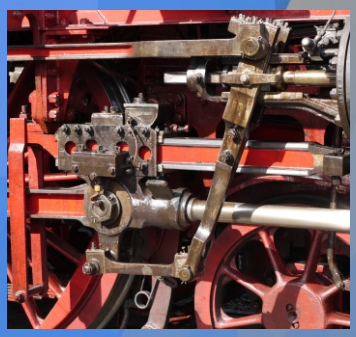
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DIGITAL INFRASTRUCTURE IN GEORGIA AS A CONDITION FOR SUCCESSFUL APPLICATION INDUSTRY 4.0

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Abstract: *New generation of digitized factories in Industry 4.0 is based on a combination of cyber-physical systems (CPS) and digital technologies, to provide an integrated and intelligent synergy in production process, linking the physical, digital and virtual world. Industry 4.0 uses production systems, CPS, CPPS, SCPS and robots in combination with digital technologies IoS, IoP, IoT, IIoT, IoE, CC and etc. The digital infrastructure of a country can be evaluated using different development indices, such as: IDI, EGDI, TII, OSI and etc. The paper is given of trend analyzes of development indices (DI) for using ICT and the Internet., EGDI and TII in Georgia for the period 2003 to 2018.*

Key words: *Industry 4.0, digital infrastructure, Internet infrastructure, ICT Development Index (IDI), e-Government Development Index (EGDI), Telecommunications Infrastructure Index (TII).*

1. Introduction

Republic of Georgia is a Eurasia country in the Caucasus region, which is divided into 9 regions, 1 city and 2 autonomous republics. These in turn are subdivided into 67 districts and 12 self-governing cities. It borders with Russia in the north and northeast, Turkey and Armenia in the south and Azerbaijan in the southeast. In the west, it reaches the Black Sea shores of about 310 km. Georgia occupies an area of 69700 km² with 3904204 population (according to estimates for 2019). The country's main and largest city is Tbilisi, with over a million people. Major cities in Georgia are: Kutaiszi, Batumi, Rusztavi, with over a 100 thousand people and etc.

Georgia is a member of the following international organizations: Council of Europe, Organization for Security and Co-operation in Europe (OSCE), EUROCONTROL, World Trade Organization (WTO), GUAM (Georgia, Ukraine, Azerbaijan and Moldova) Organization for Democracy and Economic Development, and is also a signatory to the NATO Partnership for Peace program and etc.

Gross national income (GNI) of Georgia is 14.3 billion US$ and GNI per capita is 3.760 US$ in 2017 according to The World Bank (WB). Georgia's exports are over 2.7 billion US$, and imports are more than 7.9 billion US$ in 2017 according to The World Bank (WB).

2. Industry 4.0

Industry 4.0 (fourth industrial revolution) is a new generation of digitized factories that are based on a combination of cyber-physical systems (CPS) and digital technologies, to ensure the integrated and intelligent synergy of the manufacturing process, in which the physical, digital and virtual worlds are connected.

Industry 4.0 is dominated by new intangible software and management technologies, compared to the material ones.

Industry 4.0 uses manufacturing systems (FMS, RMS, IMS, AMS, CMS, RMS, SMS, CBMS, etc.), Cyber-Physical Systems (CPS), Social-Cyber-Physical Systems (SCPS), Cyber-Physical Production Systems (CPPS), robots, control units (NC, CNC and DNC), controllers (PLC, PIDC, DMC, IMC, MFC, MPC, MRC, etc.) in combination with digital technologies: Internet of Services (IoS), Internet of People (IoP), Internet of Things (IoT), Industrial Internet of Things (IIoT), Internet of Everything (IoE), Cloud Computing (CC) and etc. [1-4, 8-12, 19-21].

It also utilizes all standard technologies applied in Industry 3.0: software technologies (CAA, CAD, CAE, CAM, CAMA, CAP, CAPP, CAQ, CAR, CAS, CASE, CIM, PLM, etc.) and industrial software (SCADA, etc.), communication infrastructure, security system, digital industrial services, etc.), Big Data (BD), etc. Industry 4.0 involves the complete digitization of all production processes and the implementation of the aforementioned digital technologies when creating an idea of a product, product engineering, manuacturing organization, manufacturing realization, process control and the provision of industrial services. Everything becomes digital and smart in it: digital cities, smart factories, smart homes, smart cars, smartphones, etc.

Figure 1 shows an industry 4.0 workspace in which the research areas are categorized as smart: smart projecting and design, smart machines, smart monitoring, smart control, smart time scheduling, smart planning, etc. [21].

The authors of this paper analyze and research the application of the new industrial strategy Industry 4.0 in Georgia [7, 14-15].

3. Digital infrastructure in Georgia

For the successful implementation of the Industry 4.0 concept of a country or region, its digital infrastructure is important.

The digital infrastructure of a country can be evaluated using different development indices (DI), such as: IDI (ICT Development Index), EGDI (e-Government Development Index), TII (Telecommunications Infrastructure Index), OSI (Online Service Index) and etc. Accordnig to development indices (DI) can identify successful implementation of Information and

Communication Technologies (ICT) and digital infrastructure of a country or region, as one of the prerequisites for successful implementation of Industry 4.0.

In papers [5-6, 13, 16] analyze some of the development indices (DI) in Serbia and Georgia.



Figure 1: *Industry 4.0 framework [21]*

3.1. ICT and Internet infrastructure in Georgia

In 2000 Georgia had only 20000 Internet users, while in December 2018 it had 2658311 Internet users, with penetration from 68.1 % population according to IWS (Internet World Stats) (URL: https://www.internetworldstats.com/).

In December 2017 Georgia had 2100000 Facebook subscribers, with penetration from 53.8 % population according to IWS (Internet World Stats).

Tables 1 and 2 are shown of ICT and Internet infrastructure indices in Georgia in 2008 and 2018.

Table 1: Tabular view of ICT and Internet infrastructure indices in Georgia in 2008 [17]

No	ICT and Internet infrastructure indices	2008
1.	Internet per 100 users	7.49
2.	PC per 100 users	4.70
3.	Cellular Subscribers per 100 users	38.43
4.	Main Telephone Lines per 100 users	12.47
5.	Broadband per 100 users	0.61

Table 2: Tabular view of ICT and Internet infrastructure indices in Georgia in 2018 [18]

No	ICT and Internet infrastructure indices	2018
1.	Fixed telephone subscritions per 100	21.24
2.	Mobile cellular telephone subscriptions per 100	140.95
3.	Percentage of Individuals using the Internet	58.01
4.	Fixed (wired) broadband subscriptions per 100	17.57
5.	Active mobilebroadband subscriptions per 100 inhabitants	64.03

3.2. E-Government Development Index (EGDI)

The EGDI (e-Government Development Index) is a composite index based on the weighted average of following three indices: Telecommunications Infrastructure Index (TII), Human Capital Index (HCI) and Online Service Index (OSI). The EGDI which assesses e-government development at the national level [17-18].

The EGDI index is based on data collected and publication of United Nations E-Government Survey (UN-EGS) and analyzes the ranking of the 193 United Nations (UN) member states, from 2003.

The value of the EGDI index ranges from 0 to 1, and is divided into four quartiles: Low with a abbreviation LEGDI (EGDI values in the range of 0.00 to 0.25), Middle with a abbreviation MEGDI (EGDI values in the range of 0.25 to 0.50), High with a abbreviation HEGDI (EGDI values in the range of 0.50 to 0.75) and Very-High with a abbreviation VHEGDI (EGDI values in the range of 0.75 to 1.00).

According to the 2018 data, there were 40 countries in the first VHEGDI category, 71 countries in the second HEGDI category, 66 countries in the third MEGDI category and 16 countries in the fourth LEGDI category.

Figure 2 shows the trend of the EGDI index in Georgia from 2003 to 2018. According to data from 2003 to 2018, according to the EGDI index, Georgia was largely in the HEGDI category.

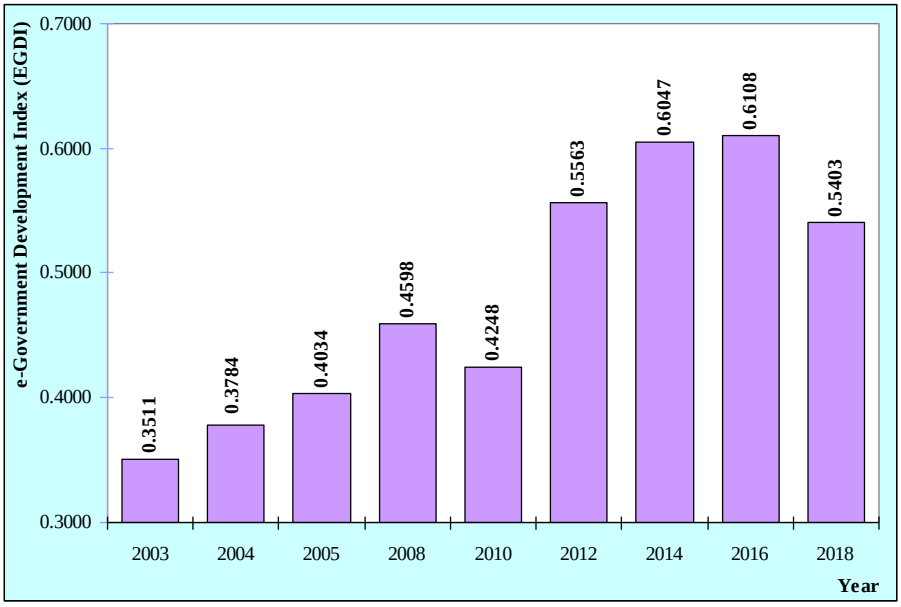


Figure 2: *Trend of the EGDI index in Georgia from 2003-2018*

3.3. Telecommunications Infrastructure Index (TII)

The TII (Telecommunication Infrastructure Index) is a composite index based on the weighted average index of five primary indices based on basic infrastructural indicators, which define a country's ICT infrastructure capacity [18-19].

The TII index is based on data collected and publication of International Telecommunications Union (ITU) and analyzes the ranking of the 193 United Nations (UN) member states.

The TII index is an arithmetic average of five indicators [18-19]:

- Internet users per 100 inhabitants;
- number of main fixed telephone lines per 100 inhabitants;
- number of mobile subscribers per 100 inhabitants;
- number of wireless broadband subscriptions per 100 inhabitants and
- number of fixed broadband subscriptions per 100 inhabitants.

Figure 3 shows the trend of the EGDI index in Georgia from 2003 to 2018. According to data from 2003 to 2018, according to the EGDI index, Georgia was largely in the HEGDI category.

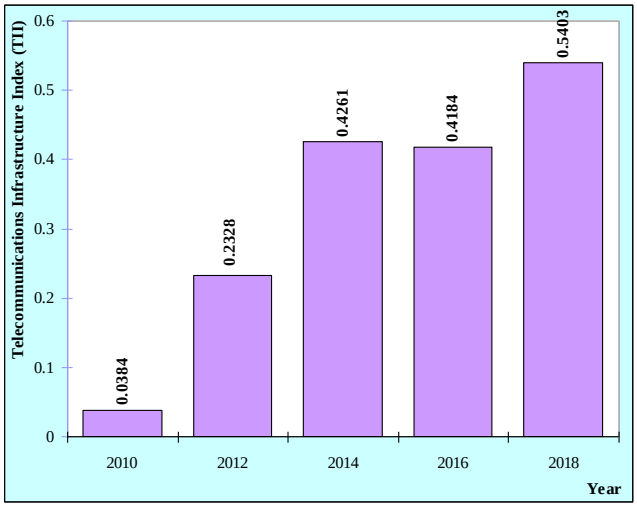


Figure 3: *Trend of the TII index in Georgia from 2010-2018*

4. Conclusion

Development indices (DI) for Information and Communication Technologies (ICT) and Internet infrastructure in Georgia are on the constant growth.

The EGDI index had an increase of 196.33 % in 2018 compared to 2003.

The TII index had an increase of 1407.00 % in 2018 compared to 2010. This means that the implementation of

ICT and Internet infrastructure has increased many times over this period (from 2010 to 2018).

Acknowledgment

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INDUSTRY 4.0 APPLICATIONS IN WET WIPES MACHINES

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Abstract: *Wet wipe machines are machines for high capacity production at high speeds. Even the short downtimes of the machines in the production area lead to huge losses for manufacturers. However, in these machines; unexpected breakdowns such as belt breakage, bearing damage, sensor motor failures, pneumatic air leaks are frequently encountered. In order to prevent unwanted stoppages, a sensor, actuator and plc based application has been implemented to prevent failure parameters and to detect faultlessly by monitoring the operation parameters. As a result of the studies carried out, our wet wipe machines that we produce have been adapted to the industry 4.0 concept.*

Keywords: WETWIPES MACHINE, INDUSTRY 4.0, PREDICTIVE MAINTENANCE

1. Introduction

Today's technological developments, increasing energy need, changing and developing competition conditions make maintenance and repair activities even more important. Maintenance and repair activities constitute one of the important expense items of the enterprises.

As technology evolves, labor costs decrease and investment costs and automation-oriented facilities increase. Increasing investment and maintenance costs are also increasing. Production losses as a result of unexpected breakdowns during production may hinder the implementation of production plans. Nowadays, the interruption of the current production causes huge costs, even in minutes.

Maintenance and repair of malfunctioning machines is both laborious and costly. In case of unexpected, sudden breakdowns in the operation, maintenance and repair takes a long time and it may be difficult to find spare parts depending on the location of the failure. Of course, production losses and costs increase in the meantime [1]. Although the intervention after failure is a kind of maintenance method, considering the current conditions, the understanding of intervention to the machine before the failure occurs becomes more and more important.

The understanding of intervening machines without a breakdown is an approach developed to get the highest efficiency from a machine and to minimize production losses due to a downtime or maintenance. This understanding for monitoring the situation in running machines; it is called predictive care. The data collected without stopping the machine with the current predictive maintenance methods are examined and comments are made. As a result of these comments, the occurrence of malfunctions in these machines is estimated and appropriate stops are planned and intervened in the appropriate time. In this way, interruption of the defective area in the machine before the incidental situation occurs, prevents unnecessary downtime and costs. Bearing damage, sensor-motor failures, pneumatic air leaks, etc. are frequently encountered in wet wipe machines.

In this study; in order to prevent unplanned stops, a sensor, actuator and plc based application has been realized for preventing the failure sources and detecting them without fail by monitoring the operating parameters. In the application, data from sensors and motor drives were collected and statistical calculation tools on plc were used to determine the operating data deviating from the standard values and to determine the faults beforehand. An application has been developed which detects the amount of air leaks in the compressed air circuit.

2. Bearing Damage Detection

In this method, the vibrations of the machines are measured and analyzed periodically. Changes in vibrations are monitored using previous data. If there is a vibration caused by the fault, the vibration trend will increase. In the meantime, if the situation is serious, the machine will be serviced immediately and the necessary repairs or parts replaced. This method of monitoring machines without interfering with their work closely, eliminates unnecessary stoppages and prevents unnecessary parts replacement. As the point of failure can be detected in advance, a future maintenance and repair program can be established, and any failures that may cause sudden stops can be eliminated [2].

It is important to decide which expression should be selected as the unit during the measurements. Displacement, velocity and acceleration measurements have their own advantages and disadvantages [4]. This decision is made according to the speed of the machine to be measured (Hz). The figure 2.1. illustrates this situation better**.**

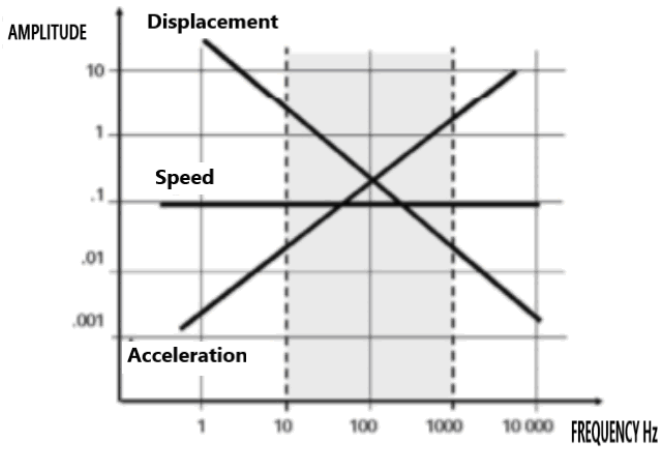


Fig. 2.1. Amplitude-Frequency Graphic

As shown in Figure 2.1, measurement using displacement should be used on low speed machines. That is, it should be used on machines with a speed of less than 10 Hz (600 rpm). Because in low-speed machines, a large part of the vibration energy is located in the low frequency zone. Measurements using acceleration are used in high-speed machines. It is easier to comment if the acceleration is used on machines with a speed of 1000 Hz or more. As seen in Figure 2.1, the speed can be used in a wider frequency range and gives efficient results. Speed is an amplitude unit that can be used in most measurements. It is important to know which unit

to use during measurements. If we do not act accordingly, we may not be able to make healthy measurements and make healthy analyzes. Our values and decisions can be misleading.

Vibration Amplitude ie the intensity of vibration, peak value, inter-peak value, RMS and average can be expressed in four ways [6].

The peak value is the distance from the zero point to the peak, ie the maximum value at which the vibration signal reaches a point [6]. This value is X0. It is used to express the amplitude of the velocity or acceleration of vibration. Inter-peak Value is defined as the value that the signal receives from the maximum peak to the minimum peak. It usually refers to the displacement of vibration [5].

RMS (Root Mean Square) is the square root of the average of the squares of the values a signal receives at time intervals t1 and t2.

The mean is the arithmetic mean of the value a signal receives over the time interval t1-t2. As mentioned earlier, the units of vibration amplitude values are; displacement, velocity, acceleration. Amplitude values can be transformed into each other [5].

Average = 0.637 x Peak (2.1)

Average = 0.9 x RMS (2.2)

Peak to Peak = 2 x Peak (2.3)

Peak = 1,414 x RMS (2.4)

Peak = 1.57 x Average (2.5)

RMS = 0.707 x Peak (2.6)

RMS = 1.11 x Average (2.7)

All these basic expressions form the basis of the vibration analysis foot of predictive maintenance and provide an understanding and analysis of the analysis. When measuring, electric motors, fans, pumps, compressors, such as rotating rotating at a certain speed in the system's own bodies and the sensors closest to the bearings are collected with the help of data [7].

Since taking measurements from all bearings on the machine will make the system complex and costly, only the term has been taken to take measurements with sensors from long and expensive bearings. 4 acceleration sensors are mounted on the roller bearings for monitoring 4 bearings in the system. The signals of the sensors are connected to the inputs on the plc for fast data input.

The vibration spectra of the normal operation from the sensors are initially sampled and introduced to the system, then the system compares the average of the initial graph with the average of the spectral graph at run time. When the deviation from the standard average value reaches the threshold value in% entered on the screen, this is shown to the user as a warning and the user is able to see the spectral graphs of the start and the time of failure. The purpose of showing the spectral graphs to the user is that the fault is not always welded. In addition to bearing damage, coupling misalignment, belt tension problems can cause abnormalities in the spectrum graph.

3. Detection of Sensor Failures

A statistical display was designed using opc-ua program function blocks and io-link sensors to detect sensor and motor faults. The machine continuously compares the collected data with the threshold values. Easy detection and addressing of faults has minimized downtime due to failure and ensured end-user satisfaction.

Conventional digital sensors produce zero or multiple signals for the situation. In order to design intelligent machines within the scope of Industry 4.0 transformation, it was felt that digital sensors should provide information to the user by creating additional data indicating the sensor operating status besides zero and one values. Thanks to the io-link communication protocol, sensors developed in this context have been able to transmit various data in addition to zero and one signals over the signal terminals.

Various data is collected from optical, magnetic and inductive sensors which are used extensively on wet wipe machines and correction is made when the first signs of the failure are taken before a possible mechanical or electrical failure occurs.

The biggest problem frequently encountered with optical sensors is the faulty signal condition caused by the accumulation of dust or dirt on the lenses of optical sensors. In addition to the digital signal, the reflective io-link optical sensors compare the intensity of the transmitted light with the intensity of the reflected light and send data to the plc about the lost light intensity. When the decrease in light intensity exceeds the set threshold value, the system displays a warning for the user and directs the user to check the status of the sensor.

Similarly, magnetic and inductive sensors transmit numerical values about their distance from the metal or magnetic surface. The loosening of these sensors, often used to determine the reference position, and the loss of their original position, result in simple failures that take hours of detection. Taking a reading other than the standard reading distance heralds that the sensor loosened and often shifted from its position. In this case, the user is directed by the machine to the control of the respective sensor.

4. Detection of Motor Failures

Nowadays, as an extension of the Opc-ua protocol, there are advanced predictive maintenance program blocks for predictive maintenance, which reduces the load of the programmers and easily integrates the predictive maintenance software that most programmers are forced into.

Prolonged detection of asynchronous motors for long periods of time without failures or possible failures is important. There are certain types of malfunctions. The faults encountered are those caused by specific reasons or working conditions. The reasons of the faults that we call as the specific faults of the motor depend on the behavior of mechanical and electrical forces inside the motor.

An imbalance in the asynchronous motor results in instability of the stator windings and / or changes in the stator air gap. As a result, changes in the space harmonic distribution of the motor will occur. [7]

Frequency inverter devices used in speed control of induction motors also monitor the motor insulation voltage and generate an output signal in case of change and inform the main controller. Figure 3.1 shows the possible failure types. [9]

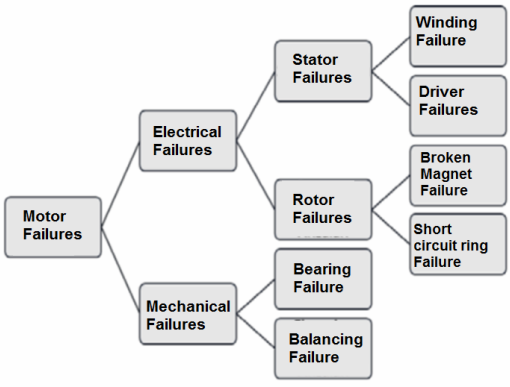


Fig 4.1 AC Motor Possible Errors.

In some cases, the motor does not have any problems, but the mechanical stresses in the system to which it is connected increase the temperature and current of the motor. In such cases, the current of the motor is continuously monitored in order to detect the fault before the system is locked or the thermal relay to which the motor is connected is tripped. It is difficult in most cases to determine that the motor current goes out of standard, because the motor draws current at different amperes due to the varying mechanical power requirement on the motor. In the newly developed inverter technologies, the motor current is sampled along with the voltage frequency and a power profile is created.

As soon as the motor values which are out of standard behavior are determined as a result of these samples realized in the frequency inverter, a signal is sent to the main controller. Similarly, the drives of the servo motors continuously monitor the motor torque value, the current drawn by the motor and the vibration values taken from the encoder and inform the main controller.

5. Determination of Air Leakes In Pneumatic Circuit

Preventing compressed air leaks is an important opportunity to save energy. Leaks often occur in safety valves, pipe and hose joints, throttle valves, start couplings and pneumatic elements. In many cases, leaks are caused by inadequate maintenance rather than inappropriate installation. If leakage can be sufficiently aware of the power wastage, leakage-related leakages can easily be recovered as energy savings. The figure 5.1. shows the approximate power values wasted by leaks caused by holes of different sizes when the normal operating pressure is 6 bar. [10]

Hole Dia.-mm-	Air leakage (6bar) lt/hour	Compression Power 6bar (kW)
1	1	0.3
2	10	3.1
5	27	8.3
10	105	33

Fig 5.1 Power loss table

In order to detect and address compressed air leaks, the method of measuring the pressure drop by trapping air into the circuit was used. In this method, when the machine is not operating but energized, the valves are programmed to be closed by the system and the pressure transmitters report the pressure drops in the air line until the machine moves again. The system is programmed to display a warning on the machine screen in case there is a decrease between the initial pressure value and the end pressure value measured by the sensors more than the threshold value entered into the system. These threshold values are determined as shown in Figure 5.2 in the relevant standards. [11]

Cylinder Dia. (mm.)	8, 10, 12	16, 20, 25	32, 40, 50	63, 80, 100	125, 160, 200	250, 320
Leakage Amount (Lt/hour ANR)[a]	0,6	0,8	1,2	2	3	5
[a] ISO 8778.						

Fig 5.2 Acceptable Air Leakage standarts

As can be seen from the figure, the values indicated in the standard indicate the volumetric losses. In the first trials, flow sensors were used instead of pressure transmitters, but these sensors were found to be nonfunctional at very small flow values. Mathematically, since the air volume trapped in the circuit is known, the pressure drop is converted from “dm3/h” to “mbar/h”

6. Conclusion

Unplanned downtime in machines with large capacity productions such as wet wipes production imposes huge costs on enterprises. The companies with these lines want to use predictive maintenance methods in order to reduce unplanned downtime, but in most cases the fault detection systems that are required to be added to the machine later cannot work in full compliance or cannot be commissioned due to the difficulties of integration. In this study, an important part of the predictive maintenance methods reached by the current technology is included in the machine automation system. Predictive maintenance systems generate a large amount of data, storing the raw form of these data is a problem. After analyzing the data, the data is cleared from the memory and in case of problems, it is presented to the user in a statistics screen via a screen. In this way, the user is recovered in complexity and accesses only the filtered data he needs. At the end of this study, the efficiency of our wet wipe machines was increased thanks to industry 4.0 applications.

7. Acknowledgment

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IEC 61499 BASED CONTROL OF CYBER-PHYSICAL SYSTEMS

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***Abstract**: Monitoring and control of Cyber-Physical Systems (CPS) have many challenges related to the heterogeneous environment, the high degree of interaction between the components and the high requirements for functionality and scale. The paper presents an analysis of the state of the art in this area and proposes and analyses different combined approaches for control of CPS based on IEC-61499 standard. The approaches are divided in two groups. The first group of approaches combines IEC-61499 standard with advanced methods of software engineering, such as formal methods and model-driven development, based on UML/SysML. The second group uses other standards as IEC-61512 and PLCopen to be combined with IEC-61499 standard in order to improve the development lifecycle of cyber-physical systems.*

***Keywords**:* CYBER-PHYSICAL SYSTEM, INDUSTRY 4.0, IEC-61499, IEC-61512, PLCopen, UML/SysML

1. Introduction

The global competition between enterprises and the new production strategies adopted by enterprises require the need for a new type of information and control systems, characterized by a high degree of horizontal and vertical integration, as well as self-organizing characteristics, in order to quickly adapt to changes and disturbances from the environment. Cyber-Physical Systems (CPS) is a very appropriate concept. They are physical and engineered systems whose operations are monitored, coordinated, controlled and integrated by a computing and communication core [1]. They are unique in that the components can be distributed both spatially and temporally, and include complex networks of feedback controllers and real time communication. The impact of CPS is revolutionary and pervasive as stated by CPS Public Working Group at NIST (National Institute of Standards and Technology) [2] as the development of these systems is related to the emergence of autonomous vehicles, smart grids, smart cities and homes, robots, smart medical devices, telemedicine, Internet of Things (IoT) etc. Some of the main nonfunctional properties distinguishing CPS are: real time, reconfigurability, scalability, context-awareness, interoperability, resilience and security. The synergy between cyber and physical systems can be both at the nano-level and also at the level of "system of systems". Still, however the science is owed to CPS; the lack of theoretical foundation and methodologies creates barriers that may hamper the adoption, commercialization, and market success of new CPS applications [3].

