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INFRASTRUCTURE OF SMART VILLAGES WITH APPLICATION OF ARTIFICIAL INTELLIGENCE AND SENSORS WITH NEW TECHNOLOGIES

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Abstract. The purpose of this study is to develop mathematical models and software applications that facilitate the creation of smart villages and regions in the Republic. By integrating advanced technologies and optimizing various interconnected systems, this research aims to enhance sustainability, improve resource efficiency, and elevate the overall quality of life for residents. Through a comprehensive needs assessment, data analysis, and mathematical modeling techniques, this study seeks to address the specific challenges faced by villages and regions, and propose innovative solutions that maximize the potential for economic development and citizen well-being. The development and deployment of software applications will support the efficient management of critical infrastructure, including energy, transportation, waste, and healthcare systems. This study also emphasizes stakeholder engagement, ensuring that the smart village and region initiatives are tailored to the unique needs of the local communities and aligned with their aspirations.

Keywords: Smart village, mathematical modeling, software, information communication technologies.

AMS Subject Classification: 97R40, 97R20.

1. Introduction

Villages with smart economies combine entrepreneurship and industry with smart governance, signaling, logistics, and transport. This means that villages continue to be formed within the framework of smart village components as they continue to grow. This article will examine the role and application of mathematical models and software in creating smart villages and regions. The most highlighted component is how renewable energy sources are linked to ICT. In this context, there are various models and applications related to smart villages in the world. The aim of the study is to explore the possibilities of using mathematical modeling and software in intelligent rural projects and to propose solutions to the problems encountered.

The problems experienced in areas such as transportation, environmental pollution, energy, drinking water, human health and safety have had a negative impact on the life of the villages. It has also reduced the quality of life of citizens living in these areas. In recent years, technology has made a significant contribution to solving rural problems, improving local public services, and raising the quality of life for citizens as a whole. Using information and communication technologies [2-5], smart villages are residential areas where applications are used to enhance the life quality of citizens living in rural areas in order to minimize the negative effects of rural living and to improve the living standards of citizens living in rural areas.

Technology that is an important component of smart rural architecture consists of four layers: detection, network, operations-management, and application. All these technological layers have undergone changes and transformations thanks to big data. In the Sensor layer, sensors and terminal devices are created, while at the network level there are telecommunications and related services. The other layer contains platforms such as management, maintenance and security. Vodafone Smart Village, the world's first smart village, as a new generation rural life model, not only increases productivity, but also contributes to the development of the environment. Vodafone Smart Village, which ensures the sustainability of agricultural resources by preventing soil and water pollution thanks to smart systems, is an example of ecological agriculture with a special sprinkler, early warning system, irrigation management and farmer awareness training. Vodafone Smart Village's next-generation village life model combines traditional farming methods with the possibilities of advanced technology. With the spraying facility installed in Vodafone Smart Village, the negative impact of spraying on the environment is minimized and sustainability in reaching healthy food is ensured. On the other hand, diseases and pests in the crops grown during the period from sowing to harvesting are detected under the control of agricultural engineers and specialists, and pesticides are applied on the spot, timely and correctly. Vodafone Smart Village also contributes to recycling by converting agricultural pesticide packaging waste into secondary raw materials through various physical or chemical processes and re-introducing it into the manufacturing process. Thanks to recycling, chemicals are prevented from harming nature. Agricultural early warning systems are also used in Vodafone Smart Village. Thanks to the special programs used in these systems, without the need to go to the field, it is possible to be warned about diseases and pests in advance. In addition, unnecessary spraying can be avoided, and the producer is given the necessary time to take natural precautions. In this way, soil and water pollution, food residues resulting from unnecessary spraying are prevented. In the Smart Village, farmers are informed about environmental impacts directly related to product quality, as well as the latest technological methods. Farmers are informed about the use and management of pesticides and fertilizers, water education and management, environmental damage of stubble burning [1].

2. Main text

In the current conditions, the countries of the world are looking for ways to achieve sustainable development and try to implement it. The concept of sustainable development is a qualitatively new approach from a socio-economic and ecological point of view, and it combines the following 3 main problems: 1. The sustainable development of the economy must correspond to the ecological system of people's life support. 2. A fair distribution of the current natural resources and material opportunities should be provided not only for the current generations, but also among the future generations. 3. Natural capital should be equally distributed in society and the needs of social groups should be met. The concept of sustainable development is based on 5 main principles: 1. Humanity can really give development the character of sustainable and long-term existence. Thus, sustainable development can meet the needs of the present generation and at the same time preserve the ability of future generations to meet their own needs. 2. Restrictions in the field of exploitation of natural resources are relative in nature. The exploitation of natural resources is related to the modern level of social organization, as well as the ability of the biosphere to eliminate the consequences of human activity. 3. It must be necessary to satisfy the ordinary needs of all people and to create conditions for the realization of everyone's hope for a better life in the future. Without it, sustainable development is simply impossible. One of the main causes of environmental and other disasters is poverty, which has become a common phenomenon in the world. Therefore, poverty alleviation is one of the main factors. 4. The lifestyle of people with large means (capital and material) should be reconciled with the ecological capabilities of the planet, especially energy consumption. 5. The number and rate of population growth must be reconciled with the changing production potential of the earth's global ecosystem. Scientific studies show that in the current conditions, it is necessary to apply the "Green economy" model in order to move to sustainable development in our territories freed from occupation. The "green economy" model has attracted the attention of scientists and international organizations as a very important tool for realizing sustainable development. For this reason, in 2012, at the UN conference dedicated to sustainable development (RIO-20), it was decided to switch to a green economy model by most of the world's countries. Among the countries that are the main initiators of programs related to the green economy - Norway, Denmark, Australia, Israel, Germany, Spain, Sweden, etc. should be specially mentioned.

