements of any economy. With a focus on the Egyptian economy, SMEs account for nearly seventy to eighty percent of the Gross Domestic Product, i.e. GDP. They employ nearly sixty-six percent of the total workforce and seventy-five percent of non-agricultural work force. They contribute to nearly fifty-nine percent (thirteen for small enterprises and forty-six for medium ones) of the total industrial production. As a result, the SMEs contribution to the economy is quite significant. The last official report done in 2016 by the Central Agency for Public Mobilization and Statistics, or CAPMAS, in regards to SMEs, stated that they reached 2.45 million enterprises, accounting for more than ninety percent of total private enterprises in Egypt. In 2015, it was estimated that the number of SMEs reached nearly 2.78 million, where the annual increase in SMEs was nearly thirty-seven thousand [18]. Cloud computing promises to deliver many business benefits to SMEs, mainly in the form of much lower costs, as they would only need to pay for the resources they need and at a much better ROI of their limited resources. As a result, these enterprises get to focus on their core competencies, and as such, they deliver better value to their customers and they gain competitive advantage [18].

3 RESEARCH PROBLEM

To investigate the current status of implementing the Cloud computing system in Egypt, the paper identifies the benefits and challenges that the companies in Egypt face.

4 RESEARCH METHODOLOGY

The data collection process consists of two man phases; semi-structured interviews were conducted first to help the researcher formulate the questionnaire, which was conducted as the second phase, in addition to the literature review. Questionnaires were conducted with fifteen employees from different departments, and face-to-face semi-structured interviews were conducted with the Supply Chain or Operations managers and IT managers. The questionnaire consists of eleven questions divided into two main sections, starting with the questions collecting demographics – the department and corporate title – and are then followed by Rating Scale questions, Yes/No questions and open-ended questions collecting input on how each individual would rate the current system in terms of functionality, such as whether it supports business' processes well enough, and in terms of compatibility, such as the ease of access and transparency; there were also questions to test individuals' familiarity with Cloud computing, the system's benefits and challenges and their openness to using it. Semi-structured interviews were held with six current managers and operators from both the supply chain and IT department at Carrefour Egypt, Coca Cola Egypt and Nestle Egypt. We have chosen them according to their positions that carry a lot of expertise and knowledge about their managerial and operational factors that are applied in both departments, all in order to help us understand the major barriers that affect Cloud computing.

5 DATA ANALYSIS

Data was collected in the form of semi-structured interviews conducted with the IT Managers and Supply Chain Managers of each of the three companies followed by questionnaires issued to 15 employees of different departments within the three companies. It was noted that the awareness of the Cloud computing system is in general low, and that many of the respondents were not familiar with the system due to the lack of awareness on becoming better acquainted with technology. Furthermore, in terms of benefits, Cloud computing's benefits were all rated very highly and during interviews, the most highly rated benefit was that of cost reduction. On the other hand, in both the semi-structured interview and questionnaire answers, the biggest challenge seemed to be data security, as it is hosted on a server with other companies. Most managers also noted that the need for an efficient Internet service was also of concern due to the general nature of Internet services in Egypt, which is not very good. In terms of resolving challenges, most managers focused on the means of resolving the security issue by applying some form of authorization means to disallow unauthorized individuals and service provider personnel from accessing sensitive firm data. The respondents in questionnaires also applied a similar idea regarding that data security issue. Finally, although data security was considered as a very sensitive challenge, most managers and respondents seemed to support changing the current IT system into a Cloud based system, which supports the assumption that the system's benefits outweigh the risks. Regarding the Respondent Familiarity with the Cloud computing System, the results showed that most respondents were not in fact familiar with the system of the Cloud computing technology and its application on supply chain management.

Concerning the ratings of the benefits of the Cloud computing system, this question helped achieve the second objective, which is to establish an idea about the benefits and drawbacks of Cloud computing in the mind of a related professional. The question was showed in the survey as follows:

Rate the following benefits of the Cloud computing system from 1 to 5, with 1 being lowest and 5 the highest.

	Cost reduction (no capital cost but only an operational, pay-per use, cost)
	No large capacity computers needed as software is run by the service provider
	Ability to use anywhere, at any time
	Easy start-up with minimal delay, as transferring to the cloud is a simple, quick process
	Tailored to the firm's needs
	Elasticity in decreasing or increasing processing and work-load demands
	Power saving and environmentally friendly (is only powered when needed for use and does not require full time operation)

The results of the survey showed that the benefits rated as follows:

- **Cost reduction (no capital cost but only operational, pay-per-use cost)**

The results suggest that 71% of the respondents would view this benefit as very high, meaning that it is a huge benefit of Cloud computing, which supports speculations regarding the high costs that arise with applying a desktop ERP system.

- **No large capacity computers needed as software is run by the service provider**

The results suggest that 53% of the respondents would view this benefit as one that deserves a very high rating.

- **Ability to use anywhere, at any time**

71.1% of the respondents showed this benefit to be of very high importance.

- **Easy start-up with minimal delay, as transferring to the cloud is a simple, quick process**

The results show that most respondents rated this advantage as very high, suggesting that most of them view it as a benefit of a very high value.

- **Tailored to the firm's needs**

The results suggest that most respondents viewed this benefit to have a very high rating.

- **Elasticity in decreasing or increasing procession and work-load demands**

This suggests that most respondents with 80% rated this criterion to be of very high importance. Cloud computing also has faster time to market launch on demand, elastic IT services which enable the applications and infrastructure to be in one place, thus leading to facilitation in traditional IT services.

- **Power saving and environmentally friendly (is only powered when needed for use and does not require full time operation)**

The results show that 73% of the respondents rated this benefit with a very high value supporting the strength of the benefits provided by the Cloud computing system and matching with what was discussed earlier in the cloud benefits. Thus, the benefits found can be summarized as follows:

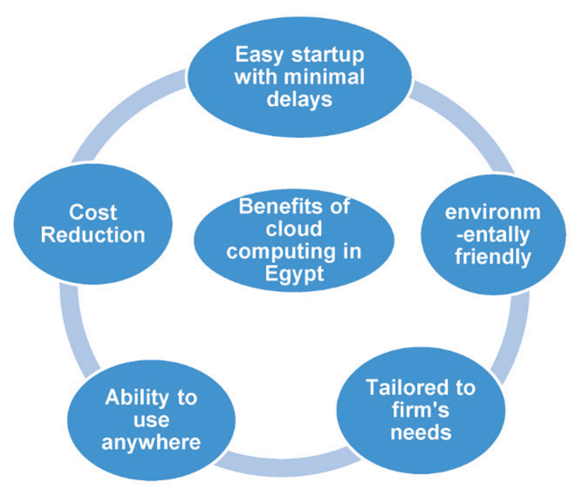

Figure 2 Cloud Computing Benefits in Egypt by the author

Considering the evaluation of the drawbacks or challenges facing the companies in Egypt towards implementing the Cloud computing system, the question was showed in the survey as follows by using the Likert scale:

Rate the following drawbacks of the Cloud computing system from 1 to 5, with 1 being the lowest and 5 the highest.

	Data can be accessed by the service provider
	Multiple users are hosted on the same computer by the service provider
	The need to outsource computer services
	The need for an efficient Internet service
	Data bottlenecks must be considered and resolved to avoid cost buildups

The survey showed the following results:

Rating drawbacks of the Cloud computing system

This question helped achieve the objective two of understanding the views of professionals on the benefits and drawbacks of the system.

- **Data can be accessed by the service provider**

The results show that almost all respondents, with an exception of 1, (97.8%) would view the value of this drawback, which is the accessibility of data through the service provider, as very high, which provided support to the literature stating that data security is a significant drawback of Cloud computing systems.

- **Multiple users are hosted on the same computer by the service provider**

77.8% of the respondents rated this drawback as having a very high value, supporting the idea that one of Cloud computing's most prominent drawbacks is data confidentiality in terms of the level of access that can allow installation of data to unauthorized users.

- **The need to outsource computer services**

33.3% of the respondents were on moderate, followed by low, which is only 1 respondent less than moderate, thus the majority of them suggesting this challenge as moderate or low in risk. This supports the assumption that the majority of Cloud computing's drawbacks are not very risky. However, it is still a challenge because they could lose their existing experts by being obliged to outsource the system to another company.

- **Need for an efficient Internet service**

The results show that the highest number of respondents (48.9%) rated this challenge to be of a very high risk. This result puts weight on the assumption that due to the Internet service quality being low in Egypt, applying Cloud computing may be risky and hard for companies in Egypt, which contradicts with what was found in the literature review that described this challenge as less risky and the application depending on the Internet speed, which is a common problem in Egypt.

- **Data bottlenecks must be considered and resolved to avoid cost buildups**

The results show that most respondents (57.8%) rated the issue of data bottlenecks to be of high importance. The data transfer bottlenecks are also a challenge when applications become data-intensive. If applications could be pulled across the boundaries of clouds, this would complicate data placement and transport, and as a result, cloud users and cloud providers would have to think about the placement at every level of the system if they wanted to minimize costs.

The results received from this question were the following: 3 very high rating averages, 1 high and 1 moderate, suggesting that the drawbacks of Cloud computing carry a relatively high risk to the respondents, especially in terms of data security, as supported by literature. The answers from this question acted as a means to address the problem statement regarding the risks and barriers preventing companies in Egypt from applying Cloud computing in the Supply Chain management. Thus, all Cloud computing challenges found under the study in Egypt could be summarized as follows:

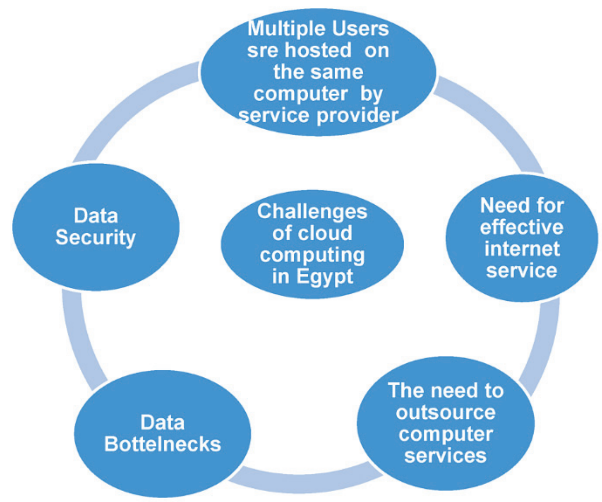

Figure 3 Challenges of Cloud computing in Egypt by the author

Regarding the respondents' personal opinions on the Cloud computing system's drawbacks minimization:

Only four respondents gave an answer to these questions, while the rest did not have a suggestion to give other than that data security was a vital issue to be addressed. The four respondents were:

- the IT supervisor in Carrefour who said that password protection that does not allow any unauthorized access to sensitive data and requires permission for access could be added,
- the ERP Application Consultant in Coca Cola who said that the service provider could create a means for an IT employee within the firm to be the one systemizing the access and activities on the system so that the service provider would not need to access the firm's data, thus maximizing security and decreasing the need to outsource services,
- the IT specialist in Coca Cola who said that a passcode could be installed on sensitive data,
- the IT specialist in Nestle who said that data security could be increased if the service provider could create walls to protect the users on the system from accessing the information of other users on the same server.

