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Contents

Dear authors,
Dear readers,

Welcome to the twenty-fifth edition of the Journal of Information Technology and Applications (JITA), published by Pan-European University APEIRON Banja Luka. The JITA publishes quality, original papers that contribute to the methodology of IT research as well as good examples of practical applications.

The content of this issue of JITA consists of seven papers. The first paper, entitled "Basic Mathematical ATM Model for Time Based Navigation In U-Space Environment" by V. Milosevic states that Time Based Navigation Mathematical model is a navigational tool which allows instant management of distance, speed and time on more effective way. Time Based Navigation Mathematical model is only different way of use of this measuring tool where every aircraft on its route has precise navigational time clock for accurate destination arrival.

The next paper is "Linear wireless sensor networks as the physical layer of smart street parking systems" by A. Ahmetspahic, G. Popovic and G.Djukanovic. In this paper, the authors described the characteristics of these networks, the problems that are specific, as well as possible applications, and they are pay special attention to the application of LWSN in smart street parking lots

The third article "Comparative Analysis of Relational and Non-Relational Databases" by P.Ranilovic, D.Marinkovic, N.Sikanjic presents the results of research into the use of relational and non-relational databases, as well as their comparative analysis. A theoretical overview of the comparative analysis by different segments of relational and non-relational databases is presented.

In the paper "Aircraft Performance Modeling with Polynomial Function using Small Variable Units Technique", V. Milosevic outline the use the Small Variable Units Technique as effective method to transfer nomograms' data in polynomial equitation which can give us different mathematical models of an aircraft performance. In combination with time based navigation, digitalization of aerodynamical characteristic will be a step forward to Continuous Climb and Descent Trajectories, as the most optimal one.

In the paper "Panel analysis in function of Measuring the Impact of higher education on international competitiveness of the Western Balkan Countries" by M.Landika, Z.Racic and B.Kondic they claim that expressing and measuring the results of the educational process is a continuous and complex process, and requires the application of adequate methodology, such as a panel analysis model.

This paper "Digitalization of Sound using Pulse Code Modulation (PCM)" from the authors S.Tomic and D.Drljaca focuses on Pulse Code Modulation (PCM) as a technology for digitizing analog signals. PCM is a widely used technique that enables precise encoding and transmission of analog information through digital pulse signals.

The last article in this issue "Analysis of public administration, effects and impact of digitalization and interoperability in public administration" by J.Dzino, S.Dzino and D.Injac presented parts of public administration as well as the influences of public administration. The effects and influence of digitalization and interoperability in institutions in B&H, strategic approach to the development of public administration, the relationship between Vision and Technology as an indicator of business success in public administration are given.

Gratitude

On behalf of the Editorial Board, we would like to thank the authors for their high quality contributions, and also the reviewers for the effort and time invested into the preparation of the JITA

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We would like to thank many who have read and/or commented on earlier versions of this journal including Leonid A. Baranov, Yuri M. Inkov, Efim N. Rozenberg, Leonid A. Mylnikov, Katarina Držajić Laketić and Dražen Marinković. However, any errors or shortcomings remain my full responsibility.

Conflicts of Interest

The author declares no conflict of interest.

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Basic Mathematical ATM Model for Time Based Navigation In U-Space Environment

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Contribution to the State of the Art

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Abstract: Time Based Navigation Mathematical model is a navigational tool which allows instant management of distance, speed and time on more effective way. Time is a kind of specific imaginary dimension which describes real life dynamicity. Most efficient tool for time measuring, which precisely represents nature of time, is a circle with angles inside, well known as "clock". Time Based Navigation Mathematical model is only different way of use of this measuring tool where every aircraft on its route has precise navigational time clock for accurate destination arrival. Implementation of this model can offer higher level of navigational precision in longitudinal and lateral domain, effective speed correction calculations and management in time domain, constant identification and recalculation of total time error and also can be used as safety net tool to define conflicts in UTM Air Space.

Keywords: Digitalization, propulsion, aircraft, U-Space, Electrification, ATM, environmental friendly, zero emissions, arrival management, artificial intelligence.

Introduction

Technical development of the 21st Century has brought vast of different business models and need for more efficient and effective methods for general, private and cargo air transportation. Following recent developments in the air traffic domain some main processes and development areas can be identified as:

- Digitalization of air navigation and air traffic management with the future involvement of artificial intelligence, as augmentation of actual processes and procedures.
- High Altitude Operations ("HAO") with high speed, high power propulsion aircrafts or low speed, low power propulsion aircrafts.
- Further development of vertical take-off and landing capability of aircrafts with quadricopter configuration.
- Introduction of "U-Space" as air space class and need for intensive and effective personal and commuter air-transport for urban areas [1].
- Introduction of ultra-light composite materials for aerodynamically high efficient aircrafts.
- Electrification of aircrafts propulsion systems with the aim to achieve more environmental friendly and zero emissions standards.

All those developments require intelligent Air Traffic Management (ATM) system with more efficient methods for air navigation, aircraft separation and effective real time administration of air operations with intensive data exchange and sharing.

Actual ATM system for general transportation (GAT) has proved its value as very robust and safe but it has many characteristics that have to be changed or adapted in order to introduce solutions from mentioned development areas.

"U-space" is the most ATM demanding domain due to projections of intensive future air traffic in significantly small air space volumes over urban areas [2] what will arise following issues which have to be taken into account:

- Air safety solutions of actual ATM system are based on large buffer volumes which are space demanding.
- Separation methods are based on vertical and lateral separation with complex methods of

longitudinal or time separation models which haven't jet been developed to the level of practical use.
- Navigation precision is calculated according to the sum of errors that are generated due to various reasons without or with weak models for their correction, and basically total navigational error only classify navigation method on different types (e.g. PBN, precision or non-precision approach).
- Procedures for approach and landing consume large areas of space volumes and specialized ATM services need to handle those operations. [3]
- With increase of number of air operations in relatively short period of time actual ATM procedures and methods became more complex and more energy demanding for aircraft propulsion systems with extension of time needed for actual flight of an aircraft (e.g. holding procedures).
- Digitalization of air navigation models require complex and weight demanding IT and communicational ground and aircraft on-board equipment.
- Variety and quantity of data that have to be processed and exchanged are time and capacity demanding what increase latency and bandwidth of real-time data exchange [4].
- Arrival management (AMAN) has significantly short horizon for arriving traffic and air traffic planning and management models are overloaded with rapid increase of traffic.

Following previously mentioned issues intelligent U-Space ATM system has to fulfill different requirements and has to be capable to develop:
- Navigation model with full precision in all four domains (altitude, lateral, longitudinal and time navigation) with automatic navigational error calculation and management.
- Aircraft separation models need horizontal separation as primary method and vertical separation as additional procedure.
- Energy efficient "Direct-to" and "On-Spot landing" ATM procedures with possibility to use charging mode of engines during descend, arrival and landing phases of flight [5].
- Simple and safe methods for high intensity air traffic management in relatively small air volumes.
- Seamless AMAN with extended time horizon for real time air space and ATC capacity planning up to departure and pre-departure phases of air operations.
- Small weight footprint of ground and onboard IT, COM and NAV equipment and small data exchange footprint for U-Space ATM network [6].

Summarizing everything mentioned U-Space environment require robust model of time based navigation which is capable to cover all previously mentioned issues and fully use already introduced achievements in ATM and COM domains.

Basic Mathematical Model for Time based navigation

Idea of Basic Mathematical Model (BMM) comes from theoretical principle of speed correction value which is related to the available time up to "Destination point", which says that:

"Correlating the speed correction value in function with the available time till the destination point (correction time), the resulting speed correction has tendency to infinity as the time for the correction goes toward zero, and vice versa if correction time goes toward infinity."

Practical implementation of this principle says that, in moment when some delay on route is identified, speed correction for that delay has some value and that value grows as correction time toward certain destination leaking out.

Mathematical Model for Time based navigation is a mathematical description of this principle and Time Distance Angle (TDA) is the core of the model which represents the nature of time and speed corrections as an aircraft flies toward destination point. The value of TDA is growing up over the time and it has the value of 180 degrees on the destination point simulating infinite value of speed correction at zero moment of correction time. Calculations of TDA are based on basic geometry of circle and proportion of pages and angles in triangle and basic geometry of TDA is presented on figure 1.

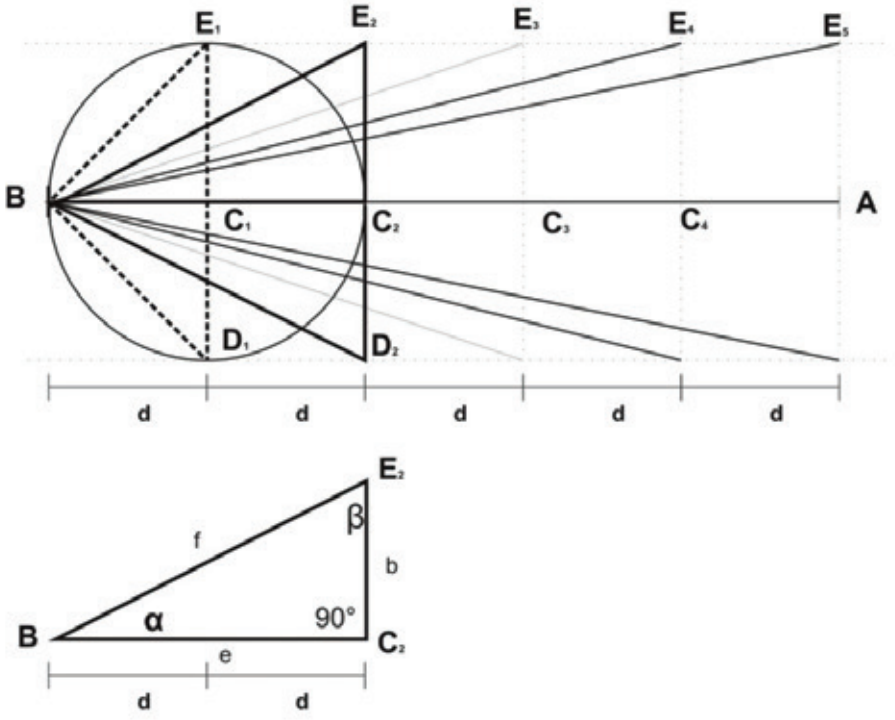

Figure 1.

Mathematical model uses a situation of aircraft trajectory from point A to point B and on that trajectory point C_1 is marked as position of an aircraft. A circle with center in point C_1 with radius d, which refers to the distance of BC_1=d, defining points E_1 and D_1 orthogonally to the aircraft speed vector and the connections of points E_1, B, D_1 will produce the angle of 90^0 ($\sphericalangle E_1BD_1$).

Defining distance d as distance that an aircraft will fly in time period of one minute implies that the angle $\sphericalangle E_1BD_1$ will go from 90^0 till 180^0 in time of one minute. Doing the same thing at point C_2 implies that value of angle $\sphericalangle E_2BD_2$ refers to the time period of two minutes. Extracting $\triangle E_2BD_2$ triangle, the page BC_2 (page e) refers to the page E_2C_2 (page b) in proportion of 2:1. This means that the angles β and α are also in proportion of 2:1 what gives us the value of angle α of 30^0. As the angle α is exact one half of angle $\sphericalangle$E2BD2 than we can conclude that two minutes before the end of aircraft trajectory the angle that connect points orthogonally defined to the aircraft speed vector at the distance that refers to two minute of flight will have value of 60^0. In further text this angle will be called Time Distance Angle (TDA) and distance "d" will be called Time-Distance Value (TDV). Same logic will be applied to all other points from C_2 till C_5 and value of TDA angle will be calculated by formula:

$$TDA = 2 * \frac{90^0}{(n_d + 1)}$$

$$n_d = | t_{[min]} |$$

Value of n_d refers to the absolute value of number of minutes till the end of trajectory. This formula allows TDA calculations from the beginning of aircraft trajectory.

In real situations during the actual flight, using the same Time-Distance Value (d) at real GNSS position related to position of a Destination Point, the Real TDA will be formed and compared with projected (required) TDA for exact moment of time what defines actual delay or overtime what is expressed as value of Total Time Error (TTE), at figure 2.

TTE Correction - Air and Ground Speed Correction Algorithm

If TTE is identified at early stage of flight the correction by the speed is possible. Any kind of delay at moment C_2 produces aircraft's position C'_2 and lover value of Real

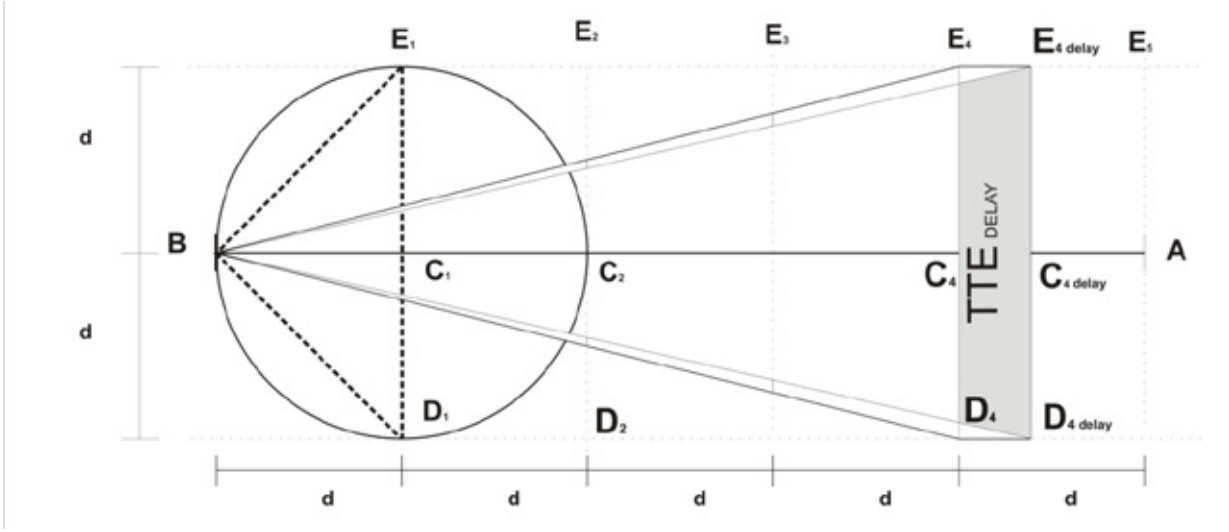

Figure 2.

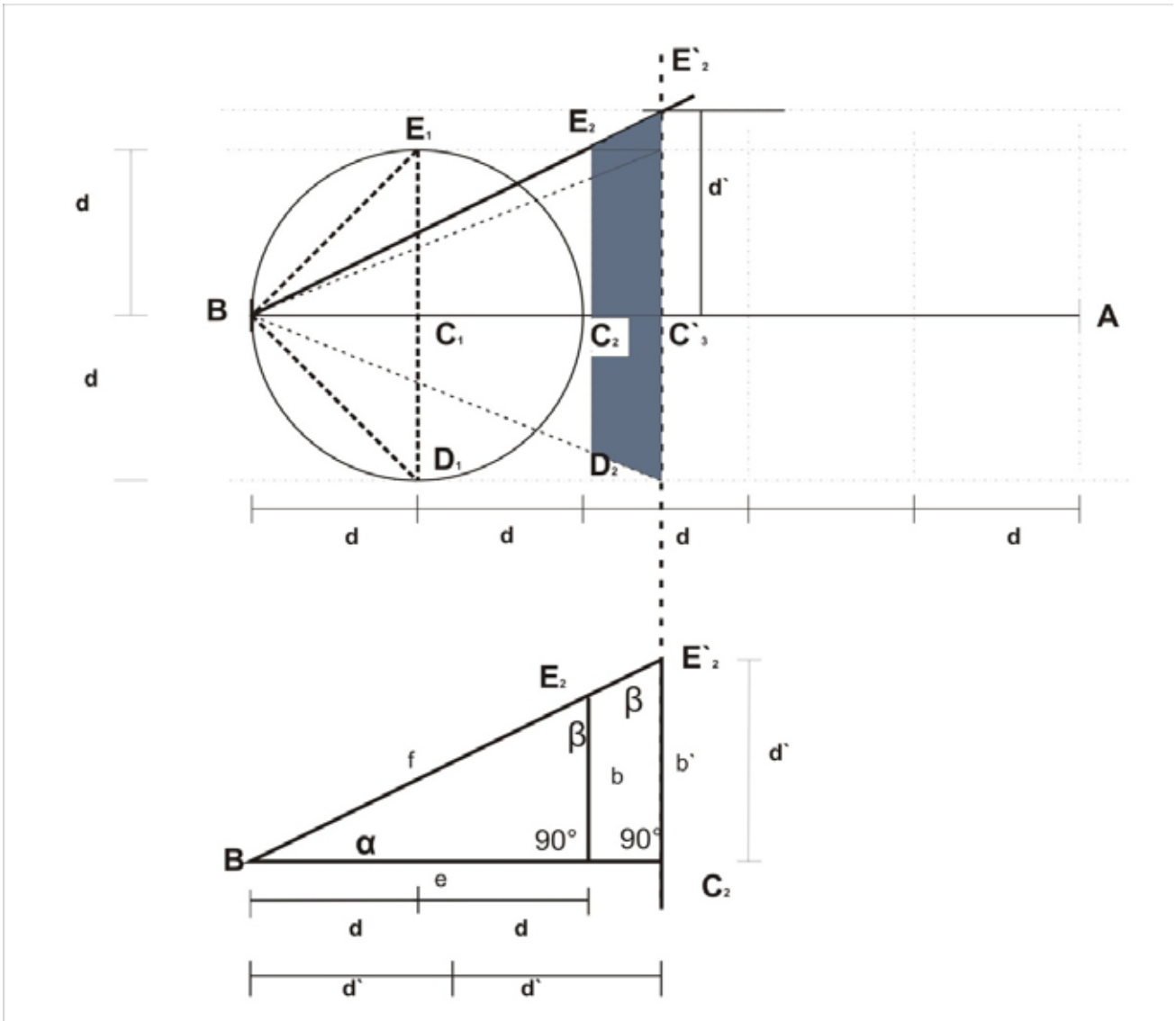

Figure 3.

