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Digital Sustainability in Agriculture: Twofold Approach

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Abstract

The article is devoted to the issues of sustainability of agriculture in the context of active digitalization of the economy. The paper identifies and defines two main areas of digital sustainability of agriculture. On the one hand, the introduction of digital technologies has an impact on the development of agriculture and rural areas, and on the other hand, the process of digital transformation itself has a certain level of sustainability. To study the role of digitalization in achieving the goals of sustainable development in agriculture, a comprehensive analysis was carried out in three areas. Firstly, the theory and practice of introducing digital technologies have been studied, the types and characteristics of sustainability indicators, internal and external factors, as well as tools for improving sustainability in agriculture have been considered. Secondly, the relationship between the indicators of the use of information and communication technologies and the development of economic entities in the industry has been identified. Thirdly, a statistical analysis of the impact of digitalization on indicators characterizing the agricultural sustainability was carried out using the variability indicator as the main criterion. As part of the study of the sustainability of the digitalization process in agriculture, the influence of business models of the digital economy and technology on the businesses was studied in terms of the stages of value creation and directions for ensuring sustainability, the links between the sustainability of the organization and digital transformation strategies were clarified and systematized. The study used FAO statistics and IMD World Digital Competitiveness Ranking.

Key words

Digitalization, Sustainable development, Agriculture

1. INTRODUCTION

The development of the world economy at the present stage is inextricably linked with progress in the field of computer technology, neural networks, robotics and the process of introducing digital technologies in almost all areas the political, social, cultural life of society, and in all sectors of the economy [17]. The scientific and practical interest in digitalization is due to its great economic importance in the application of innovations in production and commercial processes and the formation of sustainable mechanism for the functioning of enterprises.

The digital economy is now the locomotive of the development of both individual companies and entire countries, despite their size, and digital technologies have changed the way both the entire market and the individual organization work along the entire value chain [22]. As a result of digitalization, improved resource management is achieved, viability of companies safeguarded, flexibility in decision-making increases, and trust in interaction with customers and partners improves.

A key area of digital transformation of the economy, at the national and supranational levels, is to change approaches to doing business through the introduction of modern information technologies to achieve overall efficiency. The transition to a digital business makes it possible to manage change by integrating production with information technology, resulting in greater efficiency in the use of resources and increased flexibility and the ability to quickly adapt to the changing needs of stakeholders to achieve the company's goals [31] and, therefore, ensures the maximization of profitability [26].

The greatest value, both from a scientific and practical point of view, is the contribution of digitalization to solving global problems of mankind and achieving sustainable development goals. Digitalization contributes to the "greening" of production processes, allowing to reduce the impact on the environment, but also provides new opportunities for the implementation of sustainable development practices in most aspects of the organization's activities, including economic and social [12].

One of the most important areas of the economy is agriculture, which, along with industry, services and digitally driven innovations, are the four key drivers of global economic growth. [4]. Industrial agriculture which is now seen as an integral part of the value chains that underpin our economies, providing invaluable services to society [20] does not fully meet modern sustainability requirements and is extremely wasteful. Modern agricultural production is associated with various problems, such as the depletion of non-renewable natural resources, soil damage, the adverse effects of agricultural chemicals on human health and the environment, the agricultural sector is a key factor in the climate crisis, reducing CO2 emissions and halting biodiversity loss [21].

The transition in agriculture from the traditional form to the "green economy" is a forced process due to the unfavorable environmental situation. The main task of the "green economy" is to increase the volume of agricultural production without disturbances in land use to preserve soil fertility, reduce the negative consequences of agricultural activities on the quality of products, raw materials and food that provide food security, stability and strengthening economies [3].

The "green economy" in its component is aimed at resource-saving technologies and environmentally friendly production, which reduce the risks of pollution in the environment. Further development of agriculture is associated not only with greening, but also with digitalization. In this context, digital technologies are considered by policymakers as a key technological solution to make agriculture more environmentally sustainable and create so-called climate-smart agriculture [21].

The current digital transformation in agriculture combines IoT, cyber-physical systems, artificial intelligence, big data, machine learning and cloud computing with agricultural machinery [28]. This requires modernization of digitalization processes in the agricultural sector, as well as the creation of special mechanisms and practices to ensure the transition to new technologies of organizations, industries and regions where an increasing number of environmental and quality standards are expected to be observed [3].

Digitalization, providing tools to achieve the social, environmental and economic goals of the concept of sustainable development, has led to the emergence of new problems and has caused the need to consider an additional component, which can be called digital. Digital sustainability is now a prerequisite for achieving sustainable development in the conventional sense.

From the point of view of economic development, the goal of digital sustainable development is to create secure conditions for the functioning of digital infrastructure, processing and transmission of big data, and reliable software. Sustainable “digital being” emphasizes the need for long-term structural changes in digital and social systems in order to maintain social cohesion and solidarity, while recognizing the need to reduce environmental and resource consumption to sustainable levels.

The study of digital sustainability is a prerequisite for achieving sustainable development, which requires deep theoretical and methodological study, as well as the creation of special mechanisms and practices to ensure the comprehensive sustainability of organizations, industries and regions. This study is devoted to the investigation of this relation, as well as the identification of new scientific solutions that can be used in the development of conceptual provisions, prospects and tasks of digitalization in the agricultural sector.

2. DIGITALIZATION AND SUSTAINABLE DEVELOPMENT OF AGRICULTURE: THEORETICAL ASPECTS

The transformation of the economy, called digitalization and carried out through the introduction of digital technologies in the production and marketing activities of the enterprise, is currently the main paradigm of accelerated economic development. Digital technologies refer to information and communication technologies, including the Internet, mobile technologies and devices, and data analytics, used to improve the generation, collection, exchange, aggregation, aggregation, analysis, access, retrieval, and presentation of digital content [23].

Approaches to the definition of "digitalization" may differ both depending on the scale of the tasks to be solved, and in terms of the specifics of a problem. At the level of consulting, digitalization implies the use of digital tools to solve individual tasks of the enterprise. In a broader sense, digitalization involves, firstly, the introduction of digital technologies into various sectors of the economy and spheres of society in order to improve the well-being of the population and improve the quality of life. Secondly, it is the use of digital products by organizations and enterprises in each individual aspect of their activity, leading to an increase in profitability. Thirdly, it is the process of creating new types of information, algorithms, methods and tools for data processing, improving the competencies of workers, forming a new branch of the economy.

The digital transformation of the economy implies five key areas, namely strategic orientation, customer focus, information technology infrastructure, talents, opportunities and capacity building, innovation and organizational culture [24]. As a result of digitalization, an increase in the efficiency of activities is achieved by optimizing and automating business processes and the coordinated operation of information systems, which together ensure the effective functioning of the material basis for the production of goods and services.

The concepts of stability and equilibrium are fundamental in the general theory of systems, physics, biology, ecology, sociology and economics, which is defined and investigated in different ways depending on the goals and level of analysis: from the stability of individual functional characteristics of the object of study to the stability of socio-economic systems of the micro-, meso- and macro-level. Although sustainability is a relatively new concept, it has its roots in movements such as conservation or socio-economic justice [6].

Traditionally, sustainability is measured by the performance of doing business using indicators such as income, profitability, employment, and contribution to other business sectors that make up the economic dimension of sustainability [25]. Modern sustainability theory expands the range of valuation criteria in such a way that companies should pay as much attention to social and environmental issues as they do on profits [12].

Agriculture is a global and diverse industry, as well as one of the largest economic activities and one of the most important factors of the economic growth [1]. The agriculture is also a source of livelihood for 86% of rural residents, while 40% of the world's population is provided by means of subsistence through agriculture and food production [15]. Therefore, for the sustainable development of the world economy, it is necessary to increase the productivity of the world's agriculture as a basis of global food system, while increasing its sustainability in order to increase the sustainability of the world's economy and to cope with the effects of climate change, water scarcity and other problems [13].

The concept of sustainable agriculture is ambiguous, and there are many different points of view on sustainability. The U.S. Department of Agriculture identifies three pillars of sustainability: (1) long-term profits; (2) land, air and water management; (3) quality of life for farmers, ranchers, and rural communities. In this way, sustainable agriculture provides a long-term increase in agricultural production and farmers' incomes while protecting the environment [14].

According to another definition, sustainable agricultural production has five main attributes: (1) it conserves resources, (2) it does not cause environmental degradation, (3) it is technically affordable, (4) it is economically viable and (5) it is socially acceptable. The main objective of sustainable agriculture and rural development is to increase the level of food production in a sustainable way and ensure food security [11]. Although agriculture is recognized as a way to achieve sustainable development, the goals of economic, environmental and social sustainability often contradict each other [33].