3. Foreign experience in smart city and smart village project

With the development of the information society, city governments are increasingly dependent on the flow of information. Vehicle flows, road traffic violations, crime, the location and condition of urban infrastructure, the behavior of citizens, and their opinion about the policy - all this information is a useful resource for the authorities, so big data is collected for analytics, forecasting and strategic planning, and identifying problems and bottlenecks. "Smart" city (Smart City) is an interconnected system of information and communication technologies with the Internet of Things, which is designed to simplify the management of urban processes and make the urban environment safe and comfortable. This system can include not only sensors, information systems, transport, and other infrastructure, but also the people themselves because they form their own, user space of the Internet of Things, which is connected with the Internet of Things created and managed by the city authorities. The smart city concept emerged in the 1990s. This period was characterized by a technological approach, and the main actors were large technology companies. In the 2000s the approach of improving the quality of life (to attract highly qualified workers) began to prevail. These two approaches are based on consumerism and competitiveness.

Beijing has introduced a virtual Beijing Citizen Social Service Card, which contains key information about the individual (passport data, etc.). With a virtual card, you can pay with smartphones for purchases, etc. In Chengdu, residents of the city pay using QR codes and facial recognition. Tianjin Eco-City (30 km 2 of former swamps) will be built using solar and geothermal energy, and the heat generated by a nearby power plant will be used for heating. Half of the water demand will be provided by recycled and desalinated water. It is planned to introduce an effective system for collecting, classifying, and processing waste, unmanned buses, and smart bus stops. You can not ignore Japan and the cities created by corporations. For example, Panasonic creates sustainable smart cities (sustainable smart towns, SST). The company launched its first smart city (Fujisawa SST) in 2014 at the site of a former factory. In cooperation with local authorities, the company has turned SST into a suburb of Fujisawa (442,000 people in the city, 2,000 people in SST). Homes in SST are single-family, with solar panels and batteries. Residents of the suburbs can order the rental of electric cars, bicycles, and scooters on the city portal or track the delivery of parcels (by couriers or robots). The company has also piloted some technologies at SST before commercializing them, such as smart air conditioner sensors that find the optimal temperature for sleeping. In April 2022, the company opened an SST in Suite. According to the idea, the city should accommodate 500 people. The city has a residential complex, a nursing home, a kindergarten, and for preparing for exams. SST has CCTV cameras, outdoor electronic displays, and high-voltage power equipment installed, making SST less prone to failure. The cameras are equipped with a face recognition system to collect and analyze data to detect falls, traffic congestion, wheelchairs, canes for the blind, and other objects. Comparing the experience of these countries, several features can be identified. In the case of the UK, the emphasis is on the massive collection of big data, open data to citizens, and engaging them in solving the problems of the city. In addition, London participated in the Sharing Cities program [1] in connection with the "green agenda" together with Bordeaux (France), Lisbon (Portugal), Burgas (Bulgaria), Milan (Italy), Warsaw (Poland), which was sent to including the development of common solutions for the sustainable development of cities, the creation of long-term partnerships between participating cities. In addition, technologically, London can rely on local start-ups. According to Forbes, tech startups raised $25.5 billion in 2021 (double the amount in 2020), more than in other European cities. During the year, the number of startups increased by 20 [11]. In China, the state plays a leading role (carries out overall planning, and sets the agenda), and cooperates with Chinese technology companies. Smart cities in China are collaborating with Singapore to build green city infrastructure. China's projects are very large both in terms of scale and investment and due to the rapid development of the economy, China has many platforms where technologies can be tested. In Japan, it is corporations that play a leading role in the development of smart cities, especially if cities are built from scratch. The emphasis is on the comfort of the urban environment in the conditions of improvement of a compact area. Compared with the Russian experience, the Chinese approach is more likely to work in Russia: government agencies cooperate with Yandex and Sberbank (formerly Sberbank) and other companies in the formation of a digital economy. At the same time, the initiative comes from above, i.e. the development of smart cities is determined mainly by the state. However, it cannot be said that Russia can boast of such large-scale projects as the construction of full-fledged cities[12].

Concept of "Smart Village" and "Smart City".