TDA angle compared to the Projected TDA. Measuring distance C'_2 and E'_2 which will be new Time Distance Value (TDV' or "d'- d prim").

The figure 3 shows that triangles $\triangle\triangle E_2BC_2$ and $\triangle\triangle E'_2BC'_2$ are similar with same angles and proportional triangle pages, what means that,

$BE_2 : E_2C_2 = BE'_2 : E'_2C'_2$

Focusing on TDV' and that it jointly represent time and distance, it can be also used as intensity of speed vector expressed in distance (Nm or km) per minute, and if we multiply it by 60 we will get the required "corrected or calibrated" speed (in knots or km/h) for the accurate time arrival to the Destination Point.

Basic ATM Operational Concept Principles of TDA

In real life TDA construction method can be used for projection of on-screen navigational marker as efficient ground speed manipulation tool followed with real time speed correction calculations. Basically the main task will be to keep required and real TDA marker joined together, using real time speed correction calculations what is described on figure 4.

This model also provides very convenient environment for the use of artificial intelligence and automation of all Time Based Navigation processes, where the position and addresses of marker's pixels on the screen could be compared and used in decision making processes.

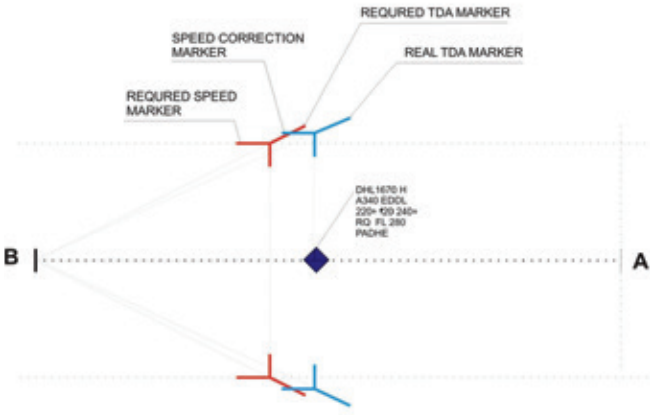

Figure 4.

Different applications of Basic Mathematical Model for Time based navigation

Using the same logic from figure 3. the construction of the algorithm for early UTM conflict identification can be defined for the ATC management. If two different aircrafts at the same moment of time are flying toward the same Destination Point with different distance and different speed but the same Time Distance Angle then this conflict situation has very high probability.

Having in mind that only the value of TDA is used as element of conflict detection it can be applied as a filter and even in a flight planning phase as robust ATM Capacity Flow Management Tool.

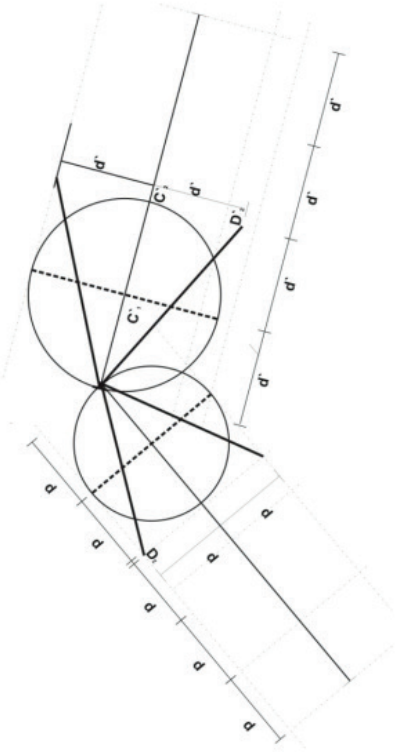

Figure 5.

Advanced characteristics of the Time Based Navigation Mathematical model

Time Based Navigation Mathematical model characteristics can be used to achieve the goals needed for accurate and synchronized ATM for U-Space environment with high level of traffic intensity and dynamicity. The most important of all characteristics could be described as:

- Higher level of navigational precision in longitudinal and lateral domain.
- Effective tool for speed correction calculations and management in time domain.
- Constant identification and recalculation of total time error.
- There is no need for deeper analysis what generates time and navigation errors.

- Can be used as safety net tool to define conflict in air traffic.
- Simplifies arrival and landing procedures.
- Allows construction of "Direct-to" and "On-Spot landing" UTM procedures.
- Harmonize air traffic and provide environment for energy efficient UTM procedures.
- In combination with other aircraft performance management tools can provide environment for Continuous Climb and Descent Operations.

CONCLUSION

Time Based Navigation Mathematical model is a navigational tool which allows instant management of distance, speed and time on different and more effective way, offering possibility that every aircraft on his route has precise navigational time clock for accurate destination arrival.

Implementation of this model can offer higher level of navigational precision in longitudinal and lateral domain, effective speed correction calculations and management in time domain, constant identification and recalculation of total time error and can be used as safety net tool to define conflicts in U-space enviroment.

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Linear Wireless Sensor Networks as the Physical Layer of Smart Street Parking Systems

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Contribution to the State of the Art

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Abstract: Wireless sensor networks (WSN) represent a set of different technologies that, in cooperation with each other, form the basis for the realization of the physical layer of the concept of smart cities. Miniaturization of sensor devices and decreasing energy consumption, both for data processing and for mutual communication, as well as simple implementation and low cost, make WSN indispensable for a large number of different applications. Many of the applications imply a linear infrastructure that is subject to monitoring, and as such requires a linear deployment of sensor nodes. This form of WSN represents a special class of networks that we call Linear Wireless Sensor Networks LWSN. In this paper, we will describe the characteristics of these networks, the problems that are specific, as well as possible applications, and we will pay special attention to the application of LWSN in smart street parking lots.

Keywords: IoT, LWSN, Smart City, Street Parking, WSN

Introduction

The topology and architecture of WSN wireless sensor networks depend on several factors: the network application, the configuration of the terrain on which the network is implemented, the available technologies and the routing protocols that will be applied in the network. A special case are Linear wireless sensor networks LWSN, which in the topological view represent a linear structure of successively connected sensor nodes. A whole range of applications that monitor infrastructure of a linear nature require exactly this kind of sensor network architecture. Some of the most popular are:

Monitoring of highways: the large length of highways that need to be monitored without human presence makes it necessary to install a sensor network that will cover the entire length of the highway and perform the necessary readings such as: congestion and traffic interruption, traffic accidents, foreign objects on the road, weather conditions, speed violations, etc. [1].

Supervision of the electric power network: Supervisory systems for the transmission and distribution of electric power acquire a large number of parameters that enable more efficient planning of maintenance and exploitation of the network. Timely information can prevent problems in the network. Sensors can be used to measure voltage, temperature, humidity, irregularities in the network, etc. [2].

Monitoring of the border zone: One of the biggest problems in every country is the protection of the border zone and the prevention of illegal crossing of people and goods. Very long border lines and often inaccessible terrain represent difficulties that are neither easy nor cheap to solve. The only way for efficient monitoring is enabled by modern technologies, primarily wireless sensor networks. Different types of sensors are used for this, such as: cameras, thermal cameras, motion detectors, seismic sensors, etc. [3]. The collected data is delivered in real time to the center for monitoring the border zone.

Supervision of water pipelines, oil pipelines and gas pipelines: Distribution of oil and gas is carried out by branched and long networks of oil pipelines and gas pipelines. In addition to pipes, these networks contain pumps, control stations, various meters, etc. The entire infrastructure must be continuously monitored due to the importance and price of the raw material being transported, as well as possible dangers related to the flammability of substances and pollution of the natural environment (especially when it comes to underwater oil pipelines). Measurements are made of pressure in the pipes, temperature, flow, etc. The data is transmitted in real time in order to be able to react in time in case of any damage to the infrastructure. Measurements are made along the entire route, where a most of the route is not manually accessible [4] and the routes can be extremely long, up to several thousand kilometers.

Supervision of railway tracks: The safety and security of the railway road infrastructure is one of the key problems in the traffic of every country. WSNs provide a unique possibility of monitoring the entire route of the railway, regardless of its length and inaccessibility [5,6]. Timely notification of obstacles on the tracks, damage to the infrastructure, and irregularities in the operation of classic signaling is extremely important for saving human lives and property [7].

Monitoring of river flows: One of the most common applications of WSN is focused on measurements and readings of various physical quantities that quantitatively and qualitatively describe phenomena in nature. River flows are one of the most important natural resources of any country and it is necessary at all times to have accurate information on various aspects essential for the monitoring and management of watercourses. Traditional monitoring is slow, expensive and often impossible due to the circumstances on terrain. Sensors are most often used to measure water level, degree of water pollution, temperature, etc. [8].

In this paper, the authors will present the advantages of applying LWSN in linear smart parking lots. We will describe the comparative characteristics of individual network segments, specific problems caused by this form of infrastructure and possible solutions for optimization.

Related works

A large number of authors were engaged in research related to various possibilities of WSN application in smart parking systems. The aim of our research is to improve certain specific aspects essential for the functioning of the system. Here we will briefly mention only some of the research that was interesting to the authors of this paper when studying the problem.

In [9], a WSN that detects the occupancy of each of the parking space in the indoor parking system is analyzed. Each parking space has a sensor node that periodically signals the occupancy status visually or acoustically.

The GPS system for navigation was used in [10] as a way to model the availability of parking spaces. In this work, Poisson processes and algorithms based on artificial intelligence (modified version of the MIN-MAX algorithm) are used, which help the driver to choose a parking space that will be vacant with the highest probability. Magnetic and ultrasonic sensors are used for this.

In [11], a system for intelligent parking management was proposed, where the WSN consists of different types of sensor devices for vehicle detection in each of the monitored parking spaces. The system informs drivers about availability and guides them to a free space in the parking lot.

Here, we are particularly interested in parking spaces right next to city streets. In [12], one such system for free parking space management called Street Parking System SPS (Street Parking System) was proposed, which uses magnetic sensors for vehicle detection and ZigBee technology for wireless communication between sensors. The system showed 99% reliability in vehicle detection. A similar system was proposed in [13] where an LED display is used to indicate the available parking space.

A system that performs the detection of a free parking space and its reservation was proposed in [14]. The place is reserved based on the distance of the user and the recommended parking price, taking care to ensure that the total capacity of the parking lot is used evenly.

An innovative concept was proposed in [15], according to which the intelligence in the network is distributed and the decision-making is decentralized. The system is scalable since the addition of new

network segments does not require re-engineering of the communication infrastructure, but fits into the existing network through the gateways that join them. Two types of sensors are proposed, magnetic and visual for vehicle detection.

The IoT system for parking in smart cities, based on cloud computing, is described in [16]. Ultrasonic sensors are used to detect the proximity of the vehicle to the parking lot and the occupancy of parking slots. Infrared sensors are used at the exit and entrance gates to help update the number of vehicles in the closed parking lot. Advanced optimization techniques are used to evenly distribute the load on city parking lots.

In [17], a system that uses IR sensors to detect the presence of vehicles in parking spaces is presented. The system consists of a monitoring module and a central module. The monitoring module consists of a ZigBee transmission unit, a LED display and a microcontroller that manages the data detected via the IC sensor. After the sensor detects the presence of a car, it sends information to the microcontroller to display the status of this parking space on the LED display and then sends this data via the ZigBee interface to the central module using a chain network topology.

Smart parking architecture

The architecture of smart parking is based on the application of sensors that perform readings of certain physical quantities and acquire data in the desired form. The entire system must be automated, without people involved, and meet the requirement of minimal energy consumption. Sensors are connected to the network wirelessly, since cabling is very expensive and inefficient. Wireless sensor networks obtained in this way are sometimes called PSN (Parking Sensor Networks) in the literature and have the following properties:

- Sensor nodes are stationary, installed usually on the surface of the asphalt surface, placed at relatively small distances from each other
- The topology of the network is linear and is determined by the topology of the roads
- The area covered by the sensor must not overlap with the areas covered by neighboring sensors, so that parallel multiple detection does not occur.
- The speed of the package formation depends on the speed of the vehicle's arrival at the parking place as well as the speed of its departure.
- Information on parking space availability is delivered in real time

WSNs collect data of interest from the desired location in real time. This data is transmitted to the place where it is processed and where it is possible to implement a large number of different user applications related to smart parking. An example of an application is checking availability, guiding you to a parking spot, and automatically booking and paying for parking via smartphone. Figure 1 shows the general architecture of the smart parking system.

Street parking lots

Modern technological development is largely focused on the need to improve the quality of people's

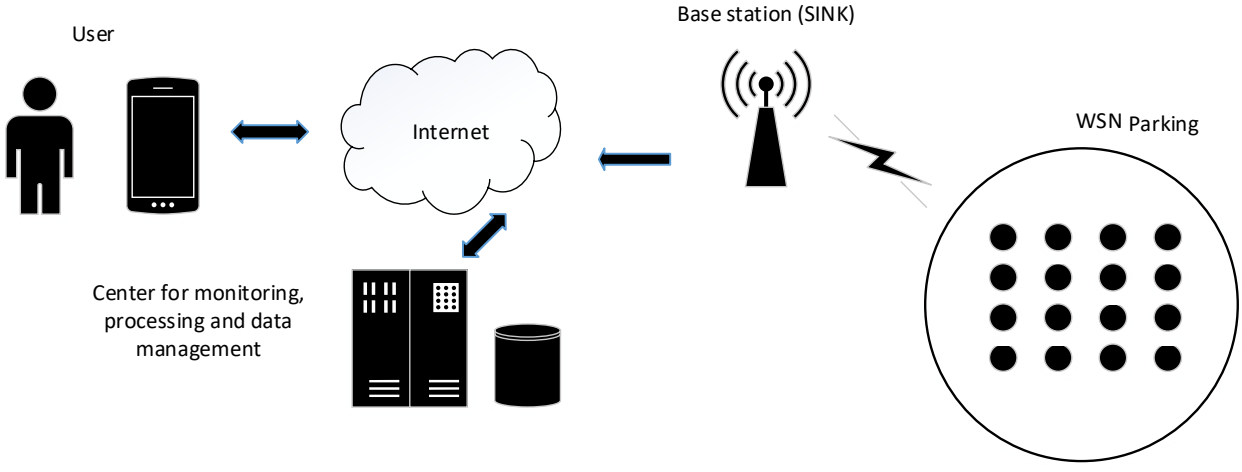

Figure 1. *General architecture of the smart parking system*

everyday life in many areas. In this sense, the idea of a smart city and IoT is a framework that provides unlimited possibilities for mapping the parallel existence of the physical and digital world and introducing new technologies into a whole range of segments of modern life. IoT has found its application in a large number of fields: industry, communications, data mining, agriculture, health, etc, but the concept of smart cities has opened up space for many new ideas where the final range cannot be anticipated. Smart parking is one of the most important segments of the smart city system, which can have the greatest impact on increasing the quality of life of its users.

Due to the constant growth in the number of cars, finding a parking space in the centers of larger cities has become an extremely big problem that has consequences for both car owners and society as a whole [18].

The number of closed parking lots in cities is limited, and in the centers it is never enough to meet the needs of drivers. For this reason, street parking lots are a very good solution to alleviate the problem. If drivers have real-time information about the availability of parking spaces and their exact location, the efficiency of parking in central city areas increases significantly. Wireless sensor networks are an ideal solution for managing street parking lots due to their low consumption and physical dimensions, as well as their low cost [19].

Street parking lots are areas on city streets, namely on the roadway, sidewalk or partially on the roadway and partially on the sidewalk, as can be seen in Figure 2 [20]. Drivers find this way of parking significantly more attractive than off-street parking lots or parking garages. Parking on the street enables closer contact with the objects that are the goal of the trip, in this way the least amount of time is spent for parking and walking to the goal. Street parking lots are interesting for drivers who have a short stay at the destination. However, these parking lots can also have a negative impact, which is reflected: in the reduction of road capacity, the speed of vehicle movement in the streets where these parking lots are located also decreases, there are often short interruptions or stoppages in the flow of traffic, and as a result, we have an increase in time journey and there is an increase in the emission of harmful gases, the risk of a traffic accident is increased for all participants in the traffic (vehicle driver, motorcyclist, cyclist, pedestrian, etc.). Street parking lots can be constructed depending on the parking angle (longitudinal parking, diagonal parking and vertical parking).

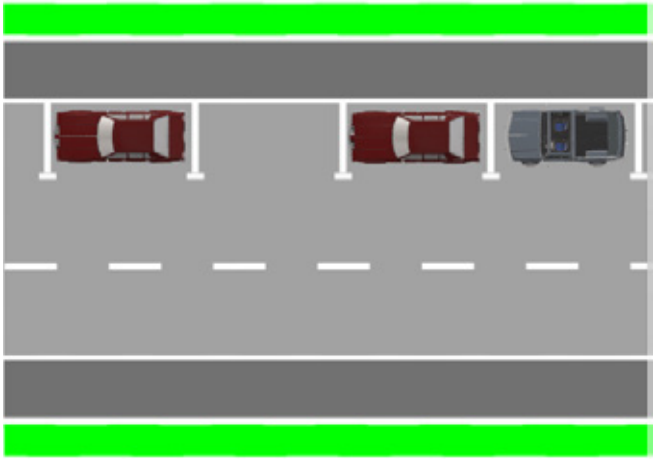

Figure 2. *The Street parking*

The problem with street parking lots is related to the possibility of their monitoring and integration into the smart parking system. Dispersion of parking spaces on a wider area that is a function of public use reduces the possible options for connection with the monitoring and control center. Here, there is no possibility for a ramp to the entrance to the parking lot or for centralized counting of entrances and exits and thus the occupancy of available parking spaces. A wireless sensor network is the only way to acquire data of interest from the terrain intended for street parking. Due to the topology of these parking lots, linear wireless sensor networks are imposed as the only supporting architecture. Implementation in practice, however, is accompanied by a whole series of specific problems.

Linear wireless sensor networks LWSN

In LWSN, sensor nodes are distributed in a linear structure. In this way, a two-dimensional network which is very narrow in one dimension and long in the other, is formed. As a consequence, communication in one hop to the sink in such networks is not possible, and the traffic generated in a node far from the sink will be transmitted to the destination using a large number of other sensors as relay nodes, so

the data will be delivered with a delay that cannot be ignored

Sensors located closer to the sink represent a bottleneck in the data transmission network. The closer they are to the sink, the faster they drain their energy reserves, because the amount of data that the sensor as a relay node forwards to the LWSN increases significantly with the decrease in the sensor's distance from the sink, as can be seen in Figure 3 [21]. This is why it is necessary to somehow balance energy consumption in the network, which is a very challenging problem.