To meet the challenges of modern enterprises, CPS must meet certain requirements, which can be summarized as follows:

- The architecture of these systems must be decentralized, based on the knowledge product/resource;
- Interactions between the elements of these systems must be abstract, generalized and flexible;
- Control must be reactive and proactive;
- Control must be self-organizing.

An option to deal with these requirements is due to the rapid development of electronics, information and communication technologies, which has led to the emergence of a number of new technical tools and innovations such as: fieldbus, smart devices (with built-in microprocessors), fuzzy programmable controllers and more. Other way is the replacement of the centralized structure of information and control systems with the distributed ones, which has significantly greater advantages than the centralized ones. A natural reaction to these changes is also the IEC-61499 Standard for development of distributed systems for process measurement and control [4, 5].

One of the ways to tackle the challenges facing today's cyber-physical systems, associated with achieving a high degree of interoperability, agility and reconfigurability, is the transition from a centralized architecture of information and control systems to a distributed one. Promising trend in this direction is the implementation of the IEC-61499 standard, offering reference architecture and models for development of distributed control systems. The main aim of the paper is to summarize and compare different approaches for development of IEC-61499 based cyber-physical systems through their combination with other different approaches and advanced methods of software engineering. After the introduction a short analysis of control for CPS and IEC-61499 standard is undertaken in part 2. In part 3 different combined approaches for IEC-61499 based control of CPS are presented and discussed. Finally some conclusions are done.

2. Short analysis of CPS and IEC-61499 standard

2.1. Control in CPS

The structural and behavioral complexity of cyber-physical systems poses great challenges in terms of the methods and environments for their design and analysis. It is necessary to develop the theoretical foundations of CPS, as well as to create software platforms with appropriately defined levels of abstraction, architecture, languages for modeling different aspects of CPS and transformations between these models. Especially important are methods that have to integrate the discrete dynamics of the computing part with the continuous dynamics of the physical part and the stochastic nature of communications, which must be expanded to cover a wider context. There are three main approaches to designing the CPS:

- Networked control systems - The emphasis on these approaches is on the communication between the different components of the system. There are two main approaches for data acquisition from the physical part of the CPS: timed driven and event driven sampling. The latter approach requires continuous monitoring of the physical system. Compromise approach, the so-called self-triggering approach, is related to the determination of safe intervals during which the physical system is not observed and the time when the data is collected. Particular attention is also paid to methods of addressing the effect of delayed network signals, such as scheduling or stability analysis methods. Other important tasks that seek a solution, especially from the field of control theory, are to determine the optimal placement of computations and to deal with the availability of channels with very low data rates. An overview of networked CPS is given in [6].

- Hybrid control systems that emphasize their continuous and discrete dynamics. Various approaches are known, among which the most popular are hybrid automata using different mathematical formalizations to reflect the transition between discrete states and the evolution of the continuous states over the time. Among the most frequently used are finite state machines and timed automata, bisimulation, transition systems, linear hybrid automata (LHA), rectangular hybrid automata (RHA), temporal logic and others. It should be noted that there are a lot of software tools that allow the synthesis of control systems and their formal verification, such as UPPAAL, HyTech, etc. Some analysis of these approaches are presented in [7, 8];

• Distributed hybrid systems – One of the most often applied approaches uses software platform, called middleware, which uses an appropriate abstraction of complex systems and offers architecture for the rapid deployment of CPS applications [9]. The successfully applied architectures include: component-based, service-oriented, agent-based, and the CPS 5C (connection, conversion, cyber, cognition and configuration) architectures [10]. Another successfully applied approach is based on the Embedded Virtual Machine (EVM) and uses a modular architecture that separates the tasks from the unreliable physical part allowing the integration of system components and their run-time reconfiguration [11]. Other successful approaches use specialized programming languages such as Giatto, Esterel, Signal, etc. or the Model Driven Development (MDD) approaches. MDD [12] are some of the most promising and challenging approaches for development and maintenance of highly distributed control systems such as CPS. Here the systems are presented as models that conform to meta-models, and the model transformations are used to manipulate the various representations. The main difference from other development methods based on models is that MDD uses models as inputs to parameterized implementation generators, i.e. implementation is (semi)automatically generated from the models.

In the next section of the paper an analysis of the IEC 61499 standard in respect to its application for development of distributed monitoring and control for CPS is presented.

2.2. Short overview of IEC-61499 standard

The IEC-61499 standard [4] defines the basic concepts and reference architecture for the design of reusable and component-based distributed control systems. At the heart of the standard, the concept of "function block" (FB) is the basic structural unit of the application. The function block can be used to define reusable software components that, based on a chosen methodology, can be used to design complex, decentralized, distributed control systems. The term “Function Block” is defined by Lewis as: “an abstract mechanism that allows encapsulation of industrial algorithms in a form that can be easily understood and applied by an engineer who is not skilled in the implementation of complex algorithms” [5]. The standard defines three basic types of function blocks: basic, composite and service interface and 3 types of reference models, on the basis of which a distributed control system can be designed at different phases of its life cycle: system model, device model and resource model. The system model specifies the distribution of an application between devices, and a single device can perform multiple applications. Devices are containers of resources that make it possible to run function blocks on the network independently. The resource model specifies the location where an application is running, providing the basic resources for doing so. There are several engineering environments that support the development of control systems based on the IEC6199 standard such as for example FBDK (Function Block Development Kit) [13], 4DIAC [14], FBench [15], ISaGRAF [16] and nxtStudio [17]. Although the industry is aware of the benefits of using IEC 61499, this standard has not yet been widely applied in the industry. The main reasons for this are the immaturity of the development tools and the lack of a sophisticated integrated development environment (IDE) and integrated design methodologies that facilitate component-based development of automation systems throughout the whole development lifecycle.

The main advantages of the standard with respect to CPS can be summarized as follows:
• IEC-61499 standard allows the integration of a time-triggered mechanism with SIFB-based event triggered systems;
• The reference architecture and models based on IEC-61499 standard support the reuse of the developed CPS components and shorten their development and configuration time;
• The distributed control structure achieved, facilitates the reconfiguration of the system by inserting, deleting and replacing functional components based on IEC-61499 standard;
• The models offered allow the creation of a library of IEC-61499 based reusable components for different application areas.

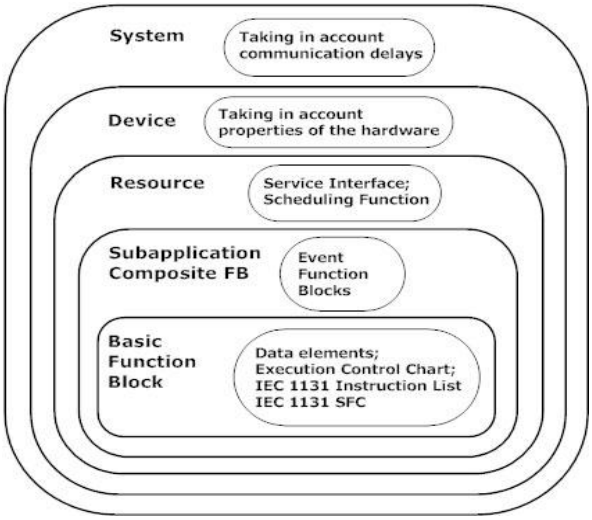


Fig.1: *Overview of IEC-61499 based models*

3. Short analysis of the combined IEC-61499 based approaches in the field of CPS

3.1. Classification of the approaches

Fig.2 summarizes the approaches proposed, which aim to increase the potential for implementation of the standard and increase the efficiency and quality of the developments, which can be divided into two groups:

• Approaches representing a combination of IEC-61499 based models with advanced software engineering approaches and tools, such as formal specification and verification methods, the use of agile models in software development processes, the use of UML/ SysML to extend development stages, or as an alternative to the design of IEC-61499 based control systems;

• Approaches that combine the concept of the standard with the successes achieved in the control of specific production areas, such as batch control (ANSI / ISA S88 - ISO-61512 standard [18]) and the PLCopen motion control initiative based on the IEC standard - 61131-3 [19].

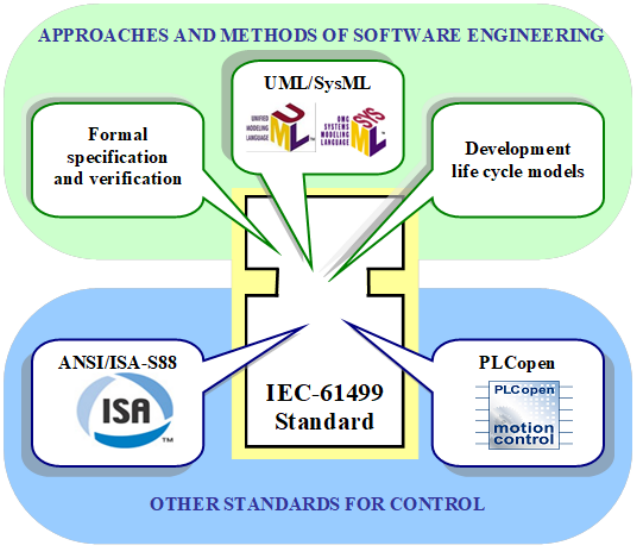


Fig.2: *Systematization of approaches for the development of IEC-61499 based management systems*

The next part of the paper presents the ideas of only a subset of approaches using software engineering achievements, which in the last part of the report will be illustrated with a specific example.

3.2. IEC-61499 based approaches combined with software engineering methods

A. Combined approach using IEC-61499 standard and formal specification

Combining the concept of IEC-61499 standard with the capabilities offered by the formal specification and verification approaches, leads to a significant increase in development efficiency due to the fact that, at relatively early stages, the specified control system can be verified based on the application of different formal methods and approaches. Fig.3 illustrates in a general way the idea of engaging in the development of the stages of formal specification and verification of models using the model checking method. It should be noted that this approach can be implemented with various formal methods and software. For example, in [20, 21], for the purpose of the formal specification of the system, Petri SIPN networks were selected, and for its verification the possibilities for transforming the network into a timed automata and NuSMV product implementing the model checking method using BDD diagram and SAT method. Alternatively, NuSMV may be replaced with UPPAAL, as demonstrated in [22]. This product can also be used on its own by specifying the control system model with timed automata, and the requirements may be defined using temporal logic.

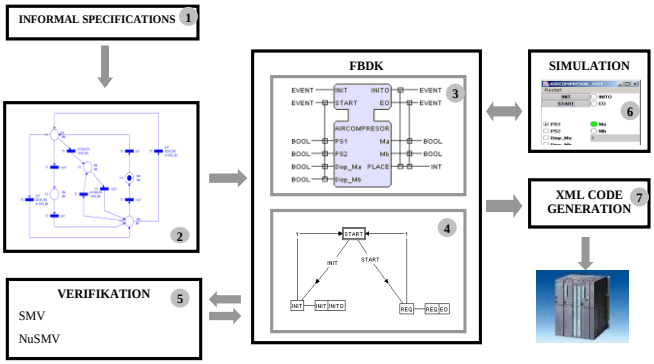


Fig.3: *Combined approach using IEC-61499 standard and formal specification*

B. Combined approach using IEC-61499 standard and UML/SysML.

The unified UML modeling language [23] and its profile for system engineering SysML [24] can be used in various ways in the development phases of IEC-61499 based control systems. A detailed overview of these approaches is presented in [25]. The approaches proposed by the authors differ in the degree of development of UML models, the development environment, and the version of UML used or the additional inclusion of SysML. For example, [26] proposes an approach using the UML1.4 version, based on IBM's Rational Rose programming environments and the UML-MAST profile, which aims at modeling the real-time characteristics of the system. Old versions of UML are also used in [27, 28], but in these cases the use of CORFU engineering environment, directly related to the IEC-61499 based FBDK development environment, is proposed for development purposes. The development of the UML language and the creation of a SysML profile for system engineering improve the language's usability in real-time systems development, enabling it to cover the entire development lifecycle. In this regard, different approaches with and without the help of the SysML profile in the Telelogic Rhapsody environment currently owned by IBM have been explored [29, 30]. It should be noted that the approaches proposed are applicable to both discrete and continuous systems. Significant is the success in the formalization of UML and the ability to verify and validate the proposed models at different phases of their development, which is a challenge to further improving and refining the approaches proposed. An attempt is also made to design a multi-agent control system based on the IEC-61499 standard and using UML/SysML [31].

3.3. IEC-61499 based approaches combined with other standards

A. Combined approach using IEC-61499 standard and ANSI ISA S88 (IEC)

The proposed approach for monitoring and control of CPS supports the development of reusable software components based on the combined use of three different formalisms: the IEC-61499 standard for distributed process measurement and control systems, the IEC-61512 standard for batch control and the Signal Interpreted Petri Nets (SIPN), which are used as a tool for formal verification of the correctness in the behavior of the developed components or CPS. IEC-61512 provides domain specific models for design and control of batch production processes. The models allow the description of continuous production of finite quantities of materials (batches) from two distinct views – physical and control (cyber). The approach is illustrated in fig.4, and includes the following steps:

- Functional component development - each physical component as for example pressure sensor, temperature sensor, level sensor, valve and pump, has corresponding cyber component (i.e. functional component). If several components are employed for an equipment or unit module, their software components are then compounded as a composite component. The functional component can be instantiated several times;
- Control recipe modeling using SIPN - the procedural control of each unit procedure;
- Mapping of model to an IEC 61499 based application - The SIPN model with regard to the functional component is mapped into IEC-61499 by using some rules.

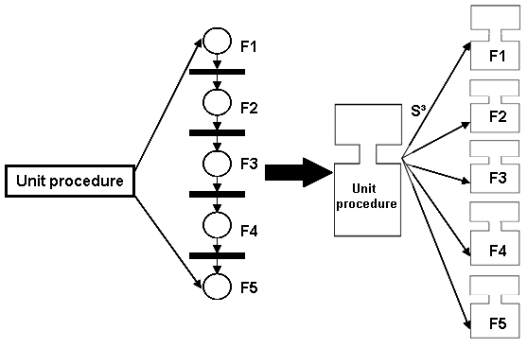


Fig.4: *Basic models in IEC-61499*

B. Combined approach using IEC-61499 standard and PLCopen (IEC-61131)

Within PLCopen, there are rich libraries of functional blocks, algorithms, control systems and development environments based on the IEC 61131-3 standard. It is essential to be able to use these developments in the design process of distributed control systems based on IEC 61499 standard. There are two main approaches to do this:

• Inclusion of IEC 61131-3 based algorithms as an integral part of the IEC 61499-based FB algorithms [5];

• Transformation of the function block based on the standard IEC 61131-3 into a functionally compatible IEC 61499 based function block.

In the second approach, the data (input or output) that are Boolean for the IEC 61131-3 based block is transformed into events (respectively input or output), as shown in Fig.5.

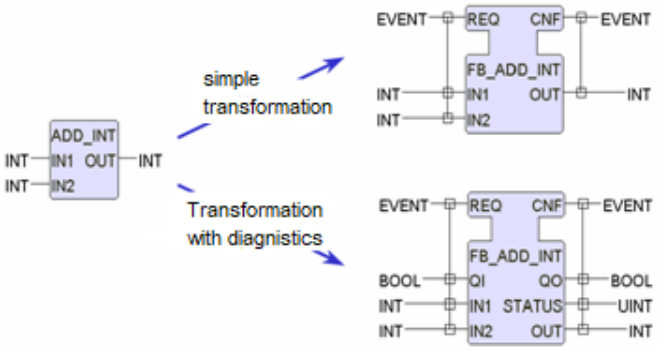


Fig.5: *Transformation of PLCopen to IEC 61499 Standard*

4. CONCLUSIONS

The combined use of the IEC-61499 standard results in a significant improvement in the quality, safety and efficiency of the designed GSP. However, there are still some obstacles and disadvantages that can be summarized as follows:

- IEC-61499 standard does not provide verification capabilities for the control logic, either at the design stage or after online reconfiguration;
- The standard does not allow modeling of the physical part of the system;
- There is no possibility for parallel control logic;
- The implementation semantics need to be improved to be independent of deployment platforms (deterministic) and to respond to real-time constraints;
- Lack of advanced interfaces for communication with the upper levels of management and control;
- Lack of middleware for real-time messaging that enables the distributed development of CPS signals and cognitive functions.

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RULES FOR CHOOSING COMPONENTS OF A SINGLE DIGITAL PASSPORT FOR THE GENERATION OF CAD DESIGN SOLUTIONS

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Abstract: *In previous articles, it was shown that for "Industry 4.0" production one of the important tasks is the collection, storage, analysis and processing of product data and related design and production procedures. This determines the implementation of PDM, ERP, MES and/ or EAM systems at enterprises and the construction of a metasystem based on them - a single digital passport. Its content allows to automate the generation of design decisions for timely management decisions, as well as to propose an approach to solve the problem of minimizing the impact of the human factor for the tasks of Industry 4.0. Therefore, the work presents the results of the development of the rules for choosing the components of a single digital passport for the generation of design solutions based on the principle of building a fuzzy Takagi-Sugeno-Kang network. The results obtained will allow to formulate a criterion for the similarity of the production object and the design and production procedure in the digital environment to the given requirements based on linear approximation methods.*
KEYWORDS: *SINGLE DIGITAL PASSPORT, CHOICE OF DIGITAL PASSPORT COMPONENTS, CAD DESIGN SOLUTIONS.*

Introduction

Current trends in the development of engineering and technology contribute to the automation of various production processes based on the implementation of a new paradigm - Industry 4.0. Its main idea is to minimize (up to an exception) the influence of the human factor [1]. In this case, one of the important tasks is the organization of the collection, storage, analysis and processing of data and related design and production procedures [2] at all stages of the life cycle of an electronic product (LCP) due to:

- Implementation of ERP, PDM, MES and/or EAM management systems at enterprises;
- Integration of these systems to organize timely access to information for each participant in the product's life cycle;
- Determining the types of product data that should be generated and stored using the previously mentioned systems;
- Organization of the uniqueness of the input points of various types of product data indicating the types of systems by which it is implemented;
- Determining the sequences of design and production procedures at each stage of the product's life cycle.

The implementation of this is ensured by the construction of a single digital passport at the enterprise, which is reflected in the eponymously named methodology [3], proposed by one of the authors of this article. The single digital passport is a metasystem containing information about the electronic product, as well as design and production procedures indicating the types of control systems used to implement them, based on the ontological approach. This allows to automate the generation of design solutions that provide a similar representation of production facilities and procedures in a digital environment, and also offers an approach to solve the problem of minimizing the influence of the human factor for the tasks of Industry 4.0. Thus, the following methods were developed: a methodology for generating design solutions for CAD, CAD mathematical apparatus [4] and rules for choosing descriptions of the components of a single digital passport [5].

The results obtained were used to develop the rules for choosing descriptions of the components of a single digital passport based on the principle of constructing a fuzzy Takagi-Sugeno-Kang network [6], on which this article focuses on.

The task of selecting components descriptions of a single digital passport for the generation of CAD design solutions

Thus, the idea of developing rules for choosing descriptions of the components of a single digital passport is based on the fact that, parameters characterizing the electronic product at the stages of its life cycle are determined. That is to say:

$$Request_Process = (RP_1, RP_2, \dots, RP_P),$$

where RP_i – parameters of the life cycle stage of an electronic product ($i \le P$).

In addition, descriptions of the components of a single digital passport are known,

$$G(C) = \left(G_1(C_1), G_2(C_2), \dots, G_K(C_K)\right),$$

which allows to present an electronic product, the design and production procedures in a digital environment based on lists of components of a digital passport and corresponding lists of parameters.

Moreover, the components of a digital passport are formed according to information about the electronic product at the stages of its life cycle $R(C) = (C_1, C_2, \dots C_k)$ and the requirements for the passport $Reques_System = (RS_1, RS_2, \dots, RS_S)$ presented at a particular enterprise [4,5].

Then, in accordance with the Takagi-Sugeno-Kang principle, the rules shaping for choosing components descriptions of a single digital passport consists of the following stages:

1. Shaping the rules for verifying the proximity of the option to describe the components of a single digital passport to the parameters of the stages of the life cycle of an electronic product.
2. Verification of the implementation of each generated rule.
3. The choice of descriptions of the components of a single digital passport that satisfy the parameters.
4. Verification of the compliance with the Gauss-Markov conditions.

Rules development for choosing components descriptions of a single digital passport

Stage 1. Since the descriptions of the components of a single digital passport are given by fuzzy variables, it is possible to formulate rules that verify the proximity of the description variant of a digital passport component to the parameters of the life cycle stage. That is to say, the following set is formed as follows:

$$R_1: \{\left(RP_1 \text{ ecmь } g_{11}(\overrightarrow{C_1})\right) AND \ (RP_2 \text{ ecmь } g_{12}(\overrightarrow{C_1})) \ AND \dots AND \ (RP_P \text{ ecmь } g_{1P}(\overrightarrow{C_1})\};$$
$$R_2: \{\left(RP_1 \text{ ecmь } g_{21}(\overrightarrow{C_2})\right) AND \ (RP_2 \text{ ecmь } g_{22}(\overrightarrow{C_2})) \ AND \dots AND \ (RP_P \text{ ecmь } g_{2P}(\overrightarrow{C_2})\};$$
$$\dots$$
$$R_K: \{\left(RP_1 \text{ ecmь } g_{K1}(\overrightarrow{C_K})\right) AND \ (RP_2 \text{ ecmь } g_{K2}(\overrightarrow{C_K})) \ AND \dots AND \ (RP_P \text{ ecmь } g_{KP}(\overrightarrow{C_K})\}.$$

Stage 2. Each of the presented rules is intended to verify whether a particular requirement specified by 0 or 1 corresponds to the description contained in the digital passport. Regarding this, checks of the following form are performed:

$$IF\ (R_1)\ THEN\ G_1(\overrightarrow{C_1}) = a + \sum_{j=1}^{P} b_j \cdot RP_j \cdot g_{1j}(\overrightarrow{C_1});$$

$$IF\ (R_2)\ THEN\ G_2(\overrightarrow{C_2}) = a + \sum_{j=1}^{P} b_j \cdot RP_j \cdot g_{2j}(\overrightarrow{C_2});$$

$$IF\ (R_K)\ THEN\ G_K(\overrightarrow{C_K}) = a + \sum_{j=1}^{P} b_j \cdot RP_j \cdot g_{Kj}(\overrightarrow{C_K}).$$

Therefore, verification of compliance with the rules allows to formulate a linear dependance between the requirement - the input parameter - and the description taking into account the coefficients a and $b_j, j = \overline{1,P}$.

Stage 3. Then, the choice of components descriptions of a single digital passport should satisfy the formula:

$$G^*(\vec{C}) = \beta \cdot X + \varepsilon,$$

where X – deterministic matrix of dimension $K \times P$, such that $X = RP \cdot G$;

β – column vector containing elements $\beta = (a, b_1, b_2, \ldots, b_K)$.

That is to say, the choice of components descriptions of a single digital passport comes down to searching the elements of the column vector β.

Stage 4. To verify the legitimacy of the submitted statement, verification of several Gauss-Markov conditions should be performed [7]:

1) the model is set in the form defined at the stage 2;
2) $G^*(\vec{C})$ – matrix in the form defined in step 3;
3) $\mathrm{E}(\varepsilon) = 0;\ \mathrm{E}(\varepsilon^2) = \sigma_\varepsilon^2$.

Therefore, it is possible to generate CAD design decisions based on the similarity criterion specified, using the least squares method.

Conclusion

Thus, the rules for choosing components descriptions of a single digital passport have been developed, which allow to generate CAD design solutions, which correspond to the search for elements of the column vector β.

Compliance with the Gauss-Markov conditions allows to formulate a criterion for the similarity of the production object and the design-production procedure in a digital environment to specified requirements based on linear approximation methods.

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RESEARCH CHALLENGES OF INDUSTRY 4.0

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Abstract: *The paper describes the definitions of industry 4.0 and the factors that influence their formation. It describes the areas that it affects and which are involved in the formation of a new generation industry. Paper also discusses problems that arise in areas related to industry 4.0 when combining them and possible ways to solve them, especially the organization of the production process. Making a focus on properties of software for industrial devices.*

***KEYWORDS**: INDUSTRY 4.0, INDUSTRIAL ENVIRONMENT, ARCHITECTURE OF SOFTWARE SYSTEMS*

1. *Introduction*

Industry 4.0 is a very widespread term first used at the Hanover exhibition in 2011. It has many definitions, and combines a large number of different areas and technologies. Now it is often used as a synonym for the fourth industrial revolution.

The development of modern technologies brings this moment closer and closer, but there are still quite a lot of tasks. Which require attention, most of which are not related to any particular area, but to the way of organizing the interaction of these areas and integrating them into a single production system.

The paper considers the definitions for industry 4.0, the main areas and problems of their integration, including from the point of view of software systems.

2. *Definitions of industry 4.0*

Industry 4.0 is a fairly new term that includes many different areas. For this reason, there is no single definition of it and everyone interprets it differently. The wording often depends on the point of view of the author and the field that he is considering for use in the next generation industry.

For the first time, the term was used at the Hanover Industrial Exhibition in 2011 and denoted the strategy of the German government to computerize production, but it was very widespread and today is often used as a synonym for the fourth industrial revolution. It is believed that the first industrial revolution was the beginning of the use of the power of water and steam, the second - the use of electrical energy, and the third - the use of programmable logic controllers and the development of telecommunications.

Thus, the definition of industry 4.0 can be given in terms of the prerequisites for the fourth industrial revolution, for which it is necessary to highlight its main directions. These areas can be considered the Internet of things (IoT) and cyber-physical systems.

Today we are surrounded by a large number of embedded systems. They include room temperature controllers, water leakage sensors, various car systems. smartphones and more. However, all these systems cannot be called cyber-physical. All of them are designed as independent devices, and in cyber-physical systems a key feature is the integration of devices into a single network [1].

Cyber-physical systems can be described as a set of controllers to which various sensors or actuators are connected on the one hand, and to data transmission networks on the other. In other words, this can be seen as a set of embedded systems that can share the data and resources that they possess.

Also, often the definitions are based on modern areas of technology development, which also have a significant impact on production. This includes autonomous production systems that divide production into parts, the management and optimization of which can be carried out independently. The desire to store and transmit information in digital form leads to the emergence of a fully digital environment, which, in turn, opens up possibilities for modeling and using virtual and augmented reality. The physical reduction in the size of electronic components and the reduction in their cost also opens up new possibilities for their application, for example, the use of RFID tags in logistics.

On the other hand, differences in the production of a new generation can be determined from a managerial and economic point of view. This includes reducing development time, personalizing products up to batches from the same model, decentralized management and efficient use of resources.

Thus, 4 main points of view on industry 4.0 can be distinguished. which influence the formation of definitions: production, business, products, consumers.