It should be noted that the concepts of "Smart village" and "Smart City" are planned to be implemented in the territories freed from occupation. The application of "Smart Village" technologies will create conditions for the development of social innovations and small entrepreneurship in those areas and will also increase the attractiveness of the Karabakh region as a technological innovation-startup center. We can note that the implementation of the "Smart Village" project has already started in the Third Agali village of Zangilan district. The "Smart Village" project will be carried out mainly on 5 components. This project will cover the areas of housing, production, social services, "Smart agriculture" and alternative energy. The energy demand of the village consisting of 200 houses to be built will be obtained only from alternative energy sources. In general, the concept of "Smart village" and "Smart city" is applied in many countries of the world. These concepts will act as a decisive factor for the application of global innovation-oriented projects to technological opportunities in Azerbaijan and the world as a whole. Today, 54% of the world's population lives in cities, and this proportion is expected to reach 66% by 2050. Considering the above facts, it can be said that the implementation of "Smart Village" and "Smart City" projects in our republic is inevitable. Here, it is envisaged to collect databases based on cloud technologies and apply management forms based on their bases. Forms of management can be in many ways. As mentioned, many topics can be touched on, from waste collection to municipal and executive bodies continuing their work. A green energy zone should be created within the framework of the "Smart Village" and "Smart City" projects. This means that the supply of electricity here will be in more efficient way and the energies collected in the energy sources will be continued without power outages. One of the theoretical knowledge applied in "Smart Village" projects is to avoid the cycle of decline. The expansion of these projects in the liberated territories will help to integrate the villages into other cities and regions, to prevent shortages of resources, agricultural goods in general, and social services. It should be noted that the "Smart Village" and "Smart City" projects are implemented in many countries and cities. Examples of these are cities like Singapore, London, New York, and Amsterdam. One of the nuances that we can see when we pay attention to is that these cities can also function as tourist centers. This means that the "Smart Village" and "Smart City" projects will help to make the beautiful corners of Karabakh better known in the world in the future. Today, it can be said with a sense of pride that the "Smart Village" and "Smart City" projects are being implemented in Karabakh and other territories freed from occupation. These are the prospects of sustainable development in the territories freed from occupation. As the President of Azerbaijan Ilham Aliyev said, the use of alternative and renewable energy sources is modernity, innovation, and ecologically clean technology: "This is our vision of the future. [16]"

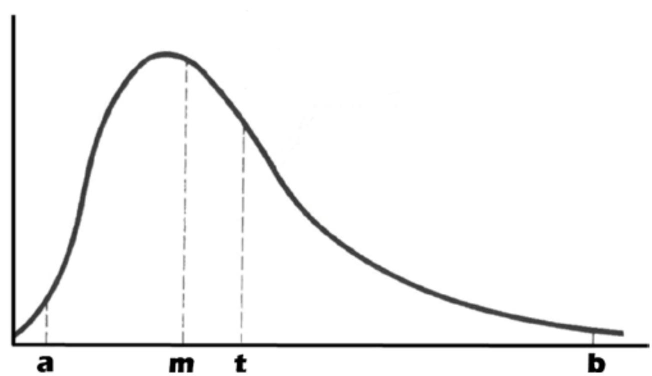
The policy of using alternative and renewable energy sources implemented in the country gives reason to think that the concept of "Green energy" will have a positive effect on the fulfillment of the tasks set. Based on the construction concept based on the most modern technologies, extensive restoration works have been started in our territories destroyed as a result of the Armenian occupation. Thus, in the period after the 44-day war, large-scale projects are being implemented in the direction of the sustainable development of Karabakh. All partners and interested countries are involved in reconstruction and reconstruction. There are already concrete agreements and the interest of foreign countries in the process of reconstruction of Karabakh is increasing. President of Turkey Recep Tayyip Erdogan said during his speech in the Milli Majlis of the Republic of Azerbaijan: "When the Azerbaijanis were forced to leave Karabakh, they did not destroy any place. Azerbaijan is rebuilding the places it destroyed. Together we will build them and create a new Karabakh." Within the framework of the Strategic Action Plan on the restoration of territories freed from occupation, the implementation of infrastructure reconstruction projects has begun. The restoration and construction of road and electricity infrastructure have already gained momentum in all 7 regions, as well as in the liberated areas of Hadrut and the former Agdara region [14]. Specific tasks were given regarding the implementation of the planned projects for the restoration and reconstruction of the district centers and villages. In the restoration program, issues of unification of small villages, construction of residential areas, and construction of social facilities and service areas were also clarified in all regions freed from occupation. According to the information we received from official sources, the established principles for the restoration and settlement of the territories have passed the final discussions, and the distribution and schedules of the works to be carried out in individual regions have been agreed upon with the relevant institutions, and specific tasks have been given for their implementation. One of the most discussed issues related to the restoration of territories - the criteria and principles of unification of small villages - is already known. But what principles will the restoration and reconstruction projects in Kalbajar and Lachin, which have harsh mountainous areas and are of military strategic importance, be based on? The answer to these or other questions is more obvious in the example of Kalbajar, which is the largest among the regions freed from the occupation in terms of its territory and number of settlements. In the projects to be implemented in both Kalbajar and Lachin, two points stand out: major reconstruction of inter-district road infrastructure and unification of small villages. It can be seen from the restoration program that special importance will be given to the construction of roads connecting both regions and ensuring their connection with other regions of the republic. The consolidation of small villages applies only to settlements located in remote areas, villages located in areas close to roads and other communications will remain in place. It should be recalled that Kalbajar district with an area of 1961 sq. km or 196.1 thousand hectares (excluding the territory of 23 villages that were transferred to Kalbajar from Aghdara district) consisted of 126 settlements before the occupation: Kalbajar city, Istisu settlement and 43 administrative-territorial districts 124 villages. However, according to the restoration documents, only 58 settlements of the region, including Kalbajar City, Istisu settlement, and 56 villages, will be rebuilt. This means that 68 small villages in the region will be connected to other large settlements. The list of villages to be integrated into large settlements in the restoration program is also reflected in the Strategic Action Plan [13]. Thus, all residents of the Kalbajar region, whose population is 75 thousand 714 people, will be settled in 1 city, 1 settlement, and 56 villages. According to the recovery plan, the reconstruction of settlements in Kalbajar will be carried out in 4 stages. First of all, the areas to be restored include 13 settlements: Kalbajar city, Istisu settlement, Zar, Keshdak, Kilincli, Qamishli, Hajikand, Ilyaslar, Lev, Zallar, Bashlibel, Aghjakend, and Zulfugarli villages. In the second place, the reconstruction measures for the residential areas to be restored are divided into 3 phases. It is planned to restore 39 villages in the first phase, and 5 villages in the second phase. The restoration and reconstruction of Agdaban village and 23 settlements included in the administrative territory of Kalbajar of the former Agdara region will be implemented in the third phase. In the process of starting the restoration and reconstruction of our territories, first the brotherly Turkish and then the Italian companies began to operate [15].