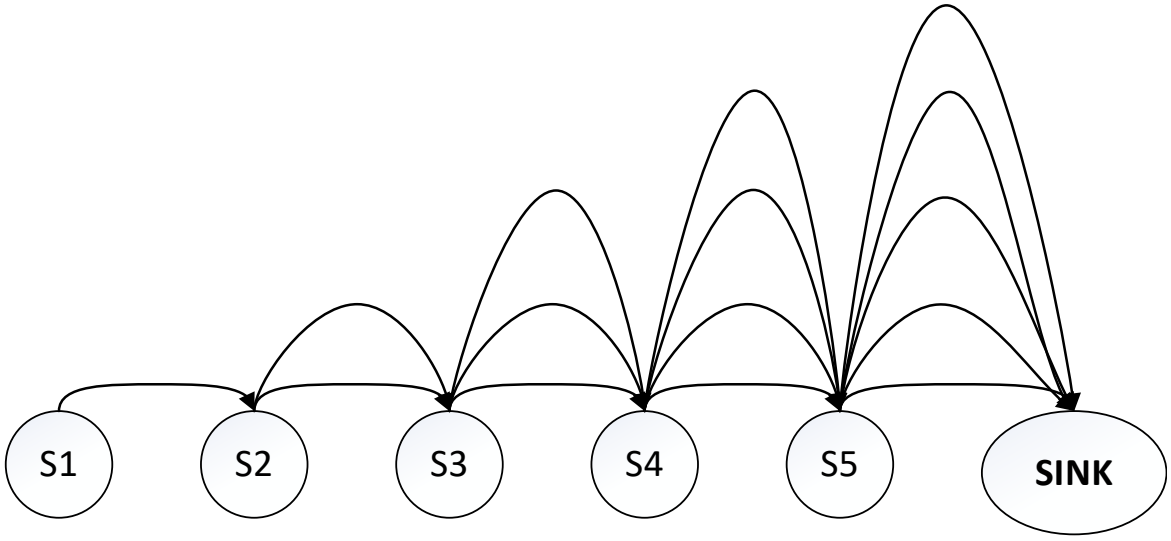

Figure 3. *Increasing traffic density with decreasing sensor-to-sink distance in LWSN*

This problem can be solved in two ways. The first implies inhomogeneous energy distribution in the network, and the second the implementation of appropriate energy-efficient data routing protocols. The first group of solutions includes, for example, a model in which the sinks are relocated in such a way that their new position enables a more even energy consumption of the associated sensors [22]. In this way, however, the system of linear WSNs is somewhat disturbed. There are a number of suggestions for solving the problem in another way. These proposals can be grouped into two categories [23]: multi-hop access and mobile data collection MDC (Mobile Data Collection).

The multi-hop approach is always related to the hierarchical WSN architecture. In the general case, the hierarchical network in LWSN consists of three levels of sensor nodes:

1. BAN (Basic Sensor Nodes) basic sensor nodes perform the primary function of reading and measuring at the location of interest, basic processing and forwarding of data to higher levels.
2. DRN (Data Relay Nodes) relay nodes that aggregate the data collected from the lower level and forward the data to the first higher level.
3. DDA (Data Dissemination Node) nodes for extended access, this is an optional layer that can be located between the second layer and the control center if the architecture and size of the network require it. If it does not exist, the DRN nodes take over. The method of data transmission to the control center depends on the applied technology. It is usually one of the mobile access technologies (4G, 5G) or one of the satellite technologies. If the distances are shorter, some of the short-range wireless technologies can be used.

Figure 4 shows the classic architecture of a hierarchical linear wireless sensor network.

Nodes at one level can be organized into clusters, whereby only one of the nodes in the cluster is selected in some way and that one will forward the data of all other members of the cluster to a higher level, as well as the data collected by itself [23]. We call these nodes CH (Cluster Head). CH nodes form a chain structure with each other, where again based on different criteria (depending on the applied protocol), a Chain Head is chosen, which performs traffic aggregation and forwards all data to the Network Control Center (NCC).

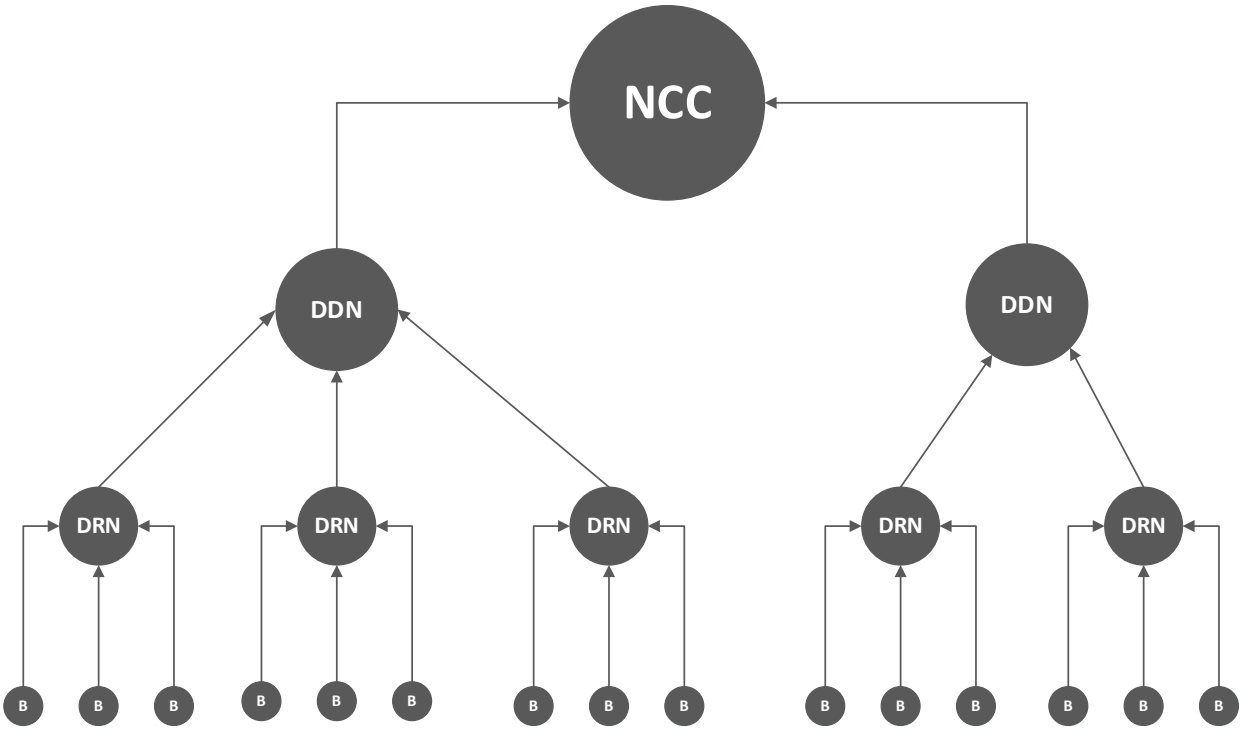

Figure 4. *Hierarchical architecture of LWSN network*

The MDC approach uses mobile nodes that periodically, when needed, or randomly visit each sensor node in the network, download the collected data from each node and transmit them to the sink. The advantage of LWSN for the application of mobile nodes compared to WSNs with other topologies is that the layout of the nodes is known in advance and, given the chain structure, is easy to navigate. Mobile elements can move on the ground as UGV (Unmanned Ground Vehicle), through water as AUV (Autonomous Underwater Vehicle) or through the air as unmanned aerial vehicles or UAV (Unmanned Aerial Vehicle) [24]. Underwater mobile nodes have a limited field of application and are not of interest here. Due to the configuration of the terrain, land mobile nodes cannot always perform all the necessary movements, so it may happen that the acquisition of data from certain parts of the network is missing. In addition, these devices have large delays due to the low speed of movement, which depends on the conditions on the ground. UAVs move three-dimensionally in space and do not have the limitations of terrestrial mobile elements, and due to the specific conditions of application in LWSN, they prove to be the only possible solution. The problem of the consumption of batteries needed to drive the UAV is overcome by the element returning to its destination or going to the next station, where its batteries can be replaced or recharged.

UAV can be used at different levels of the network in a wireless sensor network. At the lowest level, UAVs can play the role of basic mobile SN sensor nodes, whose primary task is to read various data from the field and deliver them to the processing site. The use of UAVs at this level significantly expands the sensor field beyond the area covered by static sensors. If UAVs are used at the second level of the wireless sensor network as relay nodes, all network communication with higher levels is done via the UAV. Readings on the ground are still taken by static sensors arranged and grouped appropriately. The use of UAVs at the third level of the wireless sensor network implies that several UAVs are used in the network, which collect data from the basic level directly from SN or from relay nodes. If a multi-hop network is used at lower levels, further communication is carried out according to distributed sinks or directly with the NCC. Figure 5 shows the case where the UAV is used on the third layer of the network architecture.

LWSNs applied in street parking lots can be kilometers long. The multi-hop architecture covering

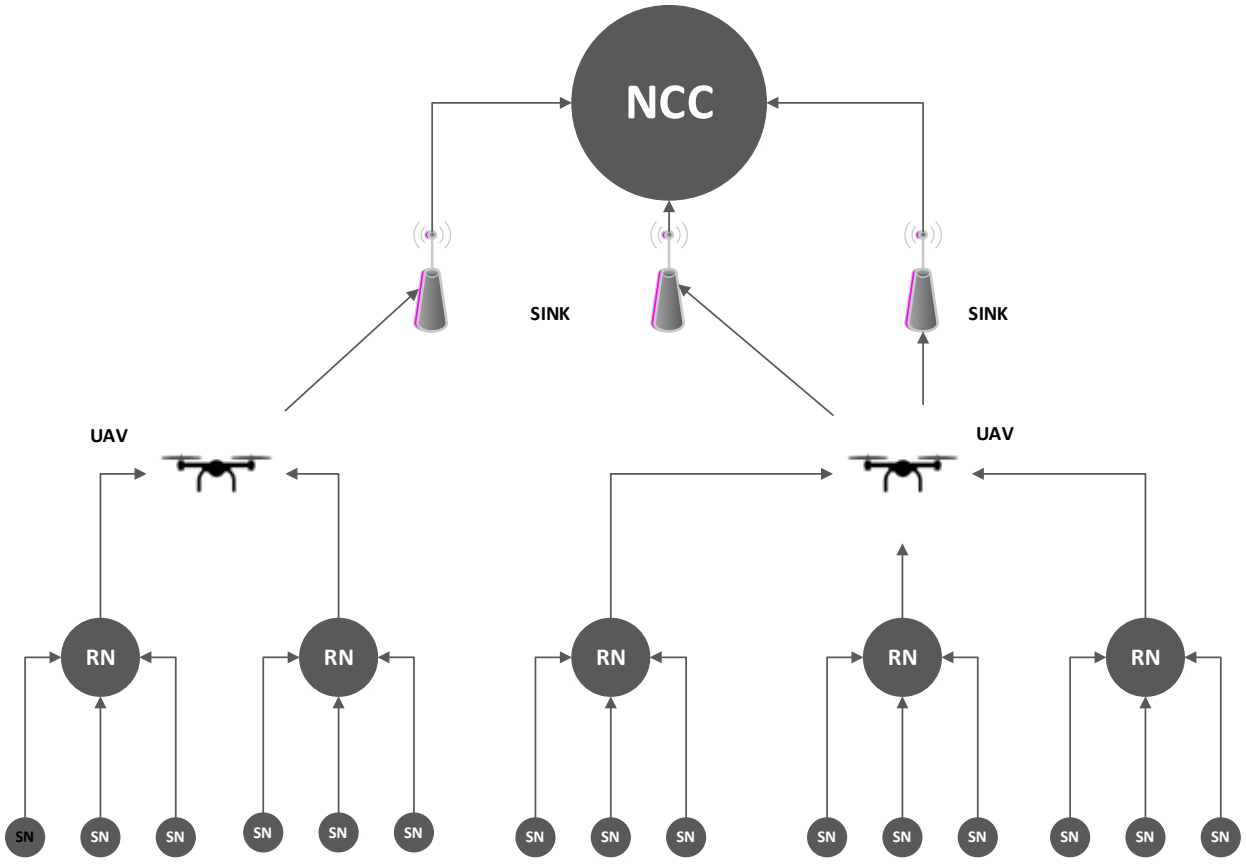

Figure 5. *MDC architecture of LWSN with application of UAV on the third layer*

these networks should deliver all collected data to the NCC processing point. Due to the length of the network and large propagation routes, energy in these networks is consumed relatively quickly. UAV devices have the ability to replenish energy as well as replace batteries, meaning that energy in these networks is a less critical resource. The UAV collects data from each node individually or from relay nodes where data aggregation is performed from a lower level, which causes a significant delay in the network, which is not a critical problem in Multihop networks. The UAV stores the data it collects along the route in a buffer, until it reaches the range zone of the higher layers of the network, and only then does it deliver. If the buffer capacity is exceeded, some of the packets are irretrievably lost.

Both approaches can be used in urban areas to acquire data from smart parking lots. However, the authors recommend a multihop architecture. The problems accompanying this type of architecture are primarily related to limited power supply capacity, and it is necessary to find suitable transmission protocols that will optimize energy consumption.

Conclusion

Parking in the centers of large cities is one of the most frustrating activities for their residents and visitors. Given that the concept of smart cities is primarily intended to raise the quality of life of all participants to the highest possible level, it is clear that smart parking lots represent one of the most important segments. Data collected from the scene in real time, transmitted through the appropriate infrastructure and used on simple applications provide a platform that provides drivers with all the necessary services that enable easy parking even in the most complex conditions. In this paper, we based ourselves on the description of the infrastructure suitable for a smart parking system in the conditions of street parking, which are very attractive in the absence of closed parking spaces in the city center. Two possible architectures of linear wireless sensor networks are presented. Both approaches can be used in urban areas to acquire data from smart parking lots. However, the authors recommend a multihop architecture. The problems accompanying this type of architecture are primarily

related to limited power supply. Tt is necessary to find suitable transmission protocols that will optimize energy consumption, and the authors plan to focus on this segment in their further research.

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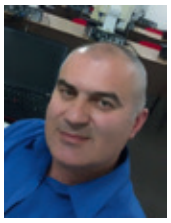

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COMPARATIVE ANALYSIS OF RELATIONAL AND NON-RELATIONAL DATABASES

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Contribution to the State of the Art

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Abstract: This paper presents the results of research into the use of relational and non-relational databases, as well as their comparative analysis. A theoretical overview of the comparative analysis by different segments of relational and non-relational databases is presented. Comparative analysis through the practical application of databases is shown through the use of applications for measuring system performance.

Keywords: relational databases; non-relational databases; comparative analysis; MSSQL; MongoDB

INTRODUCTION

As the IT market develops rapidly, there is a need to check available database solutions, but also to adapt them to different conditions. The current situation in the IT world, as well as the great popularity of NoSQL databases, encourages more detailed research and analysis of why non-relational databases are being used more and more today, in addition to standard good relational databases. Relational and non-relational database models, as well as their comparative analysis, are presented in this paper.

COMPARATIVE ANALYSIS - THEORETICAL REVIEW

Many traditional relational databases have been used in a very large number of applications so far. New technologies have been developed with the aim of dealing with increasing amounts of complex data. Choosing the most suitable database can sometimes be tricky, and such comparisons make it easier for the user to choose the appropriate database that can meet all the needs of the application. The user uses SQL or another structured query language to manipulate and define the data, and then applies a predefined scheme to analyze the data. SQL is great for complex queries, however even the smallest change in the database can affect the functionality of the entire system. With NoSQL databases, dynamic schemes are used to manage data that does not have to be stored in tables, but can be displayed in documents, graphs, columns, and so on. For decades, the predominant data model used for application development was the relational data model used by relational databases such as Oracle, SQL Server, MySQL, PostgreSQL, and others. It was not until the mid-2000s that other data models began to be significantly adopted and used. The term NoSQL is used to distinguish and categorize these new classes of databases and data models. When choosing a modern database, one of the biggest decisions is whether to choose a relational (SQL) or non-relational (NoSQL) data structure. Although both relational and non-relational are viable options, there are key differences between these two types of databases that users must keep in mind when making a decision.

A. Database architecture and scheme

At the most basic architectural level, the biggest difference between the two technologies is that SQL databases are relational, while NoSQL databases are non-relational. SQL databases use a structured

query language and have a predefined scheme for handling data. SQL is one of the most versatile and widely used query languages, which makes it a common choice for many use cases. It is perfect for complex queries. However, SQL can be too restrictive. Predefined schemes must be used to determine the structure of the data in order to work with it. All data must have the same structure. This process requires significant preparation in advance. If there were ever a desire to change the data structure, it would be difficult and would disrupt the entire system. On the other hand, NoSQL databases have dynamic schemes, and data is stored in many ways. Column-oriented storage, documents, graphs, and similar can be used to store data. This flexibility means that documents can be created without first defining their structure, that each document can have a unique structure, that the syntax can differ from database to database, and that fields can be added at an indefinite time interval.

B. Database scaling

SQL databases are vertically scalable in most situations. It is possible to increase the load on a single server by adding more CPU, RAM or SSD capacity. NoSQL databases are horizontally scalable. More data can be managed which adds more servers to the NoSQL database. Horizontal scaling has greater overall capacity than vertical scaling, making NoSQL databases the preferred choice for large, frequently changing data sets.

C. Data structure

SQL databases are table-based, while NoSQL databases are document stores. SQL databases are better for multi-row transactions, while NoSQL is better for unstructured data such as documents or JSON. SQL databases are also often used for legacy systems that are built around a relational structure.

D. Optimal workload

Relational databases are designed for transactional and highly consistent online transaction processing (OLTP) applications and are good for online analytical processing (OLAP). On the other hand, non-relational databases are designed for many data access patterns involving low-latency applications as well as semi-structured data analytics.

Choosing or recommending a database is a key responsibility for most database professionals, and "SQL vs NoSQL" is a useful rubric for informed decision-making. When considering any database, it is also important to consider critical data needs and acceptable trade-offs to meet performance and uptime goals. Choosing the right database is not easy. An optimal but unknown database can negatively impact the entire project, while a suboptimal but known tool can be sufficient to get the job done.