In developed countries, there has been a transformation of agriculture into an industrial process of food production, which provides food to the population of their countries in excess. In developing countries there is low-productivity agriculture of the extensive type, which is based on manual labor and does not provide the population of these countries with enough food, as a result of which part of the population is malnourished and even hungry [2], [10]. At the same time, the industrial system of agricultural production is wasteful and causes significant harm to the environment through depletion of soils, destruction of natural biodiversity, pollution of nature with mineral fertilizers, pesticides and waste products.

To achieve the Sustainable Development Goals, the agricultural sector must be as sustainable as possible in terms of production in a cost-effective, environmentally sound and socially inclusive manner. The agricultural sector can play an important role in ensuring a country's resilience to global economic and financial shocks, and it is often the best sector to cope with the economic crisis [10].

Agriculture faces a variety of environmental, economic and social challenges that require a transition to sustainable development and integration, which is one of the most significant ongoing transformation processes in global agriculture [8]. The digital transformation of agricultural production based on the principles of sustainable development does not have a single template and, of course, is associated with regional and local specifics.

The current practice of agricultural activity cannot be limited only to the formation of organic agriculture or sustainable intensification of agricultural production. This requires process automation and robotics, agricultural information applications, cyber-physical systems, appropriate tools and machines, as well as the collection and analysis of large amounts of data [5], which increase the productivity and profitability of the farm and preserve the environment, contributing to sustainable agriculture [34]. To prevent global challenges in the field of food and biological security, humanity needs a new type of agriculture that corresponds to the circular or waste-free economy model and the principles of sustainable development through the integration of cyber-physical systems, Internet of Things technologies, artificial intelligence and machine learning, big data and analytics, as well as cloud technologies with agricultural machinery [28].

The processes of digitalization of agriculture in the world come unevenly. It depends on the level of education, income, the proportion of older people, communication interests, lack of skills in obtaining information services, etc. In part, the lag of the agricultural sector in informatization is due to the specifics of the agricultural sector, which is focused mainly on traditional information processing technologies, the low level of development of digital communications infrastructure in rural areas, as well as significantly lower incomes of the rural population. Agricultural producers from developing countries face a lack of scientific and practical knowledge on innovative technologies, the absence of accurate forecasts for prices for agricultural products, as well as the underdevelopment of the logistics, storage and delivery system, which leads to high production costs and low competitiveness.

The current level of digitalization of agriculture is insufficient, primarily due to the lack of the necessary resources for the introduction of modern equipment and technologies, and the high costs of technology implementation and limited knowledge and skills are serious obstacles [18]. This leads to the use of outdated equipment and technologies by small and medium-sized agricultural producers, primarily from developing countries, which reduces their competitiveness both in the domestic market, where they are affected by the pressure from large producers, and in the external market. As a result, the benefits of digitalization are limited to industrialized countries with the focus on the production of well-known and widely grown crops such as wheat, maize and rice, which increases the risk of unsustainable intensification practices [27].

In addition, access to specialized information resources, where one can get the necessary information to optimize activities, is practically absent or fragmented for small size farmers. The existing measures of state support for agricultural producers do not have a targeted focus on the introduction of advanced technologies and on supporting the development of the necessary market and legal architecture for ICT and smart agriculture, with due regard to ethical issues [8].

It should be noted that agricultural production has a huge development potential, based on improving the efficiency of the use of land, labor and biological resources. In order to make full use of these resources, it is necessary to improve production technologies and develop a management system based on high-level information systems. The principal feature of these systems is the processing of large amounts of quantitative information, the results of the analysis of which make it possible to increase the efficiency of production activities, improve technological solutions and the material base of production, and develop systems for processing, storage, sale, delivery of finished products to consumers.

The allocation of resources, products, materials, energy and water can be realized in a more efficient way based on intelligent models that create positive or reduce negative impacts on the environment and society. Sustainable agriculture based on digital technologies, combining environmental, economic and social goals, can make a significant contribution to reducing poverty, eliminating hunger, ensuring food security, combating climate change, as it is considered one of the main strategies for achieving the SDGs [9].

To do this, digital innovation must create value for all stakeholders involved in the production and distribution process, pursuing social and environmental goals along with commercial ones. Social and environmental sustainability in agriculture derives from economic sustainability, while referring to the availability of sufficient

food for all humans, animals and plant species in the world [16]. GDP growth in agriculture contributes to poverty reduction at least twice as much as in any other sector [30].

Labour remains central to agriculture, employing 1.3 billion people worldwide, accounting for about 25% of global employment [32], and to create an environmentally and socially sustainable farming system in the context of digitalization of agriculture, consideration of labour and labour relations is key. Digital transformation is changing the way human resources work, simplification and automation of processes with the consequent improvement of the decision-making process increase the efficiency of human resources [19].

The social results of the digitalization of the economy are associated, first of all, with the creation of conditions for decent work and improvement of labour safety, but primarily with the preservation and increase of employment while reducing unemployment in rural areas. The digitalization of agriculture can further affect the employment opportunities and job profile of farmers and agricultural-related professionals [29].

Agricultural technologies contribute to increasing agricultural productivity and incomes while reducing the burden on resources and the environment, and promote innovations that provide an environmental component of sustainability. Some of the key performance indicators of environmental innovations used to measure environmental sustainability include recycling rate, water footprint, carbon footprint, waste reduction rate, and energy consumption. Today, digital technologies are used to measure and track progress in the environmental component of sustainability, protecting the environment by optimizing the use of resources, reducing greenhouse gas emissions and creating a circular economy.

A systematic approach, the creation of a digital infrastructure, digital inclusion and network readiness, the integration of people and technologies into "appropriate management structures" are necessary conditions for obtaining the full positive results of digitalization in the neutralization and preventive elimination of negative trends. The latter, among other things, are related to the fact that digitalization creates new differences and strengthens existing ones, not only between individual countries and regions, but between different genders, different age and socio-ethnic groups. Governance is proved to be critical in the areas of IT legislation, policy harmonization and targeted investment [7].

However, as a tool for creating sustainable values paradigm, digitalization initiates the emergence of a new problem of sustainability of the intelligent industrial system handling data and information. Information technologies longevity, viability and safety, including the collection, recording of information, its transmission, coding, processing and use, become critical.

Among the problems that enterprises need to solve in the process of digitalization, the following are of the greatest importance. First, the problems of cybersecurity including the protection of sensitive data and reliability cloud storage, and defense against espionage, fraud, hacker attacks, viruses and terrorism. Secondly, the problems of data transmission are speed and quality. Thirdly, the skills and qualifications of employees and training in specific skills of a new technology in the workplace is becoming critical, as the rate of "obsolescence" of key skills is increasing.

Sustainability of agricultural production means the possibility of long-term planning, reducing the time spent on searching for goods, allows one to standardize all the most important trade and technological processes and operations, organize their implementation with minimal expenditure of labour, material and financial resources. Instability is harmful to economies, including the agricultural sector, as it amplifies business cycles and stifles domestic investment, and can be so toxic that it reduces long-term growth.

The stability of a process or phenomenon is an indicator that reflects changes in its numerical expression of latitude and depth over a certain period of time. The opposite phenomenon of stability is volatility, which is the degree of fluctuations of various indicators, indices, stocks and exchange rates, etc. In the field of finance and exchange activity, this is the range of values of the price of the selected asset, fixed in a specific time period, in the field of production it is the difference between the highest and the lowest levels of production over a certain period of time. Volatility as a statistical measure measures the spread of data around its average over a period of time and serves as a good indicator of sustainability.

3. ASSESSING THE IMPACT OF DIGITALIZATION ON AGRICULTURAL SUSTAINABILITY

The main purpose of this study is to determine and evaluate the consequences of the introduction of digital technologies and business models for the sustainability of agriculture and to do this it is necessary to quantify the relationship between the digitalization process in agriculture and changes in sustainability indicators. This requires data describing the progress in the digitalization of the industry, along with a numerical expression of indicators of the functioning of the agro-industrial complex.

Currently, there are no generally accepted methods and universal tools for solving the above mentioned problem. Digital agriculture should help to maintain a balance between the goals of growing food production and consumption and the goals of preserving the environment. Measuring the impact of digitalization on agriculture and its sustainability should take into account the specifics and diversity of the objects under study, the dynamics of changes in the main indicators in the process of digital transformation, as well as the features of social and economic consequences.

The research methodology is based on the analysis of digital modernization processes and statistical data of the agricultural sector. One of the indicators of sustainability is the volatility of agricultural indicators, determined on the basis of a time series of statistical data. Similarly, it is possible to analyze the level and change in the dynamics of digitalization of the industry. The methodological basis of the proposed approach is the method of complex rating and the method of analysis of variance.

Limitations are related both directly to the definition of a set of factors and to the methodology for collecting data for calculating estimates under conditions of objects heterogeneity. It is often not always possible to highlight the impact of digitalization on the performance, efficiency and sustainability of organizations in the agricultural sector. So, often the results of digitalization include the introduction of modern technologies that are not directly related to the discrete way of presenting information. In addition, most of the existing ratings are focused on the level of national economies and are only conditionally applicable to the study of the digital transformation of the economy in the context of individual industries, such as the agro-industrial sector.