Turkish companies have started working mainly in road construction and building business enterprises, while Italian companies have started working in the reconstruction of electricity infrastructure. It should be noted that companies from different countries want to join the restoration of our territories freed from occupation. In this regard, Russia, Italy, Pakistan, Afghanistan, Iran, etc. the companies of the countries have applied to the government of Azerbaijan regarding participation in the restoration and reconstruction process in the territories freed from occupation, and the companies of some countries have started negotiations with the relevant institutions and companies of our republic in this regard.

Development of mathematical models in the Republic

Various techniques, software and mathematical models can be used to implement a smart village project. Basically, the mathematical model and software work by showing all the project activities in the project network and then making various calculations based on the network, taking into account the durations and relationships between each activity. The work to be done is organized in the form of a network. The time for each activity is estimated and the dates for each phase of the project are determined by some simple arithmetic operations. The sequence of activities that make up the longest path in a network is called the critical path. Thus, the critical path represents the completion period of the project. Network diagram descriptions can be done with the Program Evaluation and Review Technique (PERT) [6]. Like CPM, PERT also uses network diagrams. The main difference between the two methods is that in the PERT technique, activity durations are treated as random variables that can be determined by optimistic, pessimistic, and feasible estimates, while in the CPM technique, the duration information consists only of deterministic values. The scope of the method is wider than the critical path method, because the PERT method allows taking into account activities with unknown duration in the program. CPM can be considered as a special case of PERT method [12].

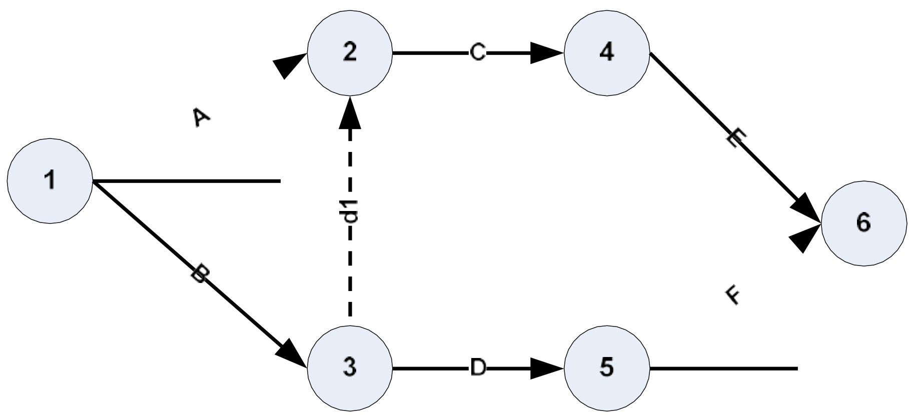
Figure 1. PERT technique



Source:https://acqnotes.com/acqnote/tasks/pertanalysis#:~:text=Program%20Evaluation%20and%20Review%20Technique,time%20to%20complete%20a%20project.

In calculating the expected duration of activities, the approach brought by the PERT technique can give more realistic results. PERT calculates the durations related to the activities in the project with the formula "t = (a + 4m + b) / 6" according to the above beta distribution. Here "t" indicates the calculated duration of the activity. In the formula, "a" represents the optimistic duration of the activity (the shortest possible duration), "b" the pessimistic duration of the activity (the longest possible duration), and "m" the most probable duration of the activity. Project networks (network diagrams) have two different representations, activity-on-arc (AoA) and activity-on-node (AoN), activity-based and event-based. These displays differ according to the definition of activities on the network. Accordingly, in the "AoA" notation where activities are represented by arrows, each arrow represents an activity. Nodes where arrows come out and come in represent events. Activities are defined at nodes in the "AoN" record, where activities are specified at nodes.