Once a user has decided whether to use a SQL or NoSQL database, he must move his data into it. Data migration is a complex process that can present serious challenges. If there is a problem with that operation, Xplenty's Extract, Transform, Load (ETL) helps with automated functionality and a code-free visual interface to facilitate data transfer. Extensive support is available for all SQL databases from their vendors. There are also many independent consultants who can help with SQL database for very large applications, whereas some NoSQL databases still need to rely on community support. Only some external experts are available for NoSQL functionality.

SQL is usually a good choice and is fairly universal for most projects. However, for more specialized work, a NoSQL database can provide a much more efficient result. When you need to find a fast and scalable database, if you don't mind sacrificing some robustness, MongoDB might be just what you need. The use of both SQL and NoSQL databases has its place in modern software development. Each of them has its advantages and disadvantages. NoSQL databases can include SQL elements, while SQL databases can offer some of the advantages of NoSQL through new functions.

Comparative analysis – practical work

A. Installation

For the purposes of using databases, it is necessary to install servers and a tool for working with databases. MSSQL Express Server and MSSQL Server Management Studio 2018 were used in the project work to create relational databases. To create non-relational databases, we used MongoDB server v5.0 and MongoDB Compass. The procedure for installing and setting up both databases is very simple, but installing the MongoDB database requires addition-

al steps, such as setting folder permissions, adding system variables, and the like.

B. Syntax

The SQL language is used by relational databases. SQL is used to define data and to manipulate data. It represents a reliable and safe language for working with complex databases, as well as database queries. It has certain rules that must be followed when using it, and for that reason it is limited. An example of an SQL query is as follows:

```
INSERT INTO Izdavac (Naziv)
VALUES ('Rezim Beograd');
```

Non-relational databases, unlike relational databases, do not use the SQL language to define data, but store all data in JSON format. JSON (JavaScript Object Notation) is one of the standards for storing text designed for readable data exchange. In addition to the JSON format, BSON (Binary JSON) is also very often used, which enables the recording of additional data such as binary data and the like. An example of a NoSQL query is shown below:

```
db.izdavac.insert({"Naziv":"Rezim Beograd"});
```

Table I. *Display of Different Queries Over Databases*

MSSQL	MongoDB
SELECT * FROM Film	db.Film.find();
CREATE TABLE [dbo].[Zanr]([ZanrId] [int] IDENTITY(1,1) NOT NULL, [Naziv] [nvarchar](20) NULL, CONSTRAINT [PK_ZANR] PRIMARY KEY	db.createCollection("Film");
INSERT INTO Osoba VALUES ('Marko', 'Markovic', '1985-12-17', 'Vidovdanska bb')	db.Osoba.insert({"Ime":"Marko", "Prezime":"Markovic", "DatumRodjenja":'1985-12-17', "Adresa":"Vidovdanska bb"};
UPDATE Osoba SET Adresa = 'Banjalucka bb'	db.Osoba.updateMany({}, {$set:{"Adresa":"Banjalucka bb"}});
DELETE FROM Osoba WHERE Ime= 'Marko'	db.Osoba.deleteOne({"Ime":"Marko"});
DELETE FROM Osoba	db.Osoba.deleteMany ({});
SELECT F.Naziv, F.VrijemeTrajanja, Z.Naziv FROM Film as F JOIN FilmZanr as FZ ON FZ.FilmId = F.FilmId JOIN Zanr AS Z ON FZ.ZanrId = Z.ZanrId WHERE F.Naziv = 'Novi 2 film'	db.Film.find({Naziv:"Novi 2 film"});
SELECT COUNT(*) as Kolicina FROM Film	db.Film.count();

By using SQL and NoSQL databases, differences in the syntax of these databases can be observed. This paper will use the MSSQL database, which is a representative of SQL or relational databases, and the MongoDB database, which is a representative of NoSQL or non-relational databases. Given that the access and content of these databases is different and the syntax is significantly different. In order for one to better see the differences between the syntaxes, the table with basic queries in MSSQL and MongoDB is shown below.

C. Structure

Data within the database is logically organized according to the database model. The database model itself determines what the logical structure of the database may look like. The relational model is based on relations, and data is displayed in tables. Relational databases are based on tables. A table consists of columns and rows, and each column is defined as an attribute of the table. Rows within a table are defined as an "n-tuple" of the table. As mentioned earlier, MSSQL is limited and it is necessary to define precisely for each attribute which data type will be placed.

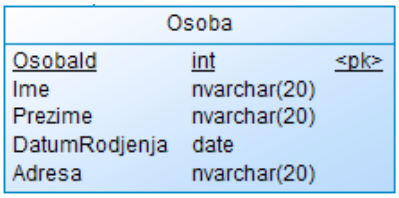


Figure 1. *View of the table Person with exactly defined attribute types*

Non-relational databases are dynamic, and the user determines which attributes and data to place within the collection. There is a great difference be-

tween relational databases that use tables and non-relational databases that use documents. Within the collection, data can be placed according to the user's wishes, and these data can also differ in each subsequent entry according to the number of parameters that will be passed. Using non-relational database models, there is a certain freedom and it is much simpler to add new types and new data. A view of one data set within the Person collection is shown in the image below. It can be concluded that during each data entry, the name of the attribute that is placed is also entered, and for this very reason, the possibility of entering a smaller number of attributes opens up.

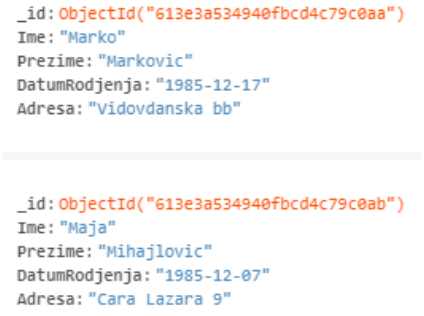


Figure 2. *View of the table Person with exactly defined attribute types*

TIME COMPARISON OF EXECUTION OF QUERIES USING MSSQL AND MONGODB DATABASES

In this part of the paper, the results obtained by executing different queries using different tools will be presented. After the obtained results, comparisons of the time needed to execute queries on the databases will be made. Client Statistics within MSSQL Management Studio was used to measure the time required to execute queries against the MSSQL database.

When executing a query against MongoDB, using the console, a function was used to display the necessary information after the query was executed:

db.Film.find().explain("executionStats");

After the function is successfully executed, an object containing the data "executionTimeMillisEstimate" is obtained, which returns the time required to execute the query. Using MongoDB Compass, the time required to execute a query can be found using the "Explain Plan" tab where you can get the exact performance and data about the executed query. All queries and performance tests were run on a spec laptop:

- Intel Core i7-7500U
- 16GB RAM DDR4
- Maxtor Z1 SSD 480GB, 6Gb/s
- Windows 10 Pro

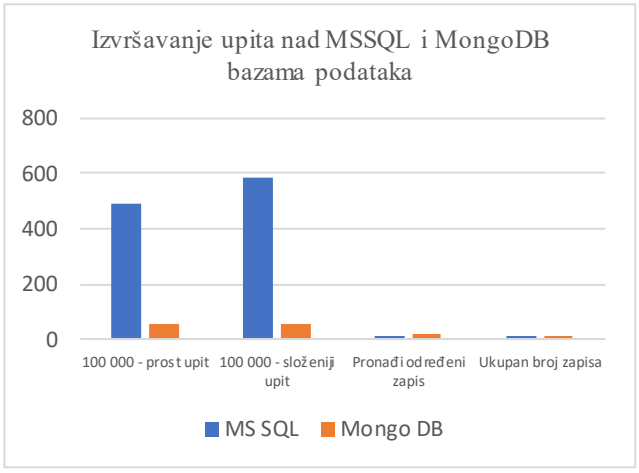
Table II. *Display of Executed Queries*

MSSQL	MongoDB
SELECT * FROM Film	db.Film.find();
SELECT F.Naziv, F.VrijemeTrajanja, Z.Naziv FROM Film as F JOIN FilmZanr as FZ ON FZ.FilmId = F.FilmId JOIN Zanr AS Z ON FZ.ZanrId = Z.ZanrId	db.Film.find();
SELECT F.Naziv, F.VrijemeTrajanja, Z.Naziv FROM Film as F JOIN FilmZanr as FZ ON FZ.FilmId = F.FilmId JOIN Zanr AS Z ON FZ.ZanrId = Z.ZanrId WHERE F.Naziv = 'Novi 2 film'	db.Film.find({Naziv:"Novi 2 film"});
SELECT COUNT(*) as Kolicina FROM Film	db.Film.count();

Table 3 shows the results of query execution times of different complexity on the MSSQL database and the MongoDB database. The data within both databases were identical. The number of records created in the movie table was 100,000. It should be emphasized that very often the results of executing a query on both databases are much slower the first time, when the query is executed again the execution is much faster. The results shown in the table are taken as the mean value of five consecutive measurements over the same number of records.

Table III. *Display of the Obtained Performance Times*

Execution time - MSSQL	Execution time - MongoDB	Successfully retrieved records
489 ms	55 ms	100 000
587 ms	54 ms	100 000
13 ms	19 ms	1
11 ms	16 ms	1



Graph 1. *Query execution times over MSSQL and MongoDB*

TIME COMPARISON OF EXECUTION OF QUERIES USING MSSQL AND MONGODB INSIDE THE APPLICATION

In order to be able to measure and then compare the execution time of basic CRUD operations on MSSQL databases and MongoDB databases, a project was created in which connections were made to one and the other database. The application was developed in the programming language C#. Database access is enabled using the NuGet packages MongoDB. Driver and MongoDB.BSON. Given that two databases were used, in order to enable fast and simple database changes, the connection strings containing the paths to the databases were stored inside the web.config file. Within the code itself, there are no major differences between the ways of using both databases. The steps in creating the project were creating a connection, creating methods for adding data within databases, reading, modifying and deleting (so-called CRUD operations). Created multiple methods that generated datasets depending on the passed noElements parameter. A test data set was created for testing purposes. CRUD operations on the data were performed on samples of 1, 10, 100, 1000, 10,000, 100,000 records, in order to observe the time dependence with increasing number of records. The test data set was created with the help of the createList method, which receives the variable noElements as a parameter. The method code is shown in the image below.

```
7 references
public static List<BsonDocument> kreirajListu(int brElemenata)
{
    List<BsonDocument> listaElemenata = new List<BsonDocument>();
    for (var i = 0; i < brElemenata; i++)
    {
        var naziv = "Novi " + (i + 1) + " film";
        BsonDocument document = new BsonDocument {
            { "Naziv", naziv },
            { "Orginalni naziv", naziv },
            { "Distributer", new BsonDocument { { "Naziv", "Cinema City" }}},
            { "Jezik", new BsonDocument { { "Naziv", "Srpski" }}},
            { "VrijemeTrajanja", (i+1) },
            { "DatumPremijere", DateTime.Now },
            {"Sinhronizovan", true }
        };
        listaElemenata.Add(document);
    }

    return listaElemenata;
}
```

Figure 3. *CreateList method code*

A. Data addition operation

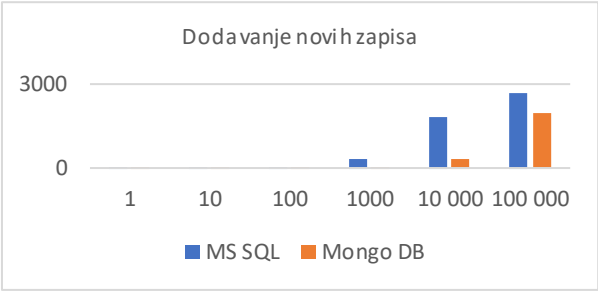
The operations of adding records to the MSSQL database do not require much effort to implement, because both MSSQL and Visual Studio are created by Microsoft, which leads to more efficient collaboration and interaction between the two platforms. The process of adding records to a MongoDB database requires almost the same amount of effort as implementing it with an MSSQL database. The only difference is that more pre-installation and preparation is required at the very beginning. Figure 3 shows the code for adding records to the MongoDB database. To add records to the database, the InsertManyAsync method is used, which is taken from the MongoDB.Driver package.

```
public static async Task<string> InsertFilm(List<BsonDocument> pplList)
{
    Stopwatch timer = new Stopwatch();
    var collection = OstvariKonekcijuNoSQL();
    timer.Start();
    var result = await collection.InsertManyAsync(pplList).ContinueWith(x => x.ToJson());
    timer.Stop();
    return timer.Elapsed.TotalMilliseconds.ToString();
}
```

Figure 4. *The InsertFilm method used to add records to a MongoDB database*

Table IV. *Display of the Obtained Times Required for Performing the Addition Operation*

Execution time - MSSQL	Execution time - MongoDB	Successfully created records
33.19 ms	7.65 ms	1
18.65 ms	19.95 ms	10
56.33 ms	11.82 ms	100
353.98 ms	51.75 ms	1000
1845.08 ms	338.91 ms	10000
2695.66 ms	1955.36 ms	100000



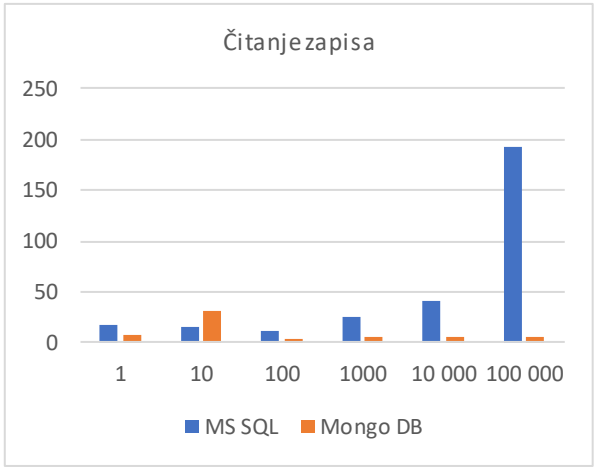
Graph 2. *Adding new records in MSSQL and MongoDB*

B. Data reading operation

Database reading operation depends on many factors. The very structure of the data and the method of saving it in the database is an important factor. Due to its unstructured nature, the MongoDB way of reading data can be quite complex when finding and searching for information in the database. Read operations mostly depend on the complexity of the data structure and how it is stored. The data used when executing the query and measuring the execution time does not have complex complexity, which results that for reading certain simple records the performance of the MongoDB database is better compared to MSSQL. By executing queries on the database and reading the data, results were obtained that show that temporal MongoDB queries are executed faster, especially in the case of a large number of simple records. The results are based on the average time it takes to perform a read operation over a different number of records.

Table V. *Display of the Obtained Times Required for Performing the Reading Operation*

Execution time - MSSQL	Execution time - MongoDB	Successfully created records
17.15 ms	8.06 ms	1
14.69 ms	31.34 ms	10
12.40 ms	3.45 ms	100
24.96 ms	5.28 ms	1000
40.36 ms	6.06 ms	10000
192.76 ms	5.90 ms	100000



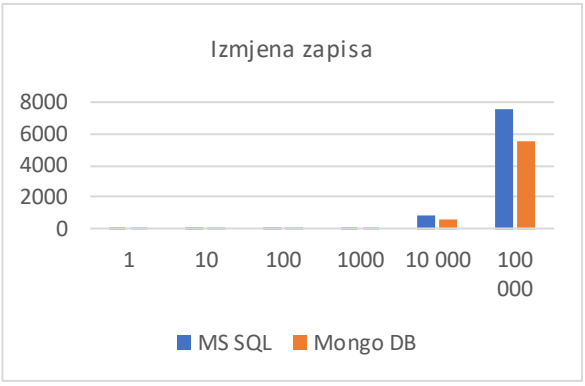
Graph 3. *Reading records in MSSQL and MongoDB*

C. Data change operation

Changes to database data can be made using different criteria. When executing the query in the application, the update of all records and the modification of two attributes within the record were used. Execution performance depends on the criteria used when finding a particular record. MongoDB achieves better results, while in situations with complex criteria, MSSQL wins. For example, changing all records that contain data of the string type "Banja Luka" in a populated place. Record change operations and their time comparison are shown in Table 6.

Table VI. *Display of the Obtained Times Required for Performing the Change Operation*

Execution time - MSSQL	Execution time - MongoDB	Successfully created records
17.27 ms	25.05 ms	1
15.61 ms	10.48 ms	10
15.52 ms	6.52 ms	100
118.85 ms	64.41 ms	1000
850.57 ms	618.78 ms	10000
7487.32 ms	5511.06 ms	100000



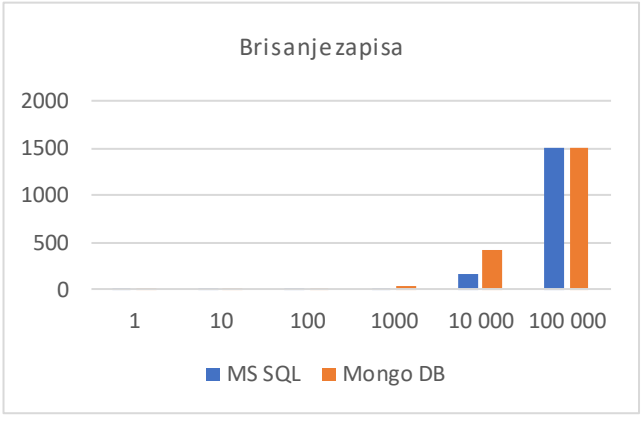
Graph 4. *Change of records in MSSQL and MongoDB*

D. Data deletion operation

The performance of deletion operations on both databases gives similar execution times. When deleting 10,000 records, a better average time is obtained for the MSSQL server, while in other cases the execution times are approx.