The main criterion of stability determined by volatility in this study is the standard deviation, that is, the square root of the variance, and the coefficient of variation, also known as the relative standard deviation, a standard measure of the variance of the probability distribution or frequency distribution. It is often expressed as a percentage and is defined as the ratio of the standard deviation to the mean. The greater the amount of variance, standard deviation or coefficient of variation (CV), the more unstable the indicator, the lower the level of stability.

Table 1. Characteristics of sustainability indicators

Type	Definition	Indicator
Economic sustainability	The ability of the system to maintain a certain level of achievement of goals in the context of dynamic transformations in the business environment.	Production of Crops and Livestock: Yield (of main agricultural products) Market price of agricultural products (Consumer Price Indices): Consumer Prices, Food Indices (2015 = 100), Consumer Prices, General Indices (2015 = 100), Food price inflation
Environmental sustainability	The ability of the system to meet current human needs while maintaining the integrity of biological and physical natural systems	Environment, Food and Waste Disposal: Domestic wastewater, Incineration, Industrial wastewater, Solid food waste, Waste - agri-food systems
Social sustainability	The ability of the system to identify and manage the impact of economic activities on social structures in order to create inclusive and resilient communities	Employment Indicators Agriculture: Share of employment in agriculture, forestry, Share of employment in crop and animal production, Share of employment in fishing and aquaculture, Share of employment in forestry and logging
Digital sustainability	The ability of the system to maintain a certain level of use of digital technologies in daily activities in the long term in accordance with the pace of development of information and communication technologies	IMD World Digital Competitiveness Ranking: Digitalization score

Source: author

As an indicator of the quantitative characteristics of digitalization, this study uses the World Digital Competitiveness Ranking (WDC) prepared by the IMD Center for Global Competitiveness. The WDC rating is

based on the assumption that there is a close relationship between ICT development and economic well-being, since ICTs play a leading role in economic development today. It measures the ability and willingness of countries to adopt and use digital technologies as a key driver of economic transformation in business, government and society as a whole.

The WDC ranking evaluates and ranks the extent to which countries are adopting and exploring digital technologies leading to the transformation of public practices, business models, and society as a whole. The use of this indicator in the current study is based on the assumption that the general level of digitalization of the economy can be used to assess the level of digitalization of the agricultural sector.

WDC defines digital competitiveness by three main factors: future readiness, knowledge and technology, and includes 54 criteria. The end result is the ranking of countries according to the score. The ranking is calculated from 1999 to 2021 and currently covers 22 periods.

In total, the WDC ranking includes 63 countries, which can be divided into three groups according to the size of the main indicator: a group of countries with a high level of digitalization, with an average level of digitalization and with a low level of digitalization. The criterion for attribution to a particular group is the country's points as of 2021.

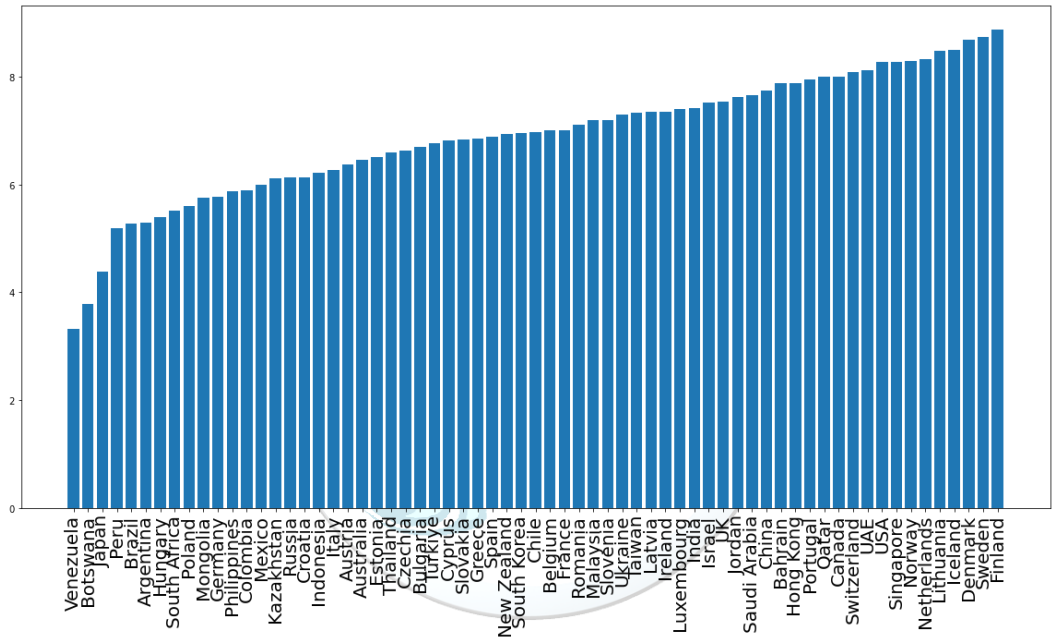

Fig 1. Ranking of countries by level of digitalization, 2021

Source: IMD

Table 2. Division of countries into groups according to the level of digitalization, 2021

Group: low (<6)	Group: mid (>6 and <8)	Group: high (>8)
Argentina, Botswana, Brazil, Colombia, Germany, Hungary, Japan, Mexico, Mongolia, Peru, Philippines, Poland, South Africa, Venezuela	Australia, Austria, Bahrain, Belgium, Bulgaria, Canada, Chile, China, Croatia, Cyprus, Czechia, Estonia, France, Greece, China, Hong Kong SAR, India, Indonesia, Ireland, Israel, Italy, Jordan, Kazakhstan, Republic of Korea, Latvia, Luxembourg, Malaysia, New Zealand, Portugal, Qatar, Romania, Russian Federation, Saudi Arabia, Slovakia, Slovenia, Spain, China, Taiwan Province of, Thailand, Türkiye, Ukraine, United Kingdom of Great Britain and Northern Ireland	Denmark, Finland, Iceland, Lithuania, Netherlands, Norway, Sweden, Switzerland, United Arab Emirates, United States of America

Source: IMD, author

The main source of data on the production and prices of crops and livestock products in the world, as well as data on employment in agriculture and rural areas, environmental data is the official statistics of FAO. Inputs can be surveys, administrative data, and assessments based on expert observations. For each time series, the data is analyzed using a grouping of countries by level of digitalization.

This study uses data from FAOSTAT, which provides consistent data on agricultural production collected by country and territory between 1999 and 2021. This study examines the most widely produced agricultural commodities around the world are: soybeans, cow's milk, sugar cane, corn, wheat, rice, potatoes. Four separate crops, such as sugarcane, maize, rice and wheat, accounted for half of global production of staple crops in 2020. These crops, as well as milk, potatoes and soybeans, are among the leading foods worldwide.

The relationship between the level of digitalization of the country and the volatility of the production of basic agricultural products is reflected through a comparison of production variances by groups of countries and by main products. In addition, the mean and variance of the score reflecting the level of digitalization is given for each group.

The volatility indicator is measured in absolute values and can take any values. In this case, the magnitude of the variance reflects the agricultural potential of countries and the share in the world market through the inequality of their size. Accordingly, a comparison of the variance of production of basic agricultural products by groupof countries does not make sense. In order for these indicators to be compared, this indicator was normalized according to the average value, that is, the coefficient of variation was calculated.

Table 3. Volatility in the production of basic agricultural products and the level of digitalization

#	Item	Group	Yield, std	Yield, CV	Score, men	Score, std
0	Maize (corn)	high	1.219123e+08	0.480421	7.965878	0.587371
1	Maize (corn)	low	1.868977e+07	0.318387	6.293251	0.762578
2	Maize (corn)	mid	3.425887e+07	0.286612	7.013835	0.650372
3	Milk, Total	high	2.580842e+07	0.107581	8.135908	0.765135
4	Milk, Total	low	9.841591e+06	0.157047	6.259932	0.716707
5	Milk, Total	mid	2.229469e+07	0.162427	7.076426	0.620418
6	Potatoes	high	5,990558e+06	0.238110	8.139093	0.763709
7	Potatoes	low	3,799338e+06	0.262995	6.404462	0.717448
8	Potatoes	mid	1.429975e+07	0.273561	7.046304	0.610254
9	Rice	high	7.978464e+05	0.085029	8.301410	0.482927
10	Rice	low	5,768022e+06	0.157398	6.428730	0.804423
11	Rice	mid	5.194949e+07	0.276016	6.944087	0.667653
12	Soya beans	high	4.785207e+07	0.252357	8.039884	0.533002
13	Soya beans	low	2.485760e+07	0.600773	6.465885	0.819132
14	Soya beans	mid	3.713105e+06	0.694104	6.898485	0.638889
15	Sugar Crops	high	2.024651e+07	0.187119	8.129806	0.809591
16	Sugar Crops	low	1.696875e+08	0.194736	6.501671	0.826126
17	Sugar Crops	mid	6.524716e+07	0.413640	6.968364	0.636904
18	Wheat	high	1.779157e+07	0.323337	8.082977	0.740549
19	Wheat	low	6,916143e+06	0.330925	6.241925	0.717237
20	Wheat	mid	2.518099e+07	0.319407	7.060352	0.617293