From the production point of view, the key is to connect all devices (sensors, robots, conveyors, etc.) to a single network and the free exchange of data between them, the ability to automatically predict and maintain equipment, etc. various production processes have a modular structure, but are interconnected, which leads to the fact that decentrally controlled different systems can be controlled interdependently. Such an organization is called smart manufacturing [2].

From a business point of view, industry 4.0 implies a link between different companies, factories, suppliers, resource managers and consumers. Each part of the production should be able to change its configuration in real time in accordance with current needs and taking into account maximizing the efficiency of use of limited resources.

Production can also be characterized in terms of production. Industry 4.0 implies that each product will have an identifier that can carry some kind of information. This allows you to track not only the movement of products, but also their condition, as well as analyze this data to help optimize the production process.

And finally, from the point of view of consumers, industry 4.0 provides the opportunity to order any product modification of your choice, even in a single copy and leave the opportunity to freely make changes to it even during production.

It can be noted that it is impossible to choose any one technology or property that can be used to characterize industry 4.0. Each definition on one side or another describes the properties that a new generation industry should have, but does so taking into account the area to which the author of this definition belongs. Such an abundance of definitions leads to the fact that for each area a definition can be given in its own special way and that a generalized definition should cover all these particular aspects.

Summarizing the requirements for industry 4.0, we can conclude that industry 4.0 generally means a method of organizing production, in the form of decentralized managed subsystems connected by a single communication network, providing mutual reconfiguration depending on the properties of each product unit, taking into account efficient use of resources.

3. *Areas affected by industry 4.0*

In industry 4.0, a large number of different areas are used. Some of them appeared not so long ago, and some have entire sets of approaches and solutions that are successfully applied in practice. In one way or another, they all influence the development of modern technologies and, in particular, modern production, however, for their complex application, the question arises from joint interaction. The following are the main areas [1].

3.1 Big data analysis.

Not only in production, but even in everyday life, there is a huge number of devices that produce data volumes at high speed. Therefore, there are tasks of storing this data, their processing and analysis. Moreover, even the analysis of previously collected data can be useful to prevent errors that may occur in the future. For example, analyzing some properties of products at all stages of its production, it is possible to make changes to the production process to improve its quality.

3.2 Autonomous robots.

Using autonomous robots allows you to look from the other side at solving many problems. In addition to the fact that they can do the work very accurately, it becomes possible to shift other hard work to them, and since they are becoming more flexible and autonomous, tasks can be not only a hard-coded sequence of actions, but high-quality sensors and computer vision allow you to make the interaction of robots and humans safe. Often mentioning autonomous robots and their use within the industry, robotic arms are meant, but this is not true. A large role is assigned to robots involved in the movement of goods across the territory of a factory or warehouse

3.3 Simulation.

Of course, the simulation of various models of products or materials has already been introduced and is widely used, but in this context, "simulation" is meant in a broader sense, namely the construction of a full copy of the physical environment and processes in virtual space. This opens up new possibilities for tuning and debugging. Any change or assumption becomes possible to check in the simulator before applying these changes in the real world. This approach not only saves time, but also safely checks changes without stopping the production process [3].

3.4 System integration.

To date, usually all participants in the production process, ranging from resource providers to consumers, are rarely closely related. This prevents the creation of automated chains in production and creates bottlenecks in the moments of communication between its components.

3.5 IIoT (Industrial Internet of Things).

The industrial Internet of things, which is an industrial variation of the Internet of things, is also an area that has a significant impact on the new generation industry. All devices and sensors combined in one network and interacting with each other or, if necessary, with higher-level controllers allow for a more flexible production process. For example, having equipped each product with a unique RFID tag, each production unit can adapt its operations taking into account the unique features of the product [4].

3.6 Information Security.

This is one of the very important aspects that often stays away. Many companies ensure the security of their systems by making them completely isolated, but this approach is no longer applicable to industry 4.0. At the same time, often existing solutions aimed at the next generation industry are extremely vulnerable to cyber-attacks. Therefore, with the development of various communication protocols between the components of the production system, the issue of opposing attacks is very serious. Reliable and secure communication approaches are the key to protecting against unauthorized access to the production system.

3.7 Cloud computing.

Already, many companies are using cloud software for some enterprise applications. In the development of industry 4.0 and cloud technologies, they will increasingly be used to deploy production systems. This will simplify monitoring and data management. And some manufacturers have begun offering cloud solutions in the area of production management systems.

3.8 Additive manufacturing.

This term includes an approach to the production of various objects from a three-dimensional model by adding layer-by-layer material. The most obvious example of this approach is the 3D printer. With the development of 3D printing technology, this approach has ceased to be used only for prototyping. Now it can be used directly even in serial production of parts from various materials. High productivity, the ability to manufacture parts on one machine and almost any shape finds their application primarily in the aerospace industry, making it possible to produce significantly lighter, but at the same time, durable components.

3.9 Augmented Reality.

Now technologies of augmented reality are only entering our lives, but in the future they should find wide application. Since industry 4.0 does not exclude people from the production process, augmented reality systems will allow workers to see instructions directly in their field of vision using augmented reality glasses or work out actions in various virtual situations in the virtual world.

It is clearly seen that part of the described areas has already been touched upon earlier when describing industry definitions 4.0. This indicates the close connection of all these areas with the industry of the new generation. Some of them can be integrated quite easily due to the fact that it is a fairly independent solution, such as an additive approach to production. At the same time, big data analysis, cloud computing and the industrial Internet of things are the areas that largely determine the structure of new production.

The technologies on the basis of which industry 4.0 is built can be divided into three subgroups. Technologies aimed at hardware changes, technologies aimed at software changes and technologies that are located at the intersection. The former includes partially environmental recognition mechanisms, communication between devices, self-diagnosis of devices, and mechanisms of interaction with the environment. Software includes mechanisms for the joint behavior of robots, big data analysis, and self-learning systems. But the most part, representing the main vector of development, is technologies lying at the intersection, the first of which are cyber physical systems and the industrial Internet of things. This also includes the collection and preprocessing of data, man-machine interaction, and, including, augmented reality and simulation. Despite the fact that, it would seem, these are mostly software solutions, they are closely related to the physical objects of the production process.

Thus, the development of a new generation industry is influenced by a large set of technologies that, in their integrated use, can ensure the organization of production, called industry 4.0

4. *Analysis of problems and approaches to their solution*

Despite the active development of all areas that make up the next generation industry, when implementing industry 4.0, problems arise that in themselves in one area or another might not arise [5].

Modern machines with numerical control (CNC) are used everywhere, but their capabilities are not enough for industry 4.0. They are a simple automated cell whose only task is to process the work piece using some existing set of tools in accordance with a

specific program - in fact, a rigid sequence of instructions. Also, this cell can include systems of loading, unloading and positioning of parts. Such machines, on the one hand, lack autonomy, and, on the other hand, the ability to interact with other components of production. Such devices should not act on the basis of direct instructions received, but be able to make independent decisions and negotiate with other devices in production. That is what is key in building a self-organizing production system. Research into the field of artificial intelligence can bring useful results to solve this problem.

Wireless data networks, when used in industry, are not sufficiently prepared to satisfy all the requirements put forward by them. Existing solutions either cannot provide sufficient bandwidth for intensive transfer of large amounts of data, or they can provide it, but are not intended for industrial applications. Perhaps the solution may be a hybrid network of a backbone wired network and wireless transmitters connected to it.

Big data analysis is a rapidly developing field today. Indeed, with the introduction of cloud computing, in the future, big data analytics will be of great value. But the main problem that needs to be solved is efficient data collection. That is, it is required to determine exactly what data needs to be collected, how it can be done, what it makes sense and how to analyze it. For example, to identify bottlenecks that reduce overall performance, you need to know the time spent on each operation. And an analysis of the state of the devices will determine the probability of their failure.

Computer security is also a big problem for modern information systems. On the one hand, it is required to ensure the preservation of confidential data, the disclosure of which can lead to huge material and reputational losses. On the other hand, it is important to prevent the possibility of unauthorized access to factory management mechanisms. Today, even using encryption and authorization mechanisms, there is no way to create a completely secure software system. Even well-known software contains various vulnerabilities. Therefore, for the new generation industry, it is required to develop special and modern methods, but it is also possible to use some classical methods, for example, storing especially important information in the company's private cloud storage.

Organization of production. Undoubtedly, today it is possible to build almost any conveyor system, but it will have a rather rigid structure. A new generation industry is required to have self-decision-making mechanisms and self-optimization and self-configuration mechanisms. These mechanisms, in turn, must rely on the physical ability to transport work pieces between any components of production, as well as the presence of devices for manipulating objects, for example, gripping devices. This will allow you to dynamically change the route of each product element in accordance with the operations required for it. As close as possible to these requirements, flexible production systems are now available, but they are intended for the production of a certain specific family of parts.

In addition to the technical tasks to be solved for building industry 4.0, many problems are caused by the integration of cyber-physical systems with various business processes. This includes interaction with suppliers of materials, delivery of goods, the formation of invoices, receipts, waybills, interaction with customers, the formation of product specifications, coordination of production dates. Each of these stages in each company is somehow formed and debugged, but the introduction of all of them into a single infrastructure of a new generation industry is not yet possible. The solution to this problem should begin by agreeing on uniform requirements for data models and the data exchange format.

Internal logistics. This is a large enough problem to highlight as a separate item. In industry 4.0, an important point is the ability to freely move parts between arbitrary points. It can be machines, storage systems or product loading points. Existing solutions using mobile robots usually impose strong restrictions either on possible routes or on the environment in which this movement is possible, for example, a pre-marked floor of a warehouse. To build a flexible and self-organizing system requires not only solving the problem of moving the robot in a dynamically changing environment from other robots, objects and people, but also a decentralized mechanism for planning movements. So, a group of robots can have a set of logistic tasks next to them that must be completed and distributed among themselves.

The emerging problems can be divided into three groups. The first group is hardware problems, which include the implementation of communication tools between devices, devices and the real world, various mechanical manipulators, and more. The second group is the integration of production processes with business processes, which includes the interaction of suppliers and consumers with the factory, monitoring the production process of each product. And the third group is the intellectual mechanisms of planning, decision making, changes in production processes and self-optimization [6].

5. *Characteristics of industrial environment industry 4.0*

Any production almost always in itself puts forward certain requirements for the environment and structure of the premises. This may be the requirements of sterile conditions, the presence of various types of doors or locks, while the placement should be quite compact, since large areas increase the cost of the factory, but it should. The correct geographical distribution of equipment by area and the availability of routes between them is a very important task, which is complicated by the individual requirements for each product and the fact that often different equipment can perform the same production steps. Thus, with the internal organization of production, the following factors should be taken into account: a large number of participants in the production process, a large number of production stages, the geographical distribution of equipment, processing time at each stage, total processing time, and some others [1].

When designing the production environment, you can resort to modeling the movement of products sequentially through all the equipment that must be visited by them. In the sequence, even for the same type of product, different equipment can be present, which makes it possible to distinguish equipment used in similar groups. This will not only determine the frequency of use of the equipment, but also the probability of using a particular type of equipment for the production of a certain type of product [1].

In general, the organization of the production process of industry 4.0 can be represented as a mechanism for the interaction of several types of agents. These are equipment:

1. Agents, which performs basic operations;
2. Transport agents, which include autonomous robots, conveyors, and so on;
3. Product agent, which is a product element.

You can pay attention that the product in this system is exactly the same agent as industrial equipment. Moreover, he is the initiator of all processing and moving operations [2].

To implement this approach, each product instance must have its own unique identifier, for example, an RFID tag, which will store, including the current state, a list of necessary operations and all other necessary information. All devices of the production process should be able to read tags from products, and have access to a centralized system that can tell what actions are required to be performed on the work piece and will track its progress along the production line [3].

This approach, in which each agent product has complete unique information about it, allows you to fine-tune the rest of the production process. For example, each engine nozzle has a mark on it, in which its individual characteristics and calibration data are encoded after testing. Agent equipment that will be engaged in the installation of these nozzles will be able to adjust their control system according to the properties of each of them [5].

The use of various transport agents also complements the requirements for the structure of production. The desire for flexible production leads to the abandonment of standard conveyor

solutions in favor of autonomous vehicles that perform the tasks of moving products across the entire production area. The special requirements arising in connection with this can be divided into requirements for the physical organization of production and for an approach to management. From a management point of view, the key is the transition from centralized management to decentralized hierarchical systems. Thus, the product agent, knowing its weight, shape, and so on, can inform transport agents of the need to move between two points. Transport agents share this information with each other and make a general decision on its implementation. At the same time, planning tasks are already shifted to the agent itself. Such adaptive behavior of agents allows them to be used in dynamic and complex environments [4].

Since the agents in the new generation industry are autonomous devices, robots, this imposes significant restrictions on the organization of the production process. Much attention needs to be paid to the perception of robots around the world, both stationary robots and mobile ones. For stationary robots, the main task is to recognize the object, its position and orientation in space. Such problems have attempts to successfully solve using computer vision. For example, it is possible to equip each part with a visual mark, a code that can be found using the camera and obtain information about the part and its position, using this data to capture the part with a robot. The same labels can be used to mark pallets for goods, places on shelves and so on [3], [7].

For mobile robots, the task of perceiving the surrounding world is closely related to the task of navigation. On the one hand, indoor navigation is facilitated by the absence of natural factors, such as rain or fog, but may be complicated not by the uniform lighting of rooms, short distances and uniformity of rooms, which complicates the task of navigation. Restrictions on the physical structure of rooms often depend on the approach chosen to organize the movement of mobile robots, but one way or another, most decisions are based on some additional layout of rooms. This can also be done with visual marks on walls or floors [7], [8].

All the properties inherent in industry 4.0 described earlier also impose limitations in the design of production. All agents must be equipped with monitoring mechanisms that allow real-time recognition of their status and various current characteristics. There must be a computer network, including a wireless one, supporting the interaction of a large number of agents [2].

An important feature of the new generation industry is high efficiency and low power consumption. This is due to the negative impact of a large number of modern industries on the environment both in terms of global warming and pollution. Also important factors are the reduction in labor force and the desire for more careful spending of limited natural resources such as oil, coal and so on [9].

6. *Requirements for software systems architecture*

Structurally, in the architecture of industry 4.0, there are 3 main levels: physical, network, and cloud. The physical layer is represented by cyber-physical systems, devices related to the Internet of things. They have digital interfaces with factory equipment, including affordable sensors. In addition, equipment at this level can receive commands from the cloud level, according to which it can configure its work to increase the quality and productivity of production. All components of the physical layer are connected to the industrial network. The cloud layer collects information from the physical layer, analyzes it, passes feedback to the physical layer and provides an interface for managing and analyzing the state of the factory to the managing staff [2], [5].

Since all devices must be able to communicate with each other, they must support common protocols. Standards based on Ethernet, OPC-UAs may be good candidates even though they do not imply real-time transmission. A common interface and connection to a single network will allow you to create a connection between physical objects and their virtual representation, which in turn will make it easy to simulate processes in industrial applications in a single form [3].

Technologies that play key roles can also be divided into several groups: production device technologies, network technologies, cloud technologies, and client application technologies. Production technologies primarily relate to ways of interacting with the outside world, such as computer vision and RFID. URLs and the HTTP protocol can be used to unify access to various network devices. JSON can be used as a data exchange format since it is well compressed and makes it easy to work with. A cloud solution for the system user is presented using the Platform as a Service (PaaS) model. By viewing statistics and analyzing the current state of the factory, users can be provided with a web interface or mobile applications [1], [5].

An important task is to solve planning problems. In the conditions of a new generation industry, this task arises to a large extent, including in the matter of logistics. It is required to provide mechanisms to support autonomous cargo movement processes. In such restrictions, decision-making should not take place centrally, but hierarchically. Transport agents should be able to share knowledge using communication mechanisms with each other, which will allow agents to plan their actions and take into account the actions of other agents. In addition, the distribution of tasks between agents can also occur selectively. The idea is to combine a hierarchical and distributed control mechanism. A certain set of tasks can be issued to a certain group of agents selected by some criterion (for example, by location), and the final distribution will already be performed between the agents independently. The advantages of multi-agent systems are high speed, adaptability and scalability. Also, this approach is well suited for use in dynamic environments [4], [8].

Decentralized management, being one of the main ideas at the core of architecture 4.0, can also introduce features that should be considered. One of these features is the possibility of mutual blocking. This can happen, for example, when using multifunctional agents. When agent 1 can perform operations A and B, and agent 2, operation B. When processing a work piece stream, a situation arises in which agent 2 will wait when agent 1 is free to transfer to him a work piece on which operation B is required, and agent 1 will wait when agent 2 will be freed up to transfer to it a work piece on which operation B is required to be performed. Just as in the case of preventing deadlocks during parallel programming, simulation of the production process and its verification with using special software [2].

Thus, the software architecture in industry 4.0 can be represented in three levels: the device management layer, the network layer, and the cloud. Being a distributed system, devices must support monitoring mechanisms and network interactions with each other, while performing their main functions autonomously.

7. *Conclusion*

In the course of the work, various definitions for industry 4.0 were considered and a generalized definition was formed. The main problems associated with the unification of the areas affected by industry 4.0 are considered, and directions for solving these problems are also proposed.

To formulate requirements for the architecture of industry 4.0 systems, the features of the industrial environment and the technology stack have been described, which can be represented in the form of three levels: device management, network level and cloud.

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METHOD FOR IMPROVING ACCURACY OF MOBILE AR NAVIGATORS

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Abstract: *The development of augmented reality (AR) technologies and the capabilities of modern mobile devices has led to the emergence of a new class of AR mobile navigation systems. One of the basic requirement of such applications is device localization and precise mapping of the route and other visual objects to observed environment, which requires high accuracy of positioning and orientation.*

This paper addresses the problem of localization precision in AR navigators and proposes general concept of improving accuracy of basic GPS-based methods by augmenting them with local device information about its position. Some algorithms and experimental results are provided to demonstrate benefits of the proposed method.

Keywords: AR NAVIGATION, AUGMENTED REALITY

1. Introduction

Basic GPS navigator is essential application for is available in almost every modern pocket gadget. However, there are scenarios in which the quality (accuracy) of GPS-based systems is insufficient. Depending on the manufacturer and model of the smartphone, its built-in GPS module under certain circumstances can determine the position with an error in 5 to 50m range, which is actually not enough for city navigation especially in AR solutions.

The most common and easiest way of positioning is to navigate solely based on GPS coordinates. However, this method has rather low accuracy and cannot satisfy minimum requirements of AR navigators especially for precise mapping of routes to video from camera in real-time. The following approaches are available to minimize positioning errors [1]:

1. Using recursive filters or probabilistic algorithms, i.e. Kalman filtering, based on processing sequences of noisy or uncertain measurements over time in order to enhance them to statistically optimal values.
2. Alternative positioning methods based on Wi-Fi, Bluetooth or radio frequency (RF) localization. The main idea is to determine current coordinates as a superposition of signals from the Wi-Fi/Bluetooth/RF beacons. These methods demonstrate good results in indoor and special scenarios with homogeneous networks, high quality signal and little noise. However, in outdoor scenarios they usually perform worse compared to enchanted GPS-based algorithms.
3. Augmenting GPS-data with extra sources of information available in mobile devices.

Advanced sensor systems of modern smartphones provide information about local displacements including changes of orientation and acceleration. This data adds extra degrees of freedom to positioning systems and can be used to increase localization accuracy. It is important to notice that output values of embedded gyroscope, accelerometer, magnetometer and other sensory devices have their own errors [2] that should be taken into account.

Moreover, AR applications use embedded camera enabling video-based simultaneous localization and mapping. This challenging task especially in outdoor scenarios requires effective algorithms and high performance devices or network services to process real-time video stream but is very promising.

Some existing AR-navigators ask the user to adjust starting position or mapping manually by dragging and rotating initial visualization in order to reduce positioning errors. Manual tuning can be avoided by correction of local displacements in correspondence with horizontal and vertical surfaces of the real world observed by camera of a gadget. In this case, local displacements can be determined by comparing images at different points in time [3]. This functionality is already available in Apple ARKit and Goggle ARCore services [4]. As the navigation speed increases, an object tracker [5] should complement image recognition from the camera.

2. Proposed method of positioning enhancement

Proposed method (Figure 1) utilizes both concepts. Video-based localization contributes to local displacement accuracy. In addition, evaluation of coordinates of the device on each step consider both global positioning data and local displacements:

$$POS_{i+1} = LOC_i + (GPS_{i+1} - LOC_i) * BIAS$$

where POS_i, GPS_i, LOC_i - are actual, GPS and local coordinates respectively. If video-based localization (AR) is used it is included in *LOC*.

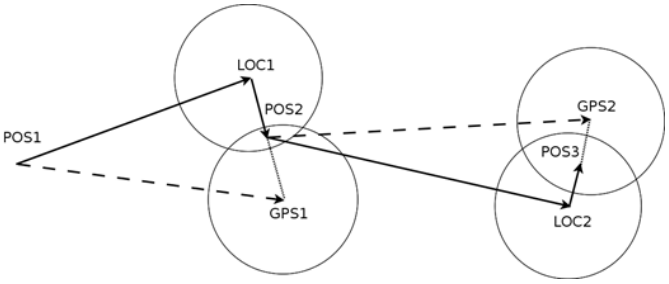


Fig. 1. ***Visualization of the described algorithm of refined positioning***

Variable *BIAS* describes the distribution of confidence between data from GPS module and local devices and determines relational reliability of each source:

$$BIAS = R_{LOC} / (R_{LOC} + R_{GPS})$$

where R_{GPS}, R_{LOC} - are confidence radii of GPS and local positioning respectively. Adjusting the value of the BIAS parameter to proper values depending on environment and device parameters allows to increase resulting accurace and makes the algorithm more flexible.

This general method is implemented in developed AR-navigator as SIMPLE and LERP algorithms [1], where LERP algorithm additionally corrects rotation angle of local coordinate system on each step.

AR navigation system

AR navigation application was developed for testing proposed algorithms. Visual appearance is presented on Figure 2. Target platform – iOS 12, development framework – d C# 6.0, .NetFramework 4.7.1, platform – Unity v.2018.2.12, xCode v.10.1. Apple ARKit was used to improve local displacements and map routes on real-time video stream from camera. Mapbox toolkit was used for 3D map visualization.

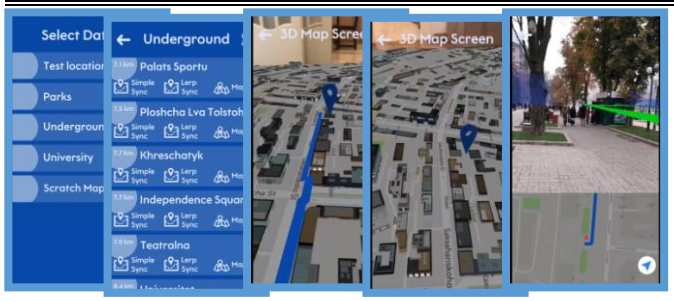


Fig. 2. ***Screens of developed solution***

Simulation results

Proposed solution was tested on iPhone 8 Plus smartphone in specially developed simulation mode allowing to study the impact of both typical embedded device errors and special cases with modified accuracies. Fig. 3 demonstrates algorithms visualization. Default GPS accuracy was around 20 m; gyroscope accuracy was close to 100%; accelerometer – around 80 compass – in range 95% –99%.

After running a series of over 200 simulations, we received following results: average deviation from actual coordinates for SIMPLE algorithm was 4,3m and 4m for LERP that is up to 50% more accurate compared to GPS. In most cases BIAS value around 0,4-0,5 provided best results making influence of local and global data equal. SIMPLE algorithm has higher tolerance to GPS errors but is more influenced by compass errors. In scenarios with compass accuracy close to 100%, SIMPLE algorithm outperforms LERP, but in all other cases, LERP shows better results.

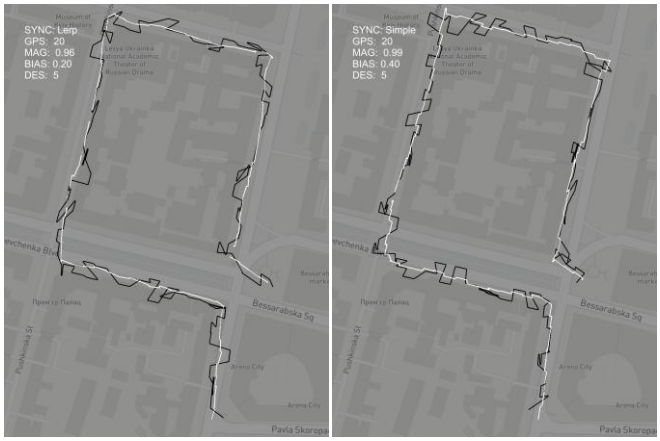


Fig. 3. ***Visual comparison of algorithms: dark trajectory - GPS coordinates, light – developed algorithms.***

Conclusions

The proposed method for augmenting classical GPS-based localization with additional data from local devices allows significant increase of positioning accuracy. Rather simple algorithms designed for typical smartphone demonstrate good results and are especially useful in AR scenarios. Application in mobile robotics[6] looks promising as well.

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THE APPLICATION OF ADDITIVE MANUFACTURING IN DEVELOPING 3D PRINTED PROSTETHICS AND ORTHOTIC DEVICES

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Abstract: This paper covers the advanced Additive Manufacturing (AM) techniques used to fabricate prostethic and orthotic devices. It reviews the available literature and summarizes the advances in medicine, computing and engineering that have led to the development of currently available prostheses. Some of the open-source bionic hands and other available prosthesis are shown, as well as the technologies and materials which are used to manufacture the parts. Since prototyping, combined with the possibility for easy maintenance and repair, is very attractive for prosthesis design, as a conclusion we summarize and discuss some of the key areas that could lead to improvements in bionic limb functionality and use.

KEYWORDS*: ARTIFICIAL LIMBS, ADDITIVE MANUFACTURING, 3D PRINTING, ORTHOTIC DEVICES*

1. Introduction

Prosthetic and orthotic devices can help patients regain mobility and limb function post-stroke or amputation, but the process of creating custom devices takes time and labor. Additive manufacturing (AM) technologies can be utilized to create assistive devices that are better tailored to each individual in less than a day.

Prostheses are devices used to replace a lost limb, while orthoses are braces used to protect, align or improve function or stability to injured limbs. A research showed that more than two-thirds of stroke victims require long-term rehabilitation, and many of them can be helped with custom orthotics. The devices can also help children with cerebral palsy, myelomeningocele and other conditions gain stability and walk more easily.

3D scanning nowadays is also pretty common in reverse engineering lost limbs in order to speed up the orthopedic development and manufacturing. In the past, to make a custom brace for a patient, the patient would be covered in plaster and would have to lie motionless until the plaster hardened. It would then be cut off the patient and the mold would be sent to a brace manufacturer. There, all measurements would be done manually, and the brace would be sent back to the doctor for a final fitting. If it did not fit, the process restarted from the beginning. Digital technology speeds up the process of creating prosthetics and makes it a lot simpler and more efficient.