Regarding the respondents' support on the application of the Cloud computing system, it was found that most participants were in accordance with the transition to Cloud computing.

These results provided a backing for the idea that the Cloud computing benefits outweigh the risks, and that the Cloud computing system is considered to be better than the currently used IT systems. This result provides an answer to the first question of this research about whether the Cloud Computing system is better than the currently used IT system as the respondents' support to changing to the Cloud Computing system shows that it must be better in some aspects than the existing IT system. Furthermore, this also provides an answer to the research question of whether the system's benefits outweigh its drawbacks as the results state that although the system has several significant challenges, the respondents are still supportive of applying the Cloud Computing system.

Accordingly, a SWOT analysis was conducted based on the above-mentioned data, collaborated with what was found in the literature review, GCI and with the results of the respondents. It was found that the implantation of Cloud computing in companies in Egypt will help in the reduction of costs, improvement of the customer service and easy access from anywhere, i.e. without restriction to the workplace. Hence, this will open a new market to the companies and increase their competitive advantage in addition to the green trends provided, and there will also be less paperwork. However, some problems may arise in terms of a lack of awareness from the customer side, and security problem. Some threats could be faced in terms of the severe competition in the local and international market, see Tab. 1.

Table 1 SWOT analysis of switching to cloud in Egypt

Strengths: • Reducing costs • Delivering better value to customers • Ability to use anywhere, at any time	**Weaknesses:** • Lower awareness of the Cloud computing system • Data security followed by being hosted on a server with other companies • Inefficient Internet services in Egypt • Data can be accessed by the service provider
Opportunities: • Green IT • New markets • Competitive advantage	**Threats:** • Severe competition • Security and frauds

Source: Author

6 CONCLUSION

While analyzing the questionnaires and the answers gained from the semi-structured interviews, it was noted that the currently used IT systems are all desktop ERP systems, supporting the information from the researched literature. Moreover, it was also noted within the questionnaires that the lowest rated criteria of the currently used IT system is cost friendliness, which is in contrast with Cloud computing that offers cost friendliness as a benefit. Furthermore, it was discovered that for the larger part, the Cloud computing system is not a familiar concept within businesses around Egypt, particularly anyone outside the IT department. Following that, it was prominent that the majority of the respondents of the questionnaire supported the idea that Cloud computing has major benefits that are mostly rated as having a high or a very high importance. On the same note, the highest ranked benefit of Cloud computing with most interviewees was once again cost friendliness, in contrast with the currently used IT or ERP systems. On the other hand, the biggest challenges of the system from the perspective of the respondents and managers were that the service provider has access to the data, several hosts being on one computer and the reliance on an inefficient Internet service. Those challenges are seen as the vital deficiencies with which the majority of the companies are faced. Additionally, it was found that the need for an efficient Internet service in Egypt is also seen as big challenge. However, nowadays, Egypt is going forward to improve its main communication and connection infrastructure as it has been mentioned before. Another major challenge, which could hinder the use of the Cloud computing system in companies in Egypt, is the data bottlenecks, while the lowest ranked drawback was the need to outsource IT services, which was not a challenging risk from the respondents' point of view. Last but not least, it was discovered that due to the discovered benefits, most respondents and managers said that they would support changing the current IT system into a Cloud computing system, supporting the theory that the Cloud computing's benefits outweigh its risks, and that it is better than the currently used IT systems.

Based on the analyzed and interpreted data, we have several recommendations regarding the application of the Cloud computing system in companies in Egypt:

- The awareness of new technology in Egypt is very low and this issue must be addressed as advancements in technology help companies achieve their maximum potential in the market, and that is vital to a firm's performance.
- Before applying Cloud computing in Egypt, further means to protect data security must be developed and researched by the service providers and developers. Moreover, protection against data loss during Internet cuts must be installed in order to ensure that the system fits the Egyptian business environment in the most optimal manner, keeping in mind the setbacks that might occur in the environment.

Notice

The paper will be presented at MOTSP 2020 – International Conference Management of Technology – Step to Sustainable Production, which will take place from 30th September – 2nd October 2020 in Bol, island Brač (Croatia). The paper will not be published anywhere else.

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Subject review

Competencies of Production in SMEs in Assembly Industries in a Digital, Volatile Business Environment

Maria Hulla*, Christian Ramsauer

Abstract: SMEs are currently confronted with major challenges such as increasing uncertainty and volatility. In order to face these challenges, agility and digitalization can be implemented. Both concepts bring about numerous opportunities and new competency requirements. Currently, there are few scientifically based, practical training courses that focus on digitization and/or agility. The aim of this paper is to provide a roadmap for the development of the training concept. In this training, participants will be able to acquire theoretical content on a learning platform in a flexible way and they will be able to apply this knowledge in a learning factory. Based on a literature overview, requirements for such a training and the necessary skills in a digital, volatile business environment will be given.

Keywords: digitalization; digital transformation; learning factories; SMEs; volatile business environment

1 INTRODUCTION

Volatility and uncertainty are constantly increasing challenges in today's business environment, especially for small and medium-sized enterprises (SMEs) [1]. The resulting rising dynamics consequently lead to market developments that are difficult to predict. Agility enables companies to proactively adapt to these uncertainties and react quickly to changes in order to optimize their economic situation by leveraging the entire value chain. [2]

For some years now, digitalization has been one of the most promising enablers in terms of productivity increase in the manufacturing industry. Future production systems will be characterized by small digitized, decentralized elements that act autonomously and that are thus able to control their operation according to external specifications. In this production network, products and materials will be clearly identifiable and localizable throughout their entire life cycle. [3] Not least because of this, digitalization offers numerous advantages such as higher quality, individualization of products, reduced costs and increased flexibility and agility. Digital transformation also leads to new competency requirements. These must be taken into account for a successful, agile orientation of companies in the age of Industry 4.0. [3, 4]

Training and teaching have not kept pace with the current advances in manufacturing and demands on the labour market [5]. Particularly SMEs face problems when exploiting the potentials of digitalization, such as a more agile orientation of the company, especially due to a lack of corresponding competencies within the employees [4, 6]. Nevertheless, only a small number of practical trainings is currently available. Moreover, traditional teaching methods show limited effectiveness in terms of developing competencies of students and employees for the current, as well as future, manufacturing environments [7]. In recent years, new training and teaching concepts have evolved. These take into account the fact that manufacturing and corresponding disciplines cannot be taught only in a classroom and that industry can develop by implementing new research results into industrial operation. [8] Therefore, modern learning approaches need to train participants in a realistic manufacturing environment and leverage industrial practice by including new manufacturing technology and knowledge [9]. Learning Factories, such as the LEAD Factory of the Institute for Innovation and Industrial Management at the Graz University of Technology, offer new, practical training opportunities that can potentially be used to build up the skills of employees.

2 THEORETICAL BASIS

In this chapter, a theoretical basis will be given on the topics of the relevance of SMEs, digitalization and digital transformation in SMEs, agility, competencies for the digital, volatile business environment and on Learning Factories.

2.1 Relevance of SMEs

The European Commission defines an SME as an enterprise with fewer than 250 employees and a turnover of up to € 50 million or a balance sheet total of up to € 43 million [10]. Additionally, it must be a "stand-alone" company and it may not be a partner or an affiliated company [11]. In Austria, SMEs are of significant relevance as they comprise 99.6% of all enterprises in the country (about 337,000 SMEs) and 2 million people are employed in companies of this kind. [12] Austria's SMEs are responsible for more than 60% of the turnover, gross value added and investments of the market-oriented economy. In 2017, the turnover generated by SMEs was around € 482 billion. [11] A similar picture can be seen in Germany, where 99.3% of all enterprises are SMEs employing 53.5% of the population [6].

SMEs are often referred to as "hidden champions" and they possess niche expertise. They mostly have smaller budgets than large companies and a more sustainable business strategy. Micro-enterprises are predominantly traditional crafts, while small and medium-sized enterprises consist mainly of manufacturing companies and IT service providers. [6]

SMEs in particular are confronted with high volatility and uncertainty in their business environment [13]. Employees in SMEs typically perform several different and complex tasks in the course of their regular work [14]. Deficiency of skills and competencies is currently recorded in production and engineering, in the craft and technical field of production and engineering, in the craft and technical field in all sectors of the Austrian economy, but even more predominantly in SMEs [15]. Furthermore, SMEs in particular are struggling to recognize the benefits of the fourth industrial revolution and to exploit its potential [6].

2.2 Digitalization and Digital Transformation in SMEs

Digitalization offers a wide range of opportunities, such as shorter lead times, improved consideration of customer needs and faster innovation cycles, and this is especially the case for SMEs. It also plays a major role in identifying, but also managing volatility [2]. Digitalization has been progressing consistently in larger companies, while SMEs still have some catching up to do [16]. A study conducted in 2017 by Arthur D. Little in cooperation with the Austrian Federal Economic Chamber (WKO) found that a large proportion of the Austrian SMEs surveyed across all industries and provinces are in the "digital newcomer" or "digitally aware" category. A study conducted in 2017 also confirms this result. According to this study, 32% of SMEs are "digital latecomers" [16, 17].

In a survey of Austrian SMEs, 1,700 participants were asked "What do you think are the biggest challenges in terms of digitization? " The most common answers were the fear of unauthorized access and the lack of competent workforce (see also Fig. 1) [18].

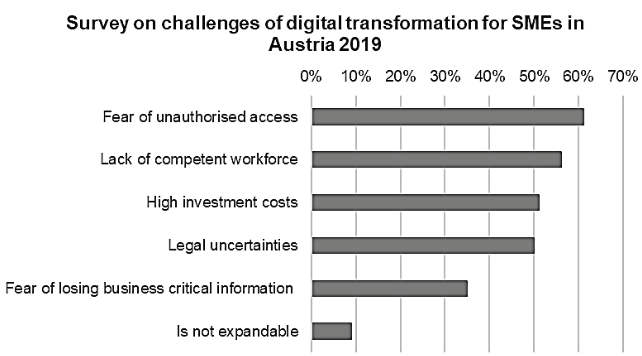

Figure 1 The challenges of digital transformation in SMEs [18].