Source: FAOSTAT, IMD, author

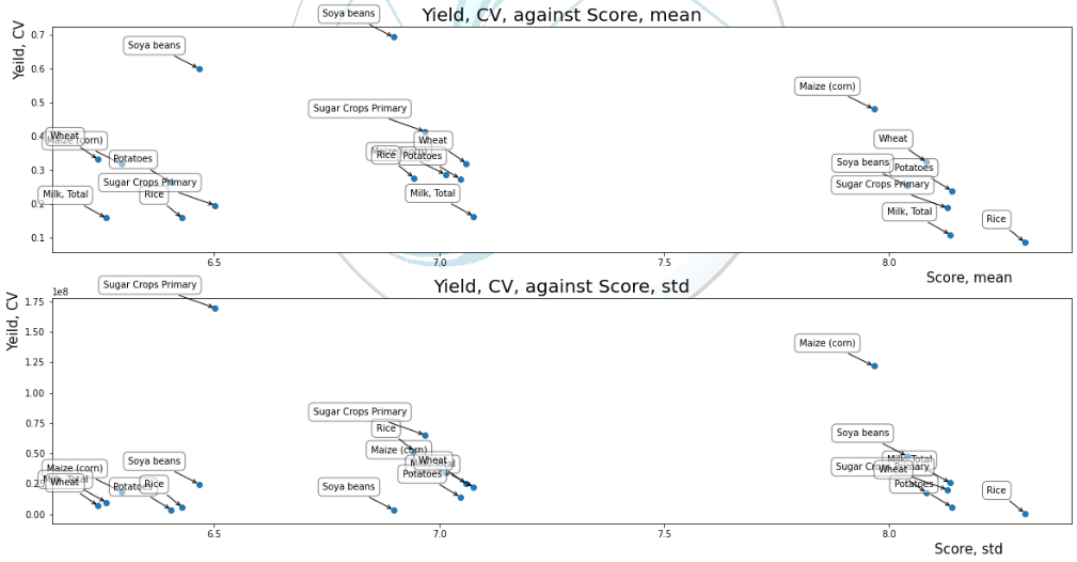

Fig 2. Volatility of the production of main agricultural products and the level of digitalization

Source: FAOSTAT, IMD, author

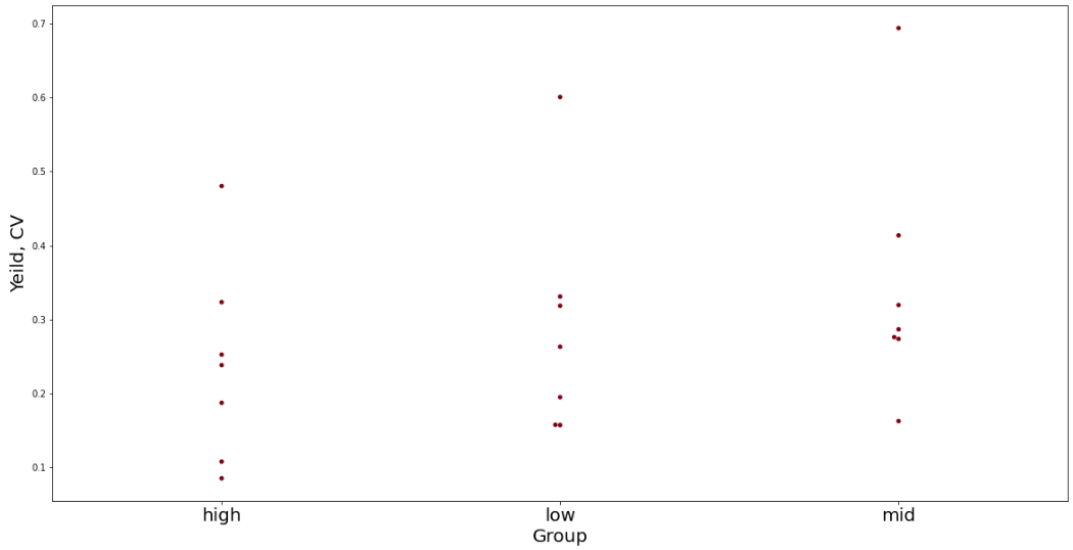

Fig 3. Volatility of production of main agricultural products by groups of countries

Source: FAOSTAT, IMD, own calculations

Using ANOVA yields statisticals such as the F-value and p-value. The F-value shows the differences between the mean values of the groups, and the p-value shows the statistical significance of the differences between the groups. If the p-value is less than a given significance level (usually 0.05), then we can conclude that there are significant differences between the groups. Additionally, if there are statistically significant differences between the groups, further analysis is carried out to compare each group to the other using the Turky test of Multiple Comparison of Means (FWER=0.05), to determine exactly where the differences are.

Table 4. ANOVA: Volatility of the production of main agricultural products by groups of countries

	sum_sq	df	F	PR(>F)
C(Group)	3.042077e+16	2.0	6.745089	0.001183
Residual	1.800868e+19	7986.0	In	In

Source: FAOSTAT, IMD, author

Table 5. Tukey HSD: Volatility of production of main agricultural products by groups of countries

group1	group2	meandiff	p-adj	lower	upper	reject
high	low	-317024	0.9836	-4607900	3973853	False
high	mid	-4233659	0.0259	-8062235	-405083	True
low	mid	-3916635	0.0054	-6870460	-962809	True

Source: FAOSTAT, IMD, author

An analysis of the volatility of the production of basic agricultural products by groups of countries, depending on the level of digitalization, shows that the coefficient of variation has a weak dependence on the variance of the level of digitalization. ANOVA confirms the existence of differences in production volatility between groups. At the same time, the Turky test clarifies that differences are observed between the groups of high and medium digitalization, as well as the groups of medium and low, while there are no differences between the groups of high and low.

The FAOSTAT Consumer Price Indices for Food (base = 2010) consist of a set of time series dating back to January 2000 compiled by FAO using population weights for aggregation by country. These indices measure the change in prices between the current and reporting periods of the average basket of goods and services purchased by households. The dynamics of agricultural commodity and food prices are an indicator of changes in the basic

principles of supply and demand. Thus, their levels are indicative of market distortions, which, for example, may portend a deterioration in food security.

Table 6. Price volatility of main agricultural products by groups of countries

#	Item	Group	Value, CV
0	Consumer Prices, Food Indices (2015 = 100)	high	0.166179
1	Consumer Prices, Food Indices (2015 = 100)	low	14.334969
2	Consumer Prices, Food Indices (2015 = 100)	mid	0.294077
3	Consumer Prices, General Indices (2015 = 100)	high	0.157989
4	Consumer Prices, General Indices (2015 = 100)	low	14.379485
5	Consumer Prices, General Indices (2015 = 100)	mid	0.260095
6	Food price inflation	high	1.633757
7	Food price inflation	low	18.435720
8	Food price inflation	mid	1.517482

Source: FAOSTAT, IMD, author

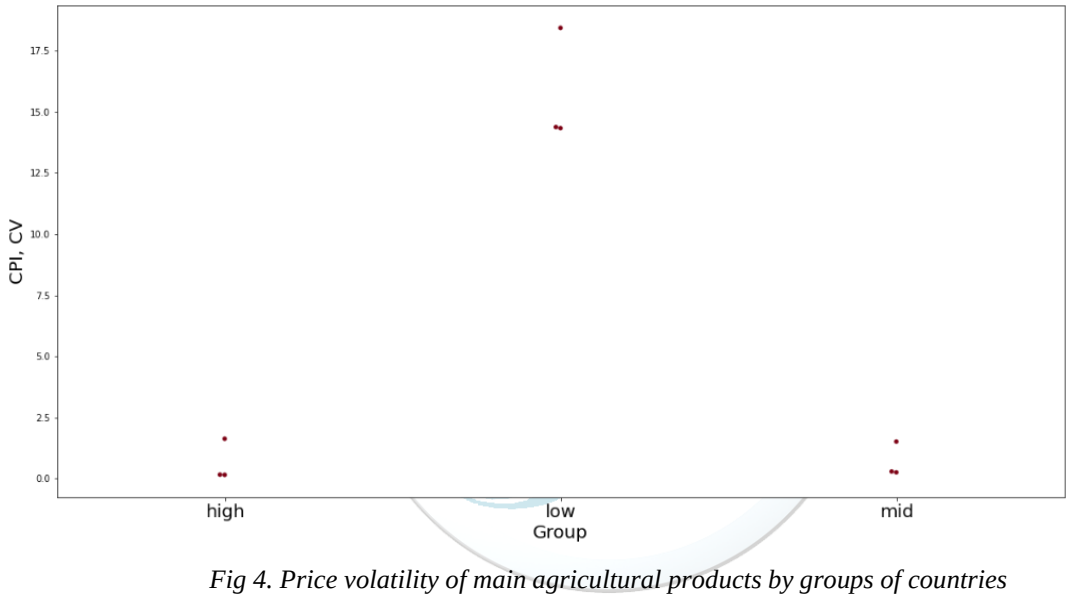

Fig 4. Price volatility of main agricultural products by groups of countries

Source: FAOSTAT, IMD, author

Table 7. ANOVA: Price volatility of basic agricultural products by groups of countries

	sum_sq	df	F	PR(>F)
C(Group)	5.225649e+21	2.0	61.957158	1.335411e-27
Residual	2.109881e+24	50031.0		