2. AM technologies used in developing 3d printed prostethics

Using additive technologies such as fused deposition modeling (FDM), stereolithography (SLA), and selective laser sintering (SLS), allows designers and manufacturers to convert CAD data to three-dimensional products. Although these methods are still not suitable for bulk production volume, designing and building prosthetic devices is a customized process in which each model needs to match its user's disability. This means the end product is unique for each patient. The design process for 3D printing a prosthetic device is similar to the traditional process—just more affordable and accessible. To summarize, the 3D-printed prosthetic process includes the following stages:

1) The stump and the rest of the arm are carefully measured so the prosthetic will fit the patient's needs and ensure maximum functionality.

2) Either 3D scanning or creating a mold for the prosthetic will allow testing to ensure accurate measurements for the final design. 3D scanning allows the form and function of the prosthetic model to be tested on the computer CAD application before printing.

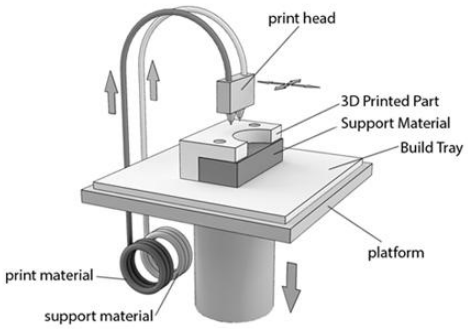


Fig.2.1 *Fused Deposition Modeling (FDM) – Schematic (Source: https://www.dddrop.com)*

3) Once the prosthetic is scanned and converted to a 3D model, there are other factors to consider. Although the 3D prosthetic device can be computer-modeled based on the scanned arm using various CAD applications, many of these models are available for free download on the designers' websites in separated documents for each part of the prosthetic. These free models can be downloaded in STL format, which is readable by all the available 3D printers. In most cases, customization should be applied in order to fit with the patient's needs; this can be done using 3D modeling applications that support exporting the files in STL or OBJ format. In contrast with the traditional process, digital 3D-modeling of the prosthetic hand contributes significantly in reducing the production cost, time, and effort required to create the model.

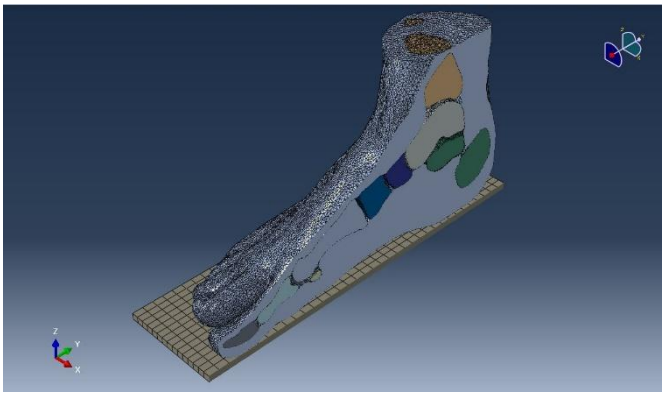


Fig.2.2 *Mesh model of a 3D scanned foot used as a reference for fabricating a prosthetic device (Source: https://3dexperiencelab.3ds.com/)*

4) The most used additive technologies for fabricating the prosthetic devices are FDM, SLA and SLS (Fig 1, 3 & 4). FDM is the cheapest of the three and it builds the model using thin layers of filament based on the STL digital model. And herein lies another advantage of the 3D-printed prosthetic: The materials used in

traditional prosthetic production significantly increase the cost of the final product, but the plastic based filament used in 3D printing is cheap and can be modified easily, even after printing. SLA can be used more or less in the same devices as FDM, but offers better surface finish and potentially the use of special reins.

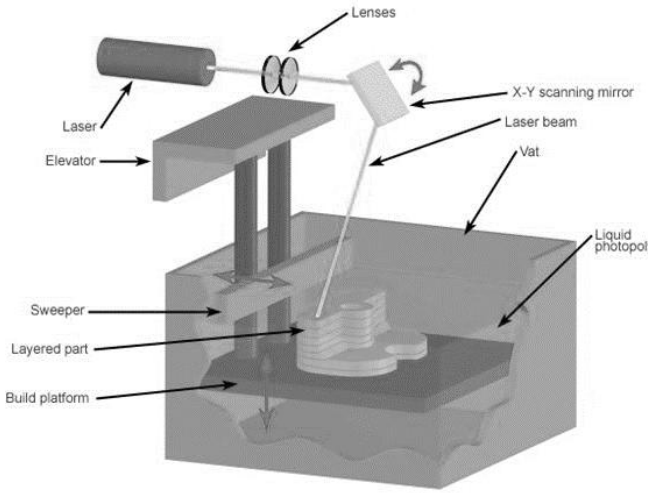


Fig.2.3. *Stereolithography (SLA) – Schematic*
(Source: http://www.custompartnet.com)

Laser sintering or laser melting is used when there is a need for metal implants for a specific need. A Melbourne-based medical device company Anatomics 3D printed a sternum and rib cage implant by using high resolution CT scans. The sternum and rib cage features a complex geometry that means the flat and plate implants traditionally used for this part of the chest can come loose over time. For this reason, the surgical team thought a custom 3D-printed implant would be a better option. The implant was designed with pieces that went over the remaining bone and allowed them to be attached securely with screws (Fig. 2.5).

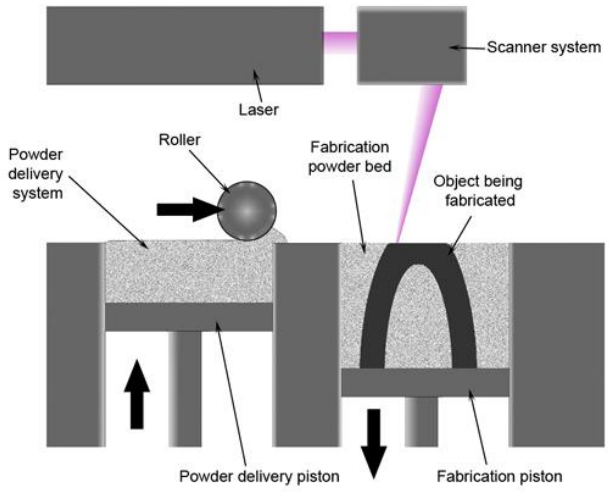


Fig.2.4 *Selective Laser Melting (SLM) – Schematic*
(Source:cadimensions.com)

5) Assemblies are put together using cords, screws, and foam padding. In just a few hours, the entire prosthetic can be put together and ready to use.

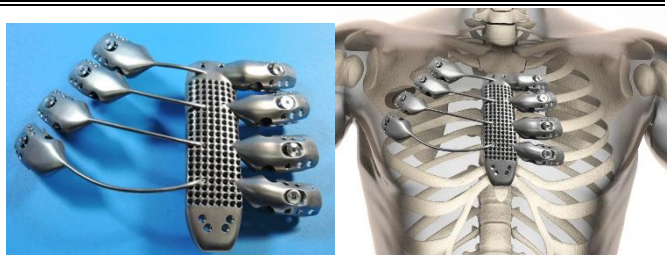


Fig.2.5 *3D-printed sternum and rib cage implant*
(Source: http://www.anatomics.com)

6) The prosthesis is then installed on the patient and evaluated for functionality. Specifically for devices meant for patients with amputated upper limbs, there is a practice period in which the patient has to learn how to move the device using the remaining muscles in his or her arm. This stage gives the designer some feedback for future prosthetics development and production processes. Many individuals, organizations, and universities are mounting initiatives to build 3D-printed prosthetics that match the efficiency of traditional prosthetics.

3. Upper limb prosthetics (bionic hand prostheses)

Upper limb prosthesis are (ULP), can be classified as follows [6]:

- Passive
  – Cosmetic Prostheses
- Active
  – Conventional (Body-Powered) Prostheses
  – Electrically Powered Prostheses
- Myoelectric Control
- Servo Control
- Push Button Control
- Harness Switch Control

Other hybrid types are also available. The authors in [6] also cover the human grip taxonomies. Feix et al. [8] summarizes 17 general grips from 33 types. The grips mostly used in the open-source projects are as follows:

- Grips
  – Pinch grip
  – Hook
  – Tripod grip
- Gestures
  – Full open / close
  – Thumbs up / down
  – Index finger point`

There are a lot of commercially available types of artificial hands ranging from more hi-tech options to more affordable, open source prostetics.

The open source options include projects like: eNable [9], Limbitless [10], NotImpossible [11], ROMP [12], Youbionic [13] and others. These prosthetics are based on more accessible 3D technologies and are meant to reduce their cost and use them in more remote regions of the world.



Fig. 3.5 *The Brunel hand 2.0 (Source: https://openbionicslabs.com)*

The inexpensive prosthetics are also very useful for children patients that are still growing. As stated in [2], only limited number of upper extremity prostheses are appropriate for young children. In these cases, most patients are fitted with either a passive prostheses or a body powered voluntary closing terminal hook device given the durability and low cost of these options. More complex devices or myoelectric devices are rarely used in skeletally immature individuals due to both cost and weight. This makes the modularity of the design a paramount issue which can be solved by scaling the size of the hand and socket. This way users can easily print new prosthetics as they grow older.

However, the inexpensive design has a few limitations that include short battery life, noise from the motors, low grip strength of the terminal device and low durability of mechanical components.

A summarization of the characteristics of multiple upper limb prosthetics fabricated with 3D printing technologies is done by Vujaklija and Farina [3]. This review is shown in table 3.1 and covers the level of disability, the actuation and other features unique to each design.

Table 3.1: *Overview of representative 3D printed upper limb prosthetics and their features (Source: [3])*

	Level of disability	Printing material	Actuation	Control	Unique feature
Origami Finger	Finger	Nylon 618	Passive	Body powered (finger phalanx)	Compliant
Cyborg Beast	Partial hand	PLA/ABS	Pre-tension /cable	Body powered (wrist)	Highly robust
Flexy Hand	Partial hand	Filla Flex	Pre-tension /cable	Body powered (wrist)	Compliant and biomimetric
Brunel Hand	Transradial / transcarpal	PLA	Electric linear actuators	EMG/IMU	CE certified
Etho Hand	Transradial / transcarpal	ABS	DC Motors	Not defined	Ball joint motorized thumb
Andrianesis' hand	Transradial / transcarpal	Duraform HST	Shape memory alloy	EMG/FSR	SMA actuators and motorized wrist
Create arm	Transhumeral	Flexi fit	Pre-tension /cable	Body powered (shoulder)	Medical grade printing material
Robotic Arm	Transhumeral	PLA	Electric servo motors	Not defined	High level motorized device

At the Wroclaw University of Technology a rehabilitation orthosis device was developed specificly for a patient with a partially-paralyzed hand. The wearable device needed to be light and comfortable, so as to avoid damaging the weakened appendage to which it's attached, in this case the patient's hand.



Fig.2.1 *The reverse engineering of the model by using a 3D scan od the hand and the final ortothic device printed in ABS plastics (Source: zmorph3d.com)*

The researchers set about tackling the problem by making a plaster cast of the patient's right hand, and then using it to create a detailed 3D model. The model was then used as a guide when using CAD software to design a mechanical solution that would directly assess the patient's needs.

The 3D printing-based CAD/CAM process often begins with a scanner to accurately capture the patient's shape. With using a CAD software instead of modifying the shape to create a positive mold, the generated final device design can include sophisticated cellular wall structures of variable thickness and stiffness. The traditional CAD/CAM process involved carving a foam mold then thermoforming uniform thickness plastic sheets around the mold. 3D printers replace those steps by precisely depositing heated plastic beads or filaments to build up the final device directly.

Once the initial 3D model I developed it can be used for more than just fabrication. Because some fractures are frequently observed in certain regions it is helpful to study the mechanical behavior of these devices to determine the most likely areas of fracture, by analyzing the stress and strain distributions, using Finite Element (FE) analysis, on a simplified geometrical model. This is done in [14] in order to assess whether or not, personalization of the scanned model is contributing to increase fracture probability.

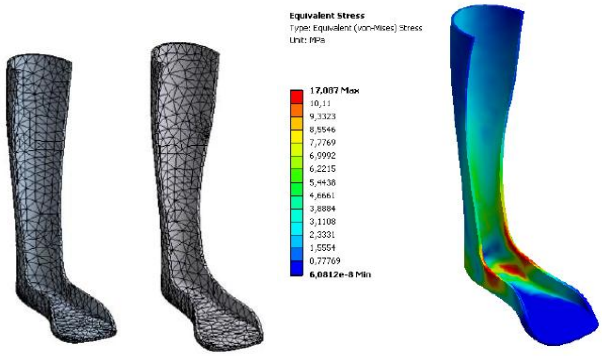


Fig.2.1 *Geometrical models with finite-element mesh (left) and FE simulation results for stress distribution (Source: [14])*

4. Conclusion

Thanks to the variable-thickness wall structures that can be generated by 3D printing, the stiffness and strength can be controlled at every point around the final device. That enables the fabrication of much lighter devices with greater stiffness in areas where support is required and greater flexibility in other areas for improved comfort. In many cases, 3D printing also allows you to create devices that are much thinner than is possible with solid, uniform-thickness plastic sheeting. Tailored stiffness, lighter weight, and greater comfort all lead to greater patient compliance and the potential for better treatment outcomes.

Additive manufacturing processes open up a lot more opportunities in fabricating prosthetic devices. The main benefit is that each prosthetic is unique and it's possible to design and adapt individual devices very quickly with the help of CAD techniques. Another important issue is in the cost and availability of spare parts. In the case of failure it is easy to print the proper parts and implement them in the device. Unfortunately, the quality level of 3d printed prosthetics in some aspects still lags behind commercially available solutions, but the further development of materials and 3D technologies tends to close this gap at an increasing rate.

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ENERGY CONSUMPTION EVALUATION OF THE HEATING VENTILATION AIR CONDITION THROUGH HOURLY ANALYSIS PROGRAM SOFTWARE

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Abstract: *During the last two decades the Heating Ventilation Air Condition (HVAC) systems have been used to enable heating, cooling and ventilation of buildings with the primary aim of meeting the requirements of thermal comfort and indoor air quality. In this research work, energy consumption in buildings has been analysed by using Hourly Analysis Program (HAP) software. The object of our research work was focused in the Polytechnic University of Tirana. Mathematical models of thermal calculations have been based on the international standard ISO 13790: 2008 on energy use and thermal performance of buildings.*

Keywords: ENERGY CONSUMPTION, HVAC, HAP SOFTWARE, BUILDINGS.

1. Introduction

During the last two decades the Heating Ventilation Air Condition (HVAC) systems have been used to enable heating, cooling and ventilation of buildings with the primary aim of meeting the requirements of thermal comfort and indoor air quality. The evolution of HVAC systems began in the early 20th century, undergoing continuous development to the present day, where various types of HVAC systems were used extensively for residential, commercial and industrial buildings. However, using HVAC systems requires a large amount of energy to enable them to function correctly. The building sector accounts for about 30% of total energy consumption in Europe and the US [2]. Thus, in a commercial building, HVAC systems consume about 5% of energy for heating, 14% for cooling and 12% for ventilation [5].

The challenge HVAC engineers face today is to use energy efficient systems, combining the efficiency of systems with the high standards for thermal comfort and indoor air quality of buildings. Today's directions in the field of HVAC relate to optimizing systems and evaluating various alternatives to achieve energy objectives. Furthermore, Albania have implemented European and international standards for energy consumptions and most of the residences have been focused on HVAC systems. In this research work, energy consumption in buildings has been analyzed by using Hourly Analysis Program (HAP) software [4]. The object of our research work was focused in the Polytechnic University of Tirana. Mathematical models of thermal calculations have been based on the international standard ISO 13790: 2008 on energy use and thermal performance of buildings [1]. The purpose of the study is to evaluate the heat and cooling energy consumption for Polytechnic University of Tirana.

2. Evaluation of energy consumption

In this section we will realize the thermal load calculations and energy consumption estimation by using HAP software. HAP software is a tool used to evaluate thermal load and system design. Secondly, it is a tool for simulations of energy use and energy consumption calculations. The study object was the Polytechnic University of Tirana. The simulation results has been used to analyze the energy use and annual energy consumption for 8760 hours of the year.

Before energy simulations can be carried out we should know information on building, environment, equipment, HVAC systems and energy prices must be collected. We have collected all specific types of information needed which are as follows:

- Climatic data for the building area.
- Information on the construction material of walls, ceilings, floors, doors and windows.
- The weight of the building and the orientation of the building.
- Interior heat gain characteristics, determined by number of persons, lighting systems, equipment and machinery inside the building.
- Data on HVAC equipment, controls and components to be used.
- Price data for electricity and energy sources to be used in the building.

Afterward, the data required for energy analysis have been entered in HAP software such as external climatic conditions, entering data for building spaces, entry data system, data entry of the equipment system, entering electricity data and entering building data. The analysis of our research work is given for the first three floors of the Polytechnic University of Tirana which comprises lecture halls, seminar classrooms, laboratories, computer rooms, libraries, offices, corridors and university lobby, with a total of 123 spaces. The Fig. 1 depicts climate conditions in our analysis which were taken from ASHRAE standard [3].

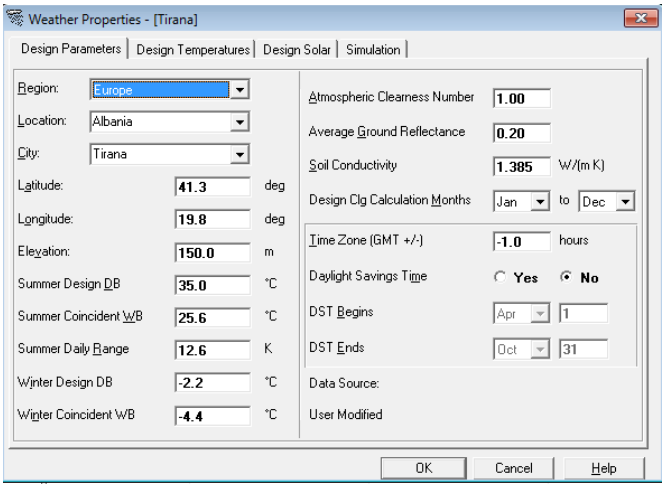


Fig. 1. *Climate conditions for Tirana city, ASHRAE standard*

The characteristics of the building elements are taken into account from the layout of the building and information about the use of the building are as follows:

- The construction type is the same for all exterior walls of the university. The design of the walls consists of 500 mm thick brick and 20 mm interior plaster. The heat transfer coefficient U is 0.517 W/m^{2}K. The total weight is 517.2 kg/m^2. The external surface absorption is of "medium" category and the absorption coefficient is 0.675.
- The university terrace is horizontal and uniform. The terrace construction consists of the following layers such as 25.4 mm interior plaster, 203.2 mm concrete soles and 9.54 mm waterproofing. The total thickness of the terrace is 238.14 mm. The heat transfer coefficient U is 2.134 W/m^{2}K. The total weight is 256.4 kg/m^2. The external

surface absorption is of the "dark" category and the absorption coefficient is 0.900.

- The type of window construction is the same across the university. The windows are double glazed with aluminum frame without thermal joints. The inner shadows were not used. The heat transfer coefficient U is 4,441 W/m^{2}K and the shading coefficient is 0.827.
- The lighting is the same for all campus settings. The lighting equipment load is 5 W/m^2.
- Electrical equipment load is 12 W/m^2.
- The activity level of the university premises is considered as "office space" with sensible heat 71.8 W/person and latent heat 60.1 W/person. The number of persons depending on the use of space is given in Table 1.

Table 1: *The persons number on the use space of university building.*

Building Informations	Number of Persons
Lecture hall	120
Workshops	30
Laboratories	15
Computer rooms	30
Library	50
Offices	2
"Silvano Pedrolo" hall	150
University hall	10
Corridors	10

3. Simulation results

The summary results has been generated by HAP software after all determined elements like heat transfer, system data and power simulation results for 8760 hours of the year are shown in Table 2 and Fig. 2.

Table 2: *Air System Simulation Results.*

Months	Terminal Cooling Coil Load (kWh)	Terminal Heating Coil Load (kWh)	Terminal Fan (kWh)	Lighting (kWh)	Electric Equipment (kWh)
January	0	126925	0	7091	17172
February	0	85644	0	6211	15040
March	0	55331	0	6590	15959
April	102	17654	0	6798	16461
May	27706	1346	0	7091	17172
June	71536	69	0	6297	15249
July	153054	0	0	7091	17172
August	0	0	0	6848	16583
September	67100	0	0	6540	15837
October	18013	15954	0	7091	17172
November	18	42855	0	6555	15873
December	0	103946	0	6833	16547
Total	**337529**	**449724**	**0**	**81034**	**196236**

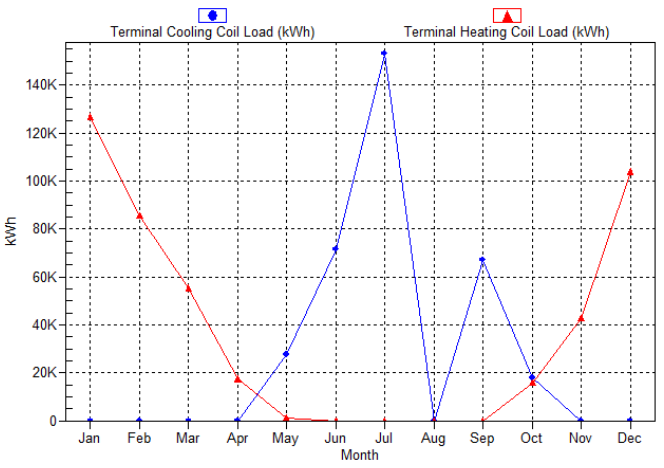


Fig. 2. *Air System Simulation Results*

From our obtained data of the simulation results, the heat-cooling thermal load for the 12 months in the year are as follows:

- Heating: Q_H = 449724 kWh
- Cooling: Q_C = 337529 kWh

Based on these results we can determine from eq. 1 and 2 the total electricity consumption for heating and cooling. (COP performance coefficient = 3.5).

$$Q_{el}^{H} = \frac{Q_H}{COP} = 128496.14 \text{ kWh} \quad (1)$$

$$Q_{el}^{C} = \frac{Q_C}{COP} = 96436.86 \text{ kWh} \quad (2)$$

The annual energy consumption for heating and cooling at Polytechnic university of Tirana has been calculated as follows by eq. 3 and 4:

$$Cost_H = Q_{el}^{H} \cdot 14.8 Lek/kWh = 1{,}901{,}743 \text{ Lek/year} \quad (3)$$

$$Cost_C = Q_{el}^{C} \cdot 14.8 Lek/kWh = 1{,}427{,}266 \text{ Lek/year} \quad (4)$$

4. Conclusion

In this research work we have briefly describe the evaluation of energy consumption in Polytechnic University of Tirana by using Hourly Analysis Program (HAP) software. The international standard ISO 13790: 2008 have been used to analyze the usage energy and thermal performance of our university building. The annual energy consumption for heating was 1,901,743 Lek/year and for cooling was 1,427,266 Lek/year. The future research work would reveal if we can reduce the annual energy consumption by changing thermal isolation of our building and also windows materials.

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INDUSTRY 4.0 AND THE DIGITAL TWIN FOR BUILDING INDUSTRY

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Abstract: *Technology and innovations have powered the evolution of Industry4.0, the fourth industrial revolution.*

State-of-the-art technologies such as the Internet of Things (IoT), cloud computing (CC), big data analytics (BDA), and artificial intelligence (AI) – all part of Industry4.0, have greatly stimulated the building industry. Digital Twin is a significant enabler for Industry 4.0 initiatives. Within Industry 4.0, the amount of digital product information generated and collected over the entire lifecycle has been growing.

Although digital twins have been around for several decades, the rapid rise of the internet of things (IoT) is that they have become more widely considered as a tool of the future. Digital twins are getting attention because they also integrate things like artificial intelligence (AI) and machine learning (ML) to bring data, algorithms, and context together

A "digital twin"—or digital replica of a physical entity—can target building industry in several sub-areas:

- *Facility management*
- *Product Lifecycle Management*
- *Smart Buildings*
- *Smart energy*

All these areas are one giant step further by creating a Digital Twin — a virtual representation of real-world buildings that can be viewed and scrutinized in minute detail. This research describes business cases and best practices in design of IoT Solutions for building industry, powered by Digital Twins. A reference architecture and prototypes which demonstrate application of Digital Twins in Smart are created as a result of this study .This research is technology agnostic, but prototypes of sample solutions are considered in the context of Microsoft Azure (Azure solutions, covering Azure Digital Twins Service and Azure IoT Stack.)

Keywords: DIGITAL TWIN, IOT, INDUSTRY 4.0, MICROSOFT AZURE, AZURE IOT STACK

1. Introduction

Digital Twin has gained significant impetus as a breakthrough technological development that has the potential to transform the landscape of manufacturing today and tomorrow [1]

The demand for affordable housing has never been higher [2], affected by a concomitant need for social, utility, and transportation infrastructure. These challenges have ensured that the construction industry continues to review and revamp itself. The changes that occur here affect society in general—the construction costs will fall and this will be beneficial for the environment will benefit. This can be achieved by efficiently using limited resources and/or ensuring that buildings are being constructed eco-efficiency [3]

Despite the industry's vast potential, increasing efficacy and productivity can only result from digitalization, new techniques for construction, and innovations. Tools such as three-dimensional (3D) scanning, building information modelling (BIM), drones, and augmented reality have all reached market maturity [4].

The fourth industrial revolution 4.0 or Industry 4.0 has introduced digital technologies, sensor systems, intelligent machines, and smart materials to the construction industry where BIM has become the central repository for collating digital information about a project [5].

Industry 4.0, a name coined to encompass the widespread integration of information and communication technologies that converge the physical and digital many areas of industry

Successful enterprises are using a full stack of technologies to achieve the goals of Industry 4.0: efficiency, speed, agility, and customer-centricity.

One of these technologies is the digital twin. Digital Twins is represented as a concept for PLM systems in the beginning of 21 century, but it is now achieving real value and presence in the industrial space. In fact, it is now recognized as a key part of the Industry 4.0 roadmap.

One of the primary reasons digital twin technology is rapidly being adopted is there are multiple use cases across the industrial enterprise: engineering, manufacturing and operations, and maintenance and service. Digital twins are made possible (and improved) by a multitude of Industry 4.0 technologies – IoT, AR, CAD, PLM, AI, edge computing, to name a few – to create a powerful tool that's driving business value.[6]

What is Digital Twin?

Digital Twin is the exact representation of, for example, a building as digital data. One example could be a database that knows everything that happened during the construction phase of a building, like:

1. A timeline of every status change reported for all activities executed to deliver the project.
2. Who reported them?
3. Issues and Obstructions that needed to be faced during the construction process.
4. When those have been resolved and by whom.

Such a database should also be considered a Digital Twin. Sure, since it really is the exact representation of the buildings construction phase after all.

Figure 1: *Digital Twin Model, described with Sablono [7].*



While other applications of Digital Twin Technology use automated sensor technology to do so, the AEC industry has to rely on humans to put the required information into the system.

"Building Information Modeling (BIM)" and "Digital Twin Technology" sound very much alike.