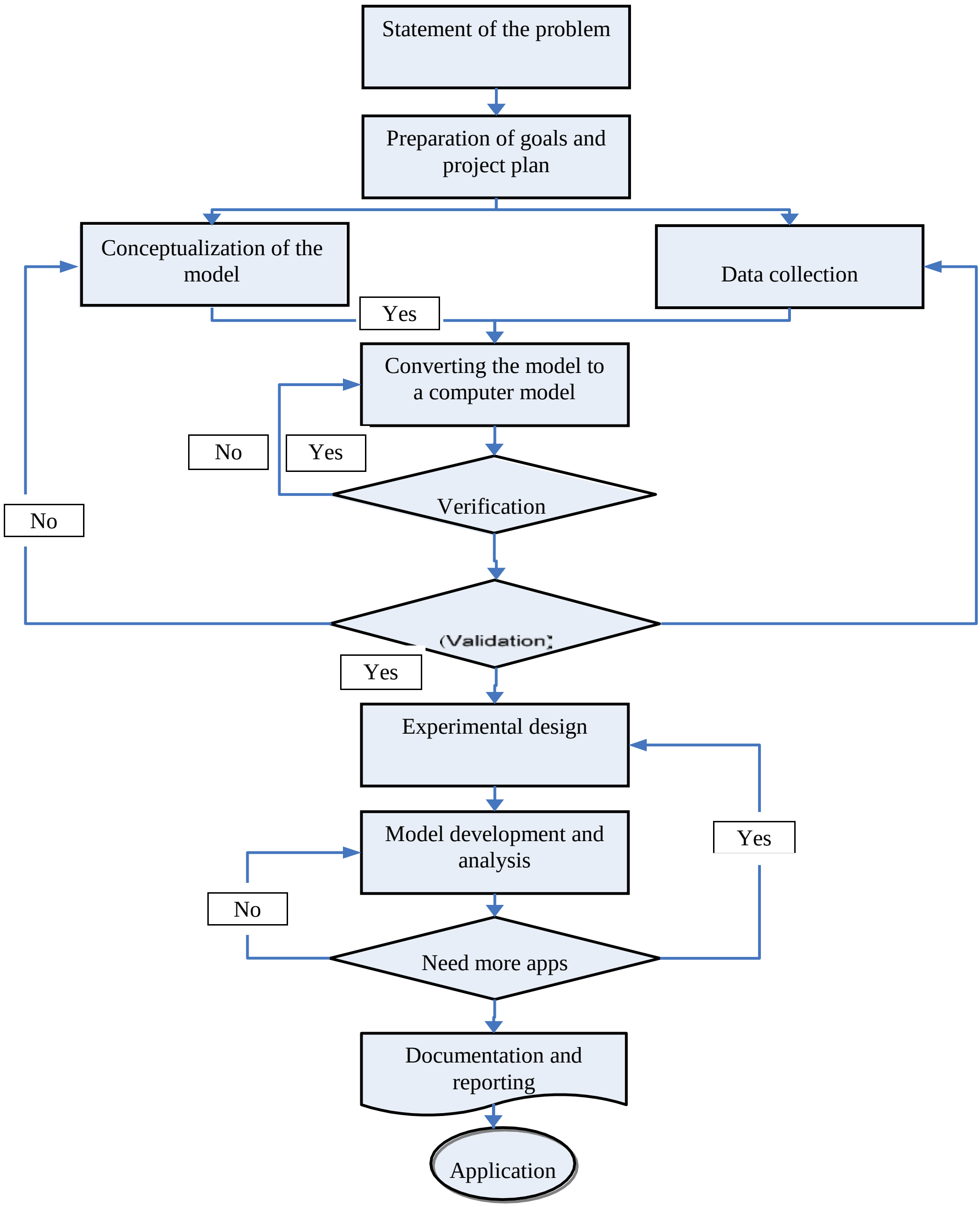
Figure 2.A grid where activities are indicated by arrows



Source: https://www.sciencedirect.com/topics/engineering/arrow-diagram

In the network diagram in Figure 2 above, activities are indicated by arrows. A closer look at the network reveals a seventh activity named "d1" in addition to the existing six activities. In this example, "d1" is a dummy activity with no time, resources, or costs, used only to describe the priority relationship. In the smart village concept, public services can be provided through information and communication technologies (ICTs) that support elements such as smart people, environment, economy, and governance. Due to the use of information and communication technologies in many areas of our lives, the amount of data is increasing day by day. With the unexpected increase in data volumes, existing traditional storage methods have become inadequate. The term Big Data was first defined in the 1990s and refers to the storage, processing, and analysis of data sets that are too large for traditional databases [3]. Big Data can be defined as the processing and analysis of unstructured, large, fast, and diverse data. Although Big Data is first thought of in terms of data volume, it actually consists of several components. The Big Data component, which distinguishes big data from traditional data storage and is called 4V, is considered as 5V along with size (volume), variety (variety), velocity (velocity). It consists of checking the quality (value) of the data. Data size, as the name implies, refers to the quantity of data. The data received is expressed in terabytes and petabytes. Data diversity is the classification of structured, semi-structured and unstructured data by sources such as sensors, social media, internet-based applications. The high velocity of data produced simultaneously from multiple sources and on a large scale also increases the speed of data processing. By analyzing the information obtained from the sources, it becomes easier for organizations or individuals to make decisions. Therefore, to make the right decision at the right time, information from multiple sources must be separated according to their value. Big data sources fall into three categories: directed, automated, and voluntary. Directional data is generated by the operator through digital control, using technological tools to focus on a person or place. On the other hand, automatic data is generated and recorded as a natural function of a device or system.