Table VII. *Display of the Obtained Times Required for Performing the Deletion Operation*

Execution time - MSSQL	Execution time - MongoDB	Successfully created records
19.35 ms	9.42 ms	1
16.62 ms	8.58 ms	10
12.92 ms	5.23 ms	100
22.09 ms	46.38 ms	1000
157.64 ms	429.36 ms	10000
1508.67 ms	1495.60 ms	100000

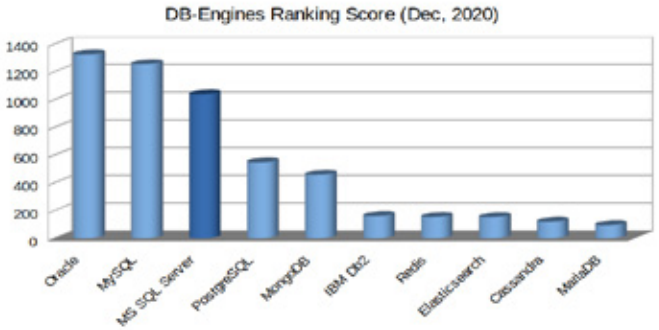


Graph 5. *Deletion of records in MSSQL and MongoDB*

E. Description of the database management systems used

The databases that were used during the development of the application for comparative performance analysis are among the 10 most famous databases in the world. According to data from database ranking site DB-Engines, the MSSQL database is in third place in terms of usage, while the MongoDB database is in fifth place. Microsoft SQL Database Management System is Microsoft's database storage tool. The first version of this tool appeared in 1989 in cooperation between Microsoft and Sybase. After breaking up with Sybase, Microsoft made significant progress in the development of its DBMS. In 1998, there were the first possibilities of using relational databases with personal computers. Its base language is Transact-SQL, which is an implementation of the ANSI/ISO SQL standard. Microsoft SQL Server Express v15.0 was used during the creation of the project, which is otherwise a free version for smaller applications and learning.

MongoDB is a representative of non-relational databases, it is a database management system that uses a document-oriented database model. It is one of the numerous representatives of NoSQL databases. It was created by Dwight Merriman and Elliott Horwitz. It uses a document-based data model because it claims to be a better and more natural way to display data. It stores data as JSON or BSON. MongoDB v5.0 was used in the project development.



Graph 6. *Top 10 databases used in 2021 according to DB-Engines results*

I.

CONCLUSION

Research in the field of databases carried out during the preparation of the paper, and the analysis of all obtained results shows that MongoDB generates better performance on a larger umber of records and on larger amounts of data. Up to 1000 records, the execution times have approximate values, while above 1000 records, much better times are observed when using the MondoDB database. By reviewing individual cases where the results are better with MSSQL databases, it can be concluded that by directly applying MSSQL Management Studio over the database, better execution times are obtained. Therefore, it can be said that MSSQL databases are suitable for small and medium applications. They are suitable when performance is not a priority. Relational databases are widely used in most applications and they perform well when manipulating a limited amount of data. One should be careful when choosing a database. Major factors such as data volume, flexibility, scheme, budget, server type, amount of transactions to be executed, and frequency should be considered. Of course, these are not the only criteria for choosing a database, as it also depends on the company, as well as the purpose for which the application is being developed.

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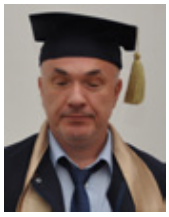

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Aircraft Performance Modeling with Polynomial Function using Small Variable Units Technique

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Contribution to the State of the Art

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Abstract: Mathematical methods of Regression analysis, with focus on polynomial regression, are useful analytical methods for trend-line definitions of an aircraft aerodynamics. Nomogram is graphical interpretation of polynomial regression analysis results and aero-dynamical performance according to different environmental parameters and requirements. If diagram defines relations of two variables, where the one is dependable of another one (*y=f (x)*), the nomogram defines relations among three variables, where the one is resulting and dependable of another two undependable. The Small Variable Units Technique is efficient method to transfer nomograms' data in polynomial equitation which can give us different mathematical models of an aircraft performance. In combination with time based navigation, digitalization of aerodynamical characteristic will be a step forward to Continuous Climb and Descent Trajectories, as the most optimal one.

Keywords: performance optimization, digitalization, composite, regression, nomogram.

Introduction

Fast technical development of new age require more efficient and intelligent way of transportation what put air-transport, air industry and aeronautical science in focus, as solution for modern business models.

Introduction of ultra-light composite materials, efficient and lighter electric propulsions and digitalization of onboard electronics, have brought various alternative aircraft constructions like quadricopters and ultra-light airplanes.

Modern standards of environmental protection, energy efficiency and tendencies for developments of air-traffic networks over large urban area for commuter and personal transportation, put in focus two main aircraft performance requests which could be defined as "On-spot landing" and energy efficient aero-dynamical performance [1].

Even from the beginning of aeronautical science an aircraft aero-dynamical performance was the main focusing issue. Earth gravity and air as medium which provides lift, drag and propulsion force of an aircraft make mathematical modeling a complex task with many dependable and undependable elements and functions.

Mathematical methods of Regression analysis [2], with focus on polynomial regression, are useful analytical methods of experimental testing of an aircraft and definition of trend-line for physical characteristics of aerodynamics which are important for further aircraft exploitation.

Nomogram is graphical interpretation of polynomial regression analysis results and aero-dynamical performance according to different environmental parameters and requirements for aircraft exploitation [3]. Comparing to the diagram, nomogram is mathematical model which presents dependencies of more than two variables, with capability to connect it selves with other nomograms in complex system what gives us mathematical model of aerodynamical characteristic of an aircraft [4].

The Small Variable Units Technique is efficient method by which nomograms' data can be transferred in polynomial equitation and give us mathematical models of an aircraft performance efficient for real time exploitation with various possibilities

for aircraft performance software design according to actual needs and requirements.

The Small Variable Units Technique

If diagram defines relations of two variables, where the one is dependable of another one ($y=f(x)$), the nomogram defines relations among three variables, where the one is resulting and dependable of another two undependable. Mathematical expression of this definition could be presented as following:

$$y=f(x) \wedge f(z)$$

Essentially, the nomogram has three-dimensional nature what is also the biggest problem when it has to be presented in two-dimensional space, like sheet of paper. The solution was found in the way that the first undependable variable can be presented at x-axis, while the cardinal (specific) values of the second one are selected and drown as a series of diagrams or lines with, in most of cases, variable displacement (Figure 1).

The values of the nomogram lines, usually, are forming the polynomial lines (parabolas) which are changing its shape according to the physical lows. Determinations of the polynomial equitation which are capable to describe those laws are the primary task of the data digitalization process. For the purpose of this research MS Excel functions will be used as operational tool.

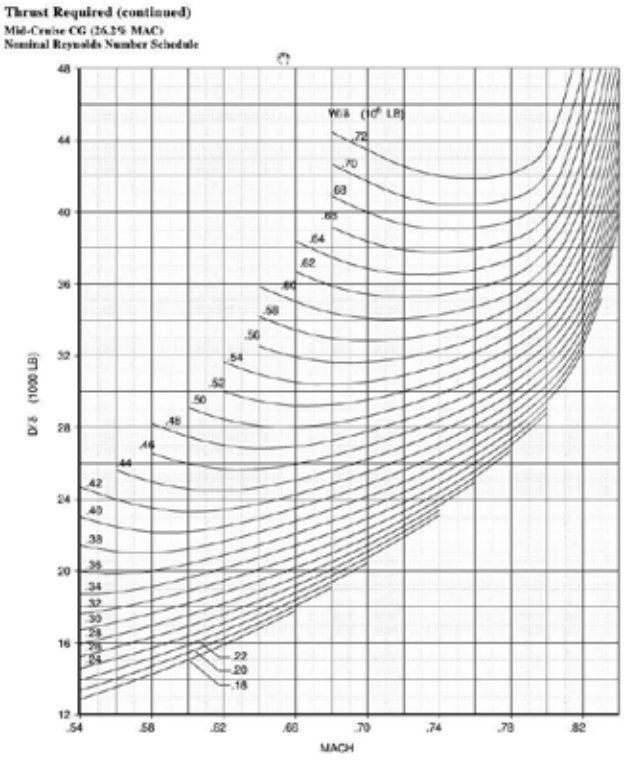

Figure 1

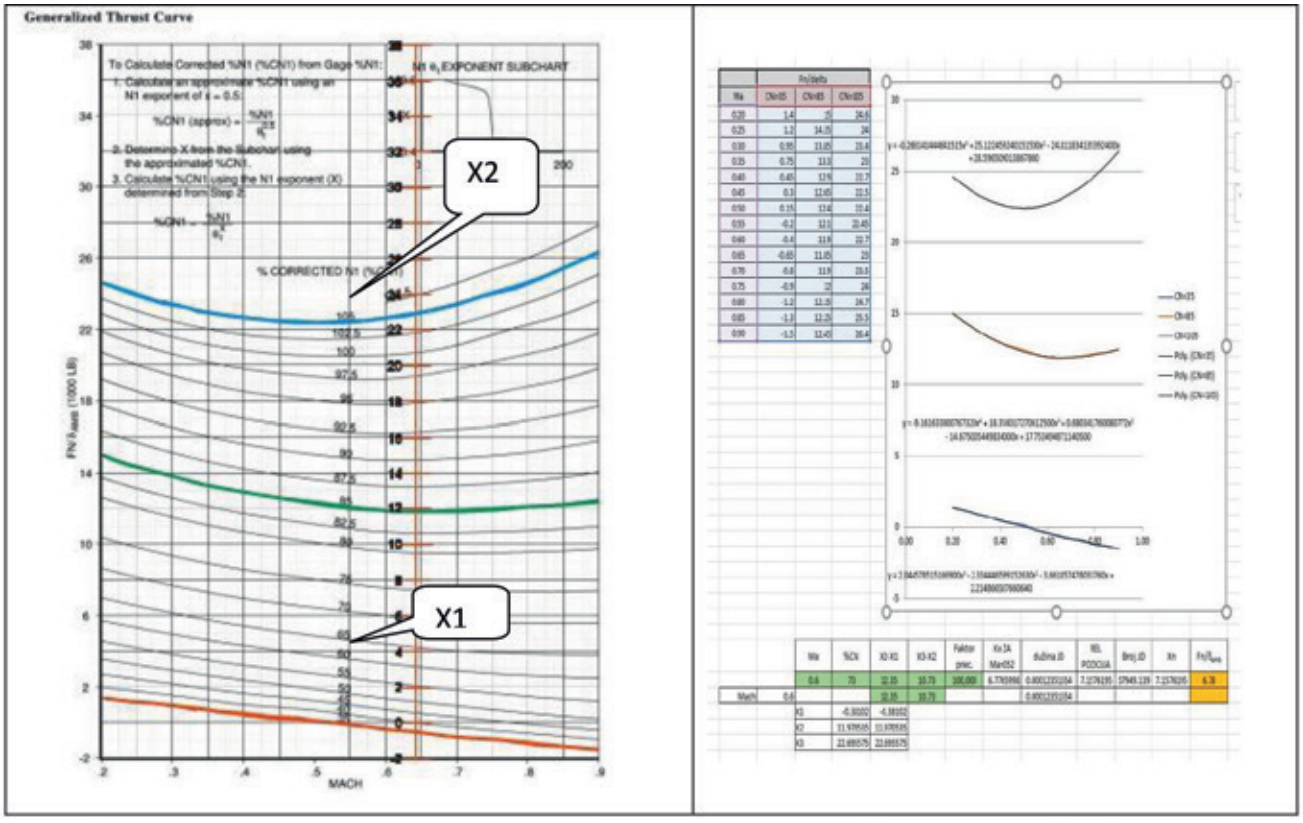

Figure 2. *Nomogram importation in Excel*

Digitalization of a standalone nomogram (three-dimensional) case

The small units with the variable length which are reflecting the variations of the bordering polynomial lines are the core of this technique.

For the successful digitalization process geometrical characteristics of the nomogram polynomial lines have to be carefully evaluated and concrete action plan must be defined, before the digitalization technique should be applied. This can be accomplished if we make the table with data from the nomogram polynomial bordering lines and form the nomogram lines area (Figure 2).

For the nomogram bordering lines the polynomial expression can be defined by the Microsoft Excel "Add Trendline" function, and the polynomial formula looks like this:

$y = 2{,}044578515166900x^3 - 2{,}334446599152630x^2 - 3{,}661857478033760x + 2{,}214866587660640$

Next step implies the relations definition between the resulting values of the function (dependable variable) and the second undependable variable. This can be established if separate table is made with the values of the cardinal lines for the specific value from the x-axis.

When the "y-z" diagram is formed, the law of the polynomial lines displacement variable can also be defined by the "Excel Add Trendline" function (Figure 3).

The third step includes polynomial lines amount calculation that the digitalized nomogram will include. If the characteristic value from x-axis enters two polynomial bordering lines formulas the difference between resulting values will be the length of the straight line between the X2 and X1 points. If this straight line is divided with infinity number the absolute precision of the techniques will be achieved and possibility to calculate the values of nomogram with infinite decimal places will be achieved.

However, with the more pragmatic approach, due to practical use, resulting straight line between bordering points could be divided with determined large number (Precision factor like 100.000) which will define the final value of the small unit that could be used in following calculations with required level of approximation. As we "walk" through the domain on the x-axis the length of the small unit will be

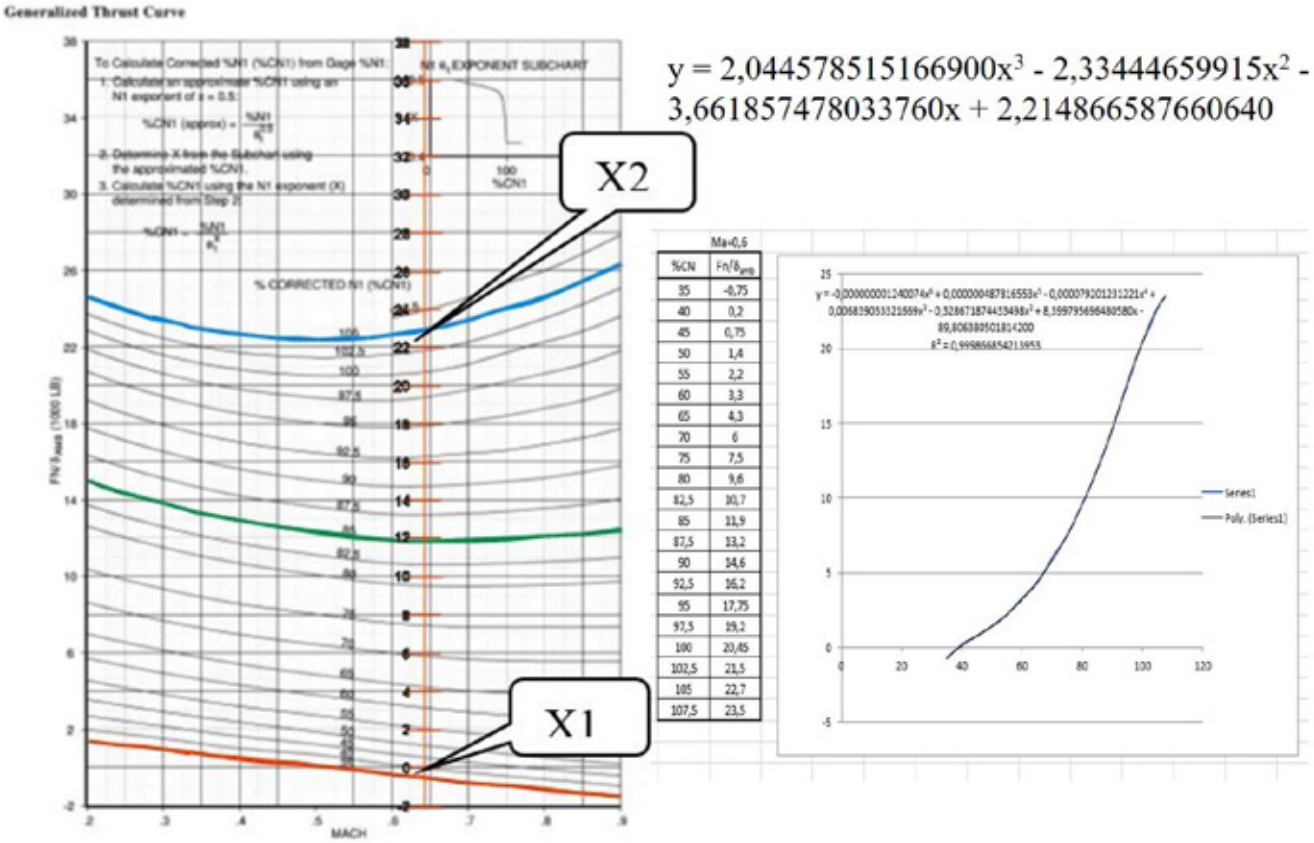

Figure 3. Polynomial lines displacement calculations

		Ma	%CN	X2-X1	X3-X2	Faktor prec.	Kx ZA Ma=052	dužina JD	REL POZICIJA	Broj JD	Xn	Fn/δ_{amb}
		0.6	73	12.35	10.73	100,000	6.7765998	0.00012351554	7.1576195	57949.139	7.1576195	6.78
Mach	0.6			12.35	10.73			0.00012351554				
		X1	-0.38102	-0.38102								
		X2	11.970535	11.970535								
		X3	22.695575	22.695575								

Figure 4. *Nomogram data digitalization calculator*

changed and ruled by the parallel point of the nomogram bordering lines, what gives us "The Small Variable Unit".

The fourth step implies the straight-line length calculation for the characteristic second independent variable values. The polynomial formula, defined in step two, can determine the position of the point, for the characteristic previously defined x-axis value that exactly one and required parabola is passing through. If the length of this straight line is divided by the length of the Small Variable Unit, the result will be the number of the small unit for the required value of the variable two. Multiplication of the Small Variable Unit value or number with its length for the required value from the x-axis domain will produce the set of points and exact shape of the required polynomial line.