Therefore, it does not come as a surprise that "Building Information Modeling (BIM) with a consistent and structured data management is the key to generate such a digital [twin] building whose dynamic performance can be studied by building simulation tools for a variety of different boundary conditions".[0]

BIM vs. Digital Twins

1. BIM Is For Design and Construction
2. BIM Isn't Designed for Real-Time Operational Response
3. BIM Focuses on Buildings Rather Than People
4. Digital Twin can give you information about the current state of build subsystems, how they are being impacted by occupant behavior when assets like HVAC or lighting might fail and much more.
5. Digital Twin a model that evolves over time to deliver more value with each new stage of the asset's lifecycle
6. In the future, Digital Twin will certainly supersede BIM software even at the design and build phase of an asset's lifecycle.

The current study is an overview of the possibilities of using Digital Twins in the construction industry. It also presents prototypes that demonstrate solutions to real cases with the Digital Twins

2. Application of Digital Twins in Building Industry

The vision of "Construction 4.0" refers to the Industry 4. in addition, is a fundamental challenge for the construction industry. In terms of automated production and level of digitalization, the construction industry is still significantly behind other industries. The trends like Big Data or the Internet of Things offer great opportunities for the future development of the construction sector. Prerequisite for the successful Construction 4.0 is the creation of a digital twin of a building. Building Information Modeling (BIM) with a consistent and structured data management is the key to generate such a digital building whose dynamic performance can be developed by building simulation tools for a variety of different boundary conditions. Along the total life cycle from design to construction, operation and maintenance towards remodeling or demolition, the digital twin follows all modifications of the real building and dynamically readjusts itself in case of recorded performance differences. Thus, for the whole life span of the real building, performance predictions generated with the virtual twin represent an accurate basis for well-informed decisions. This helps to develop cost-effective operation modes, e.g. by introducing new cyber-controlled HVAC systems. The digital twin may also analyze the building's dynamic response to changes in occupation or energy supply; it also indicates the need for building maintenance or upgrades. [8]

There are different areas for Digital Twins application in building industry:

- Energy Models for Optimization
- Analyze complex structures
- Structural Health Monitoring:
  - Increase human safety
  - Reduce maintenance costs
  - Optimize models
- Materials testing
- Smart Cities [9]
- Any kind of other IoT solution, in building industry [10]

Figure 2: *Digital Twins Concept.*

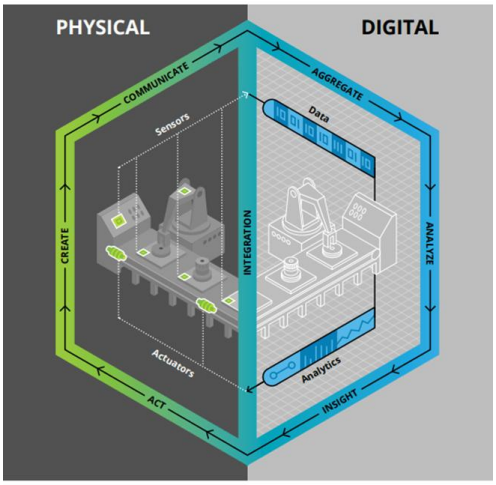
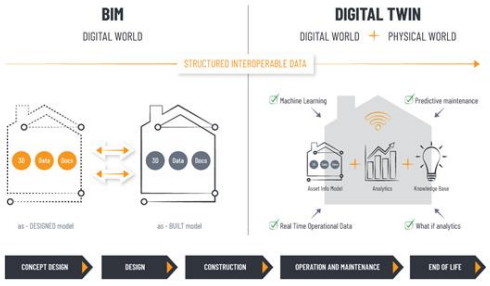


Figure 3 *BIM and Digital Twins*



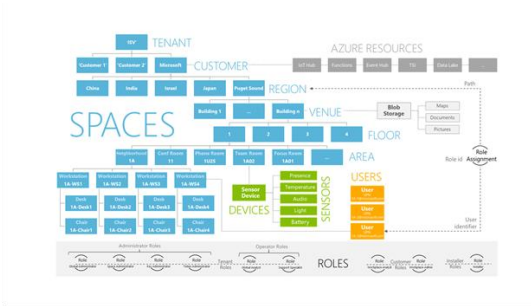
3. Digital Twins support in Microsoft Azure

Microsoft Azure – the Microsoft Public cloud offers Azure Digital Twins Service, which simplifies a lot the implementation of solutions, based on Digital Twins concept. It provides a specific extendible object model, focused on problems in building industry.

Digital Twins object models describe domain-specific concepts, categories, and properties. Models are predefined by users who want to tailor the solution to their specific needs. Together, these predefined Digital Twins object models make up an ontology. A smart building's ontology describes regions, venues, floors, offices, zones, conference rooms, and focus rooms. An energy grid ontology describes various power stations, substations, energy resources, and customers. With Digital Twins object models and ontologies, diverse scenarios and needs can be customized.

With Digital Twins object models and an ontology in place, you can populate a spatial graph. Spatial graphs are virtual representations of the many relationships between spaces, devices, and people that are relevant to an IoT solution. This diagram shows an example of a spatial graph that uses a smart building's ontology

Figure 4: *Azure Digital Twins Object Model*



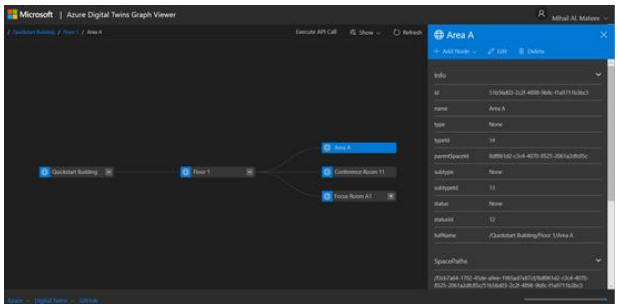
Azure Digital Twins Graph Viewer:

Azure Digital Twins Graph Viewer is an OSS project, hosted in GitHub. It is used to manage and visualize your digital space:

The solution supports:

- Stored in a Static Web Site
- AAD authenticated
- Azure SignalR
- Azure Function AAD Authenticated for query and SignalR hub
- GitHub url: https://github.com/Azure/azure-digital-twins-graph-viewer

Figure 5: *Azure Digital Twins Graph Viewer*



Azure Digital Twins in Modern IoT Solutions

There are many areas in IoT solutions, where Digital Twins technology can be used:

- Device Configuration Management System
- Device monitoring
- Device provisioning
- Software update
- Multi-tenancy
- Integration with other solution
- Raise alarms (event driven design)

3. Sample Prototypes

Smart Spaces: [Facility Management]

The problem:

The main case is that the office spaces were used inefficiently (for instance small conf rooms were occupied when bigger ones were free) or someone booked a room but the meeting did not take place.

Used services:

Azure Digital Twins Service, Azure IoT and Cognitive Services (Azure AI)

Smart spaces solution architecture:

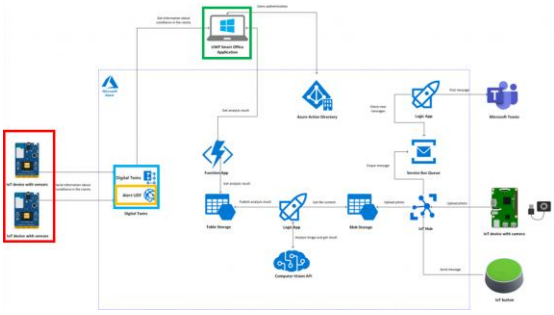
Smart Spaces solution consists of desktop application, IoT devices and services in the Microsoft Azure cloud.

To get information about conditions in each conference room and to check the number of people inside are used Azure Digital Twins and Cognitive Services.

- There are two IoT devices connected to the Azure Digital Twins, which has an IoT Hub service underneath.
- These two IoT devices have some sensors, for example temperature sensor. In the Azure Digital Twins service, there are defined User Defined Function (UDF) which is responsible for analyzing insights from specific sensors and on this basis providing clear information.
- UDF to analyze temperature data from the specific room, and provide information if it is suitable to start another meeting or if the temperature is too high.
- Azure Digital Twins provides API, so it is possible to connect to it from the web, desktop or mobile applications to retrieve information about every room.
- Cognitive Services – Computer Vision API and Logic App:

One of the IoT devices has a camera connected (right side of the architecture diagram). Snapshots are taken each specific period of time. Then the photo is sent to the Azure IoT Hub and stored in the Azure Storage in the blob container. There is a Logic App created to detect if there is any new image. Then the image is sent to the Computer Vision API to get information about the number of people recognized on the picture. The result is stored in the Azure Table Storage. Data is analyzed via Azure Cognitive Service

Figure 6: *Smart spaces architecture*



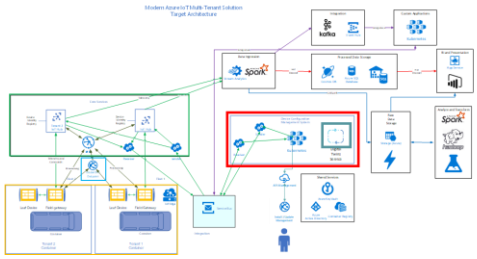
Device Configuration Management System & Multi-tenancy

Device Configuration is one of the main components of modern IoT solutions. This module is responsible for:

- Device monitoring
- Device management
- Device provisioning
- Software update

Digital Twins can be used to persist the complex model of spaces and connected devices, which is actually the data model used in Device Management module.

Figure 7: *Digital Twins in Device Configuration Management*



3. Conclusions

Overview of the current research

Current research covered several areas:

Application of Digital Twins Technology in Building Industry

- Problems
- Use cases
- Available technologies
- Implementation of prototypes for several use-cases

Future work:

Research will extended, based on data analytics over data from Digital Twins. The major focus will be solving the real life cases about prediction and maintenance, related to structures maintenance and facility management.

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DIGITAL PLATFORM FOR BUILDING ENTREPRENEURIAL SKILLS AND COMPETITIVENESS IN THE CONSTRUCTION SECTOR

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Abstract: *Digital platforms for education are one of the newest and most effective online tools for collaboration and knowledge accumulation. The construction industry could benefit from such a platform to prepare a new generation of building entrepreneurs. The web-based platform has many advantages like creating new ecosystems of data, information, knowledge, people, processes and things. Therefore, the article entitled Digital Platform for Building Entrepreneurial Skills and Competitiveness in The Construction Sector presents a modern way of obtaining business skills. It models an affordable, user-friendly digital system for learning and teaching the best practices in the construction industry.*

Keywords: BUSINESS, CONSTRUCTION, DIGITAL, ENTREPRENEURSHIP, SKILLS

1. Introduction

Information technologies are changing education and communication. More institutions, which offer educational services, try to digitize their processes. Sometimes the strategy for digitization does not work efficiently because display learning leads to eyes and mind pressure, and body deformation. Trainees get tired very quickly and are unable to learn. The worst method in construction or medical education is teaching theory without practice. Nevertheless, still, there are universities and schools, which rely only on this method and do not make even a tiny step for any change.

The purpose of this article is to suggest a brand-new digital tool for education, which combines areas of reality, digital economy, virtual economy, multi-dimensional technologies and virtual simulation of the real world. We believe that this mobile platform can build entrepreneurial skills for entering and surviving in the construction sector. To prove our statement, we complete three tasks:

1. To find the problems and barriers in front of digital education in the construction;
2. To explore the psychology of successful entrepreneurs;
3. To investigate and suggest a new and effective way of making construction entrepreneurs via a digital platform.

2. Problems and barriers in front of digital education

The construction industry in Bulgaria adopts slowly new technologies. Reasons include the lack of large investments on digital modernization, full ignorance of the technological progress, highly traditional education and economy, etc.

The youth graduate, but they feel uncertain in their knowledge and skills. Consequently, they start working something very different from their education. The relation between technical school/university and business becomes weaker. This alienation is a premise for psychological, social, technological and economic problems. To hold the youth in the area they have studied, and to motivate their advancement is an important topic.

Digital learning makes students' dream of distance learning come true. The remote study, however, has some disadvantages. The form of education causes various problems with the nervous, muscular, reproductive, endocrine, exocrine, skeletal systems. Authors argue television, computer, Internet, video games, smartphones, digital toys harm to children's and teenagers' lifestyle and their development (Mustafaoğlu, et al., 2018, p. 15). Pagani, Fitzpatrick, Barnett, & Dubow (2010, p. 429) acknowledge that early television use drives to undisciplined and passive-aggressive behaviour and attitude to learning. Based on their research, we believe modern, SMART and efficient appliances and technologies can transform the negative impact into a positive one. That way, learners could improve their mathematical, reading, analytical and digital skills.

Bingimlas (2009), based on different researchers, proves that the traditional environment seems inefficient in today's education (Bingimlas, 2009, pp. 235-245). Some of the statements he uses have originated before 18-19 years, but they are still valid. The migration increases because of this stagnation. Young people are looking for prospects abroad, where they can benefit from modern facilities and digital technologies. Both of them ease daily life and learning.

Digitization, however, replaces globalization because the first one makes the world limitless. Therefore, here, we see the need for a modern learning tool. The method should build strategic thinking and professional entrepreneurial skills. Although there are some obstacles to its introduction, the new way of study is more agile and efficient.

According to the research of OECD (OECD, 2014, p. 76), younger adults are better at using computers than older ones. 51% of people aged 16-24 are having a high level of computer skills (OECD, 2014, p. 74). As we can trace by the report of the National Statistical Institute of Bulgaria (NSI, 2018, p. 17), the number of teachers who are older than 55 years is the biggest one (see fig. 1). Therefore, here, we can see the first premise for introducing digital learning in Bulgarian schools/universities.

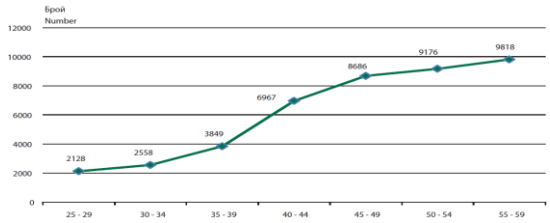


Fig. 1 *Teaching Staff in General Schools by Age in 2017/2018 School Year Source (NSI, 2018, p. 17)*[Грешка! Източникът на препратката не е намерен.]

Media Literacy Days is an event, whose mission is to highlight the power of media literacy education and its essential role in education all across countries. Bulgaria has participated in the initiative for 2017 with 55 schools in 36 towns, cities and villages (The Bulgarian Safer Internet Centre, 2018). The high interest shows Bulgarian educational institutions work for digitization but, now, the necessary funds for full digitization are insufficient in the country. On the contrary, in the U.S. the numbers of digital students have increased from 2.2mn in 2009 to 10.46mn in 2015 (Kitaboo, 2015). Despite these statistics, digital schools have not been mainstream yet because there are many obstacles for overcoming like the infrastructure, resistance to change, content curation, technological change, etc. ((Kitaboo, 2015), (Sharma, 2015), (Howard & Mozejko, 2015)).

The developing world still struggles with the lack of IT infrastructure that can support large-scale e-books and digital

curriculum distribution. Countries with a mature market like the United States, China, etc. have access to fast internet. It supports large data downloads required for digital books (Kitaboo, 2015). We think that scanning hardcopy books and storing them on servers are an old fashion comprehension for digital learning. As we saw, some researches show that display reading harms pupils' eyes and attention. People have criticized Bulgarian education for years because of theoretical learning. Reading too much unlocks imagination but locks skills, therefore, we have to seek new modern tools that unlock personal and professional competences and potential.

3. The benefits of digital learning in building successful entrepreneurs

Introducing a new way of learning bears a total shift of norms, law, regulation, administration, work style, lifestyle, etc. Schools, which are good at providing traditional services, could no longer be competitive if they do not meet the digital requirements. The last one enforces big investments. Besides, teachers, administrators, librarians, parents, students, etc. stick in old ways of learning, and any attempt for adapting them to digital learning appears a challenge. The barrier is not the resistance to change but the lack of qualified IT specialists. Hypothetically, if there is a great supply on the labour market, the prices fall as well as the size of the investment for digitization. Due to the fact, we notice risks, which correlate to each other.

The increasing demand (D) for qualified labour (qL) + its decreasing supply (SqL) multiplies inefficient performance (InEP) + total costs (TC).

$$\nearrow D_{qL} + \searrow S_{ql} \Longrightarrow \nearrow InEP + \nearrow TC$$

The deficiency of good IT cadres and large investment on small teams could lead to bad performance and unnecessary and non-recoverable costs. There are some exceptions, but Bulgarian reality shows that the recruited IT specialists are not so experienced and qualified to make the anticipated digitization. There were successful cyberattacks against some national information systems and registries, which is evidence they are not fault-tolerant and secure. Consequently, there are many losses and they could cause even bankruptcy if those risks are not calculated in advanced to take preventive measures. An interactive digital platform for education could prevent the tendency for a high number of incompetent employers and employees.

Digitization of the learning processes requires more than an ordinary scanning for pure converting existing content of documents and books to digital formats. The content of modern digital textbooks has to be both dynamic and interactive. The last one can be achieved with technologies from the newest generation – like 3D – 12D reality, simulation laboratories, etc. These technologies are very expensive but much more effective. Each country has to use its own technology or to buy from another nation. The first option consumes many resources like time, labour, energy, etc. All enlisted increase the implementation costs. Rapid technological change also magnifies them. Every old technology should be updated or replaced by a new one because as Raychev (2014, p. 16) mentions, innovations have a life cycle. When new products enter the market and they establish there, their quality, called "new" or "innovative" ceases to exist (Raychev, 2014, p. 16). Therefore, only scalable digital platforms can update their life cycle. Scalability allows succession with old technologies/versions as well as integration with new ones.

Education demands for electronic tools for collecting and analyzing students' achievements. Intelligent analytics can help detect implicit relations, as well as to organize data in a new way that is both comprehensible and useful (Atanasova, et al., 2019, p. 7). Sulova (2018, p. 241) considers that social networks are one of the richest sources of information. A properly selected analytical toolkit helps formulate many precise strategies (Sulova, 2018, p. 248). Therefore, her survey describes some available tools for data mining and knowledge extraction. Sulova & Bankov (2019) check and approve social media content-based analysis is applicable in tourism, and more precisely to say in vacation resorts (Sulova & Bankov, 2019). In our opinion, the methods they explore and propose would play a key role in an integrated digital platform for education.

Digital learning requires not only new knowledge, skills and methods but also a new philosophy of teaching. In order to review the new principles, we investigate the key characteristics of a successful entrepreneur.

Josh Downing has a very successful construction business. He is the founder and CEO of Direct Movement Group, a multimillion-dollar custom home building and remodelling business. In an interview, he shares; his success is because of combining speed and quality in providing different services. Therefore, he hires professionals who can do all facets of the construction business. They call them working superintendents that manage and do working duties throughout each job of the construction process. Downing's experience shows that the money follows the good entrepreneur who does not focus on money but focuses on the customers and meeting their needs (Bronner, 2016). The quicker the team completes a job, the more profit they preserve.

According to Burns (2013), there are five key factors, which characterize successful entrepreneurs. They are open-mindedness, strong team, perfection, adaptability, willingness to learn.

The potential business idea, product or technique should be assessed with openness. That requires independence of mind and the courage to try something new even if everybody is sceptical. Only a strong team can fulfil the realization of new ideas. A team of smart, hardworking and responsible people should be formed in advance. Successful entrepreneurs are hardworking perfectionists. Although they always try to bring new and unique products and/or services, it is impossible to devote close attention to every aspect of the business. Burns (2013) mentions the good entrepreneurs delegate, cut corners and do whatever is required. Delegating, however, necessitates well-read and well-bred team. Therefore, here, we see another advantage of a good digital platform for education. In the construction industry, the functionalities of the platform have to be more complicated to prepare skilful people in heterogeneous areas. Constructive processes are various and only well-prepared architects, engineers, workers, etc. guarantee a nicely crafted product or service. If a business has specialists from one area, for example, construction bricklayers, the company depends on bigger ones, but if it simultaneously possesses good architects, engineers, bricklayers, plasterers, painters, cranes, excavators, shutters, etc., it has more chances to survive the market. A digital platform for education and collaboration is a modern tool for achieving that.

The market and trends are not invariable, so entrepreneurs have to adapt themselves. They realize the ground can shift at any time, and they have both willingness and ability to make the required adjustments when it does (Burns, 2013).

There are some rigid entrepreneurs, who after putting a tremendous amount of time and energy into crafting a business plan, it is difficult for them to revise it later to accommodate significant new data. On the contrary, successful entrepreneurs are always prepared and ready for strategy changes. The last ones learn from both successes and failures. They honestly assess the success of a business venture and analyze what happened. They strictly follow innovations, new tendencies and changes, and endeavour to absorb whatever lessons are available. According to Burns (2013) constantly successful entrepreneurs are few because very few people can master all indispensable qualities. Personalities, who do develop and hone these traits, have the potential to excel in whatever business they choose to develop (Burns, 2013).

The comparative analysis of the successful versus unsuccessful entrepreneur is presented in table 1 (see table 1).

Table 1: **A Comparative Analysis of The Successful Versus an Unsuccessful Entrepreneur**

№	Situation	Successful	Unsuccessful
1	Potential business idea	Open-minded	Bigoted
2	Teamwork	Teamworking	Self-working
3	Changes	Adaptive	Inadaptive
4	Problems	Every problem is an opportunity	Every problem is a barrier
5	Learning and development	Endless	Until the purpose has been reached
6	Failure	Motivated to progress	Demotivated for the second attempt

Source: Adapted to Burns (2013)

4. Injection of quantum philosophy and multi-dimension visualization in a digital platform for education[Грешка! Източникът на препратката не е намерен.]

Digital learning is a combination of the complex development of all parts from the brain to the body. There are risks new digital infrastructures to grow old quickly and not to bring the return on investment. To prevent these risks, the new platform should bring the technology of the future. It should be simple but prolific.

We consider that the new infrastructure should operate in 5G network in a way even disabled people to build and to contribute to life. Some quantum principles are based on the convenience that everything is energy and the power of thoughts can create wonders (Hobson, 2012, p. 1-2).

Leibniz (1646 – 1716) describes the world as monads (McDonnell, 2016, p. 281). It resembles some comprehensions of quantum theory. In his system of metaphysics, monads are basic substances that make up the universe but lack spatial extension and hence are immaterial. Each monad is a unique, indestructible, dynamic, soullike entity whose properties are a function of its perceptions and appetites. Monads have no true causal relation with other monads, but all are perfectly synchronized with each other by God in pre-established harmony. The objects of the material world are simply appearances of collections of monads (The Editors of Encyclopedia Britannica, 2019). As Bell (2015) says, we rarely pay attention to new opportunities because we are too busy to contemplate the missed benefits. It is high time to change this thinking and people with real physical disabilities to find alternatives to look upon new activities even in the construction. (Bell, 2015).

Virtual reality can create a material world. We believe that all people with a healthy brain can build their unique world. New digital tools, virtual technologies and robots are able to help their progress. It is assumed that the realization of these innovative technologies is an excessive cost. Therefore, we consider that money and time can be alternatives. On the one hand, money can be spent for the humankind to receive a revolutionary construction change, on the other hand, only time for study and self-study can be spent. Labour is adaptable to the situation. For the developed countries, the first option is better, but for the developing and the non-developed countries, the second option is much better because it allows population retention and development.

Nowadays, software companies make many attempts to digitize the world. They offer many software solutions and online training platforms, which enjoy much interest that encourages their development. Many interactive tools for education are currently supplied on the Internet (Edmodo, Socrative, Thinglink, etc. (Chauhan, 2018)). Some of them support touch screen, 360◦ videos, virtual reality. YouTube influencers and YouTube videos for education also enjoy great interest. When we write on YouTube "How to make", the results undoubtedly show viewers' interest (Different Users, 2019). The bigger part of videos have millions of views. What we make is to centralize the functionalities that each of these platforms offers individually into a single platform that serves the needs of the construction industry.

Our platform has an administrative panel, which is only for administrators but it is beyond the scope of this report. The customer roles are in four categories – educators, learners, software providers and advertisers.

Target areas are **education and business**. The main target groups are four **teachers, students**, **employers, employees** but we also endeavour to attract more groups like IT administration, freelancers, marketing specialists and anyone with the desire to contribute to the platform. Platform users are teachers and students from educational institutions, lecturers (successful entrepreneurs/ employers) and students (workers/ employees) from the business. There are three categories courses: tract builders, speculative builders and custom builders. Currently, five modules support their needs:

Module 1: Digital Inclusion – it allows registration and course enrollment.

Module 2: Innovative Teaching – the module consists of different innovative tools for interaction with teachers.

Module 3: Distance Learning – the learning process can be both real-time inclusions as well as watching later.

Module 4: Videos and 3D Simulations for Laboratory – trainees can use 3D glasses and visual simulation techniques.

Module 5: Collaborative Learning in Virtual Environment – teachers, organizations and students all around the world can share their experience and build a new reality, starting from virtual reality, based on Leibniz's and quantum philosophy.

Our system supports studying by examples and practice – the lecturers or learners share their experience and other participants can repeat their steps by using new software and interactive technologies. The main tool for practising is via 3D modelling and virtual reality.

The menu, entitled "Quantum field", helps find new markets. The functionality is based on Google maps. It provides the opportunity to explore new territories in advanced. That reduces the risk of failure for young entrepreneurs, who have the desire to enter the construction industry but they are not familiar with the business markets.

The modules allow people, who cannot walk to contribute construction industry like projecting, creating and learning their own robots to do things instead of them.

The platform is scalable and it allows integration with any other platform, organization, etc. Our creation is both web-based and mobile, so that people learn anytime, everywhere (see fig. 2).

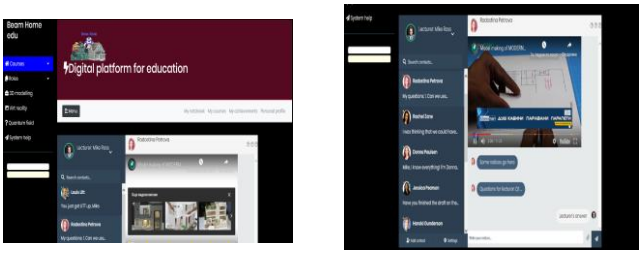


Fig. 2 *Beam Home Edu – Digital Platform for Education*[Грешка! Източникът на препратката не е намерен.]

Source: An author's project with Bootstrap

5. Conclusion

Traditional education methods become less effective because information flow is growing and outdated resources are insufficient to process it. That reflects on people's preparation. Individuals without digital education are not competitive and even robots can replace them. New ways of acquiring knowledge and skills are needed but currently used media like television, computer, the Internet, video games, software products, etc. influence negatively on personal health. On this basis, we propose a complex solution for obtaining new knowledge and skills, which benefits from new ICT. Modern information and communication technologies connect people and knowledge in a network, so a new innovative digital platform for education can reinforce connectivity and turn thoughts into reality. This is especially applicable in construction, where business success requires a variety of competencies in ethics, entrepreneurship, teamwork, conquering new territories, quality assurance and more.