Source: FAOSTAT, IMD, author

Table 8. Tukey HSD: Price volatility of main agricultural products by groups of countries

group1	group2	meandiff	p-adj	lower	upper	reject
high	low	772937788.6	0.0	551103193.8	994772383.5	True
high	mid	-1.4723	1.0	-190421725	190421722.3	False
low	mid	-772937790	0.0	-940445008	-605430571	True

Source: FAOSTAT, IMD, author

The Waste and Food Loss Database contains data and information from publicly available databases, reports and studies that measure food loss and waste across all foods, stages of the value chain and geographical areas. Globally, approximately 14 percent of the world's food worth $400 billion is lost annually between the harvest and the retail market (FAO 2019). At the same time, an estimated 17% of food is wasted at the retail and consumer levels (UNEP, 2021). Reducing food waste and loss is an important lever for broader improvements in food systems to improve food security, food safety, quality and sustainability, and efficiency.

Table 9. Volatility of agricultural waste and food loss indicators by groups of countries

#	Item	Group	Value, CV
0	Domestic wastewater	high	1.253697
1	Domestic wastewater	low	1.514900
2	Domestic wastewater	mid	4.193441
3	Incineration	high	1.852205
4	Incineration	low	2.288755
5	Incineration	mid	3.283563
6	Industrial wastewater	high	2.559102
7	Industrial wastewater	low	2.520381
8	Industrial wastewater	mid	2.799648
9	Solid food waste	high	2.799415
10	Solid food waste	low	1.653120
11	Solid food waste	mid	2.433903
12	Waste - agri-food systems	high	2.657137
13	Waste - agri-food systems	low	2.372666
14	Waste - agri-food systems	mid	3.589701

Source: FAOSTAT, IMD, author

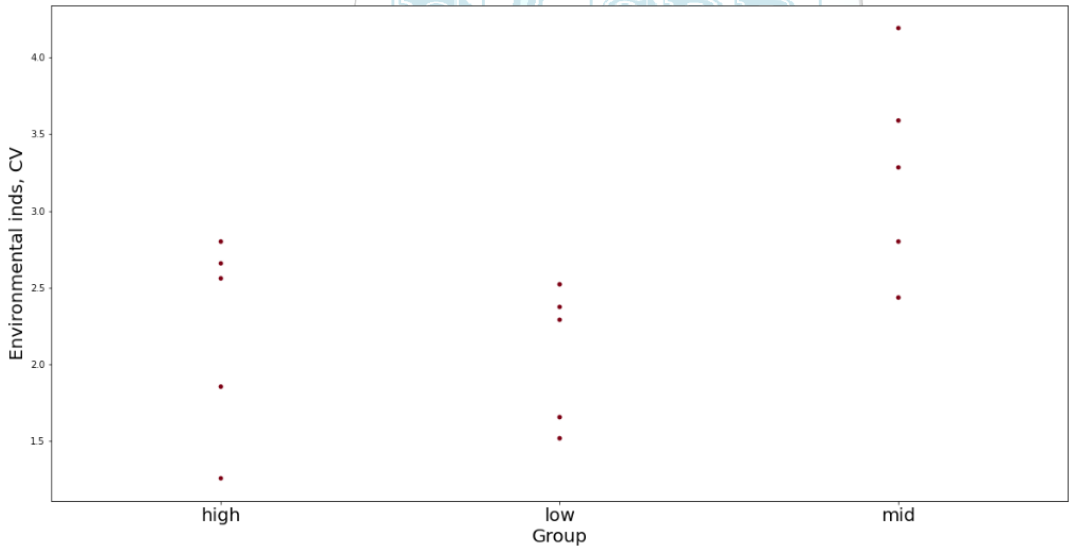

Fig 5. Volatility of agricultural waste and food loss indicators by groups of countries

Source: FAOSTAT, IMD, author

Table 10. ANOVA: Volatility of agricultural waste and food loss indicators by groups of countries

	sum_sq	df	F	PR(>F)
C(Group)	3.141093e+07	2.0	22.15747	2.454588e-10
Residual	1.174429e+10	16569.0		

Source: FAOSTAT, IMD, author

Table 11. Tukey HSD: Volatility of agricultural waste and food loss indicators by groups of countries

group1	group2	meandiff	p-adj	lower	upper	reject
high	low	106.6896	0.0	56.7038	156.6754	True
high	mid	121.6371	0.0	78.5973	164.6768	True
low	mid	14.9475	0.6202	-22.6589	52.5538	False

Source: FAOSTAT, IMD, author

FAOSTAT updates employment indicators annually using data from the International Labour Organization (ILO) database, which contains a rich set of indicators on a wide range of issues related to labour statistics. FAOSTAT records 18 indicators related to employment in agriculture and rural areas. The data provide information on employment status, agricultural units and the number of hours worked by people employed in agriculture, forestry and fisheries, as well as in rural areas, disaggregated by sex and age, if possible. Agriculture remains the second largest source of employment in the world after the service sector with 26.7 percent of total employment, with employment in agriculture, forestry and fisheries steadily declining worldwide, employing 866 million people worldwide in 2021, up from 1 billion in 2000.

Table 12. Volatility of agricultural employment indicators by groups of countries

#	Indicator	Group	Value, CV
0	Share of employment in agriculture, forestry a...	high	0.677708
1	Share of employment in agriculture, forestry a...	low	0.875553
2	Share of employment in agriculture, forestry a...	mid	1.131982
3	Share of employment in crop and animal product...	high	0.198435
4	Share of employment in crop and animal product...	low	0.036072
5	Share of employment in crop and animal product...	mid	0.085631
6	Share of employment in fishing and aquaculture	high	1.045818
7	Share of employment in fishing and aquaculture	low	0.869523
8	Share of employment in fishing and aquaculture	mid	0.544596
9	Share of employment in forestry and logging	high	0.833601
10	Share of employment in forestry and logging	low	0.897447
11	Share of employment in forestry and logging	mid	1.074318

Source: FAOSTAT, IMD, author

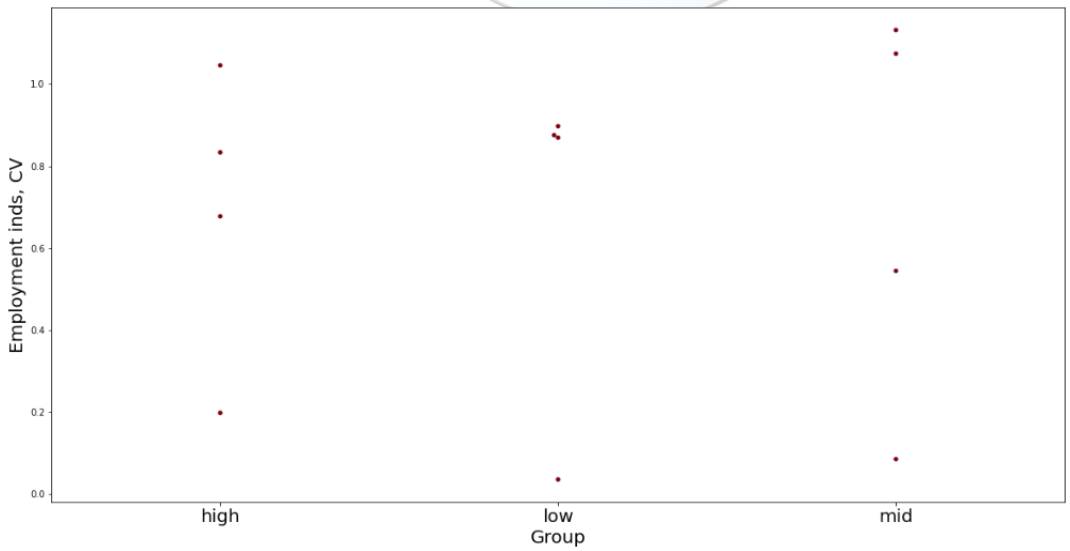

Fig 6. Volatility of agricultural employment indicators by groups of countries

Source: FAOSTAT, IMD, author

Table 13. ANOVA: Volatility of agricultural employment indicators by groups of countries

	sum_sq	df	F	PR(>F)
C(Group)	6.444539e+02	2.0	0.287545	0.750116
Residual	5,234390e+06	4671.0		

Source: FAOSTAT, IMD, author

Table 14. Tukey HSD: Volatility of agricultural employment indicators by groups of countries

group1	group2	meandiff	p-adj	lower	upper	reject
high	low	1.137	0.7341	-2.4209	4.6949	False
high	mid	0.4732	0.926	-2.4978	3.4442	False
low	mid	-0.6638	0.8523	-3.5539	2.2263	False

Source: FAOSTAT, IMD, author

An analysis of the volatility of sustainability indicators characterizing the impact of digital technologies on agricultural prices, the level of employment in the agricultural sector and some environmental indicators reveals several features. ANOVA makes it possible to conclude that there are statistically significant differences between groups of countries by the level of digitalization in the case of yield and prices of main agricultural products and indicators of waste and food loss, but denies that such a difference for agricultural employment exists. The Turky test clarifies that these differences are observed in two of the three groups in both cases.