A similar study in Germany pinpointed the adaptability of IT systems, qualification requirements for employees, the process of man-machine cooperation, work and health protection, flexibility compromises and the security of company data as the major obstacles of digital transformations in SMEs [19].

In another study, it was found that the lack of know-how and little information on digitization are the biggest challenges for SMEs [17]. To summarize, a lack of qualified people in the workforce is one of the major reasons why SMEs are still lagging behind in terms of digitalization.

2.3 Transformability Concepts

Due to an increasing degree of uncertainty, as well as high market volatility, producing companies need to constantly adapt to the changing environment [20]. Serious events such as the ongoing Covid-19 crisis and the financial crisis in 2008 showed how an impressive degree of global cross-linking enhances the scope and the scale of externally triggered business impacts [21]. Literature provides different concepts such as flexibility and agility as the means for facing these challenges. Nyhuis et al. define flexibility as the ability to adapt a (production) system quickly and without additional investment within a corridor defined by certain measures [22]. The term "agile" was introduced in the context of production by researchers at the Iacocca Institute in 1991 [23]. Agile production means to have *"a system that is capable of operating profitably in a competitive environment of continually and unpredictably changing customer opportunities"* [24]. It was defined in a similar way in 1998 by Gunasekaran who sees agility as *"the capability to survive and prosper in a competitive environment of continuous and unpredictable change by reacting quickly and effectively to changing markets, driven by customer-designed products and services"* [25].

The agility of the workforce is characterized as the ability to deal with the ever-changing customer needs and uncertain scenarios, to learn from them, to generate innovative solutions and to accomplish the said goal within the stipulated time [26]. This also leads to certain requirements for the competencies of all employees in an agile organization. Accordingly, the individual person must be enabled to be agile. This requires professional skills and extra-professional skills. In the following chapter, the concept of competence is presented and consequently, the necessary competencies are discussed. [27]

2.4 Competencies

In order to obtain a deeper understanding of competencies, the crucial first step is to distinguish between the terms knowledge and skills. The European Parliament defines knowledge as the *"outcome of the assimilation of information through learning. Knowledge is the body of facts, principles, theories and practices that is related to a field of work or study"*. [28] Within the European Qualifications Framework, skills are described as *"cognitive (involving the use of logical, intuitive and creative thinking) or practical (involving manual dexterity and the use of methods, materials, tools and instruments) abilities"* [28]. Campion et al. defined the term "competence" as *"collections of knowledge, skills, abilities and other characteristics that are needed for effective performance in the jobs in question"* [29]. Franz E. Weinert defines competencies as *"the cognitive abilities and skills available to individuals or learnable by them to solve particular problems, as well as the associated motivational, volitional [the wilful control of actions and intentions to act] and social readiness and ability to use problem solving in variable situations successfully and responsibly"* [30]. In holistic approaches, the terms "competency" and "competence" are used in a manner in which a difference is distinguished between them [31]. The knowledge stair was introduced by North for a better understanding of the term competency [32] (Fig. 2).

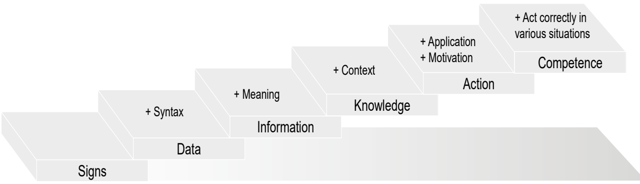

Figure 2 Knowledge stair according to North (2011) [32].

Competencies can be divided into different competency classes or models. These classes are further described in the following section.

2.4.1 Competency Classification

The division of competencies may vary depending on the author. A classification into three competency classes prevailed in the 1990s: professional, social and methodological competencies. This division continued until the beginning of the new millennium and was then supplemented by a fourth competency class, personal competencies proposed by Erpenbeck and von Rosenstiel, and it was slightly modified in other places. [33] Different authors further described other competency classes. An overview on the different classes is given in Fig. 3.

	Berthel and Becker (2013)	Erpenbeck and van Rosenstiel (2007)	Scullen et al. (2003)	Heyse (2007)	Bunk (1994)	Löwisch (2000)	Roth (1971)	Weinert (2001)	Klippert (1996)	Ertelt (2012)	Frey (2008)	Kauffeld (2006)	Peterßen (2001)	Competence Dimensions of the Conference of Ministers of Education and Cultural Affairs - KMK (2011)
Administrative competence			x											
Action / implementation-related competence		x		x		x					x	x	x	
Citizenship behaviors			x											
General competence								x						
Human skills			x											
Key competence								x						
Learning competence														x
Meta competence								x						
Methodological competence	x				x		x			x	x	x	x	
Motivation competence						x		x						
Participation competence					x									
Personal competence		x		x		x					x	x	x	
Professional/technical competence	x		x	x	x	x	x			x	x	x	x	x
Professional methodological competencies		x												
Self-competence	x						x			x				x
Situational (performance) competence								x						
Social/communicative competence	x	x		x	x	x	x			x	x	x	x	x / x

Figure 3 Competency classes (own demonstration).

For this research, the classification of Erpenbeck and van Rosenstiel will be used as it considers action- (and implementation-) related competencies and professional- and methodical-related competencies that are particularly crucial for SMEs. Competency classes divided according to these authors are described in the following section [34]:

- The personal competencies of a person refer to the individual's abilities to be aware of the consequences of their own actions, to assess themselves and to control their own actions in a creative and self-organized way. These competencies are expressed by characteristics and abilities such as flexibility, independence, ability to work under pressure or willingness to take risks.
- The social/interpersonal competencies describe the disposition of a person to self-organized action in the field of communication and cooperation.
- The action- (and implementation-) related competencies express a person's ability to act in a holistic, self-organized manner and to implement intentions.
- The ability of a person to analyse given problems and questions objectively and to solve them by using abilities, skills and knowledge is described as the professional and methodical competency. The acquisition of new methods and the creative development of the existing methods are also included.

2.4.2 Competencies in Production in Digital Transformation

As illustrated in Fig. 4, there are several factors leading to a change in competence profiles. In recent years, major factors for these have been digitalization, as well as globalization and shorter product life cycles. They have led to greater uncertainty levels and the need for agility [5].

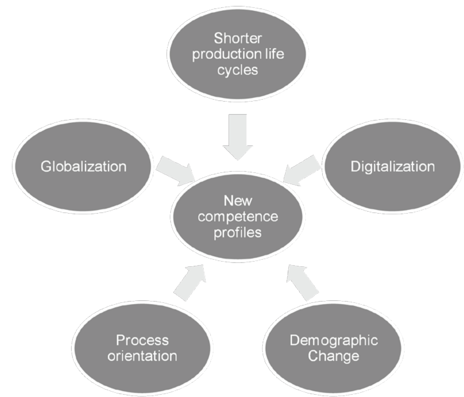

Figure 4 Changing competence profiles based on [5].

Digitalization will not only affect technology and production, but also the way we work in all its dimensions. This transformation of the work environment will change job profiles, and therefore it will require employees to be outfitted with a wide range of competencies. [5]

Personal competencies are especially important in a volatile digital business environment, since a worker´s tasks will constantly change. Therefore, workers need to adapt quickly to the changing work tasks [35]. Consequently, the workforce should focus on lifelong learning and personal development [36]. Personal flexibility concerning work contents, work time and work places, as well as open mindsets, are prerequisites for agile production in order to respond quickly to market requirements and changes concerning the environment [37]. Extending beyond this creativity and high innovation capability is also very important [38]. As every individual is embedded in certain social settings such as, for example, an organization with co-workers, the ability to cooperate, communicate and to establish social connections is of great importance [37]. In a factory of the future, interaction takes place at various different levels, for example at a human-human and human-machine level. Moreover, digital transformation incorporates an integration of processes in vertical and horizontal dimensions, a collaboration among standardized processes and the automation of collaboration. As a consequence, workers are responsible for a wider process scope and need to understand the relations between processes, disturbances, information and solutions. Building a network is essential to master these tasks [39]. In terms of action- (and implementation-) related competencies, it is of significant importance that ideas such as new technology solutions or new forms of collaborations are efficiently implemented on the shop floor. Complex concepts thus need to be broken down into realistic work packages and assigned to appropriate teams. [37] Another important competency is responsiveness, including capturing, recognizing and anticipating change, the immediate reaction to these changes and rapid recovery from change [27]. Professional and methodical competencies, also referred to as domain-related competencies, in the digital transformation include planning, control of production processes and networks [39]. Moreover, basic knowledge of network technologies and data processing are essential for the workers of the future. They will also need to be able to work with modern interfaces and to analyse the data by using software. [3]

2.5 Learning Factories

The term learning factory was first used in the USA in 2014. The number of learning factories has been constantly increasing around the world since then. [5] The learning environment of a "learning factory" is specified by [40]:

- processes that are realistic, including multiple stations, as well as organizational and technical aspects,
- a setting that can be changed and resembles a value chain,
- manufacturing of a physical product and
- a didactical concept which includes formal, informal and non-formal learning, enabled by the training participants' own actions in an on-site learning approach.

Learning factories are often miniaturized production environments close to the industrial reality. They represent models of a production system offering trainees the opportunity to implement (process) improvements and let them experience the outcomes of these changes immediately. [41]

The goal is to provide students and the industrial workforce with a close-to-industrial education environment and to let course participants experience hands-on activities though real-life projects [42]. Studies have shown that the concept of learning factories shows better performance in terms of knowledge and a capability acquisition that is better than that of traditional approaches [43]. Learning Factories follow the concept of action-oriented and experiential learning. For competency development, the assimilation of information follows first, where contents such as methods and technologies are theoretically explained and applied, and then applied and tested in the Learning Factory. In the second step, the experiential learning phase takes place where the application is experienced and seen as the basis of theoretical understanding [5].