Figure 3. The simulation and modeling steps of Banks

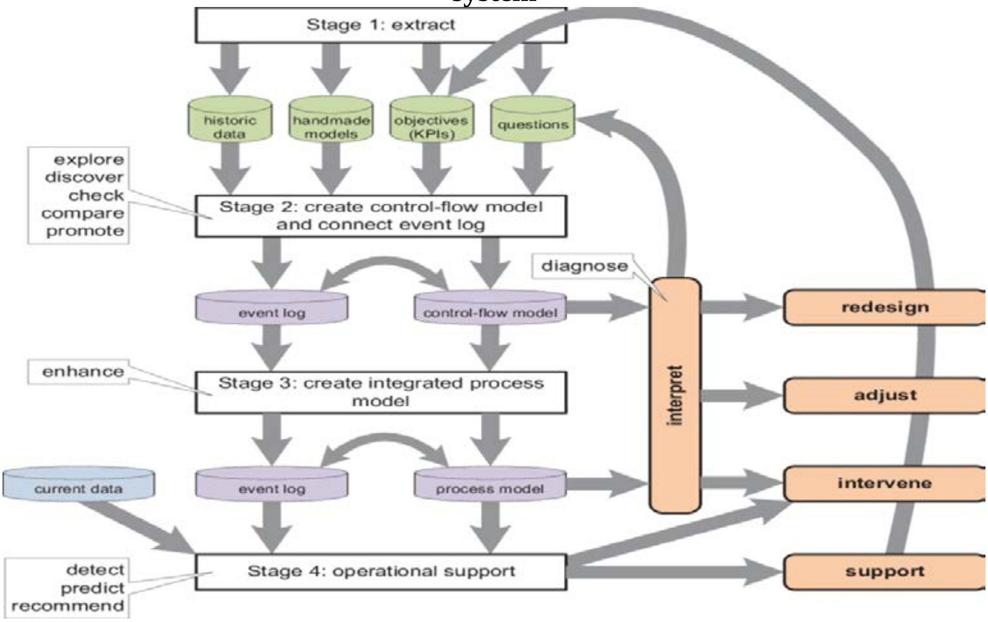


Source: Prepared by the author.

Examples of automated data include transactions across digital networks, click data, scanning of machine-readable objects such as transport cards. On the other hand, volunteered data is data that is mass-produced by users on social media or other public platforms.Big Data is used in areas such as information and communication technology, industry, engineering, business, healthcare, and transportation. However, due to the presence of local and central government agencies in the Internet environment, Big Data is a critical element for effective, efficient, and low-cost service delivery. Water and energy networks are among the most important physical systems in the smart village project, as efficient and safe water and energy services are considered vital needs. Therefore, it is appropriate to consider smart water and energy infrastructure as one of the foundations of Smart Village projects [13]. With smart irrigation automation installed in the Smart Village, irrigation operations can be controlled and monitored remotely at any time of day or night with the click of a cell phone to balance irrigation and fertilization as needed. The signals sent by the central server and received by the Vodafone SIM card of the receiver in irrigation systems activate the irrigation automation taking into account the meteorological data [8]. Thus, the plant receives the right amount of water at the right time. Water supply, seawater desalination, groundwater extraction and wastewater treatment account for a significant proportion of total energy consumption. A new mathematical model should be developed for building water and power distribution systems in smart village projects. Researchers and engineers are looking for systems that can meet the demand for water with minimal energy consumption. High-precision nonlinear network models will be designed for both water and power systems. Such a connectivity model provides a solid foundation for many future research interests, such as optimal water DSM schemes, joint optimization of water and energy systems, and joint security/reliability of micro- WEN. It is also useful for developing a coordinated scheme of electricity and water networks in case of emergencies. A Smart Village's micro-WEN is generally off-grid and its energy consumption comes mainly from renewable generation. Synchronous generators with high inertia, such as diesel generators, are used to maintain system frequency stability, not to provide electrical power. The water source may be wells or seawater desalination plants if a remote village is located on the coast. The successful presentation of the real system of the simulation created by the simulation and modeling activities depends on the correct execution of the simulation steps. Similar to these steps, the simulation and modeling steps of Banks et al. are shown in the figure below

A general modeling approach that focuses on the movement of objects within a system and the events and activities associated with that movement- A process interaction approach is a modeling approach that deals with an object in a system and the events and activities that occur when that object moves through the system. A process is the life cycle of objects during simulation. Therefore, a process is defined as a time-ordered sum of events, activities, and expectations. The analyzer determines the objects in the model considering the life cycle (processes in the system), resource requirements and queues. A life cycle can consist of various events and activities. The process showing the movement of the object in the service system is shown in the following algorithm [11].

Picture 1. A process that shows the movement of an object within a service system



Source:https://www.researchgate.net/figure/The-L-life-cycle-model-describing-a-process-mining-project-consisting-of-five-stages_fig1_229124698.