System of nomograms digitalization (multi-dimensional case)

As a difference, in this case there are three undependable entering variables which are related to the fourth resulting dependable one, what mathematically can be presented as:

$$y=f(x) \wedge f(z) \wedge f(k)$$

In this case, the values of the first variable are shown at x-axis, while another two are defined as the specific cardinal values. Practically in this situation result is expressed as the series of connected nomograms according to the list of specific values of

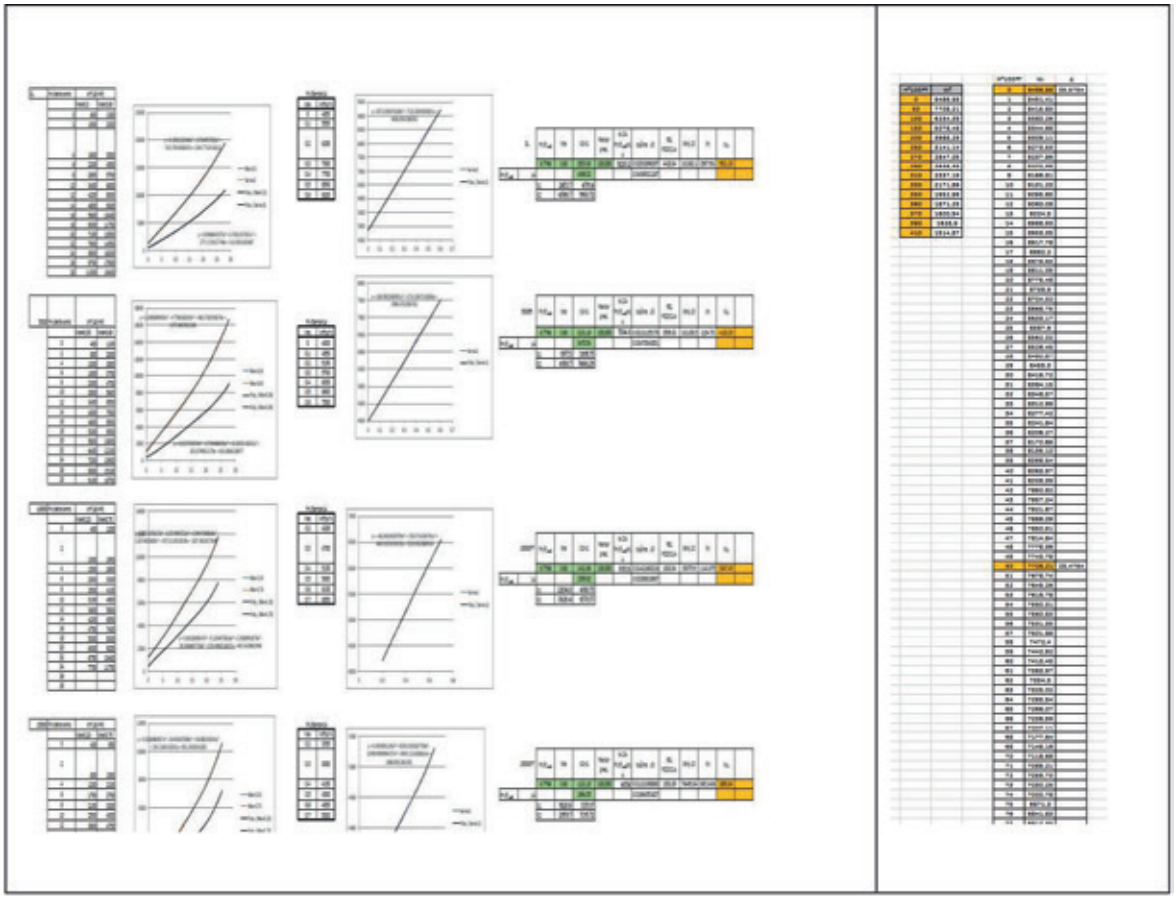

Figure 5. *System of nomograms and the dynamic database*

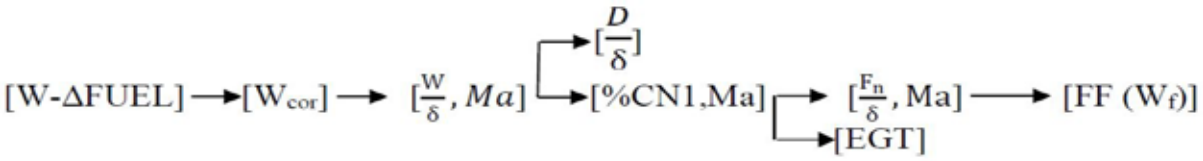

Figure 6. *Performance data calculations algorithm.*

the third variable.

In digitalization process every single nomogram will be separately digitalized in Excel in the way that for the same entering values of the first and second entering variable the result will be the set of data for all specific values of the third variable.

The characteristic Data Base table will be formed from the resulting set of data, which will be stretched out in a spectrum of resulting values for the appropriate level of decimal places (or decade units) of the third entering variable. The values between the resulting data will be proportionally filled and the specific resulting dynamic data base will be formed. The Excel "VLOOKUP" or "HLOOKUP" functions will be used to search dynamic database according to the requested criteria of the third entering variable.

Small Variable Units Technique approximations control

Aside of the fact that SVUT digitalization technique is very precise it also allows the control of approximations and errors which can be made during the process, due to various reasons. Using the "IF/AND" Excel functions every domain of the entering variables can be divided at maximum six separate co-domains. This implies that every single nomogram's three-dimensional space could be divided to the maximum of the separately digitalized 36 parts, in case that «MS Excel» is used as tool for calculations.

The second way of approximations control technique implies that set of testing data will be formed by which the level of resulting data deviations will be determined. According to the deviations data the correction function will be defined and the corrections will be in-calculated in the final results.

Mathematical model of an aircraft performance parameters calculator

Essentially the mathematical model of an aircraft performance can be defined as list of mathematical expressions which can transform various numbers

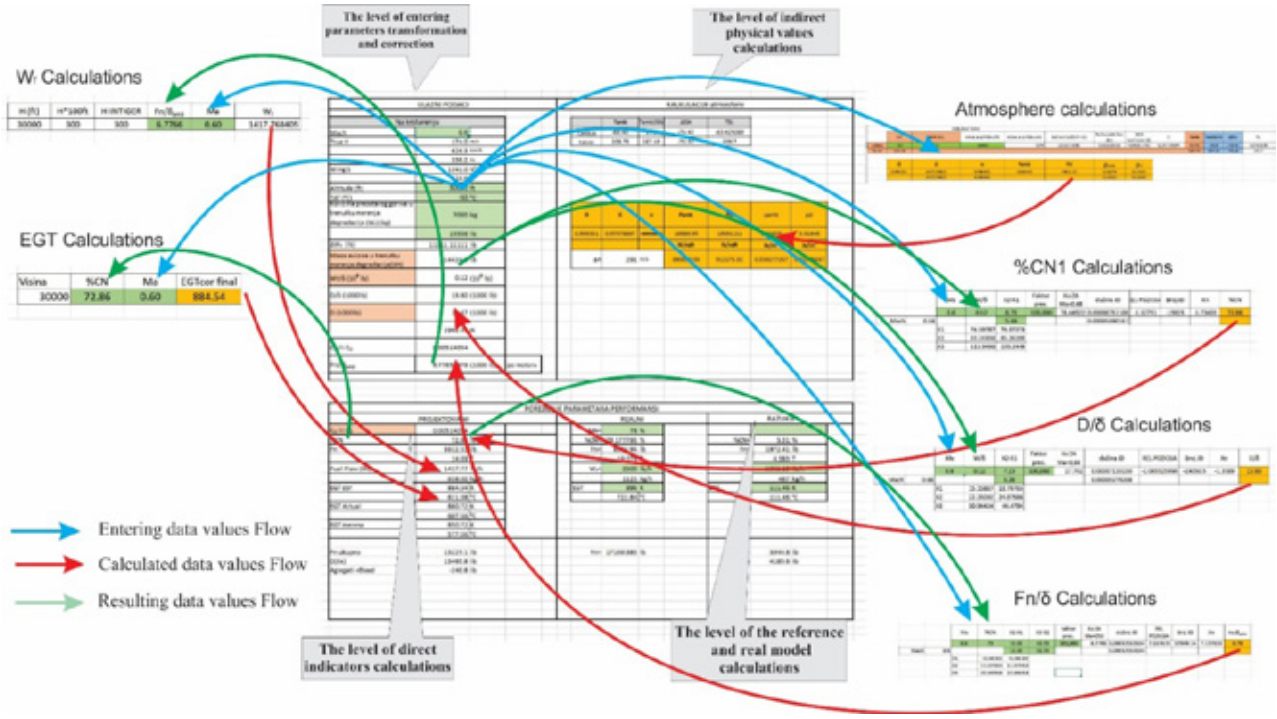

Figure 7. *Mathematical model of aircraft performance data calculated in Microsoft Excel.*

of entering data in required number of results and physical values which are necessary for the analysis.

Mathematical model of an aircraft performance parameters calculator has multilayer nature and cover different levels of calculations:

1. **The level of entering parameters transformation and correction –** which covers transformation of entering data (Ma, H, W, TAT) and its physical values in required values which will be used in further calculations.
2. **The level of indirect physical values calculations –** which implies entering data required by mid-calculations basically referred to defined real atmosphere model.
3. **The level of direct indicators calculations** – which covers the relations between the system of mathematical formulas and the entering and mid-calculated data which gives the set of resulting parameters required for the performance analysis.
4. **The level of the reference and real model calculations –** which will provide set of information data for the precise and complete performance indicators analysis.

In practical application of this technique an algorithm of required aircraft performance data will be defined (Figure 6.), and transformed in actual system of connected calculations (Figure 7.).

Conclusion

Energy efficient aircraft performance is corner stone of U-Space ATM development. Digitalization of aircraft nomograms and other experimental and testing data will provide further improvement of concepts and solutions in aircraft aerodynamical design.

In combination with time based navigation, digitalization of aerodynamical characteristic will be a step forward to introduction of Continuous Climb and Descent Trajectories, as the most optimal one.

As U-Space will be relatively smaller air-space volume, compared to the actual ones used for general traffic, with relatively short en-route phase, digitalized aircraft performance with time based navigation could provide environment for spherical or parabolic UTM system development, as a solution for requirements of dynamic U-Space Air-Traffic Management.

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For citation

Vladimir Milosević, Aircraft Performance Modeling with Polynomial Function using Small Variable Units Technique, *JITA – Journal of Information Technology and Applications, Banja Luka*, Pan-Europien University APEIRON, Banja Luka, Republika Srpska, Bosna i Hercegovina, JITA 13(2023) 1:29-34, (UDC: 629.735.3.085:517.445), (DOI: 10.7251/JIT2301029M, Volume 13, Number 1, Banja Luka, June (1-56), ISSN 2232-9625 (print), ISSN 2233-0194 (online), UDC 004

Panel Analysis in Function of Measuring the Impact of Higher Education on International Competitiveness of the Western Balkan Countries

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Case Study

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Abstract: An important aspect of the development and perspectives of the development of the socio-economic community refers to the level of coverage of the labor market with adequate staff in terms of expertise and competencies, which largely derive from the results of the educational process. Expressing and measuring the results of the educational process is a continuous and complex process, and requires the application of adequate methodology, such as a panel analysis model. The aim of the researchers is to examine the impact of higher education on appropriate macroeconomic indicators countries of the Western Balkans, which are not yet members of the European Union. The practice of such research has been formalized in Western European countries, where researchers have adequate access to the empirical material on which research is based, but also a standardized procedure for presenting appropriate indicators, which is not the case in the selected geographical area. The context of the educational process since the period of introduction and adoption of the determinants defined by the Bologna Declaration, is going through a turbulent process of transformation. The next turning point in the education system is justified by the pandemic caused by the COVID - 19 virus.

Keywords: econometric model, economic growth, international competitiveness, panel analysis, crisis management

Introduction

Educational activities shape the individual development of each inhabitant. The level of state development is directly related to the educational structure. The level of education represents personal, but also general intangible capital, and it is important to pay significant attention to it on a personal and general level.

It is a common that the level of education correlates with social status, employment opportunities and the acquisition of material goods. The benefits of education do not remain on a personal level, but are reflected in the wider community. Education requires material investments by the individual, and by the social community, or the state as well. The amount of investment in the educational process determines its quality, and the future rate of return through the achieved result in the educational process.

Higher education throughout history has been considered the privilege of selected individuals. Over time, the aim has been to expand the circle of educated people through measures that facilitate access to the higher education system. Measures that have significantly facilitated access to the higher education system are investments in that system. Investments in the education system have different forms and amounts, and whose effects are not explicit in terms of contribution to the social system.

The research is based on a panel analysis whose task is to provide information on the impact of the higher education system on the international com-

petitiveness of the countries covered by the research.

The analysis refers to the Western Balkan countries, such as Albania, Bosnia and Herzegovina, Montenegro, Kosovo, North Macedonia and Serbia, and it covers the period from 2007 to 2020.

LITERATURE OVERVIEW

Human capital is the basic driving force for every socio-economic system, with education being considered an important element. The educational process is realized in a formal and informal way. It is conditioned by technological development and it is justified to consider it as a continuous need of each individual.

The pandemic caused by the COVID - 19 virus, which in a short period of time introduces changes in the functioning of all segments of business and social activities in the socio - economic community in general. [1]

Numerous research projects have treated the problems of conditionality of the educational process results, and their impact on macroeconomic indicators, such as GDP and GDP per capita. Research has proven the fact that the positive effect of higher education correlates with the degree of technological development. [2].

Eurostat points to the fact that government spending in the higher education segment in the period from 1995 to 2019 was decreasing; it was stagnant in the pre-pandemic period, while in the same period investment in primary and secondary education was above the higher education investment. [3]

The impact of income inequality[1] on GDP per capita has been proven by the construction of panel models by Brueckner and Lederman. The authors proved the conditionality of the contribution to the level of development of the country. [4]. It is important to note that researchers have proven that the inequality coefficient makes a significant contribution to transitional growth, while in the long term it has a negative impact on GDP per capita.

It has been proven that the highest degree of inequality is present in underdeveloped and developing countries, and that the impact of innovation on income inequality is dominant in relation to other factors. [5].

Research confirms that there is a positive relationship between wealth inequality and real GDP growth per capita, but this relationship is not robust to different model specifications. [6]

The impact of income inequality on the development of intellectual capital, and on long-term economic growth, is negative, and is reflected in the investment decline in the education and health systems. [7]

The educational process and business orientation institutions in the field of higher education often focus on formal processes, and unduly neglect the importance and potency of non-formal educational patterns. [8]

The fact that the number of higher education consumers is decreasing, both in our country and in the countries of the European Union and America, has been confirmed. [9] Research showed that, comparing to the previous year, the number of students dropped between 3 and 9% in the academic year 2018/2019.; in Bosnia and Herzegovina in the period from 2017/18. until 2021/22 a significant decline has been registred year by year, decreasing by 31, 11, 7.8 and 32.5% in the observed comparing to the previous year. [10]

The importance of non-formal education in ensuring employee's satisfaction in the workplace is a characteristic that is qualified among the four non-economic factors that ensure raising the level of business efficiency. [11]

ANALYTICAL FRAMEWORK OF RESEARCH

Analytical approach requires prior insight and valid knowledge of the economic prosperity of the countries covered by the survey, and this should be observed in the context of economic growth indicators of the countries surveyed, but also by comparing their growth in relation to other countries, which is done here in relation to countries that were part of the former socialist bloc and are now members of the European Union (CEE), European Union countries (EU27) and the World Bank (WB). In the period from 2019 to 2023, following the current growth trend, in the conducted estimating model, Kosovo, Serbia and Montenegro have growth that is higher compared to other observed territorial units. (Figure 1)

[1] Inequality is most often measured by the GINI coefficient and refers to income inequality

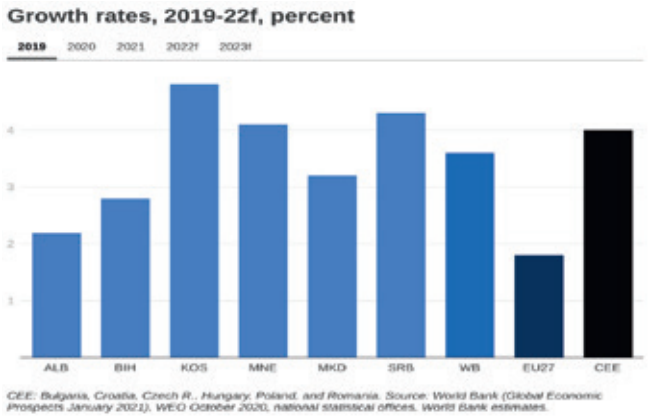

Figure 1. [12]

Considering that economic growth is a complex category, conditioned by many indicators, special attention will be paid to the category of gross domestic product growth per capita conditioned by a selected spectrum of macroeconomic indicators, which include the dimension of investment in education as one of the factors in the selected territory and time period.

Educational Structure and Employment in the Western Balkan Countries

The development of the modern state and its key aspects are related to unemployment, educational needs and the ability of the educational system to respond to them in an adequate way. Considering the fact that there is a correlation between unemployment and the level of education, the European Commission identified a key problem related to the transition of young people from the educational process to a specific work environment [13]. It was noticed that the support for the young population when entering and staying on the labor market positively correlated with economic growth and living conditions.

The sensitivity to business cycles is higher among young population compared to the older working population, and an additional challenge relates to the lack of work experience among young people, which significantly complicates their employment. In the period from 2008 to 2013, youth unemployment increased, and after reaching its peak 2013, it began to fall until the corona virus crisis. The unemployment rate was 16.9% in the European Union, 17.2% in the Eurozone, and 35% in the Western Balkans [14].

In the Europe and the Western Balkans labor market, there is a phenomenon of "overeducation" which refers to the fact that there is a mismatch between the needs of the labor market and workers's education, where knowledge and skills are above the demands and real needs of the labor market, which leads to a decline in the cost of labor of workers who accept jobs below their abilities, but also a low level of job satisfaction. The phenomenon of "brain drain" means the migration of highly skilled and educated young people from poor, developing and less industrialized countries to richer, more developed ones that provide them with better working and / or living conditions than those they can achieve in their home country.

Problems can be overcome by changing the approach to the youth labor market without or with limited work experience, by enabling young people to gain work experience within the profession for which they are educated, and thus increase personal competitiveness in the labor market.

THEORETICAL MODEL FROM EMPIRICAL OBSERVATION

The intention and task of the specific research project were to clarify the conditionality of investments in the higher education system on the economic development of the Western Balkan countries that were not (yet) members of the European Union. The time frame of the research was from 2008 to 2020, and the empirical material was taken from the database on the World Bank's website. (World_Bank, Global-economic-prospects, 2021)

Dynamic Approach to Empirical Analysis of Concrete Indicators

Empirical analysis and measuring the impact of investment in higher education on the selected indicator of economic development with respect to the teritory and time component is possible and efficient by using the methodology of panel (data) analysis. Panel analysis is a complex and relevant econometric technique, the results of which clarify a number of complex research issues. The quality of the panel data results is conditioned by the adequacy of the empirical material used for their generation.