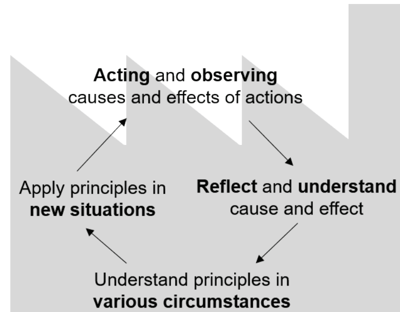

Figure 5 Training circle in Learning Factories based on [5]

The learning factory used for this research is termed the LEAD Factory and is operated by the Institute of Innovation and Industrial Management of the Graz University of Technology. It represents a manufacturing site where a 60-part scooter is assembled.

3 GOALS AND RESEARCH QUESTIONS

Based on the initial situation, the overall goals of the research are:

1) to highlight the challenges SMEs face in today's volatile digital business environment;
2) to determine which competencies will be required of the (production) workforce in the future;
3) to evaluate how these competencies can be taught and
4) to design and test training courses on the derived learning objectives including the current challenges of SMEs.

The first two goals are tackled in this paper. From these questions, the following research questions can be derived:

Which are the relevant competencies workers need in a volatile and digitalized environment in SMEs in the assembly industry?

4 METHODOLOGY

In this chapter, the methodology is described. First, the overall research framework of how to reach all four goals as it has been mentioned in Chapter 3 is tackled. The literature research will then be described.

4.1 Overall Methodology

In the introductory research phase, a (literature) overview is first created. The research perspective will be considered in the form of scientific journals and books. The industry perspective will be taken into account by means of the latest studies and industry insights from stakeholders, consulting firms and other stakeholders. In this phase, the research gap is identified and the requirements of training will be defined. In the conceptual research phase, a detailed literature study will be conducted (see Chapter 4.1) and semi-structured interviews with 10-12 industry representatives of SMEs in the manufacturing industry will be conducted. The interviews will be analysed with MAXQDA, a software (tool) for a qualitative and mixed methods data analysis, and they will be interpreted for the following research phase. The descriptive phase includes the development, testing, implementation and analysis of a questionnaire. This survey will be conducted according to Forza (2016) [44]. The results of this phase will be used to create training modules based on the results of the descriptive phase by means of didactic transformation. The end-product of the research consists of training modules, which are tested and evaluated. An overview of the research is shown in Fig. 6.

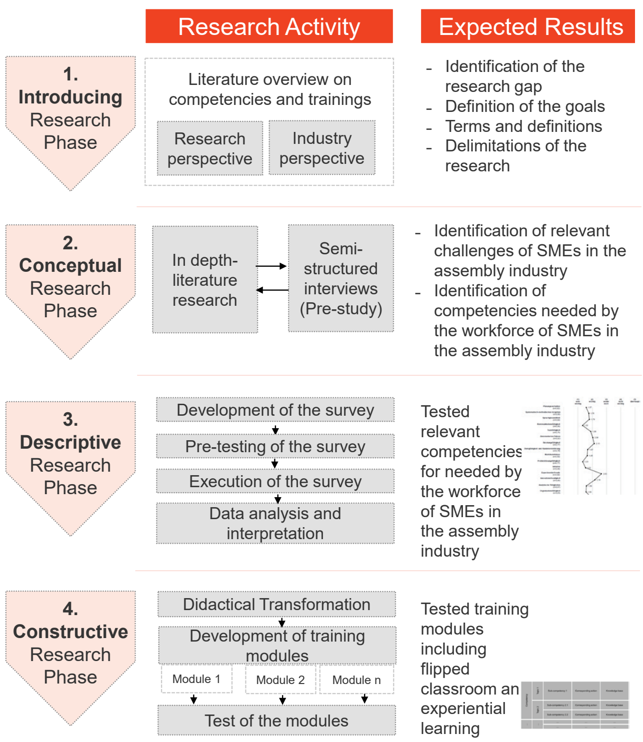

Figure 6 Overall Research Methodology based on [44, 45, 46, 47, 48].

4.2 Literature Research

In the first and second research phase, a literature research is conducted. While in the introducing research phase, an overview of only the current research and industry insights is created, and an in-depth literature research is performed in the second phase. The literature search is performed according to von Brocke et al. (2009) [49].

For the selection of the studies, the following process, excluding the forward and backward search, was performed (Fig. 7). After the selection of relevant articles, literature is analysed according to Webster and Watson (2002) [51].

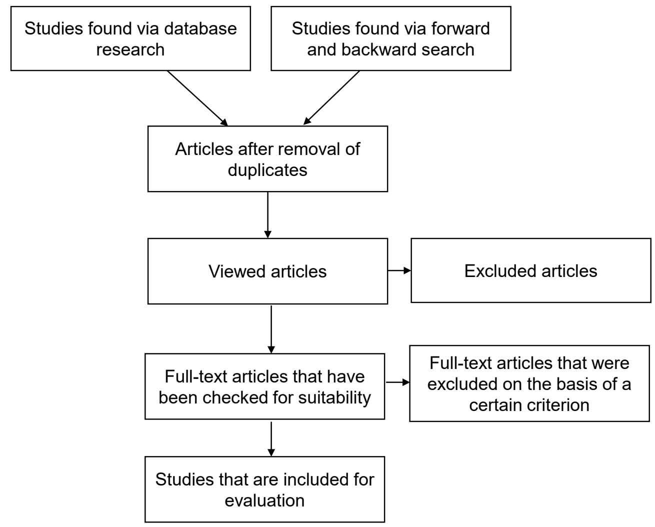

Figure 7 Methodology to select relevant studies [50]

5 RESULTS
5.1 Requirements for Trainings

Based on an extensive literature search on topic challenges in SMEs, trainings for digital transformation and transformation concepts, as well as competencies and competence development, the following requirements for trainings in a volatile digital environment were derived:

Competency-oriented. The training modules need to be competency-oriented, meaning that there needs to be a structured approach for training, and an assessment that is designed for a specific outcome. The training should assist individuals to acquire certain specific competencies, in order to ensure that they are able to perform tasks to a specified standard under certain conditions. This means that the learning objectives need to be defined very clearly before the training starts. The main organizational aim is then to generate competency models for the defined functional roles that contribute to company-wide strategic goals. Competency models are defined as a set of typically between ten and thirty competencies that define the capabilities of successful performers [52].

Maturity-based. When looking at the digitalization of companies, it is not enough to focus on technological aspects only. Taking the organizational and cultural aspects into consideration, as well as the knowledge and skills of employees, are of far greater importance. Modern technologies make it possible to build a database using this input. However, it must also be possible for the organization and its actors to make good use of it in order to achieve the overall goal of adapting the company to the changing conditions. Maturity models such as the acatech Industry 4.0 Maturity Index serve as a step-by-step guide for the required developments. These maturity models include all relevant aspects for the transformation and help to determine which competencies are still lacking for the task of successfully introducing digitalization.

Flexibility and changeability concepts. Numerous changeability concepts such as workforce agility and multi-skilled workforce have been developed during the past years.

In scientific articles, it has been demonstrated that concepts such as an agile workforce contribute significantly to achieving agility throughout the entire organization [53]. For this reason, it is important to further examine the competencies needed for these concepts and to incorporate them in the training.

Multiple-case scenarios. As training should also deal with volatility and uncertainty leading to unpredictable situations, it is important to include different scenarios in the learning environment.

Incorporation of main technologies. As the main value, and thus the potentials of digitalization incorporate the use of digital technologies, it is crucial to include these technologies in training.

	Eller et al. (2020) [54]	Waltersmann N. (2019) [55]	Erol et al. (2016) [3]	Kravcik et al. (2018) [56]	Hämäläinen et al. (2018) [57]	Petrillo et. Al. (2018) [37]	Saunila et al. (2019) [58]	Taipale-Erävala et al. (2015)	Lehner (2018) [60]	Sousa and Wilks (2018) [61]	Gamache et al. (2019) [62]	Abel and Wagner (2017) [63]	[64]	Vieru et al. (2015) [65]	Hubschmid-Vierheilig et al. (2019) [66]
Ability to build and maintain networks							x	x			x				
Ability to create value based on digitalization								x							
Ability to interact with modern interfaces (HMI)			x			x				x	x		x		
Actuator Technology		x									x				
Adaptability and ability to change	x										x		x		
Agility									x	x		x	x		x
Analytical skills				x	x		x	x							x
Basic knowledge on embedded systems/CPS		x									x		x		
Basic knowledge on sensor technology		x	x			x					x				
Capability to think innovative and entrepreneurial	x			x			x	x		x					x
Collaboration in networks	x		x		x	x	x			x				x	
Communication skills and sharing knowledge			x			x	x	x		x				x	
Continous/lifelong learning	x		x			x									x
Creativity	x		x			x	x		x				x		x
Data analysis	x		x		x	x				x	x		x		x
Data integration skills	x		x							x	x				x
Data/information processing	x						x			x			x		x
Decision making skills										x			x		x
Embracing change	x						x	x					x		
Generate new knowledge	x		x			x							x	x	
Generic knowledge about digital technologies	x		x			x					x				
Human Robot Interaction		x								x					
Implementations of ideas on the shop floor	x							x							
Intercultural competence			x			x	x								
IT and ICT competencies	x	x	x	x	x				x		x	x	x	x	x
IT Project Management	x							x		x			x		
IT Security					x								x	x	
Opportunity recogintion	x									x	x				
Organizational and process of understanding		x	x			x		x			x		x		
Personal flexibility			x	x	x	x	x	x	x	x		x			x
Problem solving skills	x		x		x	x				x			x		
Self and time management				x			x								x
Team work	x		x			x	x			x					

Figure 8 Competencies in SMEs for digitalization.

5.2 Literature Research on the Competencies in SMEs

The literature research was carried out between April and May 2020 and Google Scholar, Scopus, ScienceDirect and TU Graz Digilib were used. Studies that were published between 2014 and 2020 were incorporated. The languages of the articles were German and English. The search was focused on the following keywords: sme OR "Small and Medium sized enterprises") AND (competenc* OR skill) AND (digitization OR digitalization OR "digital Transformation" OR "Industry 4.0". Fifteen most promising articles were further analysed. Fig. 8 shows the results of the research.

When making a count of the individual competences referred to in the literature, the following were found to be the most frequently mentioned: IT and ICT competencies, personal flexibility, creativity, ability in collaboration and organization and also the process of understanding in networks.

6 CONCLUSION

SMES are currently facing challenges such as volatility and uncertainty. The concept of agility and digitalization are promising enablers to overcome these challenges. Nevertheless, SMEs are still struggling to transform themselves into digital enterprises and to exploit the potentials of digitalization. Furthermore, only very few (practical) training opportunities exist at the present time that incorporate changeability concepts and/or digitalization. For this reason, the authors aim to explore the competencies needed in SMEs in a digitally volatile business environment and hence, to further develop training.