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ANALYSIS OF THE POWER TRANSFORMER OPERATION SUPPLYING A COMBINED NON-LINEAR LOAD IN THE PUBLIC SECTOR - PART II: INFLUENCE OF THE CURRENT HARMONICS

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Abstract: *Much of the technical equipment in energy, industry, commerce and the public sector (electronic equipment, electric motors, furnaces, chargers, uninterruptible power supplies, etc.) are inherently non-linear loads and are sources of harmonic distortion of currents. Non-linear loads adversely affect all components of the power system: they increase losses in transformers and electric motors by thermal loading their windings, increasing dielectric and/or mechanical losses and generally reduce the efficiency of the electrical system. The paper deals with operation of a power transformer that supplies combined non-linear load in a public building.*

KEYWORDS: *ENERGY CONSUMPTION, ENERGY EFFICIENCY, POWER SYSTEM HARMONICS, POWER QUALITY, TRANSFORMERS, ENERGY MEASUREMENT, SMART GRIDS*

1. Introduction

The standard transformers have low temperature tolerances when handling non-linear loads. Until recently, the only solution to power these ones was to choose a larger by power transformer to cope with the additional heating of the windings and the steel core (these states are most often caused by harmonics with number ν = 3, 5, 7, 11 and 13). This solution is economically and technically unacceptable anymore. The degree of handling of such loads and the poor operating results have not been adequately investigated, but it is known that in case of continuous duty with overheating of transformer insulation, the lifetime of the transformer is shortened.

The durability D (in units of time) decreases twice with each temperature rise θ by $\Delta\theta$ about the permissible temperature value for a given insulation class. It has been experimentally found that for Class A insulation $\Delta\theta = 8K.$ For example, at 105^0C the insulation is durable $D = 16$ years, at 113^0C - $D = 8$ years, at 121^0C - $D = 4$ years, etc. In practice, this method of calculation is called the Montzinger rule. For other classes of insulation, $\Delta\theta$ has other values; e.g. for Class B $\Delta\theta = 10K,$ for Class H - $\Delta\theta = 12K,$ etc.

Other disagreeable effects of harmonics are: overheating of neutral conductors and panels, circuit breaker disconnection, grid voltage disturbance, equipment failure, electrical fires, malfunction of controllers, and communication line disruptions.

2. Technical considerations

Electricity is essentially a specific commercial product and as such it must have the necessary qualities. The widespread concept of Power Quality (PQ) means the uninterrupted delivery of electricity to consumers, with grid voltage parameters within certain limits allowing the normal operation of the grid-connected loads. Today, PQ is even more important for two main reasons. They are related to the presence of many modern types of loads, which on the one hand need a good PQ and, on the other, make it worse due to the nature of their action. As an example, it is sufficient to mention the impulse power supplies used in most computer, communication and many other electronic devices, control units of DC and AC motors with variable speed, luminaires, etc. There are numerous areas of human activity where the deterioration of PQ is associated with significant financial losses, notably in continuous production in the industry (according to statistics in the European Union, annual losses in the industry and the public sector due to poor electricity quality are close to € 10 billion The responsibility for the quality of electricity is shared between producers and transmission companies on the one hand and consumers on the other.

A significant and steadily increasing part of the loads, with different functional features, are non-linear, which causes non-sinusoidal currents. This trend makes it increasingly urgent to establish international criteria and a system for assessing the impact of harmonics, but also for recommendations for designers of electrical equipment and technical equipment, because harmonics have long been not a local problem, but rather a global one.

The most significant negative effects of harmonics can be attributed to:

- Zero conductor overload on three-phase groids. The sum of the main harmonic currents of the three phases flowing through it is 0, while the sum of harmonics is not 0 and may even exceed the phase current. According to research, the current in the zero conductor of the electrical grids in public and commercial buildings is 1.5-2 times higher. Undoubtedly, this should be taken into account when designing grids.
- The energy losses in the transformers are increasing, which means additional heating and shortening of the service life.
- Incorrect activation of safety relays and contactors in phases is possible due to increased current amplitude.
- Many control electronic units switch off when the mains voltage goes through zero. In the presence of harmonics, erroneous switch off can occur.
- It is known that the neutral conductor of a three-phase system, which feeds single-phase harmonic-generating consumers, may have a load greater than that of phase conductors (e.g., long three-phase lines, fluorescent lamps without harmonic filters, or a three-phase line that supplies a single-phase switchboard for computers and other office equipment). In such cases, it is necessary to check the cross section of the neutral conductor by collecting the current imbalance between the three phases and the sum of the currents in the three phases of the harmonic components multiples of 3. It is advisable to use four-pole circuit breakers with protection and on the neutral conductor.

The quality of electricity as a specific commercial product is regulated by many standards. For example, EN 50160 "Voltage characteristics of electricity supplied by public distribution systems" is limited to the quality of electricity in low and medium voltage grids and sets acceptable limits for all voltage parameters, i.e. limited to supply facilities without assessing the state of supply and/or impact of loads. There is a need for practical guidance already in the design (or reconstruction) part of energy facilities to address these issues. Such recommendations are given in IEC 60076-7: "Power transformers. Part 7: Loading guide for oil-immersed power transformer ". European manufacturers and consumers follow the recommendations of IEC standards [1]. Although a member of the IEC, the US has its own standards in this area [2]. UK complies with the strict requirements of their G 5/4 standard (for example, direct connection of inverters with a power exceeding 40 kW is not permitted). Basic evaluation criteria, guidelines and recommendations for limiting the harmonics returned to the grid by non-linear loads are also given in IEEE 519-

1992: "Recommended practices and requirements for harmonic control in electrical power systems" [1, 3, 4]. The standard is practically useful for industrial and public three-phase consumers. Non-linear loads in single-phase grids are beyond the scope of the standard. Their poor impact is difficult to assess because it has a cumulative effect. In [5, 6] a typical composition of the complex load for the domestic sector is given: induction motors with low power - 35% and lighting - 65%.

In a three-phase, four-wire system, the zero conductors can be strongly affected by non-linear loads connected to single-phase circuits with a voltage of 230 V. In a four-wire grid with single-phase non-linear loads attached, the odd harmonics multiples of the third harmonic: third, ninth, fifteenth, etc. - are not zeroed but summed to zero conductor. In systems with many single-phase non-linear loads attached, the current in the zero conductor may in fact exceed the phase current. The result is excessive overheating. There are no current limit switches in the zero conductor. Higher current in the zero conductor can also cause additional voltage drop. Zero bars and conductors are generally sized to carry the full value of the rated phase current. They can be overloaded due to an additional sum of current harmonic multiples of three flowing through the zero conductors [7]. For this reason, the sizing of electrical equipment in industry and the public sector in view of the effects of harmonics should be approached responsibly and their selection adjusted to the full power factor taking into account the presence of harmonics:

$$PF = \frac{\cos\varphi}{\sqrt{1+THD_I^2}} \quad (1)$$

Transformers are sensitive to current harmonics because all current harmonics generated by non-linear loads flow through them, exerting different effects simultaneously, all with the result of overheating:

- Increasing losses from stray currents in the windings, proportional to the square of the current and the square of the frequency (the main reason for overloading of transformers by harmonics).
- Increasing the losses in the active resistance of the windings as a result of the current flowing, increasing the active resistance of the skin effect at high frequencies.
- Increasing losses in the steel of the magnetic cores.

The transformer industry is considered to be one of the most conservative, although there is also evolutionary rather than revolutionary development. The main directions are reduction of operating and production costs, application of modern structural materials, increase of reliability and improvement of the used insulating and magnetic materials. Transformers become more economical and energy efficient, more technically advanced and become smart. The new smart solid state transformers have a computer chip that can quickly and efficiently regulate the voltage. This allows efficient load management and optimization of electricity consumption. Such transformers can vary the voltage depending on the consumption, include wind turbines, photovoltaic panels or diesel generators in the home grid. Grid congestion will no longer be a problem and energy will be redistributed, increasing it in low cost hours. Smart transformers can combine several energy sources with different characteristics, starting with a low-voltage grid and ending with a diesel generator if needed. Such a grid would provide uninterrupted power supply without additional complex equipment. In addition, the voltage will be maintained with a view to the stable operation of household consumers. In the US, tests with such smart transformers have been conducted, with up to 3% savings in electricity. One feature of smart grids is the ability to "communicate" between the energy system and the energy provider to provide uninterrupted power supply in an emergency.

Experts have identified the following advantages of these new transformers [9, 10]:

- - Weight reduction and reduction in overall dimensions to almost 40%. This enables the use of smart transformers in operating substations without further structural modifications, under light transport conditions.
- - Reduction of up to 90% of nominal load losses, which significantly increases the efficiency.
- - The new transformers have the capability of limiting the short-circuit current, and this in emergency modes would protect the power system.
- - At the expense of significantly reduced reactance, the transformer without regulation will provide voltage stabilization.
- - High resistance to overload without damaging the insulation.
- - Significantly low noise levels at work.

In addition, these transformers are environmentally friendly and fireproof. Specialists from Toshiba, Mitsubishi Electric and General electric are working in this field to accelerate their deployment [7, 8, 9, 10].

In order for the K-factor to be correctly determined, each load must be identified by its harmonic spectrum and amplitudes. The choice of acting harmonics is a problem in determining the K-factor of the load. It is important to know that for the same non-linear load, the calculations may vary depending on which harmonics we choose to look at. Even small harmonic currents with a high sequence number substantially alter the end result. In the case of combined power supply of different types of non-linear loads, the K-factor of the power transformer is selected equal to the largest of the non-linear loads (otherwise the operation of the transformer is unreliable and unsafe). The advantage of using K-transformers is that they are usually more energy efficient than using a conventional transformer with higher power and lower load. The choice of a K-transformer for a particular non-linear load, regardless of power, does not mean that it is protected from the harmonic components of the voltage (causing the magnetic circuit to heat up), from mechanical stresses or from the harmful influence of the occurring resonance phenomena.

The approach to determining the K-factor used in Europe and the US is fundamentally different. The European standards EN 50464-3 and EN 50541-2, respectively for oil and dry three-phase transformers, give the following formula:

$$K = \left[1+\left(\frac{e}{1+e}\right)\times\left(\frac{I_1}{I_\nu}\right)^2 \times \sum_{\nu+2}^{\nu=N}\left(n^q \times \left(\frac{I_1}{I_\nu}\right)^2\right)\right]^{0.5} \quad (2)$$

where: e is the ratio between the 50 Hz sinusoidal winding losses and the DC losses with the same effective value. If not available as a catalog value, it can be assumed to be 0.1; I_1 is the effective value of the first harmonic current, and I_ν - the higher harmonic currents; ν - harmonic number; q is a constant that depends on the design of the windings. If not available as a catalog value, 1.7 for circular or rectangular coil transformers and 1.5 for low voltage foil winding transformers may be considered.

The K-factor calculated in this way takes values between 1 and 2. The maximum continuous power that a transformer subjected to non-sinusoidal currents can be loaded is reduced by dividing its nominal power by the K-factor. In fact, resizing occurs because a transformer with a higher rated one must be selected for a given operating capacity. From the review made so far, it becomes clear how important it is to identify the location, the nature of the manifestation and the influence of different harmonics on the entire power supply grid. In this case, the purpose is to analyze the operation of a power supply transformer for a public-sector object: a public building with non-linear loads.

3. Research results

In [8], a schematic diagram and measurement results were presented to establish the levels of harmonics in operation. Due to

the possibly poorly designed connection to the individual phases and the combined manifestation of non-linear loads, the uneven load of the three phases was found. For the sake of complete evaluation, we decide to make a K-rating of the load, to measure harmonic levels, to determine the full power factor and to detect errors in the reading of electricity. Analytical evaluation of the obtained results will show us whether the investment in an energy efficient transformer is justified. This would reduce energy losses and reduce environmental impact, as well as reduce repair and maintenance costs.

The power transformer in question supplies various non-linear loads and has the following data: type TMX 630/20-10/0,4 kV, $u_k\% = 4.39\%$, Dy_N5, IP 54, cooling system ONAN. Consumption of energy consumption is two-tariff, low voltage side.

The electrical energy quality analyzer METREL MI 2292 has been used to measure the electrical quantities, with an observed period of 48 hours, counting every 15 minutes. Power, power consumption, harmonic current profile and voltage up to $\theta = 25$ and $\cos\varphi$ are observed for each phase. Consumers in the building are a combined non-linear load for the transformer. The load rating and installed capacity are distributed as follows: lighting - 32 *kW* installed power, K-4; UPS without input filters - installed power 2 *kW*, K-13; servers, computers and peripherals with a total installed capacity of 121.75 *kW*, K-20. There is no indication of the nature of the load on the part of residential customers connected to the separate phases.

The K-rating of the particular combined load is performed according to the recommendations in [1, 2, 5, 8]:

$$P_{LOAD} \times I_{LK} = Index \cdot of \cdot Load \cdot K - ratings \quad (3)$$

Lighting: $32 \times 25.82 = 826.24$

UPS without input filters: $2 \times 57.74 = 115.48$;

Servers, computers and peripherals: $121.75 \times 80.94 = 9854445$.

Or the average value of the load index is obtained as follows:

$$Total\frac{kVA_{I_{LK}}}{P_{\sum LOAD}} = I_{LKaverage} \quad (4)$$

$$I_{LKaverage} = \frac{10796165}{155.75} = 69.32$$

Since the power supply grid is already in place, the evaluation of the load rating is "post factum": the recommended transformer should be less than 630 kVA and K-20.

After processing the data from the specialized equipment, the instantaneous values of the three phase currents can be observed, Fig. 1, and the harmonic composition of each, Fig. 2.

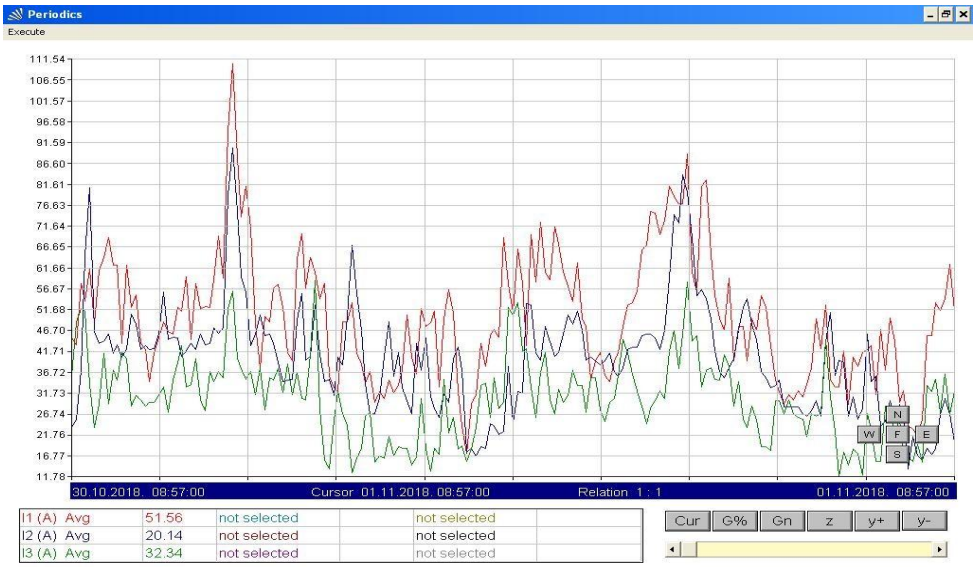


Fig. 1. *Instantaneous values of the observed currents in the three phases.*

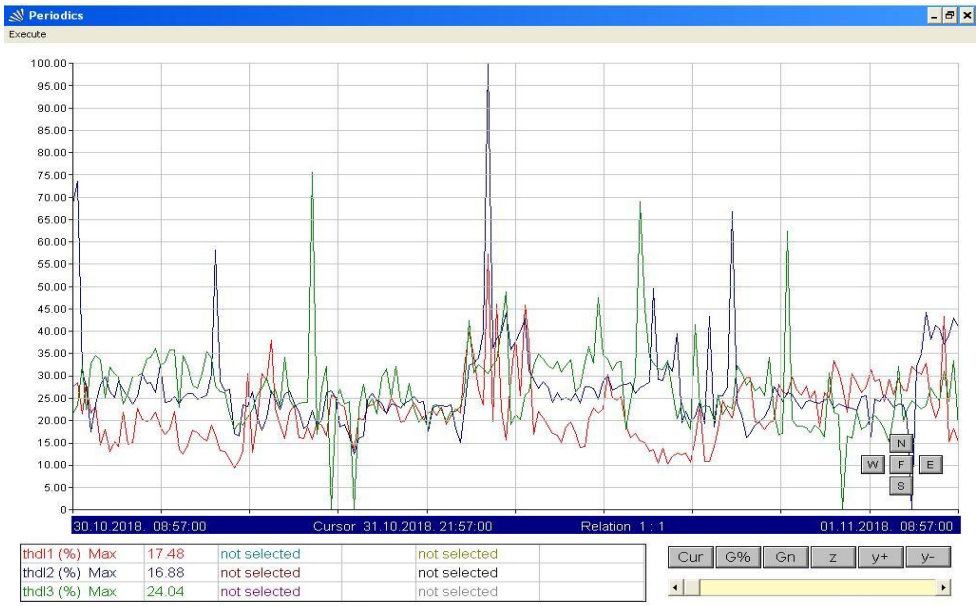


Fig. 2. *Harmonic composition of the three phase currents.*

The data analysis shows uneven loading of the individual phases, close to the limit of moment asymmetry and high harmonic levels, Fig. 3. Phase B is the most disadvantaged: the busiest and with the overall harmonic composition for the observed period $THD_{I2} = 36.94\%$. For this reason, we observe the change in the current and its harmonic composition, Fig. 4.

For a clear understanding of the problem (at what times during the whole observed period the influence of which harmonics is the most unfavorable) and to determine the frequency of manifestation of the individual harmonics with a cumulative assessment of their influence, we solve the constructive Pareto diagram, Fig. 5. The analysis shows the following: the hours during which highly non-linear loads are included are from 8:30 am to 1:00 pm and 1:15 am to 6:15 am; capacities for daytime consumption are in the range 38.8 *kW* up to 92.45 *kW*; capacities for nighttime consumption with a strong non-linear load are in the range 30.62 *kW* up to 40.12 *kW*. With the highest values, harmonics with numbers $\nu = 3,5,7,9,11$ are above the recommended values.

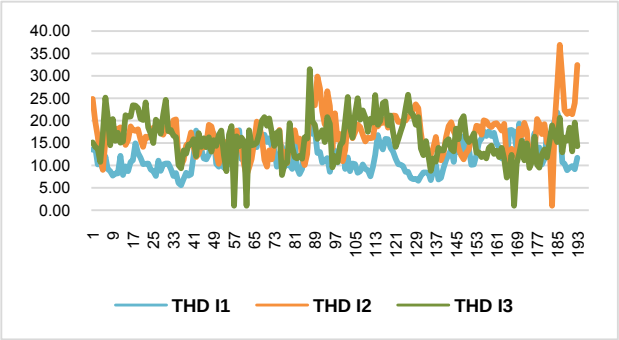


Fig. 3. *Total harmonic distortions for all three currents* THD_I %.

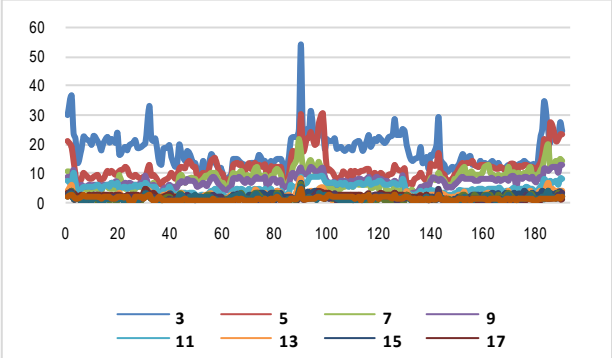


Fig. 4. *Variation of harmonic components (*$\nu = 3$ *to* $\nu = 25$*) of the current of the second phase* I_2*, [A].*

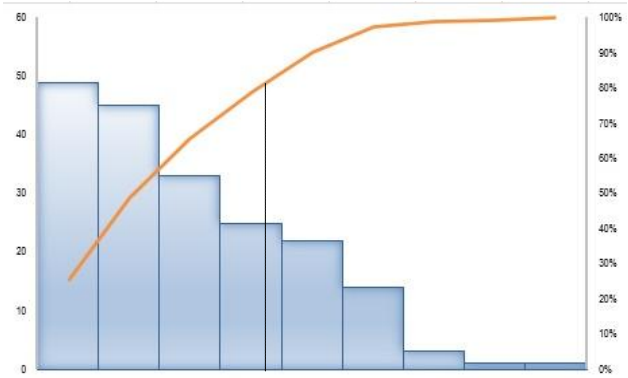


Fig. 5. *Pareto diagram for the distribution of data according to the frequency of manifestation with the cumulative line.*

4. Conclusions

The treated transformer supplying the combined non-linear load operates at load level $\beta = 4.86 \div 14.67\%$ at $THD_{I1max} = 39.88\%$, $THD_{I2max} = 68.45\%$, $THD_{I3max} = 64.45\%$ or there is a classic case of a oversized transformer. In case the track is to be reconstructed and other single-phase users will be connected to the individual phases, it is recommended to choose a transformer with less power and a K-factor 20 with a uniform phase load.

Since transformers are very expensive equipment and in order to avoid the constant inconvenience for consumers of wasting money and energy, it is necessary to determine the winding losses at going current values. Losses in the windings due to eddy currents are generated due to skin and proximity effects and have not yet been determined. It is recommended to use filters to suppress the influence of the harmonics.

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BIOECONOMICS - A STRATEGIC SECTOR IN THE CIRCULAR ECONOMY

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Abstract: *The concept of a circular economy is a model of production and consumption that minimizes waste in the environment. It brings benefits not only to nature but also to the economy and society as a whole. This is a model aimed at extending the product life cycle. When a product reaches the end of its life, the materials of which it is composed continue to be reused. This is repeated many times to minimize waste disposal. In practice, this means sharing, borrowing, reusing, repairing and recycling existing materials and products as long as possible. The bio- economy in the European Union is growing much faster than the rest of the economy, which will lead to the creation of more jobs and the continuation of the digital transformation of the European economy. Bio-economy covers all sectors and systems that use biological resources. It is one of the largest and most important sectors of the EU and includes agriculture and forestry, fisheries, agro-food, biomass and bio-based products. Its annual turnover is about 2 trillion euros, and it employs about 18 million people. Bio-economy is also a key area for stimulating growth in rural and coastal areas. The new bio-economy strategy fits in with the Commission's efforts to further boost jobs, growth and investment. It aims to improve and expand the sustainable use of renewable sources to overcome global challenges such as climate change and sustainable development. The purpose of the study is to analyze the situation in Bulgaria for the development of the bio- sector in terms of production capacity, potential for growth of the bio-production sector, to study the conditions, difficulties and prospects for the development of exports of bio- products. The analysis will serve to evaluate the opportunities for Bulgarian bioeconomy development, the innovation encouraging measures in this sector and the diversification of this sector. The results of the Bioeconomy research distinguish strategic areas: sustainable consumption and production through responsible consumers and producers; knowledge society through information development and training; government to help adapting to new business realities; climate change and energy; sustainable transport and mobility; conservation and sustainable management of biodiversity and natural resources; public health and risk prevention with an emphasis on environmental quality; demography and migration and social inclusion; challenges in the field of sustainable development; global poverty reduction.*

Keywords: BIOECONOMICS, CIRCULAR ECONOMY, IINDUSTRIAL SYMBIOSIS, SUSTAINABLE DEVELOPMENT

1. Introduction

The concept of a "circular economy" emerged in the second half of the twentieth century, although the idea for it was very old [1]. One can even say that it has emerged since the emergence of economic relations, but as a result of rapid economic boom and industrialization has been left in the background [2].

A more in-depth study of human history shows that so far, economic relations have been largely circular [3]. Materials that have been used to produce various goods over time, have either been incorporated into new ones or have been discarded, but due to their organic nature, have decomposed [4].

Until the twentieth century, there were virtually no synthetic materials, such as plastic products today,that cannot be degraded naturally in nature [5]. As a result of technological advances beginning in the mid-19th century, a linear economic model has gradually emerged whereby raw materials are used to create goods and are discarded after their useful lives. It relies on access to large quantities of cheap materials and energy sources. The point is that in order to increase sales, manufacturers build defects in appliances to stop working after a certain warranty period or after a certain number of cycles, and thus force consumers to buy new ones [6].

All this leads to the creation and maintenance of landfills for non-consumable goods, but due to the presence of toxic substances in the composition of some of them initiate pollution processes in the environment [7]. Environmental pollution - the atmosphere, water and soil, in some industries - begins with the extraction of raw materials and the production of products.

In recent years, there have been a number of alarming phenomena related to climate change, environmental pollution and poor quality of life [8]. These phenomena reveal the weaknesses of the linear model in economic development according to which goods are produced, then consumed and finally discarded, without looking for ways to reuse them [1], [9].

Unlike the traditional linear economic model, the circular economy model offers a different approach - once they fulfill the functions for which they are created, goods (various objects and materials) need to be recycled in order to become a resource again. In this way, the materials used are transformed into a resource for the production of new products and rotated in a closed cycle, achieving a state of the economy without waste [10], [11].

2. Exploration

The bioeconomy covers all sectors and systems that rely on biological resources (biomass from animals, plants, microorganisms, including organic waste), their functions and principles. It includes and interconnects: terrestrial and marine ecosystems and the services they provide; all primary production sectors using and producing biological resources (agriculture, forestry, fisheries and aquaculture); and all economic and industrial sectors that use biological resources and processes for the production of food, feed, organic products, energy and services [12]. For the European bioeconomy to be successful, it must be based on sustainability and circularity. This will stimulate the renewal of our industries, the modernization of our primary production systems, the protection of the environment, and improve biodiversity.

Bio-economic research is still in its infancy, but is viewed as a renewable segment of the circular economy that makes bio-waste and residues a new valuable resource. The aim of the bioeconomy is to build an innovative low-emission economy that integrates the requirements for sustainable agriculture while protecting biodiversity and the environment. The combination of economic models and environmental management methods with empirical biology contributes to the more efficient management of the eco-resources offered by a biological system. The application of eco-resources in the circular economy model presents the bioeconomy as a renewable sector in the circular economy, which makes it an integral part, structure-determining and strategic factor in the circular economy.

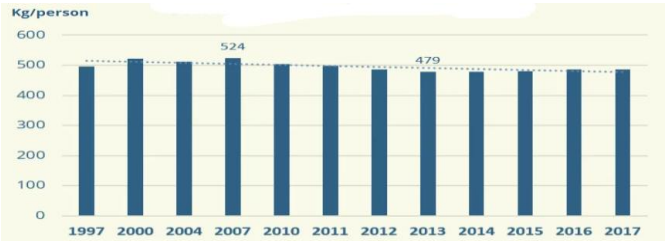
According to data from the European Commission's Research Center, bio-economy turnover by 2018 across the EU is over € 2.3 trillion. The workforce employed in various sectors (mainly the agricultural and food sectors) accounts for 8.2% of the EU-wide workforce28, representing over 18 million people. According to industry estimates, over one million new jobs could be created in the bio-industry by 2030. A strong and fast-growing ecosystem of start-ups will play a leading role in realizing this potential. These indicators place the bioeconomy among the key elements for the successful functioning of the EU economy [13].