As a result, it can be concluded that there is a certain positive impact of digitalization, the main direction of development of both the economy as a whole and agriculture in particular, on the sustainability of the latter. This influence is not universal, however, and depends on a number of other factors.

The criteria that provide a framework for investigation of economic, environmental and social sustainability, imply the sustainability of the digital transformation process itself, which encompasses a number of issues and challenges that impact to the viability and longevity of digital transformation. By analogy with indicators of economic, environmental and social sustainability, the analysis of digital stability should be carried out using the same volatility indicators of the IMD World Digital Competitiveness Ranking. The important assumption is the objectivity of this rating and score, characterizing the level of development of information and communication technologies and network economy in the countries of the world.

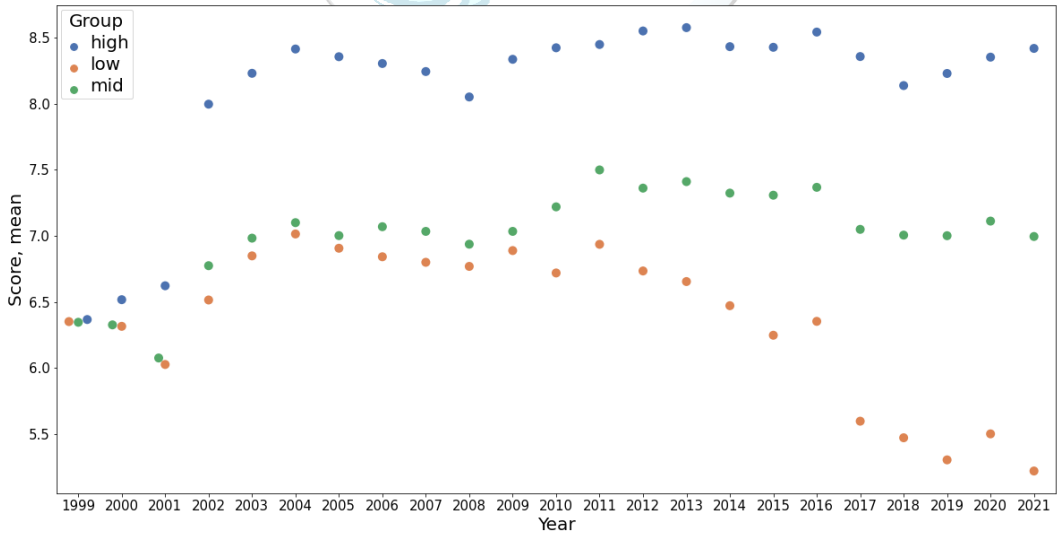

Fig 7. Dynamics of the level of digitalization by groups of countries, score

Source: IMD, author

Table 15. Volatility of the level of digitalization by groups of countries

	Group	Score, std
0	high	0.836792
1	low	1.082195
2	mid	0.939985

Source: IMD, author

Table 16. ANOVA: Volatility of the level of digitalization by groups of countries

	sum_sq	df	F	PR(>F)
C(Group)	2038.630108	2.0	1094.035144	0.0
Residual	7440.574524	7986.0		

Source: IMD, author

Таблица 17. Tukey HSD: Volatility of the level of digitalization by groups of countries

group1	group2	meandiff	p-adj	lower	upper	reject
high	low	-1.7375	0.0	-1.8248	-1.6503	True
high	mid	-1.0888	0.0	-1.1666	-1.0109	True
low	mid	0.6488	0.0	0.5887	0.7088	True

Source: IMD, author

An analysis of the dynamics and changes in the indicators of the innovative and technological potential of the countries of the world and the possibilities of their development in the field of high technologies and the digital economy revealed several features. First, there is the higher volatility and deterioration in the level of digitalization in countries with a low level of digitalization. If at the beginning of the period under review, groups of countries with a low and medium level of digitalization occupied similar positions, then by the end the difference increased in favor of the latter. Secondly, it is noteworthy that the levels of digitalization in countries with medium and high levels in the period under review changed slightly. At the same time, ANOVA and Tukey test indicate that there are differences in the levels of digitalization among the groups.

4. CONCLUSIONS

Digital transformation and sustainability are the two main trends of recent times, and the main element of digitalization is data, the main tools are information and communication technologies based on the Internet of things and services that are used in almost all sectors of the economy, including agriculture. Considering sustainability as a set of economic, environmental and social indicators, it is alleged that digital technologies radically change business processes and relationships that determine and shape the values of sustainability indicators.

An analysis of the volatility of the production of basic agricultural products, as well as indicators on agricultural prices, the level of agricultural employment and some environmental indicators indicates a definite positive impact of digitalization on the sustainability of agriculture. At the same time, there is higher volatility and a general deterioration in the level of digitalization in countries with a low level of digitalization, while in countries with a medium and high level in the period under review, the levels of digitalization changed slightly.

Although the quantitative analysis shows the presence of certain positive links between digital transformation and the sustainability of the agricultural sector of the economy, the relationship between the use of ICT and the sustainable development of actors in complex systems does not are linear and unambiguous, as they are determined by various combinations of a large number of factors that are difficult to predict, among which the political component plays a significant role. Therefore, there is a need for both new economic and mathematical approaches to modeling asymmetric relations and complex phenomena, as well as new organizational and managerial models and mechanisms for managing sustainable development in the digital environment.

In any case, the current conditions of the direction of sustainable development of agriculture show the need to implement innovative strategies and socio-economic transformation based on digitalization. Therefore, further research is required in terms of the formation of goals and directions of digital transformation, the definition of indicators that evaluate these processes at different levels, starting with an individual agricultural enterprise and ending with global agriculture.

CONFLICT OF INTEREST STATEMENT

The author declares that there is no conflict of interest.

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Examination of the Impact of Increasing the Number of Cavities in Molds on Production Efficiency

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Abstract

The industrial sector is constantly looking for ways to increase productivity and satisfy the market's rising needs. The optimization of mold design, namely the quantity of cavities within a mold, is one area of attention. The goal of manufacturers is to boost production speeds and overall efficiency by increasing the number of cavities. The aim of this study is to determine how production efficiency is affected by the number of cavities. Highlighting the advantages and disadvantages of increased mold cavities. The production efficiency of a sample product with an increased number of cavities was examined in terms of production speed, cycle time and mold costs. According to preliminary research, molds with more cavities can produce goods with a significantly higher level of efficiency. Higher cavity counts have shown the ability to boost output, shorten cycle times, and maximize resource efficiency. The need for careful quality control procedures and higher mold costs are just a couple of the potential trade-offs that must be taken into account. The findings of this study offer useful information to manufacturers looking to enhance their production procedures. By providing evidence for the effects of mold cavity count on production efficiency, the findings add to the body of existing knowledge. The outcomes can serve as a roadmap for decision-making, influencing mold design decisions and facilitating the adoption of cost-effective tactics in the manufacturing sector.

Key words

Cycle time, Manufacturing industry, Mold design, Number of mold cavity, Production efficiency.

1. INTRODUCTION

In an era defined by relentless technological advancement and shifting consumer preferences, the global manufacturing landscape remains in a perpetual state of evolution. The driving force behind this transformation is the unwavering commitment to achieving heightened levels of productivity and efficiency, which are paramount to satisfying the insatiable demands of modern consumers and competitive markets [1]. In addition, there are many national and international pressures and incentives for companies to increase their energy savings. Companies feel pressure to ensure energy savings [2]. Amid this quest for optimization, the fine-tuning of mold design, particularly the strategic adjustment of mold cavity counts, has emerged as a pivotal frontier. Manufacturers across diverse industries have increasingly recognized that the number of cavities within a mold is not merely a technical detail but a strategic lever that can significantly impact their operations. The rationale

behind this pursuit is straightforward: by judiciously increasing the number of cavities in molds, production speeds can be enhanced, operational efficiency can be maximized, and overall competitiveness can be elevated.