In this research, an extensive literature research was carried out by focusing on the competencies and the training requirements of SMEs. It was found that the most frequently mentioned are the following: IT and ICT competencies, personal flexibility, creativity, ability in collaboration and organization and also the process of understanding in networks.

In the context of a literature research, a forward and backward search according to Watson and Webster can also be performed in order to uncover and find an even broader range of relevant articles. This study is part of a research project. The next steps are to evaluate the most important challenges of SMEs and, furthermore, to gain deeper insights into the changeability concepts of the workforce. In the conceptual research phase, interviews will be carried out with representatives of SMEs and this task will be followed by a survey.

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Notice

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Subject review

Study on Deformation Behavior of Non–Hardenable Austenitic Stainless Steel (Grade X5CrNi18–10) by Hot Torsion Tests

Imre Kiss*, Vasile Alexa

Abstract: The steel's deformation resistance, in which high strain rates have an important influence on the mechanism of failure, might be obtained from a suitably instrumented torsion test. Determination of stainless steel deformability by hot torsion test is the only method that allows obtaining large deformations along the length of the test specimen, so it is mainly used to determine the characteristics at large plastic deformations. By this method, the hot deformability of stainless steel is determined by subjecting to hot torsion the cylindrical stainless steel specimens maintained at the deformation temperature in a tubular oven belonging to the Laboratory of Metal Rolling and Plastic Deformation, at the Faculty of Engineering – Hunedoara, University Politehnica Timişoara. For the experimental hot torsion tests, several stainless steel grades were used and included in a large series of studies destined to determining the deformation behavior of steel. Having in view the previous results obtained in the study of deformability characteristics of two stainless steels (hardenable martensitic stainless steel, grade X46Cr13 and non–hardenable ferritic stainless steel, grade X6Cr17), this paper includes the results of the hot torsion tests conducted to find the deformation behavior of the non–hardenable austenitic stainless steel (grade X5CrNi18–10). For analysis of laboratory hot torsion tests results the univariate and multivariate regression analysis was used, estimating the relationships among the hot–testing temperature, torque moment and number of torsions up to the breaking point of the specimens of austenitic stainless steel. Therefore, the optimum range of heating temperatures applied for deforming the studied steels results clearly from the deformability – temperature (plasticity – temperature and deformation resistance – temperature) diagrams. Correlations are useful because they can indicate a predictive relationship that can be exploited in the laboratory or industrial practice.

Keywords: austenitic stainless steel; grade X5CrNi18–10; hot torsion test; stainless steel grades; plasticity and deformability

1 INTRODUCTION

In many types of industrial operations, the equipment requires steel to withstand high operating temperatures, combined with the corrosive action of the environment [1–3]. These requirements cannot be met without the proper development of the high–alloy and quality steel manufacture, including the stainless steels, the most diverse and complex family of all steels [1–12].

Austenitic steels are stainless steels that contain high levels of chromium and nickel and low levels of carbon [1,4–8, 11, 14–16]. Known for their formability and resistance to corrosion, austenitic steels are the most widely used grade of stainless steel. They are formable and weldable, and they can be successfully used at various temperatures – from cryogenic temperatures to the higher temperatures of furnaces [2,8–13]. They contain between about 16 and 25% chromium, and they can also contain nitrogen in solution, both of which contribute to their high corrosion resistance [12–16].

Were it not for the cost of the nickel that helps stabilize their austenitic structure, these alloys would be used even more widely [1–8]. Particular ranges of sulphur content may provide improvement of particular properties [3–10]. For machinability, a controlled sulphur content of 0.015% to 0.030% is recommended and permitted. For weldability, a controlled sulphur content of 0.008% to 0.030% is recommended and permitted [3–5, 8–10].

Currently, we are familiar with various types of stainless steels, which have multiple features and properties, designed to withstand corrosive environments and various working conditions [1–21]. Austenitic steels, which contain 16–26% chromium and up to 35% nickel, usually have the highest corrosion resistance [1–5, 8, 12–16]. They are not hardenable by heat treatment and are non–magnetic. The most common type is the grade, which contains 18% Chromium and 8% Nickel.

Stainless heat–resistant steels are always in demand when extreme technical requirements are imposed on the material, due to their outstanding chemical corrosion and mechanical properties [1–5, 14–17]. The austenitic stainless steel (non–magnetic and non–hardenable stainless steel), grade X5CrNi18–10, is the standard for the austenitic grades of stainless steel due to its good corrosion resistance, ease of formability and fabrication [14–16,19–21].

Table 1 Chemical composition of steel X5CrNi18–10 [19–21]

C (%)	Si (%)	Mn (%)	Ni (%)
max 0.07	max 1.0	max 2.0	8 – 10.5
P (%)	S (%)	Cr (%)	N (%)
max 0.045	max 0.015	17.5 – 19.5	max 0.11

Austenitic stainless steels are used in a wide range of applications, including typical applications in automotive parts, food and beverage equipment, storage vessels and pipes for corrosive liquids and industrial equipment (as chemical, pharmaceutical, cryogenic, construction and mining equipment) [1–10, 14–16].

2 RESEARCH AREA

The key areas of focus in the area of the high–temperature plastic working processes are understanding the critical temperature phases at which recrystallization can be prevented and then the start and finish of the austenite transformation [5–10].

For technologists, designers and researchers, the knowledge about the characteristics of deformability (plasticity and deformation resistance) has a great practical significance, because they are important elements in establishing the correct technological process [10–18]. The change of deformation conditions existing in the industrial process, such as the temperature and the rate of deformation, are difficult to consider in correcting the deformability determined by testing. In view of this, deformability is the ability of a material to be plastically deformed without the occurrence of undesired conditions (cracking of the material during the plastic deformation, inadequate quality of the surface, coarse structure, difficulty of material flowing when filling the molds, or other commercially–imposed conditions) [4–10,13–18].

In fact, the deformability of alloys characterizes their ability to permanently deform without breaking the internal links. As the deformability of a material is expressed by the degree of deformation to which the first cracks appear, i.e. its tearing resulting from a standard mechanical test or from one specific to the industrial deformation process, it should be pointed out that the breaking process, for all industrial processes of plastic deformation, as well as for the materials plastically deformed in these processes, appears in the form of ductile fracture [4–10, 13–18].

The behavior of steels during the hot deformation process, such as rolling, is a complex theoretical and practical issue and depends on the process parameters such as deformation size, deformation rate and temperature [1–18]. One of the crucial issues is finding the interdependence between the hot plastic deformation process parameters, the steel's structure and their technological properties.

Determination of stainless steel deformability by hot torsion test is the only one method that allows obtaining large deformations along the length of the test specimen, so it is mainly used to determine the characteristics at large plastic deformations. In order to determine the applicability of a steel type for a particular service, laboratory experiments are sometimes conducted under simulated industrial service conditions and other experiments are designed to determine the specific properties of the material [14–18].

Hot torsion testing is preferred in finding these correlations experimentally, being one of the most widely used methods for the evaluation of the deformation behavior of alloys [14–18]. Traditionally, this method is used to provide basic data for the characterization of the mechanical properties of alloys under shear, but it is also useful for providing the existence of hot ductility as being dependent on both high–temperatures and strain rates of deformation [14–18]. Therefore, the analysis of the high–temperature plastic working process conducted with the application of a hot torsion test, allows the determination of the influence of plastic deformation conditions on the steel's plasticity. In fact, simulating the real industrial hot rolling process, the hot torsion testing can be used to assure the steel's hot rolling process [14–18].

The hot torsion method enables the general determination of deformability characteristics of steels in the laboratory, especially those stainless (plasticity and deformation resistance, depending on temperature) and the study of the influence of deformation conditions (rate of heating, holding time at heating temperature, friction with the tools, rate of deformation, structural changes in terms of deformation, rate of recrystallization, etc.) [12–18].

The indications regarding the variation of plasticity with the temperature, using the hot torsion method, allowed to establishing the temperature range within which the steel plasticity is optimal and in which, in general, it is recommended to perform the entire hot plastic deformation. Also, depending on the plasticity variation with temperature, a more rational distribution of the reduction coefficients per passes can be achieved, so that the plasticity property of the steel can be used as much as possible [14–18].

In the rolling process, during the heating at various speeds, the knowledge of the steel's deformation behavior expressed through two main characteristics – plasticity and deformation resistance – is of particular importance in the structure and quality of rolled products [14–18]. In this sense, we have the following technical remarks:

- Deformation resistance is the resistance that steel opposes in plastic deformability under the conditions of the processes of plastic deformation (i.e. degree and deformation speed, temperature, mechanical scheme of deformation, friction conditions, etc.). In the hot torsion test the magnitude of the torque required to the specimen's torsion expresses the resistance to deformation of that steel.
- Plasticity of steels, also known as plastic deformation, is the property to undergo permanent plastic deformation, a non–reversible change of shape in response to applied rolling forces, without any increase in stresses or loads, being dependent on the deformation speed (i.e. higher stresses usually have to be applied to increase the rate of deformation). In the hot torsion test the plasticity limit is expressed by the number of torsions up to breaking at a given temperature and deformation rate.

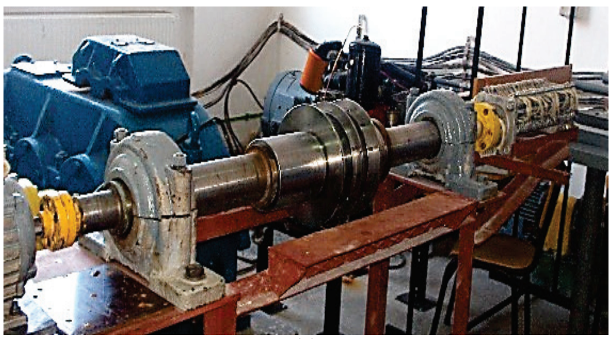
The steel's deformation resistance, in which high strain rates have an important influence on the mechanism of failure, might be obtained from a suitably instrumented torsion test [14–18]. In fact, hot torsion testing simulates the thermal and mechanical parameters under very precisely controlled conditions [14–18].