Panel data models allow the dependent variable to be expressed as a function of a number of independent variables, taking into account the influence of the teritory and time component. Depending on whether the value of a variable depends on its value in previous periods or not, panel data models can be static and dynamic. For a large number of real economic processes, such as the analyzed problem, it is optimal to apply a dynamic panel data model whose general form can be written by the relation:

$$y_{ij(+gdppc)} = a + y_{i,j-1(+gdppc)} + b_1 x_{ij(+bi)} + b_2 x_{ij(GINIko)} + b_3 x_{ij(izvo)} + b_4 x_{ij(uvos)} + m_i + \varepsilon_i$$

The meaning of the variables in the model can be illustrated by the following table.

Table 1. *[15]*

Variable	Variable type	Model mark
Annual growth of gross domestic product per capita expressed as a percentage for the i-th country in the j-th time period	Dependent	Y_{ij}
Annual growth of gross domestic product per capita expressed as a percentage for the i - th country in the previous year in relation to the year preceding the observed	Independent	$Y_{i,j-1}$
Annual growth of gross investment expressed as a percentage for the i - th country in the j - th time period	Independent	$X_{ij(+BI)}$
The value of the inequality indicator, or the GINI coefficient, which expresses the inequality expressed in the form of percentage annual growth in relation to per capita income for the i-th country in the j-th time period	Independent	$X_{ij(+GINIko)}$
Share of allocations for higher education in total allocations for education for the i-th country in the j-th time period	Independent	$X_{ij(IZVO)}$
Percentage share of highly educated population in working age population for i - th country in j - th time period	Independent	$X_{ij(UVOS)}$

a, b_1, b_2, b_3, b_4 - the model parameters whose value we determine using the appropriate panel data model;
m_i, ε_{it} - constant and residual of the model, where:
$i = 1, 2, ..., n$;
$j = 1, 2, ..., m$;
n - indicates the number of spatial units;
m - indicates the number of time units;

RESEARCH RESULTS AND DISCUSSION

The panel model adequacy for expressing the results is conditioned by the multicollinearity in the model, which is checked by determining the intercorrelation between pairs of independent variables in the model.

Table 2. *[15]*

Variable	Y_{ij}	$Y_{i,j-1}$	$X_{ij(+BI)}$	$X_{ij(+GINIko)}$	$X_{ij(IZVO)}$	$X_{ij(UVOS)}$
Y_{ij}	1	0,260*	0,142	0,151	-0,104	0,211
$Y_{i,j-1}$		1	0,402**	0,172	-0,122	-0,278*
$X_{ij(+BI)}$			1	0,126	-0,350	0,304*
$X_{ij(+GINIko)}$				1	-0,140	-0,095
$X_{ij(IZVO)}$					1	-0,196
$X_{ij(UVOS)}$						1

Correlation is significant at the 0.05 level (2-tailed).*
Correlation is significant at the 0.01 level (2-tailed).**

The results in the previous table indicate that there are no pairs of variables whose correlation exceeds 0.5, so they can be considered suitable for panel analysis.

***Table 3.** [15]*

Variable	Value
Constant	5,4836 ± 1,4347
$Y_{i,j-1}$	0
$X_{ij(+BI)}$	- 0,1052 ± 0,0655
$X_{ij(+GINIko)}$	0,6888 ± 0,2848
$X_{ij(IZVO)}$	-0,1618 ± 0,0823
$X_{ij(UVOS)}$	-0,0514 ± 0,0333
Residual	3,5394
F – test	0
Selected model	Model with fixed predictor
Observations	72

Three panel models were constructed for research purposes, as follows:
- Model without predictor;
- Model with fixed predictor and
- Model with variable predictor.

Considering the collected empirical material, adequate theoretical assumptions and checking the suitability of the model, we have a panel model suitable for quantitative presentation of regular average ratio which shows the average annual change in GDP per capita in the i-th country for the j-th year depending on the average change of other indicators covered by the model, and previously described in detail, we illustrate the following table.

itable for

$$y_{ij(+gdppc)} = (5{,}4836 \pm 1{,}4347) + 0 \cdot y_{i,j-1} - (0{,}1052 \pm 0{,}0655)x_{ij(+bi)} + (0{,}6888 \pm 0{,}2848)x_{ij(GNIko)} - (0{,}1618 \pm 0{,}0823)x_{ij(izvo)} - (0{,}0514 \pm 0{,}0333)x_{ij(uvos)} \pm 3{,}5394$$

There is a part of the variability in GDP growth per capita that cannot be explained by the country covered by the survey and that percentage averages 5.48% with an average deviation of 1.43%, as well as an increase in the inequality coefficient, where increasing the inequality coefficient by 1%, increases GDP per capita by 0.69% with an average deviation of 0.28%.

Average growth of gross investment reduces GDP per capita growth by 0.11% with an average deviation of 0.07%, and allocations for higher education as well, which, with an increase of 1% lead to an average decline in GDP per capita by 0.16% with an average deviation of 0.08%.

The modeling results show that GDP growth per capita in the previous period did not have a statistically significant impact on the same indicator in the observed time period.

The variation in the change in GDP per capita in the observed countries for the observed period not covered by the model is 3.54%, whereby additional research justifies subsequent determination of the origin and causes of this variability or confirms that there are no indicators that can not cover the model.

Empirical data that are the basis for generating this information indicate the facts that need to be taken into account in the process of planning economic policy and economic development, and can be expressed in the form of the following conclusions:

- Regardless of the level of GDP per capita in a certain period, its value in the following period can be composed in the desired direction based on the value and impact of other indicators;
- The growth of gross investment does not allow the growth of GDP or GDP per capita in the initial phase, because the effects of investment are prolonged to periods that involve the investment exploitation;
- Allocations for higher education affect the creation of GDP and GDP per capita in the same way as the previous indicator, because current investments show effects only in the coming period;
- The indicator that the share of highly educated population affects the reduction of GDP per capita

indicates the impossibility of adequate exploitation of intellectual capital in the covered territory.

CONCLUDING REMARKS

Research on the processes that affect the competitiveness and international economic position of a particular territorial unit is a complex and dynamic process, which must be continuously reviewed and analyzed in order to cover the highest possible variation in GDP per capita. The research shows that the impact of GDP per capita from the previous period has no statistically significant impact on GDP per capita in the observed period when it comes to the Western Balkans that are not yet members of the European Union, and the inequality coefficient is the only that has a positive impact on it, while the increase in gross investment, allocations for higher education and the share of the population with higher education in the total working age population has a negative impact on the increase in GDP per capita. The research and analysis results prove that the period of establishing investments, as well as investments in higher education do not give results in the period in which they are realized. The benefits of investing in higher education are possible only after the person who acquires marketable knowledge and competencies is involved in the work process that corresponds to the specific educational profile. In addition, the research and analysis results prove that the share of the population with higher education in the working age population has a negative impact on the value of GDP per capita. This fact can be objectively related to the structure of the business environment, which does not provide an opportunity for adequate engagement of highly educated workforce. Concrete measure proposals that would need to be implemented in the analyzed countries would be the development of business environment in terms of creating the need to engage a highly educated workforce.

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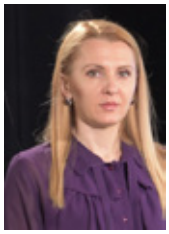

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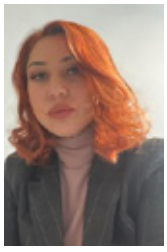

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DIGITALIZATION OF SOUND USING PULSE CODE MODULATION (PCM)

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Case Study

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Abstract: This paper focuses on Pulse Code Modulation (PCM) as a technology for digitizing analog signals. PCM is a widely used technique that enables precise encoding and transmission of analog information through digital pulse signals. The basic principles of PCM are explained here. PCM converts an analog signal into a digital form through sampling, quantization, and encoding. Sampling refers to the conversion of a continuous analog signal into discrete samples at regular time intervals. Then, quantization is applied to round each sample to the nearest possible quantization value, reducing the continuous range of values to discrete levels. Afterward, each quantized sample is encoded into a digital form. PCM is commonly used in various communication systems as well as in digital audio processing. In communication systems, PCM enables reliable transmission of voice signals, music, and other audio content over digital networks. In digital audio processing, PCM is used for recording, playback, and manipulation of sound, enabling high-quality reproduction and precise processing.

Keywords: PCM, Pulse Code Modulation, Analog Signal Digitization, Sampling, Quantization, Pulse Signals.

INTRODUCTION

Sound is a time-varying mechanical deformation that propagates through a medium as a mechanical wave. [1, p. 1] The digitization of sound has brought numerous benefits in efficient storage, precise reproduction, sound manipulation, as well as compatibility and portability. This transformation has had a profound impact on the music industry, entertainment, communication, and our daily lives, enabling us to access, share, and enjoy sound in new and innovative ways.

Precise sound reproduction is a key advantage of digitization. Analog signals are prone to quality loss during transmission and reproduction due to various factors such as noise and interference. Digitization allows for accurate recreation of the original sound without any loss in quality, enabling compatibility and portability across different devices and systems, as well as integration with other media. Digital sound can easily be synchronized with video content, video games, or animations, creating cohesive multimedia experiences.

The availability of digital sound can vary depending on the context and specific situation. Having adequate technical infrastructure is a fundamental requirement for accessing digital sound. This includes broadband internet, mobile networks, computers, smartphones, digital players, and other devices that support the playback of digital audio formats.

Fast and reliable internet connection is crucial for streaming or downloading digital sound. High data transfer speed allows for uninterrupted streaming of audio content, while a stable connection minimizes playback interruptions.

Digital sound is available in various formats such as WAV, MP3, AAC, FLAC, and others. To utilize and play digital sound, support for the appropriate au-

dio formats by devices, software, and applications is necessary.

Sound manipulation has become significantly more flexible thanks to digitization. Digital audio tools and software have enabled advanced sound processing techniques such as filtering, equalization, compression, and effects. This has opened the doors to creativity and innovation in music, film, and other areas of audio production.

SUBJECTIVE CHARACTERISTICS OF SOUND

Subjective characteristics of sound are aspects of sound perception that arise in the human brain and depend on individual differences in hearing, psychological factors, and other influences. In the context of scientific research on sound, subjective characteristics are an important category that relates to the subjective experience of sound. Some of the most significant subjective characteristics of sound are loudness, pitch, sound colour, and deviations from the expected.

Loudness represents the subjective perception of sound intensity, which relates to the perception of the amplitude of the sound wave. Pitch is the subjective experience of the highness or lowness of a sound, which relates to the perception of the frequency of the sound wave. Sound colour is the subjective experience that pertains to the characteristics of sound that differentiate it from other sounds of the same frequency and loudness. Deviations from the expected are subjective experiences that occur when a sound has some unusual characteristic, such as noise, echo, interruption, frequency change, and others.

Subjective characteristics of sound play an important role in sound design, sound engineering, psychoacoustics, and other fields dealing with sound. Understanding the subjective characteristics of sound is crucial for the development of high-quality audio products such as headphones, speakers, microphones, and other sound reproduction technologies. Moreover, subjective characteristics of sound have an impact on creating emotional responses in listeners and influence how people experience sounds in everyday life. Therefore, a deeper understanding of the subjective characteristics of sound is a key element in the development and improvement of sound technology.

OBJECTIVE CHARACTERISTICS OF SOUND

Objective characteristics of sound are physical quantities that can be measured and described based on the physical properties of sound waves.

Some of the most important objective characteristics of sound are:

- Frequency: the number of oscillations of a sound wave per unit of time (usually in seconds), expressed in Hertz (Hz).
- Amplitude: the maximum intensity of a sound wave, expressed in decibels (dB).
- Phase: the relationship between the phases of different sound waves that are interacting with each other.
- Wavelength: the distance between two points on a sound wave where the phase is the same, expressed in meters (m).
- Speed of sound: the rate at which sound propagates through a medium, expressed in meters per second (m/s).
- Spectrum: the set of frequency components that make up a sound.
- Duration: the length of time during which a sound can be heard, expressed in seconds (s).

These characteristics are fundamental elements of sound and represent key factors in its description and characterization.

PCM - PULSE CODE MODULATION

Pulse Code Modulation (PCM) is a digital technique for encoding and transmitting analog signals. This technique is used for transmitting voice signals, music, and other analog signals in digital form. PCM enables the conversion of analog signals into a digital format, which can be transmitted through digital communication systems and smart devices.

PCM utilizes the processes of sampling and quantization to obtain a digital representation of the analog signal. First, the signal is taken at discrete intervals and digitized, which is known as sampling. Then, quantization is performed, which means that discrete levels of the signal are determined based on their values. These levels are called quantization levels, and the size of each discrete level is determined by the number of bits used to encode them.

Once the analog signal is quantized, coding is used to transmit the signal over the digital system. This is achieved by encoding each quantized sam-

ple as a digital code, which is then transmitted as a series of pulses. Pulse code modulation has the advantage of being easily applicable in digital data transmission systems.

The final output signal consists of a sequence of digital codes, representing the value of the signal at each sample. The size of the output signal depends on the number of bits used to encode each sample. A higher number of bits means higher precision but also increased memory requirements for storing the digital signal.

"In modern information systems, coding methods for transmitting and processing information effectively solve a large number of problems. PCM systems, like other systems involving quantization, exhibit a threshold effect. This means that external noise has no impact on the information processing processes as long as the signal-to-noise ratio remains below a certain threshold value. Once this value is exceeded, significant errors occur. Due to their robustness against interference and the ability to directly input digital information into electronic computers, PCM methods find extensive applications in modern information systems." [2]

PCM (Pulse Code Modulation) is applied in various digital systems, including telephony, CD players, digital audio and video formats, as well as in medicine for digital processing of medical images. Due to its efficiency, accuracy, and flexibility, PCM is considered a key technology in digital signal processing and telecommunications.

- *Filtering: removing unwanted frequencies from a signal, which improves signal quality and reduces noise.*
- *Sampling: the process of taking samples of an analog signal at regular time intervals to obtain a digital signal consisting of discrete values.*
- *Quantization: the process of converting a continuous analog signal into discrete values that can be represented digitally. Quantization usually refers to the quantization of signal amplitude.*
- *Encoding: the process of converting a digital signal into a form that can be transmitted over a digital communication channel.*
- *Regeneration: the process of restoring a signal after transmission over a communication channel to reduce the effect of losses and noise on the signal.*
- *Decoding: the process of converting an encoded digital signal back into the original digital signal.*
- *Filtering: the process of removing unwanted frequencies from a signal, improving signal quality and reducing noise.*
- *Transmitting side: the side that generates and sends the signal.*
- *Receiving side: the side that receives the signal and processes it.*

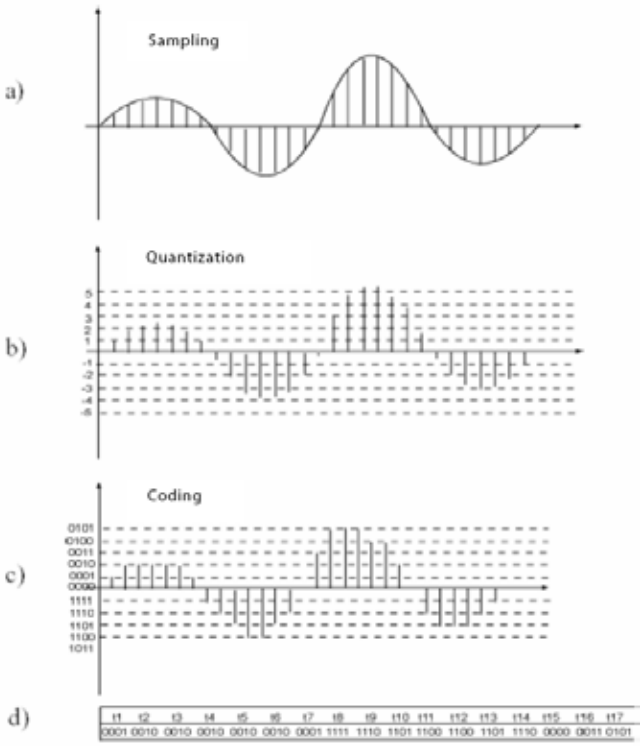

Figure 2. *The process of PCM signal generation. [3, p. 10]*

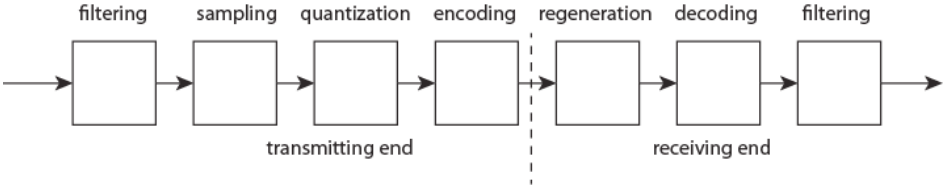

Figure 1. *Block diagram of PCM signal generation and transmission. [3, p. 9]*

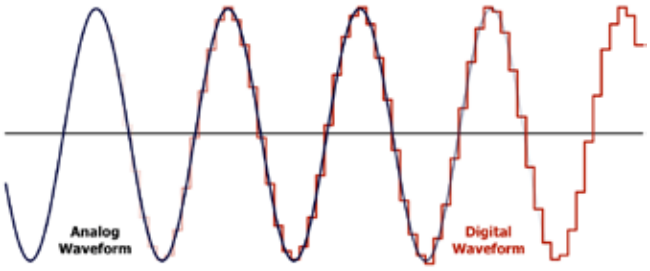

Figure 3. *An audio signal (black line) is sampled and quantized, with each sample assigned a digital value (red line) to create a digital approximation of the audio signal [4]*

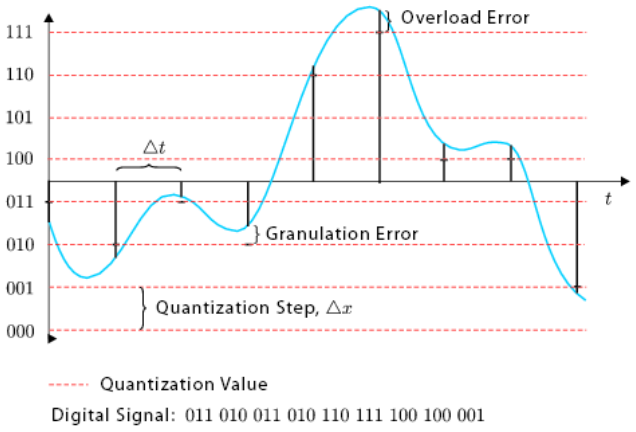

Figure 4. *Graphical representation of the process of signal sampling and quantization. [5]*

SAMPLING

Sampling is the process of converting a continuous analog signal into a discrete digital signal by taking samples at regular time intervals. Sampling is a crucial process in digital signal processing as it allows the analog signal to be transmitted and processed digitally using computer algorithms without significant loss of information from the original signal.