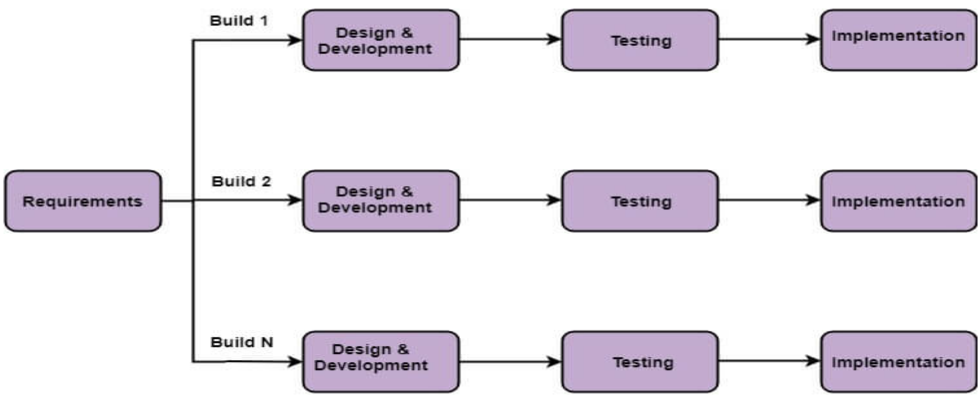
In the event scheduling approach, which uses a time-predictive event scheduling algorithm, a system is modeled by writing an "event table" that defines the changes in the state of the system as each event occurs. Based on the Future Events List (FEL), the time is advanced to the nearest event. This event and other events that take place at this time are removed from the list.

Among the modeling approaches, the two most commonly used approaches, the process interaction approach and the event scheduling approach, have advantages and disadvantages when compared to each other. Since the process program describes the entire flow of objects within the system, the process interaction approach is considered more natural and realistic than event scheduling. Another advantage of the process interaction approach compared to the event scheduling approach is that the system simulation program can be executed in a shorter time. In addition, the event scheduling approach is more flexible than the process interaction approach [10].

Simulation is an alternative approach to project planning. Discrete event simulation has significant advantages over traditional approaches such as CPM.

Above all, simulation allows for sensitivity analysis of various potential project problems, various scenarios. In addition, simulation can also take into account resource utilisation, various resource utilisation rules, and the stochastic and dynamic structure of project variables. The classical simulation approaches may also have various drawbacks. In simulation, the modeling phase requires intensive effort, and as a result, only a simulation model of the project can be created. In addition, simulation-based planning approaches have difficulties in identifying the critical path due to the lack of common information. As is known, the total slack or allowable delay is an important factor in determining whether an activity is critical or not.

Picture 2.Process incremental modeling structure



Source:https://www.javatpoint.com/software-engineering-incremental-model

Software for the creation of smart villages and regions in the Republic

Events and activities are the two basic building blocks of modeling. Events can be referred to as activities of zero duration. Activities are divided into two classes, B-activities and C-activities. Some activities have predictable start and end times. Therefore, such activities can be scheduled for a specific time. These activities are type B activities. In general, type B activities are activities that will take place very soon. Type C activities are contingent activities or joint activities. The execution of these activities does not depend only on the simulation clock. Some conditions must also be present for the action to take place. In this situation, other common objects must be ready and the simulation clock must be developed. There are three important differences between activity scanning and the three-phase approach. The three-phase approach uses a variable time increment strategy, while the action scan has a fixed time increment strategy. In Phase A of the three-phase modeling approach, after the simulation starts, the nearest event is removed from the list of instantaneous events. The simulation clock advances to the time when this event will occur. An event with the same simulation time as the time of the event is removed from the list of upcoming events.

In project planning, the number of activities, the number of resource types, the total number of activities, and the structure of the regime are factors that increase the difficulty of the problems. As the number of these factors, the uncertainty of the activities and the resources increase, the complexity of the project problems also increases.

A one-sided paired t-test was chosen as the hypothesis test for comparing the planning results of the simulation-based planning model and the MS Project 2007 software. The reason for using the paired t-test is that each of the test questions is treated separately, in other words, each test question considered is the same. A one-tailed t-test determines whether one of the compared methods is better or worse than the other. The t-statistic formula used is as follows.

$$S_D = \sqrt{\frac{\sum_{i=1}^{n}(d_i - \bar{d})^2}{n-1}}$$

$$\overline{S_D} = {S_D}/{\sqrt{n}}$$

$$t = {\bar{d}}/{S_D}$$

It is impossible to talk about an approach that fully meets the requirements when planning a Smart Village project. Especially with today's complex projects, there are many activities, resources, and priority relationships. However, there are many alternatives to carry out some activities. In real life, the duration and cost of the activities that make up the projects and the resources used for the activities may differ from the planned values. For this reason, it is obvious that it is necessary to model projects with a dynamic structure in a real and dynamic structure. However, the dynamic structure of a project cannot be represented or modeled by network diagrams such as classic CPM and PERT. In addition to the inadequacy of networks in modeling, their inability to plan projects with limited resources is also an important drawback. Many mathematical and heuristic methods that can solve the constrained resource scheduling problem deal with projects with many assumptions, and the solutions actually produced are solutions that do not represent a real project scheduling solution. In stochastic modeling approaches, modeling is quite complex and requires a difficult task. Moreover, complex project planning activities cannot be performed with stochastic models. Stochastic mathematical models or heuristics are inadequate, especially for planning and scheduling large projects.