3 METHODOLOGY FOR HOT TORSION TESTING

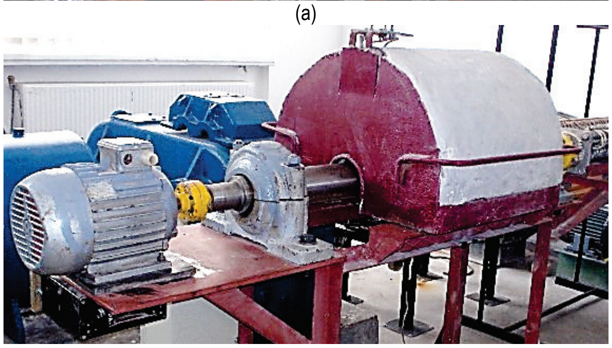
Determination of stainless steel deformability by torsion is the only one that allows obtaining large deformations along the length of the specimen, so it is mainly used to determine the characteristics at large deformations. By this method, the hot deformability of the stainless steel is determined by subjecting to torsion a cylindrical specimen maintained at the deformation temperature in a tubular oven [14–18].

The size of the required moment for torsion when the specimen expresses the resistance to deformation, and the number of torsions before failure express the plasticity limit of that steel [14–18]. Since the shear strains play an important role in the process of rolling and forging, the deformability caused by torsion reflects quite accurately the steel behavior at hot plastic deformation. Due to the fact that the specimen can be maintained in the oven during deformation, we can ensure the stability of temperature [14–18].

Existing research infrastructure at the Faculty of Engineering Hunedoara, University Politehnica Timişoara, allows the research to be carried out under the proper conditions, according to the timetable and the duration of performing laboratory experiments on hot testing of several stainless steels [14–18]. The experimental equipment (Figure 1) used to study the stainless steel deformability by hot torsion belongs to the Laboratory of Metal Rolling and Plastic Deformation [14–18].



(a)



(b)

Figure 1 The equipment for determining the hot deformability of the stainless steels a) without the heating oven; b) with the heating oven

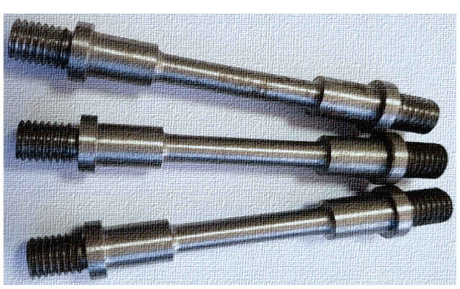


Figure 2 Austenitic stainless steel's sample for determining the hot deformability by torsion

The cylindrical specimens for hot torsion test were mechanically taken from hot–rolled steel bars, having the form and dimensions presented in Fig. 2 [14–18].

The choice of heating regime is currently mostly based on the practical experience of the companies and, therefore, the process of establishing the hot processing technology for these steels is primarily related to the heating conditions, according to their technological characteristics [10–18].

4 METHODOLOGY FOR MODELLING

For the analysis of laboratory hot torsion tests results, the univariate and multivariate regression analysis was used [16–18]. In statistical modelling, regression analysis is a process for estimating the relationships among various variables, used to understand which among the independent variables are related to the dependent variable [22–24]. More specifically, regression analysis helps one understand how the typical value of the dependent variable (or criterion variable) changes when any one of the independent variables is varied, while the other independent variables are held fixed [22–24]. In our case, we estimated the relationships among the hot–testing temperature, torque moment and number of torsions up to breaking of the specimens of austenitic stainless steel [16–18].

The multivariate regression analysis is a statistical method that is commonly used to develop causal understanding from observational data, i.e. the laboratory hot testing experiments data, in our case. Also, this approach can provide an overall knowledge for evaluating causal hypotheses of the plastic deformation regimes. Correlations are useful because they can indicate a predictive relationship that can be exploited in the laboratory or industrial practice [16–18]. When the coefficient of determination (r2) value is high (close to 1), it means that the convergence validity is high, indicating that the data have good convergence validity. Statistical graphics can be used to explore multivariate data.

5 LABORATORY RESULTS AND DISCUSSIONS

The results of experimental research on deformation behavior of stainless steel conducted by laboratory research have led to the creation of a technological rolling process based on the knowledge of the rolled material, their properties and characteristics.

For the experimental tests, we used several stainless steel grades. This study includes the results of the tests conducted to find the plasticity and deformability characteristics of the austenitic stainless steel, grade X5CrNi18–10 (Tab. 2).

We prepared 40 cylindrical samples (Fig. 2) from the austenitic stainless steel, grade X5CrNi18–10. They were subjected to torsional deformation by maintaining the deformation temperature in the experimental facility of 50 °C, within the range 800–1250 °C.

The variation of plasticity (expressed by the number of torsions up to breaking) in correlation with the hot–testing temperature is plotted in the Fig. 3. Also, variation of deformation resistance (expressed by the maximum torque) in correlation with the hot–testing temperature is plotted in Fig. 4.

Table 2 The results of the tests conducted to find the deformability characteristics of the austenitic stainless steel (non–hardenable stainless steel, grade X5CrNi18–10), at the experimental heating temperature values (800–1250 °C)

Hot torsion experiments no.	Series no.	Testing temperature, (C)	Torque moment, (daN·cm)	Number of torsions up to breaking, (–)
AUSTENITIC STAINLESS STEEL – I	01	800	200	2
	02	800	392	2
	03	800	340	2
	04	800	390	2
AUSTENITIC STAINLESS STEEL – II	05	850	192	3
	06	850	362	3
	07	850	314	4
	08	850	359	2
AUSTENITIC STAINLESS STEEL – III	09	900	276	4
	10	900	326	2
	11	900	306	3
	12	900	316	3
AUSTENITIC STAINLESS STEEL – IV	13	950	194	6
	14	950	230	5
	15	950	220	8
	16	950	227	4
AUSTENITIC STAINLESS STEEL – V	17	1000	170	4
	18	1000	176	6
	19	1000	156	7
	20	1000	194	3
AUSTENITIC STAINLESS STEEL – VI	21	1050	144	9
	22	1050	130	8
	23	1050	142	8
	24	1050	130	7
AUSTENITIC STAINLESS STEEL – VII	25	1100	133	10
	26	1100	123	8
	27	1100	127	15
	28	1100	129	12
AUSTENITIC STAINLESS STEEL – VIII	29	1150	98	9
	30	1150	102	9
	31	1150	100	9
	32	1150	80	9
AUSTENITIC STAINLESS STEEL – IX	33	1200	97	9
	34	1200	83	12
	35	1200	84	6
	36	1200	77	6
AUSTENITIC STAINLESS STEEL – X	37	1250	58	7
	38	1250	44	8
	39	1250	61	6
	40	1250	64	6

Each point within the temperature range (800–1250 °C) shown in Tab. 2, and their representations in Figs. 2 and 3, represents the arithmetic mean of four independent determinations.

Regarding the graphical representation of the experimental tests results, presented above in Figs. 3–5, the following comments and remarks need to be made:

- the variation of the stainless steel's plasticity (regardless of the analyzed steel grade), as shown in Fig. 2, indicates that it increases with increasing the heating temperature up to 1100–1150 °C; after that it decreases;
- the variation deformation resistance of a stainless steel, as shown in Fig. 3, indicates that the deformation resistance of a stainless steel (regardless of the steel grade) decreases with increasing the heating temperature.

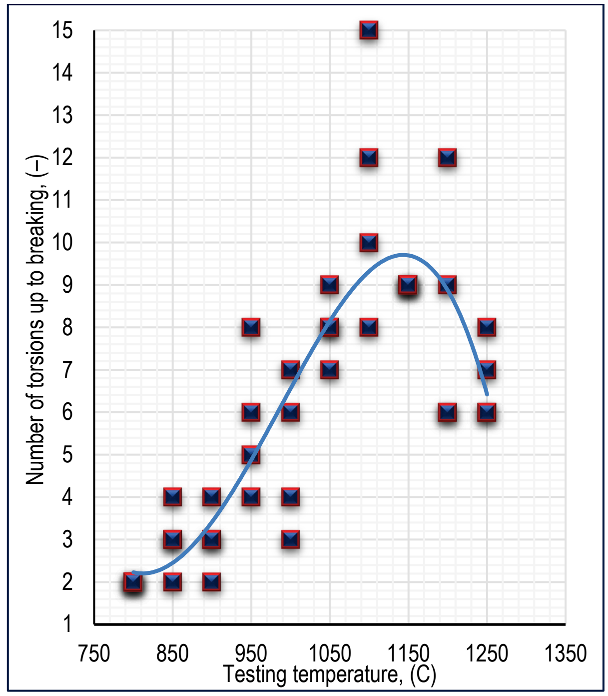


Figure 3 Testing temperature vs. number of torsions up to breaking of austenitic stainless steel (stainless steel, grade X5CrNi18–10), at the experimental heating temperature values (800–1250 °C)

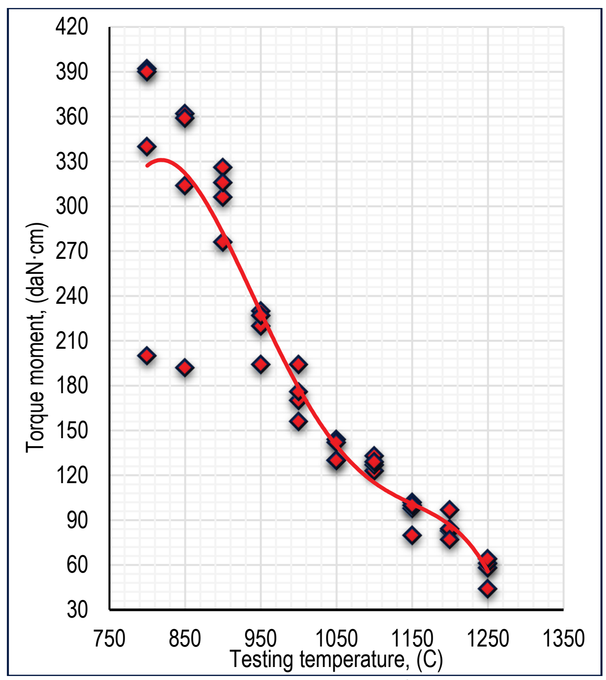


Figure 4 Testing temperature vs. torque moment of austenitic stainless steel (stainless steel, grade X5CrNi18–10), at the experimental heating temperature values (800–1250 °C)

6 MODELLING RESULTS AND DISCUSSIONS

Having in view our laboratory results on the austenitic stainless steel's deformation behavior, and also their analysis, the following remarks need to be made:

- the regression surface of plasticity (number of torsions to failure) of the austenitic stainless steel (grade

X5CrNi18–10), described by the number of torsions before failure, is shown in Fig. 5;