The practice promises to deliver tangible benefits not only in terms of output but also in the judicious allocation of resources, which is critical in an era where sustainability and resource conservation have taken center stage.

The research outlined here aims to illuminate the intricate relationship between mold cavity count and production efficiency. It seeks to provide a comprehensive assessment of the advantages and disadvantages inherent in the decision to augment the number of mold cavities. At its core, the research centers around the evaluation of production efficiency for a specific product, the plastic hinge, within the context of molds featuring an increased number of cavities. This evaluation is conducted through a rigorous examination of key performance metrics, including production speed, cycle time, and mold costs. Early findings from preliminary investigations suggest that molds endowed with an elevated cavity count have the potential to usher in a manufacturing revolution. These molds have not only proven their capacity to amplify production output but have also demonstrated an impressive ability to reduce cycle times, which can be a game-changer in fast-paced industries. Additionally, the judicious use of resources in these setups marks a significant stride toward sustainability and cost-effectiveness. However, the pursuit of higher cavity counts is not without its complexities. It often necessitates a higher upfront investment in mold costs, posing a financial challenge that manufacturers must carefully consider. Therefore, the decision to increase the number of mold cavities is a multifaceted one, requiring a balanced evaluation of potential benefits and trade-offs, as well as a thorough understanding of the specific needs and constraints of each manufacturing operation. The discoveries and insights presented in this study have profound implications for manufacturers seeking to elevate their production processes. By offering empirical evidence on the impact of mold cavity count on production efficiency, this research becomes a valuable compass for industry decision-makers. It can guide them in making informed choices regarding mold design, encourage the adoption of cost-effective strategies, and ultimately empower manufacturers to navigate the dynamic terrain of modern production with heightened precision and profitability. As we stand on the cusp of a new era in manufacturing, where technology continues to reshape industries and market dynamics, research initiatives like this one underline the industry's commitment to innovation and excellence. In the pursuit of ever-greater productivity and efficiency, manufacturers are driving the evolution of the global manufacturing landscape, setting the stage for a future where precision, sustainability, and profitability go hand in hand.

2. METHOD

This study was conducted to improve the efficiency and evaluate the cost-effectiveness of increasing the number of mold cavities in the production of plastic hinges. The primary objective of this research is to analyze the potential benefits of increasing the mold cavity numbers used in the production of plastic hinges. The plastic raw metarial which used in our hinge product is PA6 GFR30. PA6 GFR30 is PA6 nylon raw material with 30% glass fiber reinforcement. In the realm of engineering and materials science, the quest for innovative materials that offer a blend of strength, durability, and versatility is a constant endeavor [3]. Polyamide 6 with 30% Glass Fiber Reinforcement, commonly referred to as PA6 GFR30, is one such material that has emerged as a versatile and highly regarded choice in various industries. PA6 GFR30 offers a cost-effective solution for applications that require high-performance materials. Its balance of properties often eliminates the need for more expensive alternatives. The material's moldability and ease of processing allow for intricate and complex part designs, offering engineers and designers greater freedom in their creations [4]. For all these reasons, our mold and product designs are made according to PA6 GFR30 raw material.

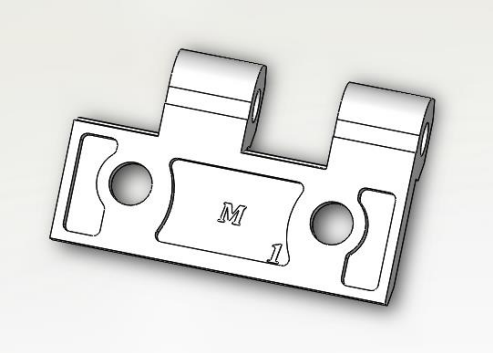

Figure 1. PA6 GFR30 Hinge Product

2.1.Data Collection Tools

The data necessary for the analysis were collected through the Manufacturing Execution System (MES) software. The need for production organizations to meet market demands for responsiveness, product quality (production without scrap), compliance with regulations, cutting production costs, and meeting delivery deadlines gave rise to the Manufacturing Execution System (MES) [5]. The MES software is responsible for recording and managing all data, including product quantities, cycle times, and other relevant informations, in the production machines. MES application keeps common data of all plastic injection and metal injection machines producing in our company. Based on these informations, it was possible to determine how many units of plastic hinges were produced over the course of one year and the cycle times required for manufacturing each product. Initially, our sample product which is hinge was manufactured with 2, 4 and 8-cavity mold.

2.2. 2-Cavities to 4-Cavities Efficiency Scenario

In the initial scenario, if our mold was not a 2-cavities but 4-cavities the time per product was 16.5 seconds, while in the second scenario, it decreased to 4.125 seconds. To calculate the efficiency increase, we can use the following formula:

- Efficiency Increase (%) = [(Initial Efficiency - Final Efficiency) / Initial Efficiency] x 100
- [(16.5 - 4.125) / 16.5] x 100 [(12.375) / 16.5] x 100 0.75 x 100 = 75%

The efficiency increase is 75%. This means that the machine has become more efficient by reducing the production time by 75%.

2.3. 2-Cavities to 8-Cavities Efficiency Scenario

In the initial scenario, if our mold was not a 2-cavities but 8-cavities the time per product was 16.5 seconds per product, while in the second scenario, it decreased to 8.25 seconds per product. To calculate the efficiency increase, we can use the following formula:

- Efficiency Increase (%) = [(Initial Efficiency - Final Efficiency) / Initial Efficiency] x 100
- [(16.5 - 8.25) / 16.5] x 100 [(8.25) / 16.5] x 100 0.5 x 100 = 50%

The efficiency increase is 50%. This means that the machine has become more efficient by reducing the production time by 50%.

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Figure 2. 8-Cavities Hinge Mold

2.4. Break-Even Calculations

When we considered producing a 2-cavity mold as our main investment, we calculated our annual earnings and break-even period to answer the question of how long it would take to cover the increase in investment costs if we had produced a 4-cavity mold at first and an 8-cavity mold at first.

"Production quantity" is the total number of units of this product produced in our company. 220000 units are produced annually. "Current operation" refers to the production method used. In this study, the product was obtained by casting, which is a chipless manufacturing method with plastic injection. "Number of Cavities (Before)" indicates the number of cavities in the initial state of the mold. "Number of cavities (after)" indicates the number of cavities in the mold if the number of cavities is different from the initial one. "Cycle Time" refers to how many seconds the product mold takes in each cycle to produce the product [6]. If the mold has 4 cavities, it represents the production time for 4 products and the production time for 2 products. Although the cycle time per product varies, the mold opening and closing cycle time remains constant. "Hourly cost" is the electricity

consumed due to the operation of the machine, the salary of the operator working at the machine, machine maintenance expenses, etc. It is the total fee calculated taking into account the factors.

"Old cost" and "new cost" is the section where the calculation is made using the previous data in the table.

Old Cost and New cost are calculated using this Formula:

- [Production Quantity/Number of cavities*Cycle time /3600]* Hourly Cost

As the last step, the Annual Profit is calculated by performing the New Cost - Old Cost process.

Production quantity	Current Operations	Number of Cavities (Before)	After Number of cavities (After)	Cycle Time(sec)	Hourly Cost	Old Cost/Tl		New Cost/TL		
	1 Operations					Injection	Total	Injection	Total	Profit per year(TL)
220000	Plastic Injection	2	4	33	244,1	1,118791667	246134,167	0,559395833	123067,083	123067,083

Table 1. 2-Cavities to 4-Cavities Break-Even calculation

Table 1 shows some production data we received from the Promanage website to calculate the break-even point. The cost of the 4-cavity mold we produced is 150,000 TL. If we calculate the break-even time according to the data in table 1. The payback period of this investment we made is 1.2188 years.

Production quantity	Current Operations	Number of Cavities (Before)	After Number of cavities (After)	Cycle Time(sec)	Hourly Cost	Old Cost/Tl		New Cost/TL		
	1 Operations					Injection	Total	Injection	Total	Profit per year(TL)
220000	Plastic Injection	2	8	33	244,1	1,118791667	246134,167	0,279697917	61533,542	184600,625

Table 2. 2-Cavities to 8-Cavities Break-Even calculation

The cost of the 8-cavity mold we produced is 200.000TL , If we calculate the break-even time according to the data in table 2. The payback period of this investment we made is = 1,0834 Years

3. RESULT

The results of the study show that increasing the number of mold cavities increases productivity and shortens the break-even point. For example, if we had produced with an 8-cavity mold instead of a 2-cavity mold in the beginning, we would have produced 75% more efficiently. Similarly, if production had been done with a 4-cavity mold instead of a 2-cavity mold, it would have resulted in a 50% increase in productivity.