In practice, the circular economy involves minimizing waste. When a product reaches the end of its life cycle, its constituent materials are stored within the economy for as long as possible.

They can be used over and over again, thus creating added value. Measures leading to a circular economy include the reuse, repair, refurbishment and recycling of existing materials and products. What turns into waste is a valuable resource [14].

To date, most of the world's leading economies have recognized the need to move from a linear to a circular economic model and make it a priority for their economic development [15].

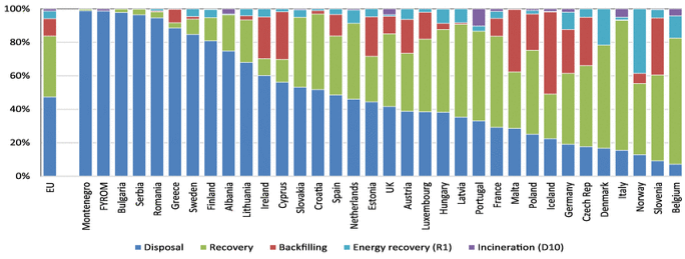
The main objective for EU countries is to reduce their waste, in line with the European Commission's strategy for the transition to a circular economy, where waste is prevented and materials are recycled. According to the latest Eurostat statistics, there has been little progress towards reducing waste across the EU by 2018. (fig.1) EU28 countries generated 487 kg of waste per person in 2017. These are only eight kilograms less than the 496 kg generated in 1997, when data for the first time were recorded in this direction.



Source: Eurostat

Fig. 1 Waste generation for the period 1997-2017, EU

Each country treats its waste differently. The data for 2017 are presented in Figs. 2 and provide detailed information on the type of waste treatment activities that have been used in different countries by 2018. The graph shows that virtually no waste is sent to landfills in Belgium, Slovenia or Norway.



Source: Eurostat

Fig. 2. Waste treatment in EU countries, 2018

Changes in waste treatment operations between 1995 and 2018 at EU level are shown in fig. 3 and 4. A significant decrease in the share of landfill can be observed, at the expense of an increased share of recycling, composting and incineration. Thus, the share of recycled waste increases from 11 to 29% between 1995 and 2018. Recycling and composting together represent 45% in 2018 compared to waste generation compared to 17.5% in 1995. This change may is also observed with respect to a significant increase in the use of energy recovery burns (R1) compared to non-energy recovery burns (D10).

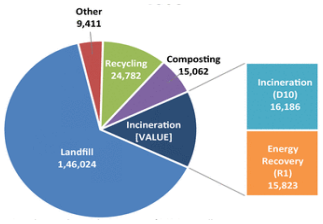
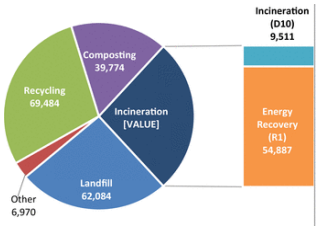


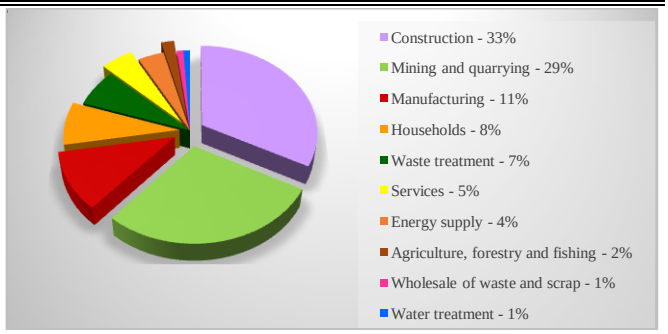
Fig. 3 Waste distribution in the EU, 1995



Source: Eurostat

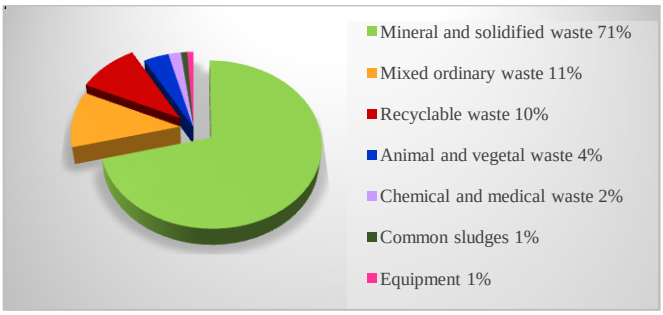
Fig. 4 Waste distribution in the EU, 2017

A breakdown of the economic sectors for 2018 year and the types of waste they generate are presented in Fig. 5 and Fig. 6.



Source: Eurostat

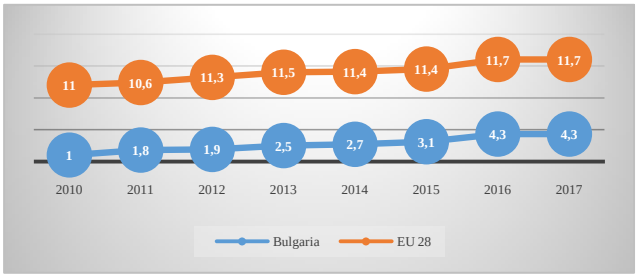
Fig. 5 Waste generated by economic sectors in the EU



Source: Eurostat

Fig. 6 EU-generated waste types

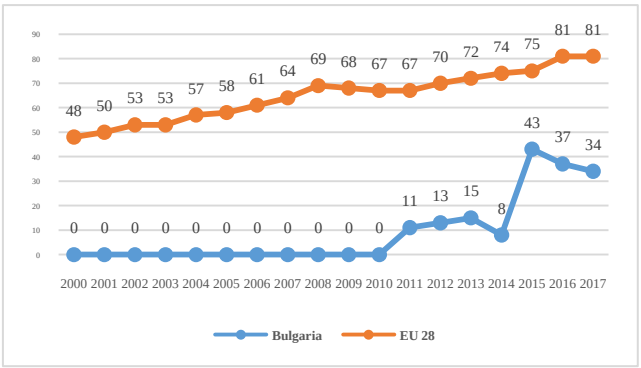
For the period 2010-2007, the level of circular use of materials across the EU has been gradually increasing. (Figure 7) By this indicator, Bulgaria also reports progress, but at levels much lower than the EU average. If we keep the pace until 2022, our country may reach the European average.



Source: Eurostat (CMU)

Fig. 7 Use of materials in the circular economy

By 2010, bio-waste is practically not recycled in Bulgaria (Fig.8). After 2015, when the circular economy policy is adopted, Bulgaria is beginning to improve its indicators in this direction. The recycling of bio-waste shows how the idea of closing the circular economy is developing and to what extent it is closed.



Source: Eurostat (CMU)

Fig. 8 Bio-waste recycling kg / person

2.1. Potential opportunities

Moving towards a more circular economy has both an environmental and economic rationale. Potential opportunities include:

- **Reduced pressures on the environment**: a circular economy would significantly reduce greenhouse gas (GHG) emissions through better waste management[3] and reduced use of resources (such as energy, water, land and materials) in manufacturing, with positive impacts on the climate. Large-scale reuse of raw materials could help reduce landscape and habitat disruption as well as marine littering, which would in turn help to limit biodiversity loss.
- **Enhanced security of supply of raw materials**: a circular economy would mitigate risks associated with the supply of raw materials, such as price volatility, availability and import dependency. According to Eurostat data, the EU currently imports, in raw material equivalents, about half the resources it consumes.[4]
- **Increased competitiveness**: a circular economy could bring savings to businesses and consumers through improved resource efficiency. A 2015 Ellen MacArthur Foundation report estimates that by 2030, a shift towards a circular economy could reduce net resource spending in the EU by €600 billion annually, bringing total benefits estimated at €1.8 trillion per year once multiplier effects are accounted for. Additionally, research suggests that stricter environmental legislation can provide a competitive advantage to businesses.[5]
- **Innovation**: a circular economy could trigger a large innovation drive across sectors of the economy because of the need to redesign materials and products for circular use. The McKinsey & Company consultancy highlights that this would apply even in sectors not normally considered as innovative, such as the carpet industry.
- **Growth and jobs**: a circular economy could strengthen growth and create new jobs. It is estimated that the transition would increase GDP by 1 to 7 percentage points by 2030, depending on whether a higher pace of technological change is taken into account,[6] and that it would have an overall positive impact on employment,[7] although jobs in specific sectors could also be threatened.

2.2. Potential challenges

A transition towards a more circular economy would face a number of barriers and challenges. Potential challenges include:

- **Finance**: a transition to a circular economy would involve considerable transition costs, such as R&D and asset investments, subsidy payments to promote new business models, and public investment in waste management and digital infrastructure.[8] For businesses, in particular small and medium-sized enterprises (SMEs), the cost of 'green' innovation and business models is considered as one of the major barriers to the adoption of more sustainable practices. The lack of appropriate finance tools for mass market development of radical innovations is also seen as an issue.
- **Key economic enablers**: a series of key economic enablers are lacking, inter alia, pricing systems encouraging efficient resource reuse and reflecting full environmental costs; incentives for producers and recyclers to work together in order to improve performance within and across specific value chains; and markets for secondary raw materials.
- **Skills**: a circular economy would require technical skills which are currently not present in the workforce. Skills would for instance enable businesses to design products with circularity in mind, and to engage in reuse, refurbishment and recycling. Missing technical skills could be particularly problematic for SMEs.
- **Consumer behaviour and business models:** a circular economy would require systemic shifts in consumer behaviour and business models, with implications for everyday behaviour, in terms of waste sorting and food waste for instance. Many industries are currently based on a fast turn-around driven by fashion (typified by fast fashion in clothes and electronic devices, among others). Businesses and consumers have little knowledge about the potential benefits of a circular economy and tend to be reluctant to adopt new business models (e.g. leasing rather than owning).
- **Multi-level governance**: a transition to a circular economy would require action at many levels (e.g. international, European, national, local, business, and individual) and in many policy areas (e.g. waste management, professional training, packaging and product design, research and development, and finance). External trade aspects and existing EU policies such as the internal market would have to be taken into account.

2.3. A new circular economy package

The European Commission put forward an initial circular economy package in July 2014, but withdrew the legislative proposal on waste included in the package in February 2015, in order to make way for new proposals. On 2 December 2015, the European Commission presented its new circular economy package containing a communication (action plan for the circular economy, together with a list of measures in annex) and four legislative proposals on EU waste policy.[9]

Among the main measures put forward in the **four legislative proposals on waste policy**, the following can be underlined:

- setting **new waste management targets** to be met by 2030, in particular increasing the share of municipal waste prepared for reuse and recycling to 65%, increasing the share of packaging waste prepared for reuse and recycling to 75% (with specific targets for various materials used in packaging), and gradually limiting municipal waste landfill to 10%;
- introducing an **early warning system** for monitoring compliance with targets;
- setting minimum requirements for **extended producer responsibility** schemes and differentiating the contribution paid by producers on the basis of the costs necessary to treat their products at the end of their life;
- promoting **prevention** (including for food waste) and **reuse**;
- streamlining provisions on **by-products** and **end-of-waste** status (the stage at the end of the waste treatment process when materials are no longer considered waste, provided they meet certain conditions);
- aligning **definitions**, **calculation methods** for targets, **reporting obligations** and provisions on delegated and implementing acts.

The **action plan for the circular economy** aims to close the loop by complementing the measures contained in the legislative proposals and to contribute to meeting the United Nations Sustainable Development Goals (SDG) adopted in 2015, in particular Goal 12 on sustainable consumption and production. The action plan highlights several broad areas for action besides waste management:

- Regarding **production**, the Commission intends to improve product design by promoting the reparability, durability and possibilities for upgrading and recycling of products through the Ecodesign Directive and extended producer responsibility schemes. It also intends to foster resource efficiency in production processes and to facilitate industrial symbiosis (turning one industry's by-product into another industry's raw material) in order to reduce environmental impacts and to create business opportunities, in particular for SMEs.
- Regarding **consumption**, the Commission intends, among other things, to better inform consumers about the sustainability of products through labelling, to encourage innovative forms of consumption (e.g. sharing products or consuming services rather than products), and to integrate requirements promoting a circular economy in 'green' public procurement.

- The Commission intends to help create **markets for secondary raw materials** by setting quality standards for materials recovered from waste, encouraging nutrient recycling in fertilisers, and promoting non-toxic recycling cycles. It also intends to facilitate the safe **reuse of treated wastewater**.
- The Commission proposes to promote **innovation** for a circular economy through a series of existing instruments (e.g. the research framework programme Horizon 2020), to foster new **skills** within the workforce, and to engage with **stakeholders** through sectoral platforms.
- The Commission plans to propose a **monitoring** framework for the circular economy by building on existing indicators.

The action plan presents measures in **five priority sectors**: 1) plastics, 2) food waste, 3) critical raw materials, 4) construction and demolition, 5) biomass and bio-based products. On **marine litter**, the Commission retains the aspirational objective set in 2014 to reduce marine litter by 30% by 2030. On **food waste**, the Commission indicates that it is committed to the 2030 target set in the Sustainable Development Goals to 'halve per capita global food waste at the retail and consumer levels', inter alia, by developing a common methodology to measure food waste and clarifying EU legislation on waste, food and feed.

Across these areas and priority sectors, several **types of measures** can be identified, inter alia:

- **legislative measures**: e.g. putting forward a revised Regulation on fertility and a proposal on water reuse for irrigation, integrating circular economy requirements in implementing measures under the Eco design Directive;
- **communications and reports**: e.g. communication on waste-to-energy, strategy on plastics, report on critical raw materials;
- **implementation and enforcement**: e.g. on waste shipments, end-of-life vehicles, or food donation and use of former foodstuffs for animal feed;
- **guidance and best practices**: e.g. integrating waste management and resource efficiency in Best available techniques Reference documents (BREFs);
- **indicators**: e.g. developing indicators to measure food waste and to assess the lifecycle environmental performance of buildings;
- **standards**: e.g. developing standards for recycling of electronic waste and batteries, promoting voluntary standards for the recycling of construction and demolition waste;
- **support**: e.g. improving the exchange of information between manufacturers and recyclers of electronic products, setting up a pilot project addressing possible regulatory obstacles for innovators;
- **financing instruments**: e.g. encouraging uptake of funding under the European Fund for Strategic Investments (EFSI) and cohesion policy funds for the circular economy.

Besides these measures, the Commission intends to **consider possible options** – such as the need to ensure the non-toxicity of recycled materials, the contribution of the bioeconomy to the transition, the improvement of date labels on food, or financial support for the transition to a circular economy.

Conclusion

The environmental approach, in Bulgaria, as a reflection of the broader concept of sustainability, is reflected in Bulgaria's National Environmental Strategy; The National Environmental and Health Program; in the Innovative Strategy for Intelligent Specialization of the Republic of Bulgaria 2014-2020. In Bulgaria, however, there is a lack of statistical information on the supply and demand of bio-products and bio-services. It is necessary to analyze the structure of production and consumption of these products. Financial measures should be combined with marketing measures to support these products. Last but not least, financial incentives are needed to start and expand the bio-sector in Bulgaria. The competitive advantages of the bioeconomy need to be widely publicized. It is necessary to develop a Bulgarian strategy so that these measures can be included in the operational programs for the coming years.

Economic progress leads to the depletion of natural traditional resources. The problem stems from the fact that the deficit covers not only non-renewable, but also renewable resources - those of ecosystems and biodiversity. The destruction of nature, which is the basis of human life, has its negative social consequences - it increases poverty and disrupts the structure of production and consumption. On the other hand, renewable resources are not valued in a decent way, which puts them at a further risk of destruction.

All of the above determines the transition to a bioeconomy and sustainable development economy. Addressing environmental issues necessarily requires macroeconomic political intervention. So far, unfortunately, no realistic model of society has been proposed that is in line with environmental values and often environmental issues become an election tool for manipulating the public.

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CIRCULAR ECONOMY OF FOUNDRY INDUSTRY 4.0

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Abstract: *The use of mathematical models of control processes in foundry such as: K-test and Chemical spectral analysis is a good set of mathematics (thermal conductivity theory) and theoretical physics (first-order phase transition) are important elements for ensuring high quality castings in micro-foundries.*

The idea of estimating the overheating of a liquid metal alloy based on the appearance of a curing process upon filling has been developed. These control processes combined with zone refining are an important opportunity to create a waste-free foundry in a circular economy in Industry 4.0.

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Keywords*: CIRCULAR ECONOMY, FOUNDRY, INDUSTRY 4.0, CONDITION OF MICROSTRUCTURE*

1. Introduction

The Industrial Revolution [1] is taking place without being interested in the enormous changes that are also causing concern for a huge number of people - not just jobs are disappearing, but entire industries are disappearing. This change requires a very good knowledge of the complete knowledge (profound changes in the education system) of the “meaning and personal orientation of each worker” [2]. The need for knowledge transfer in even the smallest family (micro-foundry) is considered in work [2] and is shown by net picture:

K N O W L E D G E	⇨ TRANSFER
PHYLOSOPHY - Methodology of Science	↓
Mathematics and Foundation of Mathematics / Fundamental Experiments and Mathematical Physics	INNOVATION
Ecology / History and XXI Century	↓ TECHNOLOGY

Fig. 1 *Subject of Knowledge Transfer → Innovation → Technology [2].*

The term ecology was coined by Greek philosophers Hippocrates and Aristotle in the study of nature. The term ecology was coined by Greek philosophers Hippocrates and Aristotle in the study of nature. The German scientist Ernst Haeckel in 1866y introduced the idea of ecology, which is today a very important interdisciplinary science and, but also the basis for an almost "revolutionary technological" policy [2].

Today it is still used, and the way of thinking is linear economy raw materials - production - product - product life – waste. An essential part of sustainable development is based on a circular economy [3 and 4]. In the foundry [5], castings are turned into waste after use, but in a circular economy they are transformed into raw materials - secondary materials (meals or alloys). For this reason, the European Commission has introduced 54 measures to create a circular economy. The use of secondary alloys is controlled by a K-test by monitoring the percentage of non-metallic impurities [5]. A mathematical model of solidification of castings in the form of K-test has been created. In Fig. 2 shows a general view of the non-stationary solidification temperature field in this test at one point in time.

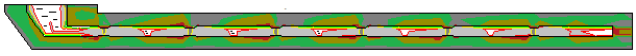


Fig. 2 *Temperature field at some moment in in the time from Stefan-Schwartz 3D problem.*

In the following Figure 3, we present the open thermodynamic system cast/mold through the finite element method and only one isotherm to identify the solidification process. The open thermodynamic system is shown with:

Commonsense and parts with serial numbers

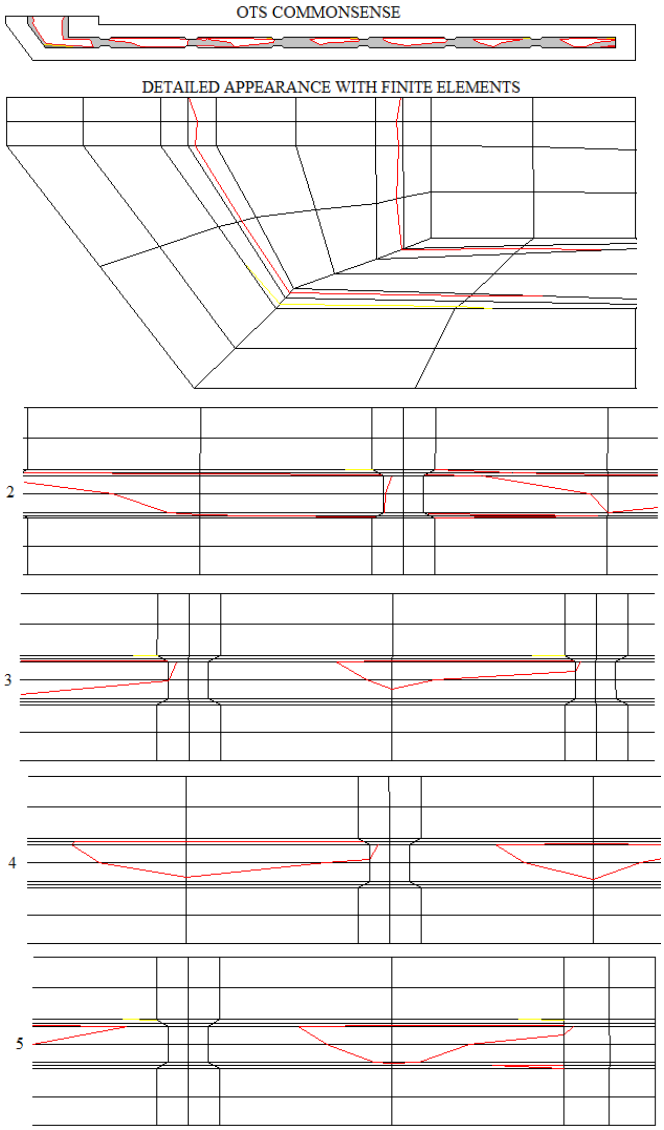


Fig. 3*. Open thermodynamic cast/mold system K-test describe by Finite elements method. An isotherm (red color) only in the volume of cast. OTS commonsense and detailed appearance with Finite elements method.*

The K-test form has protrusions that cause local vortices and help the concentration of unwanted impurities that is observed. Each subsequent melt-down for the use of end-of-life products is subject to a K-test [2, 5 ÷7].

The purpose of this work is to show the capabilities of the numerical description of the Stefan-Schwartz task of supporting and creating criteria for the circular use of secondary and fresh (primary) alloys in non-waste foundry by K-test & Chemical spectral analysis [2, 5 and 6].

2. Numerical Results of the Filling process of the cast of K-test and cast of Chemical Spectral Analysis

K-test is introduced on Figure 4 as follows: three identical consecutive time intervals, for the sake of clarity, the process is shown only in the casting, (but task is Stefan-Schwartz); follows the end of the filling: the cast in the mold for better system visibility and finally the full temperature field of the system:

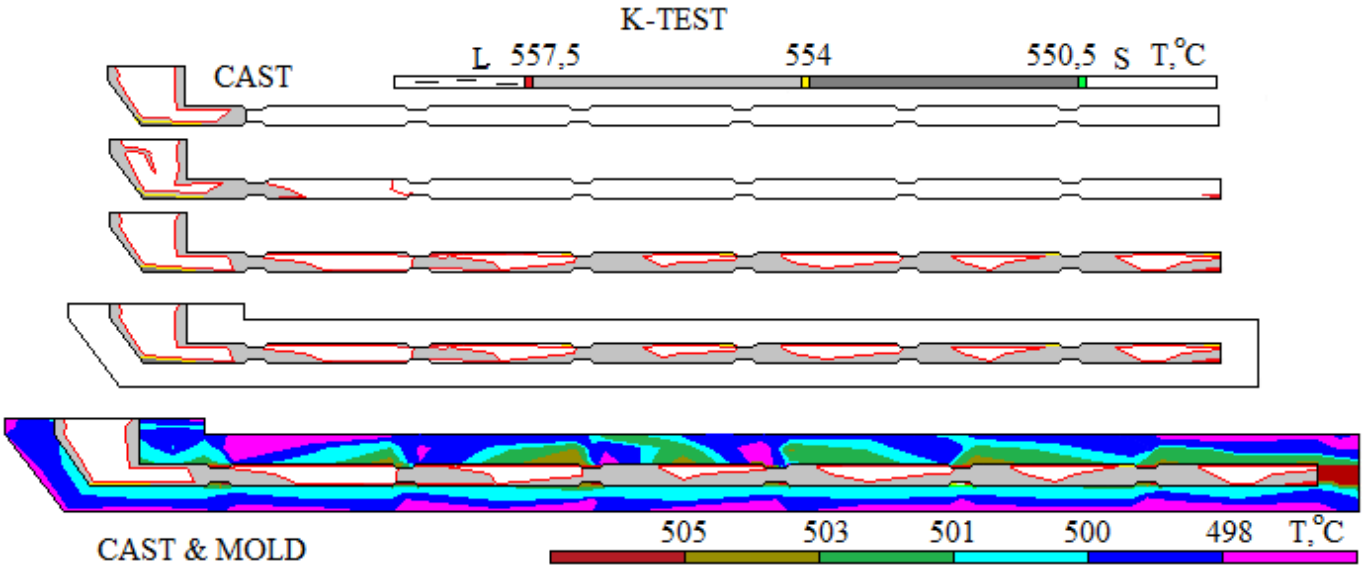


Fig. 4 *Filling with liquids the mold of the K-test.*

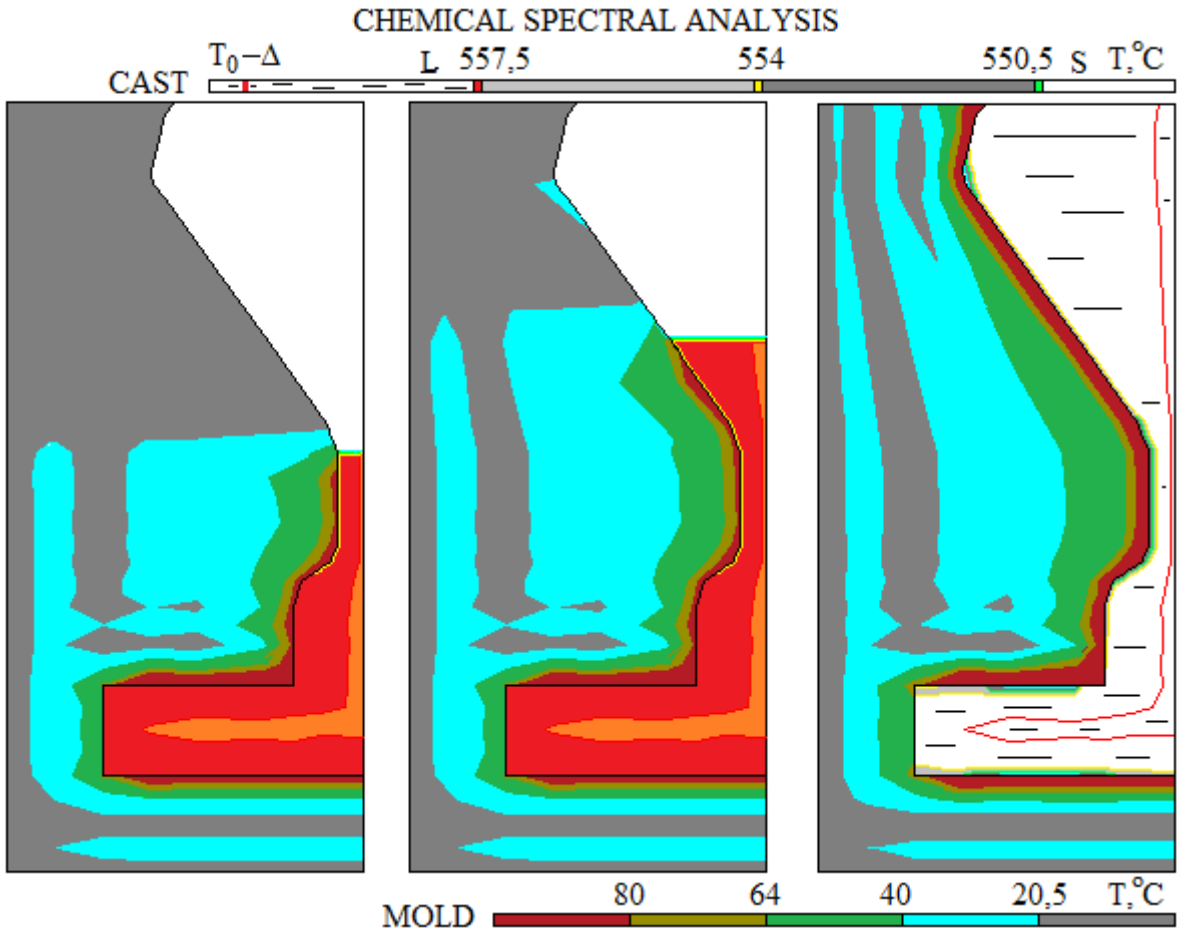


Fig. 5 *Filling with liquid alloy the mold of the Chemical spectral analysis. These test is important: just before casting and overheating estimation (T_0-Δ) by solidifying the narrow portion of the channels between the overflow and the sample.*

3. Overheating estimation by Chemical spectral analysis

To estimate the intensity of heat transfer in the cast/mold system in the chemical analysis, we propose that the value T_0-Δ, where T_0 is the initial temperature of the liquid phase and Δ is the tolerance. In the concrete case, T_0 = 664 ^{o} C, and the melt isotherm shown is T = 660 ^{o} C. Thus, at the end of the filling at Δ = 4 ^{o} C.