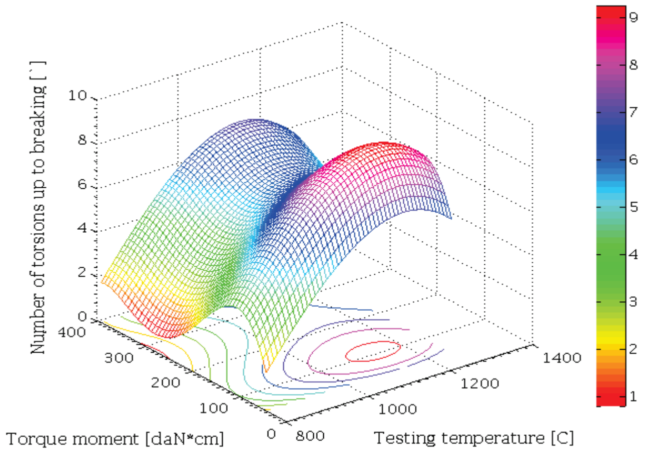


Figure 5 Number of torsions up to breaking vs. torque moment and testing temperature of the austenitic stainless steel (grade X5CrNi18–10), at the experimental heating temperature values (800–1250 °C) [equation type: $z_1 = a_1 + a_2x + a_3x^2 + a_4x^3 + a_5y + a_6y^2 + a_7y^3 + a_8y^4 + a_9y^5$, coefficient of determination: $r^2 = 0.8340$]

- this regression surface can be interpreted by technologists, plotting the regression surface in 2D coordinates (testing temperature vs. torque moment, Fig. 6), and this can be used as deformability diagram for the plasticity of austenitic stainless steel (non–hardenable stainless steel, grade X5CrNi18–10);

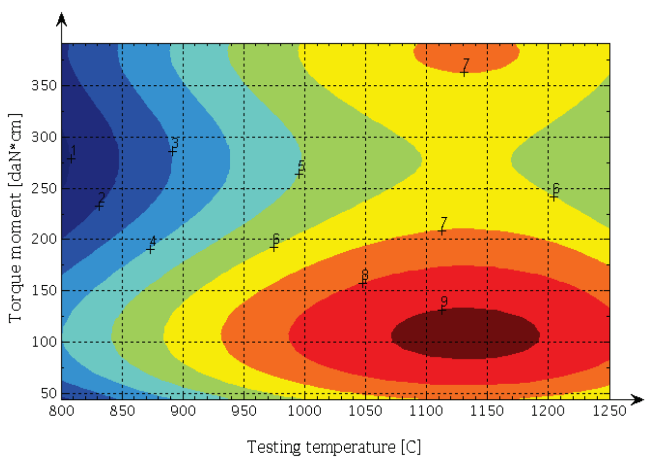


Figure 6 Correlation diagram for technological domains area of resistance to deformation: testing temperature vs. torque moment of the austenitic stainless steel (grade X5CrNi18–10), at the experimental heating temperature values (800–1250 °C)

- the regression surface of deformation resistance (maximum torque) of the austenitic stainless steel (grade X5CrNi18–10), described by the number of torsions before failure, is shown in Fig. 7;
- this regression surface can be interpreted by technologists, plotting the regression surface in 2D coordinates (testing temperature vs. number of torsions up to breaking, Fig. 8), and this can be used as deformability diagram for deformation resistance of the austenitic stainless steel (non–hardenable stainless steel, grade X5CrNi18–10);

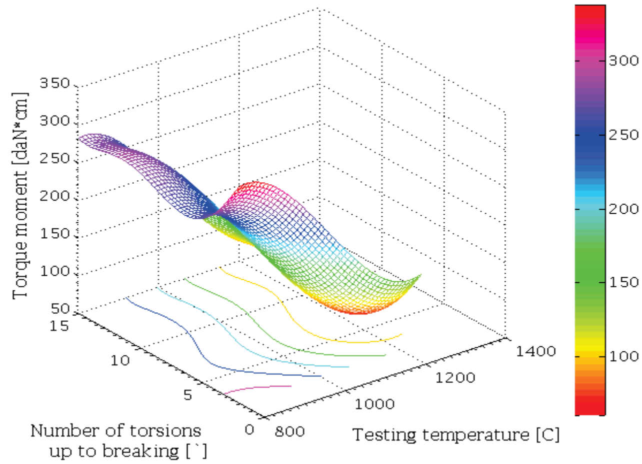


Figure 7 Torque moment vs. number of torsions up to breaking and testing temperature of the austenitic stainless steel (grade X5CrNi18–10), at the experimental heating temperature values (800–1250 °C) [equation type: $z_2 = a_1 + a_2x + a_3x^2 + a_4x^3 + a_5y + a_6y^2 + a_7y^3 + a_8y^4 + a_9y^5$, coefficient of determination: $r^2 = 0.9389$]

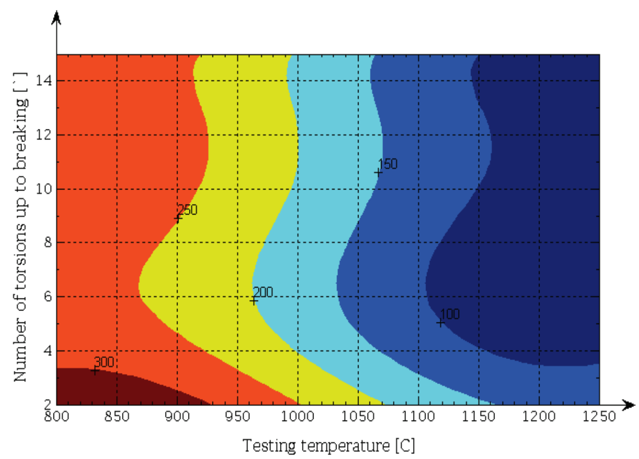


Figure 8 Correlation diagram for technological domains area of plasticity: testing temperature vs. number of torsions up to breaking of the austenitic stainless steel (grade X5CrNi18–10), at the experimental heating temperature values (800–1250 °C)

Having in view the presented results, the following remarks need to be made:

- the upper limit of heating temperatures applied for deforming the studied steel (austenitic stainless steel, grade X5CrNi18–10), as seen in the results from the correlation diagrams (Fig. 5 and Fig. 7), is in the range of 1150–1250 °C;
- the end heating temperature, for the hot deformation of the studied stainless steel grade (austenitic stainless steel), according to the same correlation diagrams (Fig. 5 and Fig. 7), is determined as optimal for 950 °C.

7 CONCLUSIONS

The analysis of the laboratory research on deformation behavior of stainless steel conducted domestically and abroad shows that the heating process for the stainless steel raises some difficult issues in the rolling process and differs from one rolling company to another, relying mostly on each company's own experience.

On the basis of the principle of shaping processes, which is used as the basic instrument useful in the analysis of the industrial rolling processes, we determined the proper thermal regimes of plastic deformation of austenitic stainless steels, from prism of the laboratory experiment. In fact, hot torsion testing simulates the thermal and mechanical parameters under very precisely controlled conditions.

In this sense, our research proposes and realizes on the one side the analysis of the austenitic stainless steels deformability – analysis materialized from prism of the laboratory experiment by hot torsion testing, and on the other side, the modelling of austenitic stainless steels plastic deformation, using electronic calculus technique in MATLAB area, and, therefore, a mathematical interpretation of the technological processes. The research on austenitic stainless steels deformability using the hot testing method experimentally defines an important chapter in the area of stainless steels plastic deformation. In addition, the mathematical modelling by regression analysis establishes a methodology for the determination of the technological parameters values, for which a rolling temperature has the desirable values or ranges. Since it is disposed of real laboratory data, the regression analysis is based on hot testing data, obtained in our laboratory.

The experimented research on deformability characteristics (plasticity any deformation resistance) of austenitic stainless steel together with the regression analysis of the hot testing results, allow for the conclusion of direct results for the plastic deformation of austenitic stainless steels and their industrial rolling.

In this stage of our research, the high temperature deformability and fracture behavior of the austenitic stainless steel (grade X5CrNi18–10) by experimental hot torsion tests is studied. This method takes into consideration the influence of the heating technology factors to a greater extent; it is simpler for technological calculations and has a better safety coefficient for the industrial practice.

Starting from the range of temperature between 850–900 ºC, all specimens of austenitic stainless steel have a sufficient plasticity, but the value of the deformation resistance is still high up to the temperature of 1050–1150 °C. The growth dynamic of the plasticity characteristics is continuous, reaching the maximum value at the temperature of 1200 °C, while reducing the resistance to deformation.

Thus, from the hot torsion tests carried out to determine the hot deformability of the austenitic stainless steel (grade X5CrNi18–10), it results that the optimal plasticity is found within the temperature range 950–1200ºC.

The temperature may be limited in the real industrial hot rolling process due to the risk of excessive grain growth during heating under industrial conditions (industrial rolling process as the phenomenon that does not occur during the heating at the torsion facility, and thus the values given for plasticity at high temperatures).

Following the analysis of these results, it can be inferred that, in practice, in order to take advantage of maximum plasticity of the austenitic stainless steel, on the one hand, it will have to be deformed at 1150 °C if the warp speed is high and at 1200 °C if the speed is low, and on the other hand, high deformation speeds will have to be avoided in cases where work is done with high degrees of reduction.

Acknowledgement

The laboratory equipment used to study the stainless steel deformability by hot torsion is subject to the patent registered with the State Office for Inventions and Trademarks (OSIM–Romania) under number 439/17.05.2010, entitled *"Equipment adapted for experimental determination of the resistance to thermal fatigue of samples placed tangentially on the generator of support discs"*, No. 54/2011. Additional information about the equipment (description, method, pictures etc.) is available in the studies [16–18], according to the below–presented references list.

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Article Title Only in English (Style: Arial Narrow, Bold, 14pt)

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Ivan Horvat, Thomas Johnson, Marko Marić (Style: Arial Narrow, Normal, 10pt)

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Abstract: Article abstract contains maximum of 150 words and is written in the language of the article. The abstract should reflect the content of the article as precisely as possible. TECHNICAL JOURNAL is a trade journal that publishes scientific and professional papers from the domain(s) of mechanical engineering, electrical engineering, civil engineering, multimedia, logistics, etc., and their boundary areas. This document must be used as the template for writing articles so that all the articles have the same layout. (Style: Arial Narraw, 8pt)

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Keywords: keywords in alphabetical order (5-6 key words). Keywords are generally taken from the article title and/or from the abstract. (Style: Arial Narraw, 8pt)

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1 ARTICLE DESIGN

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(Tab 6 mm) The article is written in Latin script and Greek symbols can be used for labelling. The length of the article is limited to eight pages of international paper size of Letter (in accordance with the template with all the tables and figures included). When formatting the text the syllabification option is not to be used.