Simulation is one of the most effective methods for best modeling and monitoring real systems. But simulation is not a solution. For this reason, it is not possible to find the best or even close to the best solutions by simulating projects. Simulation can be used to run various alternative schedules and monitor performance metrics. The behavior of the system can be observed by running the simulation model with different alternative scenarios. In project planning, it is very difficult to evaluate billions of different solutions as a result of simulation. For this reason, the study incorporates a heuristic algorithm into the simulation model that can generate several good diagram alternatives, thus limiting the solution space. In the real world, each project has its own limitations and objectives. Therefore, it would be a very lengthy and expensive approach to create a different model with simulation for each project.

It is a known fact for project managers that resource constraints for some resources may change in real projects. It is a known fact that some work resources change on a daily basis, especially during periods of high workload or at certain times of the year, or that the daily availability limit of employees working on different synchronous projects may change in a given project. In addition, the availability limit is standard for many resources. In the proposed simulation-based project planning and scheduling methodology, resource availability is evaluated as deterministic and stochastic. Accordingly, a constant daily limit is defined for resources with constant availability, while a stochastic approach is proposed for resources with variable availability. Here, the variability may vary depending on the type of source and the specific conditions. For this reason, it should be determined by which statistical probability distribution the condition of existence of each type of resource can be expressed. In the research conducted in this context, it was found that the availability of resources in the first group of test problems generally corresponds to a smooth and normal distribution, and the resource constraint is expressed by these distributions. If the resources used in the projects correspond to different distributions (exponential distribution, etc.), the corresponding probability distributions can be used in the simulation model.

ICT for a smart village typically addresses public service applications within the village and provides integrated information integrity for the sustainability and socioeconomic development of the village. Smart villages also benefit from this thematic environment where data is collected, processed and stored. However, this use of information requires new departments in municipal governments to support decision making by creating appropriate software tools, services, technologies, and new data to collect, store, and analyze large amounts of data of the village and its residents. Such a Big Data analytics platform facilitates smart village management through the timely collection of analytics data from multiple sources by decision makers. The concept of rural informatics, a multidisciplinary field, emerged from this combination of smart villages and Big Data. In addition to the general importance of Big Data, the focus is on rural development. The benefits of Big Data for smart villages include real-time system monitoring, management, and optimization [9]. Big Data plays an important role in managing traffic flow, electricity, water, and gas supply, planning new public transportation routes and networks, and managing public health and emergency response.

Result

With the use of new technologies such as the Internet of Things, artificial intelligence and sensors, the concept of a smart village has become a seriously debated topic worldwide in recent years. Smart villages are residential areas that use applications that raise the standard of living of citizens living in villages and minimize the negative impacts of rural life with the help of information and communication technologies. Big Data, artificial intelligence and the technology of the Internet of Things form the infrastructure of a smart village. Real-time and full-time monitoring of village data facilitates village management. In addition, it provides the opportunity to identify and solve existing problems of the village or potential problems in the future. Before the implementation of smart village projects, the mathematical model of the project should be prepared, and the software for the implementation and management of the infrastructure should be further improved.

Scientific Novelty:

The development of mathematical models and software for the creation of smart villages and regions in the Republic presents several novel contributions to the field:

1. Integrated Optimization Framework: This study proposes an integrated optimization framework that combines various mathematical modeling techniques to address the complex interdependencies and trade-offs within smart villages and regions. By considering multiple factors such as energy management, waste management, transportation, and resource allocation, the framework enables holistic decision-making and optimal resource utilization, leading to enhanced sustainability and efficiency.

2. Customization for Local Context: This research emphasizes the customization of smart village and region solutions to suit the unique needs and challenges of the Republic. By conducting a thorough needs assessment and stakeholder engagement, the proposed models and software applications are specifically tailored to the socioeconomic, environmental, and cultural characteristics of the region, ensuring relevance and effectiveness in implementation.

3. Scalable and Replicable Solutions: The mathematical models and software developed in this study are designed to be scalable and replicable across different villages and regions in the Republic. The models take into account the diverse nature of communities and provide flexible frameworks that can be adapted to various scales and contexts, enabling widespread adoption and long-term sustainability of smart village initiatives.

4. Dynamic Adaptability: Recognizing the dynamic nature of smart village and region development, this study incorporates iterative improvement and continuous monitoring mechanisms. The software applications developed include real-time data analytics, allowing for real-time adjustments and data-driven decision-making to optimize system performance and respond effectively to changing needs and emerging technologies.

5. Interdisciplinary Approach: This research adopts an interdisciplinary approach, integrating knowledge from various fields such as mathematics, computer science, engineering, urban planning, social sciences, and public policy. By bringing together experts from different disciplines, this study aims to provide comprehensive and holistic solutions to the challenges faced in developing smart villages and regions, fostering collaboration and innovation.

The scientific novelty of this study lies in the development of a comprehensive and customizable framework that combines mathematical modeling and software applications to optimize sustainability, resource efficiency, and quality of life in the Republic's villages and regions. By addressing the specific needs of the local communities and considering the dynamic nature of smart systems, this research contributes to the advancement of knowledge and practices in the field of smart village development.

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