At the end of the filling, crystallization begins. Heat exchange is the maximum possible for the macro-scale process, which is very difficult to accomplish. Computational physics is expanding its capabilities here.

Parameters: initial melt temperature; the coefficients of heat transfer at the working and external surfaces of the mold are fundamental to the mathematical basis of foundry - the Stefan-Schwartz problem [2, 5÷7].

4. Ecology and Circular Economy

Waste-free foundry is naturally controlled by the processes demonstrated above. The K-test monitors the use of secondary alloys by the number of melts and concentrations of undesirable impurities. The chemical analysis is directly related to the microstructure of the castings. Summarizing the results of the two analyzes allows each foundry to create a specific database.

A very important process is also the melting zone as refining of the secondary alloys after the allowable number of melts. Thus, secondary alloys are an important source of raw material for both fresh metals and reclaimed primary alloys.

This combination of processes: K-test, Chemical spectral analysis and zone refining can also be applied to semiconductor materials, production of mono-crystal castings, etc. In 3D printer technology, a combination of the processes presented is also used. Similar possibilities for applications are in micro-casting technologies.

Precision software is very convenient for high-tech micro-foundries. With the help of computational mathematics and mathematical physics, the direction for digitalization is also in the polar. What is more, creating smart factories without people [1, 2, 3, 4, 5, 6, 7}.

5. Conclusions

The mathematical models of the K-test and the Chemical Spectral Analysis allow us to determine the initial temperature conditions for each technological casting process.

The combination of the K-test, the chemical spectral analysis and the zone refining allow us to analyze and create a circular economy on a small geography scale, i.e. of interest to the micro-foundries.

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COMPARISON OF METHODS FOR EVALUATING THE ENTRANT'S CHOICE OF THE UNIVERSITY

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Abstract: *The article is a continuation and a generalisation of a series of copyright publications on the problem of choosing a higher education institution by entrants and their parents. Instead, the article emphasises the need to consider the interests of both parties: the entrants and the legal entities that act as investors of the educational process with the intention of getting a specialist for their organisation (enterprises, institutions) in the future. At the same time, an important aspect is the use of the proposed indicators by the university as a provider of educational services.*
KEYWORDS: *ENTRANT, ENTRANT'S FAMILY, UNIVERSITY, STUDENT'S ANNUAL EXPENSES, THE RATIO OF THE STUDENT'S EXPENSES AND HIS FAMILY'S INCOME*

1. Introduction

Choosing a university to study is an important life step for every young person. It is equally important for the family of entrants, as well as for the universities and the regions where these universities are located. Recently, when choosing a university, they try to use such an indicator as a ranking. However, there are many rankings. They reflect individual achievements in the field of science, education, logistics, presence in the Internet space, feedback from employers, prominent graduates, and finally the employment prospects of graduates. Some rankings are applying for an integrated assessment of each university's place in the global field of education [1;2;3;4;5;6, etc.].

2. The proposed methodology of interstate comparative analysis of educational investment capacity of individuals

The proposed methodology is taking into account the interests of all key stakeholders of the educational process, namely the entrant and his family, government and management of the state, region, community, university.

The decision on admission to study at the university is important for all participants in the educational process. Firstly, of course, one should consider the interests of the entrant who, from the position of a young person who has completed high school education (the gymnasium, secondary school, college, etc.), seeks to obtain a prestigious profession with an educational qualification of a Bachelor or Master. In this case, the prestige should be understood as a whole range of aspirations of a young man. This applies in the future, after graduation, to remuneration and high social status of the profession, as well as to a worthy career opportunity. It is not possible to list all the aspirations, as they depend on the individual. Some people expect from the profession not only material well-being, but also a prominent position in society, perhaps even internationally. It is enough for other people to get material fortune and quiet office work. Everyone counts on their abilities. The main thing is not to exaggerate in your aspirations the level of your intellectual abilities. For these reasons, you should properly orient yourself in the choice of profession, narrower - in the choice of specialty, more in the choice of educational institution, in which it will be comfortable to acquire knowledge and skills, to communicate with fellow students who have the same or similar life goals and values. In addition to the entrant himself, his family's views on studying are also important.

So, secondly, the plans, values and perspectives of the family on the entrant's education are important as well. After all, the family takes the responsibility to fund tuition. Of course, nowadays there are students who have the opportunity to pay for the specialties they consider necessary for their business activities. However, these are already seniors who may be getting a second higher education. Some people lack legal knowledge, others lack economic training, marketing, accounting or finance, logistics, etc. Speaking about paid education at universities, it should be noted that in Ukraine the further, the more students will study at their own expense, that means family funds. This is not in line with trends in European countries where there is no direct tuition payment, such as in Austria, Germany, Finland and some other countries [7;8;9;10]. At the same time, the importance lies in such characteristics of the future profession, which sometimes consist in the possibility to return the money invested in studying to the investor - family, and sometimes depend on the opportunity to return after obtaining the necessary profession, specialty to the family business. There may be a great variety of family requirements that are also difficult to predict, and even more so to consider combinations of such requirements that reflect the views of family members.

Thirdly, the interests of the state, region, or community should not be overlooked. The state expresses its interests by financing free of charge studying in those professions and specialties that are essential for the public sector. These are certain professions for the civil service, and some socially significant professions in the service, manufacturing, and public sector industries, as well as in training for socially disadvantaged citizens. State support is also needed for talented people who cannot rely on family fortune. At the same time, such persons may in the future return to the state through their professional activities much more than will be spent on their education. Simply put, a person studies from 4 to 10 years when talking about gaining not only a bachelor's or master's degree, but also a PhD. However, effective work lasts much longer, from 35 to 50 years. During such a period a person really has time to repay to society his "debts".

Regional orders may also consider these factors. A particular community, whether united territory unit or otherwise (for example, national, religious, linguistic, etc.), may also financially support certain university entrants. Of course, investing in the training of individuals by regional authorities or individual communities may require them to work for a period of time in the region or in the

community. Such agreements have existed before, exist today and are eligible for future use.

Fourthly, the universities are the stakeholders. On the one hand, the university is a provider of educational services and a recipient of tuition fees. On the other hand, it may also act as a customer and investor of the educational process for such a student, who in the future may become an employee of the university (teacher, researcher, specialist, etc.).

Thus, there may be a number of interested individuals and legal entities for whom the training of a certain specialist (bachelor, master, PhD) is necessary to ensure a certain type of economic activity.

The results of our research were presented at scientific and practical conferences and published in a number of publications [11;12;13;14;15]. However, there is a need to compare results by different approaches, to summarise those conclusions that are formalised to a single system. After all, in the aggregate, our indicators for evaluating the prospects of studying at a particular university can form a system of multidirectional assessments and create the prerequisites for making a truly objective and optimal decision. At least, this may relate to the cost estimates of alternative study projects at different universities in Ukraine or abroad. Therefore, the problem is the need to compare different options for the cost assessment of the feasibility of choosing a university by the entrant.

3. Prerequisites and means for solving the problem

The prerequisite for solving the problem of comparing different indicators of evaluating the feasibility of choosing a university is to identify options for comparison. The means of solving the problem are the selected initial cost indicators that characterise two aspects. The first aspect – the indicators which determine the student's required tuition and other related expenses. The second aspect is to characterise the ability to pay for educational services, or the solvency of the entrant and his family. Both aspects are summarised in the table.

The table shows the options for areas of assessment and selection of the university in accordance with different conditions and criteria for choosing the educational institution. We consider three options for comparing the solvency indicators of entrants' families or entrants (there are also students who are able to pay for educational services on their own). The table is constructed in such a way that a certain variant for determining the indicator (by which each of the possible educational institutions should be evaluated) is at the intersection of the solvency indicator and the cost value indicator during the study period.

Table

Options for evaluating higher education institutions by the ratio of entrants' solvency indicators and costs of studying

Indicators of the cost of studying	**Indicators for assessing the solvency of entrants**		
	Minimum salary in Ukraine, EUR	Average annual salary in Ukraine, EUR	Average annual salary in the region where the student studies, EUR
Average annual cost of studying at Ukrainian universities, EUR	Option 1	–	–
Annual cost of studying at a foreign university, EUR	–	Option 2	–
Average annual cost of studying at university in the region where the student studies, EUR	–	–	Option 3

4. Solution of the examined problem

In the first option, we model the ratio of the cost of studying (including tuition fees) with the minimum salary legally approved in the country [12]. In other words, we consider that when choosing a university to study at, one should not rely on comparing only the cost of educational services in comparable educational institutions. We propose to compare the cost of education with the income of potential consumers of these educational services. And after that we can compare relative indicators for different universities. However, in the first option, it is suggested to choose a minimum wage as an income indicator. After all, the minimum wage is the same for the whole country (or for a particular region in the case of a federal state), which makes it possible to make comparisons fairly. Of course, the payment for educational services is a value that varies at different universities due to a number of different factors. At the same time, to encourage students from other countries, universities can agree on roughly equal prices for educational services. This procedure for coordinating pricing can be initiated by intermediary organizations, recruitment agencies. In this case, universities do their educational business not so much by the way of high pricing but by the scale of student preparation. Local authorities may also be interested in this. For them, the influx of more foreign students is a factor in reducing unemployment among the local population, which is more involved in the service business to provide students with accommodation, food, transportation, medical care, recreational activities, etc. Under certain circumstances, students may undertake work that is not performed by the local population or if such work does not have a sufficiently attractive remuneration.

The second option of calculating the necessary indicator is to study the investment capacity of Ukrainian families (potential investors) to pay for educational and related services for children seeking to study at foreign universities. We have proposed an indicator of educational investment capacity [14], which allows to compare the

ability of Ukrainian individuals to cover the student's expenses abroad (at the expense of wages and salaries).

The ratio of the student's annual costs of studying and average salary is calculated according to the same methodology as in the first option. However, the first option takes into account the minimum wage and tuition fees. This approach was due to the fact that the minimum wage in unitary states, such as Ukraine, is the same for all administrative and territorial units. At the same time, the minimum wage in Ukraine can hardly be considered as an investment educational resource to pay for education not only abroad but also in Ukraine. We consider the average wage to take into account the wealth of such families who have the opportunity to invest in the education of children. Of course, the average wage in Ukraine, according to studies, is not significant by European standards. However, families usually accumulate tuition in advance, and some still insure children to provide educational services at universities in the future.

The difference between the second option and the first one is that the calculation is made not by taking into account the cost of studying, but considering all the costs of the student for the period of study at the university. This estimate can take into account the costs associated with accommodation, travel costs, transport and health insurance. Accordingly, the formula for calculating the ratio of the student's annual costs of studying at the university to the average wage in Ukraine will show the ability of the family to retain the student during the entire academic period at a foreign university. In addition, this approach is also valid when studying in Ukraine, but in a city that is distant from the family's place of residence.

Compared to foreign universities, the relevant calculations for particular countries are given in the paper [14].

The third option is to compare students' annual costs during bachelor's studies with the average annual income of consumers of these education services in the respective countries. This comparison makes it possible to see opportunities for students to earn some money to secure themselves abroad. Due to differences in wages by region of each country, we should use the statistics of the respective regions. According to our approach, the average level of income should be taken as the average wage in the provinces of Poland, the federal states of Germany, the regions of Ukraine respectively. The ratio of students' annual costs of studying to the average annual salary allows different categories of stakeholders to determine the real level of spending. For entrants, first of all Ukrainian, such an indicator will allow to estimate their spendings not only on the absolute amount of annual costs, but also on the comparison of costs with the possible amounts of earnings that is allowed to students in Germany and Poland. After all, the earnings of students correlate to some extent with the level of average wages. For the university management the proposed indicator will help to make comparisons of the competitiveness of their higher education institutions taking into account the solvency of consumers of educational services. For businesses and local governments (in the provinces of Poland, the federal states of Germany, the regions of Ukraine) this indicator can help to assess the competitiveness of their regions in attracting student youth. Student youth, as well as local citizens, are consumers of goods, services, promote the development of local businesses and thus can help in filling local budgets.

According to the third option, the formula for calculating the indicator is the ratio of the student's annual costs of studying at the university to the average salary in the region of a particular country.

The results of the calculations for the examined universities are presented in the author's publications.

5. Results and discussion

As research shows when choosing a university to study at, an entrant and his family (as individuals who pay costs of studying) should consider not only the cost of the educational services, but also the related costs of accommodation, transportation, food, necessary medical services, leisure. Similarly, the authorities and the government should consider the factor of student presence in the city, in the region, in the state. After all, they may either facilitate the inflow of students to universities, or vice versa – to constrain this flow. Such consequences are debatable for countries, regions, campuses, universities.

6. Conclusion

Each participant in the educational process – both direct (student, his family) and university, and indirect (government and the authorities of the state, region, city) – have to take into account many aspects of a person's or groups' staying in a particular territory. Relative indicators of comparing the student's (his family) solvency with the cost of studying at the university, in the country during studying give certain information about the individual's ability to study, to secure their staying in the educational institution, in the conditions of a certain socio-economic environment. Such assessment should be used by the entrant's family during the period of choosing the university, and by the university's management – to evaluate the academic and financial abilities of the entrant as a future student and graduate.

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TOURISM ECONOMICS WITHIN INDUSTRY 4.0: CORPORATIZATION APPROACH FOR UKRAINIAN REGIONS

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Abstract: *Challenges of Industry 4.0 will have a great influence on the field of tourism, as well. Society will need some places, a kind of reservations, to save and keep pure nature with variety of its wealth. Such locations will be of a huge touristic demand. That will become both a scientific and business problem in formation of brand-new ecological tourism products – to find a balance between an untouched natural reality and virtual entertainment opportunities of Industry 4.0 era. This is even more complex for developing countries, like Ukraine, and its provinces, like Kherson region. Economics of regional tourism, with corporatization processes involved, becomes an important scientific problem, considering the challenges of Industry 4.0.*

Keywords: REGIONAL TOURISM, INTERNATIONAL TOURISM, TERRITORIAL COMMUNITY, CORPORATIZATION, REGIONAL DEVELOPMENT, CREATIVE INDUSTRIES, LAND RESOURCES

1. Introduction

Regional development in Ukraine is an up-to-date problem, especially considering regional tourism. Territorial communities hold huge local resources, but are mostly not able to involve and activate them for their own prosperity. Development of regional tourism can activate corporatization processes among territorial communities, local businesses, NGOs and creative industries.

Current researches in the field, which involves incorporation of local resources in course of regional tourism development, show the actuality of the problem. Olmedo and Mateos (2015) [p.119] compare traditional and chaordic managerial models in tourist destinations, with emphasis on their difference in dealing with complexity – while first model tries to reduce it, the second one works with it. Liu et al. (2019) [p.303] prove that four main stakeholders are involved in sustainable tourism product development (e.g. festivals) – tourists, residents, government agencies, business owners. Speaking on festivals as well, Getz and Andersson (2016) [p.266] show advantages of periodic tourist events for local economies, integrating both small sponsorship and corporate support. Alonso et al. (2015) [p.410], studying cultural heritage tourism, still prove the leading role of regional tourist events in actualization of heritage. Duffy et al. (2017) [p.209] call tourism "a moderating force" for community development. Considering destination crisis management, Speakman and Sharpley (2012) [p.71] point to "order from chaos" process, being brought by different agencies and bodies within the region / destination. Moscardo et al. (2017) [p.288] directly address "the development of networks through local participation in the coordination and management of activities related to tourism" in their research. I would like to particularly highlight results of the recent research of Islam et al. (2018) [p.99] who state that "effective communication and collaboration amongst diverse stakeholder groups was identified as the key principle of an adaptive co-management approach". These conclusions can sum up the above literature review and prove the understanding of important role of informational flows among regional policy-makers and economic agents in tourism.

I propose to call this process the corporatization approach, as the term already used by me concerning tourism development in the context of European integration of Ukraine (Shmulevych, 2019 [p.237]). Tourism economics is a subject, greatly influenced by general economic development agenda and especially by regional differences. Current economic development agenda shows manifestations of Industry 4.0 era, which highly encourages creative industries growth.

2. Main results

Many evidences from creative industries around the world prove that a lot of community resources are not sufficiently considered as potentially generating financial resources. Therefore, it is necessary to create such infrastructure that would, on one hand, expand the market for resources as it is (due to the intermediary function), and on the other hand – rapidly scale up product markets, including tourism.

Ukraine's European integration leads to increase in its decentralization processes following the example of the EU. So-called regionalization is a phenomenon for Ukraine that becomes a leading force for territorial communities' development, being main, or systemic, elements of regions and the state at all. In fact, territorial organization, according to the European model, stipulates that the communities are directly adjacent to each other, i.e. there are obviously no buffer zones within the regions and all their land resources are distributed among the communities. I would examine this "land" fact in tourism perspective further in this paper.

First of all, it should be stated that regional economy is a complex system formed by the synergistic interaction of business entities associated with the region, individuals and their associations in connection with the region (physical, informational, financial etc.), as well as all those who enter the region, in particular tourists. If in the so-called "traditional" economy the processes of delivery of products to a consumer are studied, then in the "tourism" economy it is the delivery of the consumer to the products consumed – objects of tourist interest. This is a "hardly to change" situation within Industry 4.0 era. In this case, the delivery process of the consumer (tourist) is already a part of the tourist service (the product itself). That is, if in traditional products / goods the end consumer pays only a fixed price, which includes transportation costs, then when consuming a tourist service, the transportation process (the consumer itself) may be included in a single fixed price, such as a tour, or it may be paid separately. In the first case, transportation is not part of the product and the very existence of the product as a material object is not dependent on the presence or absence of the transportation process. In the second case, transportation is an organic ("energy") part of a tourist service, without which the service cannot exist in its essence. As a tourist trip = process of moving of a person.

Therefore, in the second case, the product itself – sightseeing, event, cultural heritage etc. – is not moveable, and therefore its conditional "price" may not include any transportation costs. There is a significant similarity. In both cases, the absence of consumer management will mean either leaving the finished product in storage (associated storage costs, damage, etc.) or leaving the site (potential destination) without visitors (environmental pollution, destruction, physical transformation, like anthropogenic (deforestation, sand extraction) and natural (washing off the seaside)). Therefore, the absence of consumers leads to costs. However, these costs are not constructive. Free energy in the form of cash, employee labor, natural resources that could be used for development is spent to maintain a certain stable state. The future

consumer, if the product is still stored and consumed by it, will also pay for the compensation of non-constructive "energy" costs arising from the fault of the manufacturer or the owner. Therefore, speaking about objects of (potential) tourist attention, we can come to the conclusion that it is necessary to invest in the preservation of the environment today, even without tourist flows. This allows to defer future (potential) costs for today, thus, (potentially) reduce the cost of the final product (service) in future. An interesting question arises, the search for an answer to which requires a thorough analysis. What is more profitable at the beginning of the development of international tourism in a certain region for the regional economy as a system: enabling the foreign tourist to move independently between the objects of interest in the region or necessarily provide a tour package, which would include the centralized transportation? To answer this question a corporatization agent – for example, a tourism corporation – should be successful in management of regional tourism that involves both inbound and domestic tourist flows.

Industry 4.0 implies the processes of accelerated informatization of the service sector. In this context, the impact of tourism on the regional domestic market, i.e. tourism economics, is an important issue for further research.

For example, the massive attraction of foreign tourists, let us consider, from Germany to Kherson region of Ukraine (Fig. 1) will require organic food, popular with the Germans. Thus, organic agro-production can focus not only on exports, but also on the domestic tourism market, and more specifically, the local part of international tourism market. From an economic point of view, such market will still remain a segment of the internal market. Obviously, accounting and analysis of tourists' consumer preferences is obviously important. In the example of organic agricultural production, the primary certification of land is the undisputed basis. It is clear that, along with state regulation of such sphere, the efforts of the regions and their economic entities in accounting and management of land and property complexes should be manifested. In the framework of the above, I consider it possible to introduce the concept of "land informatization", which identifies the process of creating structured, open, accurate databases at the regional levels on the ecological, geophysical, property characteristics of land. The synergy of this process will work in the direction of agriculture and sustainable tourism, which stay essential fields of economy even in Industry 4.0.

The Sustainable Development Goals are some markers that can support the success of regions and communities in the mentioned area within Industry 4.0 era. Globalization, European integration and related processes, on the other hand, require the localization of the efforts of economic agents.



Fig. 1 *Map of Kherson region of Ukraine.*

In general, the linkage of sustainable tourism with other sectors of economy, even those that do not directly participate in the creation of value added tourism product, is possible in the context of regional understanding of this phenomenon. For example, activation of light industry, involvement of small regional enterprises is possible precisely for the purpose of creating targeted products for innovative tourism products or for the rapid provision of hotel and recreational infrastructure of a region pursuing a policy of rapid tourism development in the context of this region's own uniqueness. Therefore, analyzing the systemic linkages of different sectors of the regional economic system in the context of tourism development is important. Obviously, traditional models of administrative management in the regions are not capable of providing such analytical processes. We need to look for new models of governance for regional economic systems that are able to quickly and freely use modeling methods, i.e. are able to deal with chaordic processes. It is worth noting that the greatest efficiency of systematic approaches is proved in relation to development of new markets, access to them with innovative products, in the absence of initial information, time and financial resources. This fully applies to the development of regional tourism with corporatization approach. This approach means broad integration of the efforts of regional authorities, businesses, communities and academia. The question remains about the format of such integration, which is the field of further research.

Thus, in this context of decentralization and regionalization of decision-making in Ukraine, in the context of united territorial communities' formation and in general awareness of the responsibility of communities for realizing their own economic potential, there appear problems of efficient use of land resources. This issue is especially important as a component of ecological, heritage and rural tourism development in our country. Issues of identity or difference between the concepts of "rural tourism", "green tourism", "ecological tourism" are not key in this respect, so I will consider them as a single concept in the related economic category "land resources".

Consequently, it is important to identify the role of land as a resource for the creation of products in tourism. In tourism economics meaning, land is its direct basis and spatial component of the concept of "destination". The tourist product, as a complex phenomenon, attracts the land itself as the main material resource. The effectiveness of value creation at all stages of production and sale of such a product depends, in particular, on the rational use of land resources. In my opinion, from a microeconomic point of view, tourism product occupies an absolutely unique place within two main categories – goods and services, as already partially proved above.

Manufacturing of goods involves a clear understanding and delineation of property rights. Resources required for the manufacture of a particular product are transferred to the property of the manufacturer or involved in rights of disposal, e.g. lease. This is also evident in the production of agricultural products. Forms of economic organization, such as cooperatives, agroholdings etc., only redistribute rights in order to achieve economic effects. On the other hand, services, including IT, are not based on property rights (protection of which in the form of protection of intellectual property rights is a derivative process – not basic!), but rather on individual human rights – for work, for education, for self-development, for information. Therefore, in agenda of Industry 4.0 and transition of many services to digital form, it becomes important to clearly identify the origin of their resource – information. Its free circulation is largely beyond control. Free access to informational resources creates an added value in the world every moment. In this case, the tourism product, as noted, has a uniqueness, which, on one hand, is its weakness, and on the other – the basis of investment attractiveness of its main component, i.e. land resources.

Thus, the problematic side of tourism product formation in Ukrainian regions is land binding, dependence on decisions of land

managers. But this is a problem that can and must be solved in both scientific and legal fields. Well-known researchers in the field of development economics, in particular, in rural areas, A. Janvry and E. Sadoulet (2015) [p. 551] in the study of environmental resources, including land, distinguish two types of property that are particularly important for territorial communities – open access resources and shared property resources. The latter are community-related resources with clearly defined rights of participation within the community and in the process of using such resources. Solution of this issue should be in deliberate, well-considered, clear state policy only.

In my opinion, the lack of easy, free access to the cadastral plans of any place in the region, lack of clear delineation of property rights of the state, region, community, private in relation not only to land resources, but also objects of their infrastructural development (roads, residential communications, etc.) are all problems, which should be solved also for tourism industry. Moreover, this chaordic situation directly and negatively influences prospective corporatization processes. Therefore, formation of a tourist product, which necessarily covers transportation of tourists, process of viewing the landscapes, must take place in the conditions of clear rules of access to any object of tourist and recreational interest. Creating a single information base on access to land resources, their owners and managers, understanding of their physical and geographical characteristics, environmental status is also proposed to call "land informatization", as presented above. Such a process clearly integrates in general Industry 4.0 development and happens to be a sort of condition for incorporation of land resources in tourism.

Such informatization of own land resources helps to increase the synergistic potential of territorial economic systems that can be manifested in international tourism development in particular region / destination. Foreign practice shows that even agricultural land can be used in tourism. For example, a tourist product such as the Łabiszyn International Kite Festival in Poland (Lubostroń village of Gmina Łabiszyn) directly involves the use of fields after harvesting for kite-flyings by Polish and foreign kite-flyers. This evidence shows that the typical Polish agricultural area is being transformed every year. Festival guests – tourists – replicate information about their experience on social networks, thus increasing the overall accumulation of information about these territories.

The uniqueness of the tourism product seems to be in the dichotomy of land resource use, which is the basics of agricultural production, and information, the basics of service field. In this way regional tourism differs from pure creative industries that might involve and incorporate mainly information.

3. Conclusion

Corporatization of all relevant resources within regions and their territorial communities should be considered in studying and future management of international tourism with its impact on regional tourism.

Further research is planned in direction of corporatization methodology development on the data of Kherson region in Ukraine. A huge tourist event is planned in this region in 2020 – World Kite Championship combined with the first edition of Ukraine International Kite Festival. My findings will be used in organization of the event, and further research will also be provided after relevant data collection, once the event is over.

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