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1.1 General Guidelines

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The document format is Letter with margins in accordance with the template. A two column layout is used with the column spacing of 10 mm. The running text is written in Times New Roman with single line spacing, font size 10 pt, alignment justified.

Article title must clearly reflect the issues covered by the article (it should not contain more than 15 words).

Body of the text is divided into chapters and the chapters are divided into subchapters, if needed. Chapters are numbered with Arabic numerals (followed by a period). Subchapters, as a part of a chapter, are marked with two Arabic numerals i.e. 1.1, 1.2, 1.3, etc. Subchapters can be divided into even smaller units that are marked with three Arabic numerals i.e. 1.1.1, 1.1.2, etc. Further divisions are not to be made.

Titles of chapters are written in capital letters (uppercase) and are aligned in the centre. The titles of subchapters (and smaller units) are written in small letters (lowercase) and are aligned left. If the text in the title of the subchapter is longer than one line, no hanging indents.

10pt

Typographical symbols (bullets), which are being used for marking an item in a list or for enumeration, are placed at a beginning of a line. There is a spacing of 10pt following the last item:

- Item 1
- Item 2
- Item 3

10pt

The same rule is valid when items are numbered in a list:

1. Item 1
2. Item 2
3. Item 3

10pt

1.2 Formatting of Pictures, Tables and Equations

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Figures (drawings, diagrams, photographs) that are part of the content are embedded into the article and aligned in the centre. In order for the figure to always be in the same position in relation to the text, the following settings should be defined when importing it: text wrapping / in line with text.

Pictures must be formatted for graphic reproduction with minimal resolution of 300 dpi. Pictures downloaded from the internet in ratio 1:1 are not suitable for print reproduction because of unsatisfying quality.

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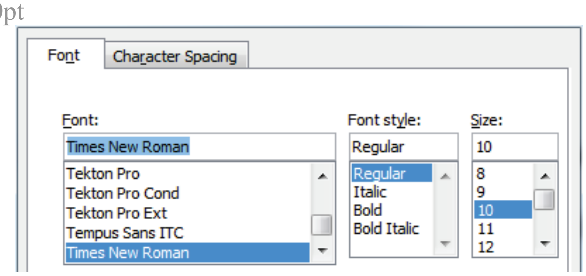

Figure 1 Text under the figure [1]
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The journal is printed in black ink and the figures have to be prepared accordingly so that bright tones are printed in a satisfactory manner and are readable. Figures are to be in colour for the purpose of digital format publishing. Figures in the article are numbered with Arabic numerals (followed by a period).

Text and other data in tables are formatted - Times New Roman, 8pt, Normal, Align Center.

When describing figures and tables, physical units and their factors are written in italics with Latin or Greek letters, while the measuring values and numbers are written upright.

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Table 1 Table title aligned centre

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	1	2	3	4	5	6
ABC	ab	ab	ab	ab	ab	ab
DEF	cd	cd	cd	cd	cd	cd
GHI	ef	ef	ef	ef	ef	ef

10 pt

Equations in the text are numbered with Arabic numerals inside the round brackets on the right side of the text. Inside the text they are referred to with equation number inside the round brackets i.e. ".... from Eq. (5) follows ...." (Create equations with MathType Equation Editor - some examples are given below).

10pt

$$F_{\text{avg}}(t, t_0) = \frac{1}{t}\int_{t_0}^{t_0+t} F\left[q(\tau), p(\tau)\right] \mathrm{d}\tau, \tag{1}$$

$$\cos\,\alpha + \cos\,\beta = 2\cos\frac{\alpha+\beta}{2}\cdot\cos\frac{\alpha\text{-}\beta}{2}, \tag{2}$$

$$(\boldsymbol{AB})^{\mathrm{T}} = \boldsymbol{B}^{\mathrm{T}}\boldsymbol{A}^{\mathrm{T}}. \tag{3}$$

10pt

Variables that are used in equations and also in the text or tables of the article are formatted as *italics* in the same font size as the text.

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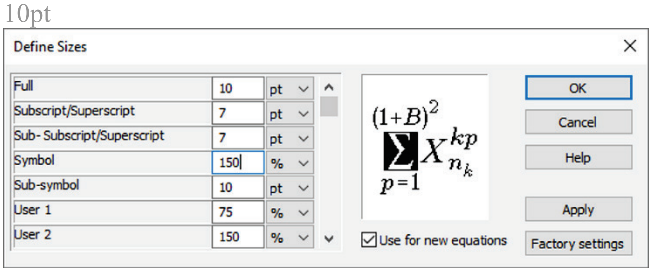

Figure 2 The texts under figures

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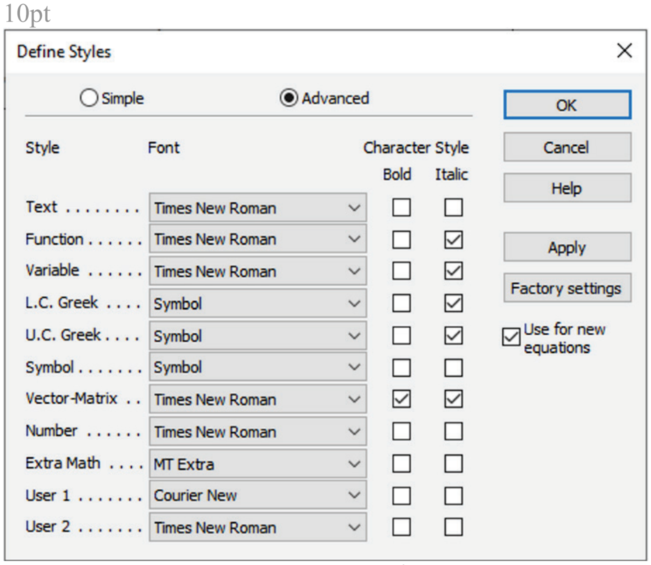

Figure 3 The texts under figures

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2 PRELIMINARY ANNOTATION

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Article that is offered for publication cannot be published beforehand, be it in the same or similar form, and it cannot be offered at the same time to a different journal. Author or authors are solely responsible for the content of the article and the authenticity of information and statements written in the article.

Articles that are accepted for publishing are classified into four categories: original scientific papers, preliminary communications, subject reviews and professional papers.

Original scientific papers are articles that according to the reviewer and the editorial board contain original theoretical or practical results of research. These articles need to be written in such a way that based on the information given, the experiment can be repeated and the results described can be achieved together with the author's observations, theoretical statements or measurements.

Preliminary communication contains one or more pieces of new scientific information, but without details that allow recollection as in original scientific papers. Preliminary communication can give results of an experimental research, results of a shorter research or research in progress that is deemed useful for publishing.

Subject review contains a complete depiction of conditions and tendencies of a specific domain of theory, technology or application. Articles in this category have an overview character with a critical review and evaluation. Cited literature must be complete enough to allow a good insight and comprehension of the depicted domain.

Professional paper can contain a description of an original solution to a device, assembly or instrument, depiction of important practical solutions, and similar. The article need not be related to the original research, but it should contains a contribution to an application of known scientific results and their adaptation to practical needs, so it presents a contribution to spreading knowledge, etc.

Outside the mentioned categorization, the Editorial board of the journal will publish articles of interesting content in a special column. These articles provide descriptions of practical implementation and solutions from the area of production, experiences from device application, and similar.

10pt

3 WRITING AN ARTICLE

10pt

Article is written in the English language and the terminology and the measurement system should be adjusted to legal regulations, standards (ISO 80 000 series) and the SI international system of units. The article should be written in third person.

Introduction contains the depiction of the problem and an account of important results that come from the articles that are listed in the cited literature.

Main section of the article can be divided into several parts or chapters. Mathematical statements that obstruct the reading of the article should be avoided. Mathematical statements that cannot be avoided can be written as one or more addendums, when needed. It is recommended to use an example when an experiment procedure, the use of the work in a concrete situation or an algorithm of the suggested method must be illustrated. In general, an analysis should be experimentally confirmed.

Conclusion is a part of the article where the results are being given and efficiency of the procedure used is emphasized. Possible procedure and domain constraints where the obtained results can be applied should be emphasized.

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4 RECAPITULATION ANNOTATION

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The literature is cited in the order it is used in the article. Individual references from the listed literature inside the text are addressed with the corresponding number inside square brackets i.e. "… in [7] is shown …". If the literature references are web links, the hyperlink is to be removed as shown with the reference number 8. Also, the hyperlinks from the e-mail addresses of the authors are to be removed. In the literature list, each unit is marked with a number and listed according to the following examples (omit the subtitles over the references – they are here only to show possible types of references):

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[2] See http://sites.umuc.edu/library/libhow/apa_examples.cfm

[3] (Style: Times New Roman, 9pt, according to APA)

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International Conference on Convergence of Smart Technologies IC2ST-2021

9th and 10th January 2021, Pune, India

Important Dates

Conference Dates : 9th and 10th Jan, 2021

Paper Submission Deadline : 15th Oct, 2020

Notification of Acceptance : 15th Nov, 2020

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Session Chair

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Vishwakarma Institute of Information Technology(VIIT), Pune, India

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Scope and relevance of the special session

The usage of artificial intelligence has been increased to a variety of applications in diverse domains. In order to build newer applications, to apply computer intelligence for developing technology enabled products and services; there is a need of convergence of artificial intelligence, Internet of Things, soft computing and Blockchain technologies. We are attempting to propose a special issue where authors can make significant contributions with respect to convergence of latest innovations and cutting-edge technologies for better tomorrow.

The convergence of AI, IoT and blockchain technologies is intended to meet very high performance outcomes. This is only achievable when all these technologies go hand in hand for producing innovative outcomes.

The common theme(s) that make the papers a coherent set but are not limited to, the following topics:

- Emergence and convergence of AI, IoT and Blockchain for intelligent systems
- Internet of Things and Artificial Intelligence for industry 4.0
- Artificial intelligence and Internet of Things
- Internet of Things and Blockchain technologies
- Intelligent cyber physical systems for industry 4.0
- Embedded systems with cyber physical systems
- Applications of Machine Learning and Soft Computing in Cyber-Physical Systems
- Digital Twin, Cyber–Physical System, and Internet of Things

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Prof. Sachin Sakhare - Professor, Dept. of Computer Engg, VIIT, Pune, India
Contact : + 91- 8208648378

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