Sampling is typically performed at a specific frequency known as the sampling frequency. The sampling frequency needs to be sufficiently high to capture relevant portions of the analog signal while also being low enough to avoid unnecessary processing and storage costs. To fully reconstruct an analog audio signal into a digital audio signal, Nyquist's theorem needs to be applied.

Sampling greatly impacts the quality of the digital signal, so it is important to pay attention to the sampling process when designing digital signal processing systems and during audio recording and playback.

NYQUIST'S THEOREM

Nyquist sampling theorem, also known as the Nyquist-Shannon theorem, was first published in 1928. [6, pp. 617-644] The theorem was formulated by American electrical engineer Harry Nyquist during his work at Bell Telephone Laboratories. Its mathematical support was later developed by Claude E. Shannon in 1949. The Nyquist-Shannon theorem provides a mathematical framework for sampling analog signals, transforming them into a discrete form that can be digitally processed.

It states that to accurately sample a signal, the sampling frequency (fs) must be at least twice the highest frequency (*fg*) present in the signal.

fs = 2 x fg

Since the human ear can perceive sounds up to 20 kHz, the minimum required sampling frequency would be 40 kHz. For added safety, compact discs have a slightly higher sampling frequency. [7]

Sampling frequencies for various applications are as follows:

Telephones, wireless microphones: 8 kHz
G.722 VoIP: 16 kHz
Music CD: 44.1 kHz
Professional audio equipment: 48 kHz
Hi-Res Audio: Up to 192 kHz

PCM was first widely used to digitize voice telephone communications to make it easier to transmit over long distances without any signal loss. The Digital Signal 0 (DS0) specification, originally set back in the 1960s and still used today, digitizes a phone call at 8 kHz at 8 bits per sample for a bitrate of 64 kbps. [4]

QUANTIZATION

By quantization, we assign each sample value of the audio amplitude to the nearest predefined binary value, thus obtaining a digital representation of the sound.

A higher number of bits enables greater precision in quantization, resulting in better sound quality.

There are two types of quantization: uniform and non-uniform quantization. Uniform quantization uses equal spacing between quantization levels,

which leads to distortion in sound due to quantization errors.

"The quantization error $e[k] = x[k] - y[k]$ occurs as a result of 'rounding' the signal level to a discrete value. It causes nonlinear distortion of the primary continuous signal $x(t)$, and it is a random variable expressed as quantization noise that appears alongside the useful signal. If the sample amplitude is close to the quantization interval boundary, the error can be largest. Since there is no predetermined relationship between quantization errors in neighboring intervals, the quantization error can be represented as a random signal with a uniform distribution" [8, p. 14]

Non-uniform quantization utilizes a non-linear quantization interval, reducing sound distortion and improving sound quality. The consequence of quantization is quantization noise, which manifests as sound distortion.

QUANTIZATION NOISE

The consequence of quantization is quantization noise, which occurs when an analog audio signal is converted into digital form due to the discretization of the signal and rounding of sample values to the nearest quantization level. This discretization leads to an error in the value, and this error is perceived as background noise during the playback or recording of digital content, although in modern digital systems, quantization noise has a very low level and is rarely noticeable. Quantization noise arises when the analog signal is discretized and infinite signal values are replaced by a finite number of quantization levels. This noise can be reduced by using noise reduction methods such as dithering, which adds a small amount of noise to the audio signal before quantization to minimize distortion.

Clearly, coarser quantization results in more pronounced quantization noise, leading to poorer signal quality. To reduce quantization noise, finer quantization is required, meaning more bits per sample should be allocated. [1, p. 16]

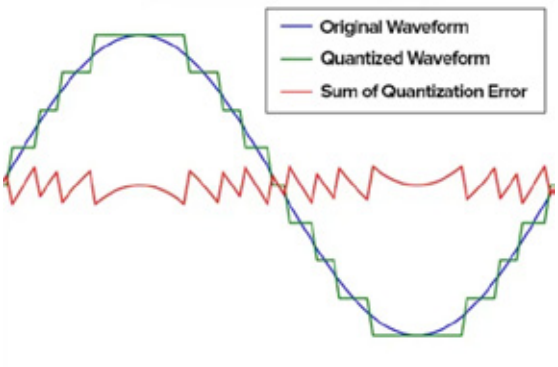

Figure 5. *Quantization noise [9]*

DITHERING

Dithering involves algorithms (coded directions given to a computer) that have to make decisions about how to handle the missing data (errors) from dropping out data in order to make the file sizes smaller.

That's the basic gist of the whole thing. Now, many websites will tell you that you're adding random noise that cancels out quantization error. That's not true. You're adding "noise" at specific places to try to smooth out gaps in data. This means that waveform analysis is occurring so particular choices can be made. There's nothing random about it. [9]

The purpose of dithering is to add a low-level broadband noise signal to the input signal, with a statistical energy distribution whose peak values correspond exactly to one quantization interval. [8, p. 16]

In other words, we add noise to reduce noise.

ENCODING

Encoding involves assigning a binary code to each quantized sample. During sound reproduction, the process occurs in reverse order. The digital pulses are decoded into their original amplitude values, which are then filtered and converted back to analog form. The analog signal can be played through speakers to hear the original sound.

CONCLUSION

PCM has become widely accepted and used in various industrial and communication applications. In communication systems, PCM enables reliable transmission of voice signals and audio content over digital networks, resulting in high sound quality and lossless transmission. In digital audio processing,

PCM is used for recording, playback, and sound manipulation, providing high-fidelity reproduction and precise sound control.

The advantages of PCM include high accuracy and precision in transmission, data compression capability, and resistance to noise and interference. However, it requires sufficient bandwidth and data storage, and there are challenges in the quantization process that can affect signal quality.

PCM is a key technology for sound digitization, offering the ability to accurately encode, transmit, and process analog signals. Its applications encompass communication systems, digital audio processing, and other areas where the digitization of analog signals is crucial. Understanding and implementing PCM contribute to improving sound quality and broader access to digital audio in today's digital age.

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ANALYSIS OF PUBLIC ADMINISTRATION, EFFECTS AND IMPACT OF DIGITALIZATION AND INTEROPERABILITY IN PUBLIC ADMINISTRATION

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Case Study

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Abstract: For the purpose of digitization and interoperability of public administration, we researched the organization and challenges in public administration in Bosnia and Herzegovina as well as in general in public administration. We presented parts of public administration as well as the influences of public administration. The effects and influence of digitalization and interoperability in institutions in B&H, strategic approach to the development of public administration, the relationship between Vision and Technology as an indicator of business success in public administration are given. We also presented a view on the provision of digitalized and interoperable public administration services.

Keywords: digitalization, interoperability, public administration, Big Data.

INTRODUCTION

The introduction of public administration in digitalization and thus in interoperability requires that we use new technologies in an innovative way. Using ten good reasons for standardization and guided by the idea that standardization helps create sustainability and benefits for all people in global society, we researched and provided solutions to improve service delivery in public administration [1].

For the purpose of digitalization and interoperability of public administration, we researched the organization and challenges in public administration in Bosnia and Herzegovina. In order to successfully carry out digitalization and implement interoperability in public administration, it is necessary to standardize business processes in order to certify the quality of business and disseminate knowledge through IT and communication technologies._

In digitalization and interoperability of public administration, it is necessary to perform analyzes of business processes, their definition both through conceptual design and through physical design, using standardized tools. An analysis of long - term practice based on experiences gained in the preparation, development and implementation of various IT projects shows that without the use of IT tools in the preparation, development and implementation of IT projects, many IT projects do not even begin, not to mention the implementation and later reengineering business processes and IT projects.

Improving the performance of standardization and modeling of business processes in public administration gives business flexibility, high availability, tolerance to errors and disasters.

The introduction of new computer technologies creates opportunities for business processes that have not been digital so far to be introduced into

new services, thus indirectly creating a market that did not exist before.

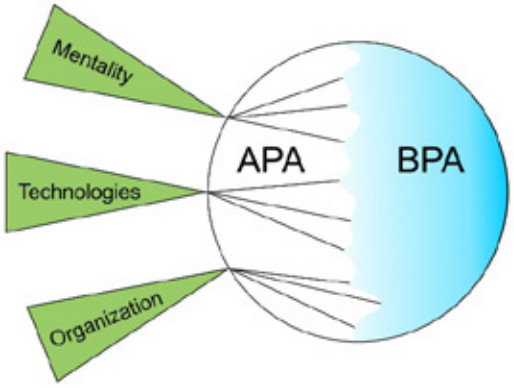
The introduction of digitalization and interoperability in public administration leads to the launch of public administration for intelligent and fast making the right business decisions in new and unexpected service conditions [2].

When creating a business strategy, successful management bodies use business intelligence to analyze and identify elements that significantly contribute to service efficiency and customer satisfaction. They base their business on the benefits of the shared knowledge and skills of all employees.

Public administration

When we observe public administration in general, it is influenced by various factors.

According to the acceptance of new technologies and the introduction of innovations, we can divide public administration into advanced public administration and backward public administration.



Picture 1. *Advanced Public Administration and Backward Public Administration*

APA - Advanced Public Administration

BPA - Backward Public Administration

By introducing digitalization and interoperability in advanced public administration, we contribute to its improvement and flexibility, and it primarily affects it:

- Mentality - why, it is a willingness to accept change, a willingness to improve the process, a willingness to improve governance. Or simply a willingness to do things differently.

- Organization - we have in our organizations - public administration, different teams that we have to learn how to talk. e.g., we have teams in public administration for: applications, network, operations and security, etc.

- Technologies - new technologies, their introduction, use, etc.

The goal is to influence the backward public administration by introducing changes in mentality, organization and technologies, to change it into advanced public administration.

By creating individual habitus, we also create a sustainable ecosystem.

Effects and impact of digitalization and interoperability in B&H institutions

The impact of digitalization and interoperability in institutions in B&H is a key driver for improving the quality of public administration. Digitization and interoperability are based on material and immaterial resources and unique knowledge of the implementation of digitization and interoperability in institutions in B&H, regardless of whether we are talking about the current we have or about some new, improved knowledge.

A strategy that implies the efficient use of resources enables the creation of knowledge that can be easily transformed into the market values of an improved organization and business processes. Research and introduction of digitalization and interoperability implies research of the connection between improved inputs and outputs, which is closely related to the performance of the organization and organizational units of public administration.

The development of digitalization and interoperability should have the highest priority in all organizations, especially in public administration, and should include, in addition to investments in development, research and investment in employees, organizations and practice.

The introduction of digitalization and interoperability should contribute to strengthening and improving the competencies of all actors and organizations, which includes the overall systemic environment in public administration.

The effects and impact of digitalization and interoperability in B&H institutions are as follows:

- Improving the process in public administration.
- Digitization of public administration.
- Interoperability of public administration.
- Provided preconditions for further work and development of digitalization and interoperability.
- Introduction and improvement of digitalization and interoperability with other institutions.
- Improving the quality of public administration services.
- Introduction of new public administration services.
- Introduction of business intelligence.
- Enabled easy creation of various reports.
- Cost reductions and Introduction of standards.

The main goal of introducing digitalization and interoperability of public administration is not only the realization but also the improvement of public administration capacity and indirectly encouraging employment and achieving sustainable development [3].

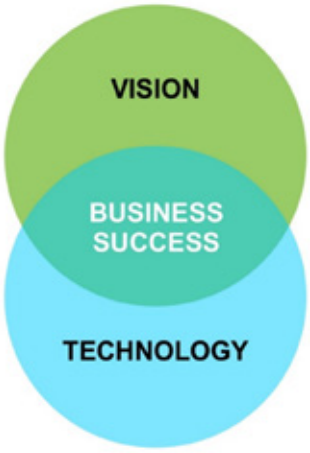
THE STRATEGIC APPROACH TO THE DEVELOPMENT OF PUBLIC ADMINISTRATION

The strategic approach to public administration and its services should contribute to improving the quality of life of all in B&H, as well as the economy by raising its competitiveness with the help of information and communication technologies that enable access to highly sophisticated and advanced electronic public administration services. The strategic approach should enable the creation of a strategic framework for a unique, functional and efficient public administration IT system that enables the provision of sophisticated and advanced electronic services.

The essence of the strategic approach is to recognize and create conditions for mutual compatibility of existing IT and communication systems and those that are coming, thus eliminating redundant functionalities.

What can be achieved with a well-designed strategy is:

- creating a safe environment for the use of public administration services,
- improving the quality of life by using advanced public administration services,
- raising the level of productivity of public administration by using IT and communication technologies and creating new competencies,
- achieving stronger connections between citizens and public administration through the use of IT and communication technologies,
- improving the competencies and efficiency of the economy through the use of public administration services and
- creating an environment and conditions for improvement and innovation thanks to the introduction of new IT and communication technologies in public administration, which is based on mutual cooperation of public administration bodies, scientific and economic institutions and recognizing the standards and functionalities of the European Union.



Picture 2. *The interrelationship of vision and technology as an indicator of business success*

Understanding technology is changing business and its basic business model is the starting point for transformation. Organizations that have introduced digitalization into their business are based on business improvement and building business intelligence systems, rather than on the application of individual technological solutions.

Business intelligence systems in public administration provide digital feedback that helps public administration gain better insight from data and turn it into intelligent action - to get in touch with business, citizens, empower employees, optimize business and create new services and business models. These rich business intelligence systems are a

combination of technology, people and processes. They define the competitiveness of the organization and the ability to improve the business processes in which it participates, and they are essential for digital transformation.

All this leads to the business success of public administration and its putting into service to everyone: citizens, businesses, and public administration bodies themselves. Achieving business success of public administration depends primarily on vision and technology. The business success of public administration itself depends on the relationship between vision and technology.

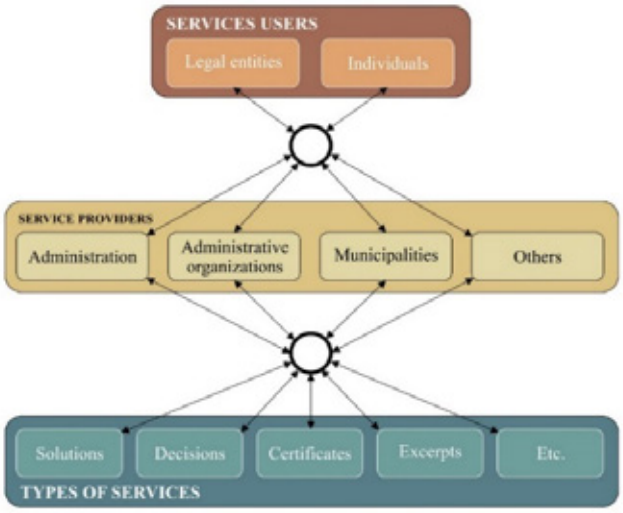
Computer technologies and vision can be used as a strategic resource for:

- improvement of business processes and thus changes in the organizational structure,
- using information technologies in creating new services and services and
- interoperability with other organizations.

The constant availability of public administration services is based on computer technologies that work constantly. In essence, the demands placed on computer technologies require their constant improvement, which is a great challenge. On the other hand, new technologies provide great opportunities to improve services, which is also a great challenge. Real - time public administration is a link between new technologies and new business process solutions.

The Decision of the Council of Ministers of Bosnia and Herzegovina accepted the recommendations [4] of the European Interoperability Framework 2.0 as the basis of the Interoperability Framework, in order to achieve the following purposes:

- exchange of electronic documents and electronic services between administrative bodies of the same level (own interoperability),
- electronic data exchange between administrative bodies of different levels (joint interoperability) and
- exchange of electronic documents and data with the institutions of the European Union and the governments of other countries.



Picture 3. *Providing digitalized and interoperable public administration services*

Users of public administration can request different types of services (listed in the picture above).

Public administration that includes all levels of the organization to the lowest level provides about 170 services or services to customers in Bosnia and Herzegovina. In order to provide free and low cost services to users, public administration in Bosnia and Herzegovina must be fully digitalized and interoperable. The power of public administration can be measured in the connection of its smallest link, i.e., the smallest organizational unit at the lowest level with all others. No matter what the industry sector, no matter what the customer base, web technology is going to be a major driving force for change. No company will be able to ignore this and any that do will fail. There is absolutely no question about that [5].

The service environments to come are characterized by rapid and radical change, with an emphasis on deliveries that are free, efficient, and user-friendly. Creating new services in public administration requires new ways of approaching service provision compared to previous service delivery. The user expresses the need for services that enable self-service or service, and the fact that the necessary data, information and the like exist in public administration.

The public administration's approach to the digital transformation platform development strategy must include three key areas for improvement:

- by creating new public administration services that enable the use of applications and data that go beyond individual devices,

- by reengineering business processes using digital tools, create new services in order to increase productivity and enable employees to focus on what is most important to them and the organization.
- for the needs of public administration to build an infrastructure that will be used to build an intelligent platform and Big Data in the cloud, which will allow public administration to integrate all its data that can be structured and unstructured, and where different public administration services can be created.

This solution enables further improvement and benefits for both public administration for citizens and the economy.

CONCLUSION

Companies that can best respond to markets that change quickly and frequently have better competitive advantages than those that fail to maintain the pace dictated by the globalization process [6]. This applies to both public administration and its ability to respond to the challenges ahead. The approach is designed to enable public administration to create intelligence systems that enable digital transformation and interoperability, through technology that enables others to improve business, build their own technologies and create solutions that help them achieve digitalization and interoperability of public administration.

By smartly managing digital transformation, we can boost productivity, increase mobility and create new digital services across and between multiple public administration organizations, as well as a wider range of citizens and stakeholders.

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