The cost of producing an 8-cavity mold is higher than that of a 4-cavity or 2-cavity mold. However, the break-even point of this investment has been calculated. The break-even point calculation includes the hourly electricity consumption cost of the machine producing the product, the hourly maintenance and repair costs, the operator's hourly wage, and other expenses. As a result of these calculations, it was determined that when transitioning from a 2-cavity mold to a 4-cavity mold, the break-even point is 1.2188 years, while transitioning from a 2-cavity mold to an 8-cavity mold reduces the break-even point to 1.0834 years.

4. CONCLUSION

This comprehensive study unequivocally highlights the pivotal role played by increasing the number of mold cavities in plastic hinge production. The results affirm that this strategy is not only cost-effective but also a surefire way to boost operational efficiency. Perhaps the most striking revelation is the significant reduction in the break-even point, a testament to the tangible financial benefits of this approach. Consequently, it is strongly recommended that companies maintain a high cavity count in their production processes, provided it remains within the confines of uncompromised product quality.

While the advantages of elevating the cavity count are resoundingly evident, it is imperative to emphasize the need for a judicious balance. As companies endeavor to maximize efficiency and profitability, they must not lose sight of the paramount importance of product quality. The recommendation to increase mold cavities should be tempered by a commitment to ensuring that each product continues to meet the highest quality standards. Striking this balance is crucial in reaping the long-term cost savings and profit potential that this strategy offers.

The strategy of increasing mold cavities not only positions businesses for immediate efficiency gains but also unlocks the door to long-term cost savings. This study illuminates how the shorter break-even point translates into sustained financial advantages for companies over time. By implementing this approach, organizations can redirect resources previously allocated to extended break-even periods towards innovation, expansion, or further optimization of their production processes. This, in turn, can result in a virtuous cycle of improved efficiency and increased profitability.

In conclusion, this study leaves no room for doubt regarding the potential for increased profitability within the plastic hinge production sector through the elevation of mold cavity counts. It underscores the prudent and potent nature of this strategy and its capacity to reduce costs while augmenting profitability. As businesses navigate the complexities of the modern manufacturing landscape, they are encouraged to embrace this approach judiciously. By doing so, they not only stand to gain

immediate efficiency benefits but also position themselves for sustained financial success, securing their place as leaders in the industry. As calculated by Arora et al. [7], the maximum number of mold cavities can be calculated based on shot capacity and Clamping Force during mold design. Companies that print small products but produce molds with lower number of eyelets in order to reduce the mold cost can see that the losses increase as the number of mold eyelets is lower than usual, taking into consideration our study.

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Sustainable Design and Maintenance of Buildings

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Abstract

The world's population is increasing, hence the growing demand for accommodation and the construction of buildings. Therefore, the amount of wastewater is increasing. Natural areas (lawns, arable land, forests, etc.) are being used for building buildings. In this manner, natural surfaces become impermeable, which leads to natural unbalance. As a result, we are witnessing formation of heat islands, an increase in temperature and rainfall runoff into the sewerage system as well as uprising consequences of climate change generally. The construction industry is one of the biggest polluters in the world, but by using sustainable construction it is possible to reduce its negative impact on the environment. The principles of sustainable construction should be applied to all phases of the life cycle of a building: design, construction, maintenance, and removal of the building. In the construction design phase, it is possible to modify the building with a slight increase in cost, which will lower future maintenance costs. It is essential to use materials thoughtfully through construction since people spend a large part of their time indoors. Environmental impact assessment is the basis of sustainable design, construction, use, and disposal of the building. Of course, various social issues involve the health and well-being of building users. We must not forget the economic aspects and total costs of the building. This is where the concept of green construction comes into play. Green building refers to both the structure and the application of environmentally responsible and resource-efficient processes throughout the building's life cycle. Green building also refers to saving resources to the maximum extent, including energy, land, water and material saving, etc., during the whole life cycle of the building, protecting the environment and reducing pollution, providing people with healthy, comfortable and efficient use of space, and being in harmony with nature.

Key words

Design, Green building certifications, Maintenance, Management, Sustainability

1. INTRODUCTION

Today, the world has reached an enviable degree of urbanization (on average, about 50% of the population live in cities), but developed regions are far more urbanized than undeveloped areas of the Earth (the proportion of the urban population is twice as high in developed than in underdeveloped countries). Such trends will continue, so the projection of the further development of urbanization indicates that in 2030, 61% of the world's population will be urban, but that the disparity between the developed and the underdeveloped will continue to be maintained, although it can be predicted that it will decrease (by that time, developed regions will have an

average of about 82%, and undeveloped only 55% of the urban population, so the ratio from 2000, which was 2:1 in favour of developed regions, will decrease to 1.5:1 by 2030) [1]. When talking about energy consumption, it is observed that the share of urban population is directly proportional to energy consumption (more urban population - higher energy consumption, less urban population - lower energy consumption) [1].

The process of urbanization entails much more changes than just the increase of population in cities. Urbanization of a certain region leads to changes in economic, social, and political structures. The accelerated development of cities leads to a decrease of the ability to provide various services such as energy, education, health care, transportation, and physical security. Further problems caused by urbanization are increased traffic, air and water pollution, destruction of agricultural lands, parks, open spaces, etc. [2]. Given that, present urban spaces hold less and less capacity as the time goes by as due to its population growth rate more and more buildings are being built, faster than ever, thus creating skyscrapers of a new generation [3].

Urbanization is also reflected in the construction of buildings. The number of building permits issued can be seen as a good indicator of building constructions. Figure 1 shows the number of issued building permits. In 2021, building permits (in terms of useful floor area, measured in millions of square meters; m²) went up by 15% in the EU (in absolute terms, +52 m²). This growth followed a decline of 8% in 2020, the peak year of the COVID-19 crisis [4].

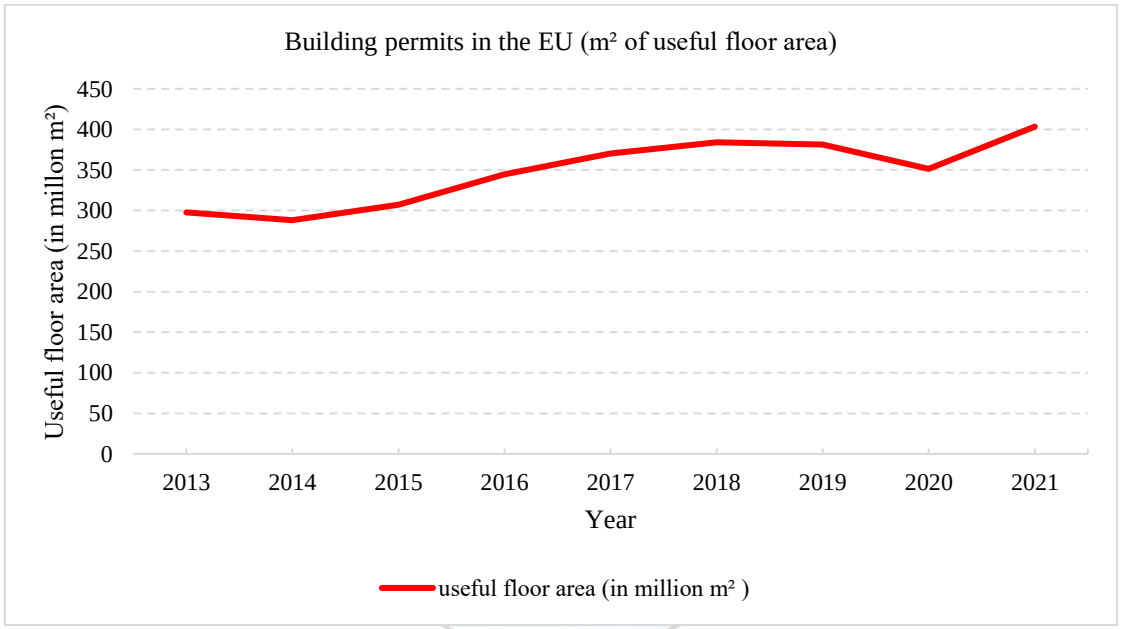

Figure 1. Building permits in the EU, 2015 – 2021 (according to [4])

Today, more than ever, the shortage of resources used in the construction of buildings is emphasized, the number of inhabitants is growing very quickly, and increased urbanization and the construction of new buildings is emphasized. New buildings occupy arable areas or areas that were under greenery, so it is important to think about the maintenance activities of existing buildings, and strive to reduce the construction of new buildings, of course, to the possible extent. It is necessary to use all the resources available to men sparingly and wisely, to build buildings carefully in the sense of paying attention to the types of materials used, the proper execution of the envisioned or designed building, the proper use of the building - use the building for the purpose for which it was designed and built, and finally, when the useful life of the building comes to an end, about the proper disposal of waste from a demolished building [5]. Certain challenges in building management, i.e. building maintenance, are shown in Figure 2.

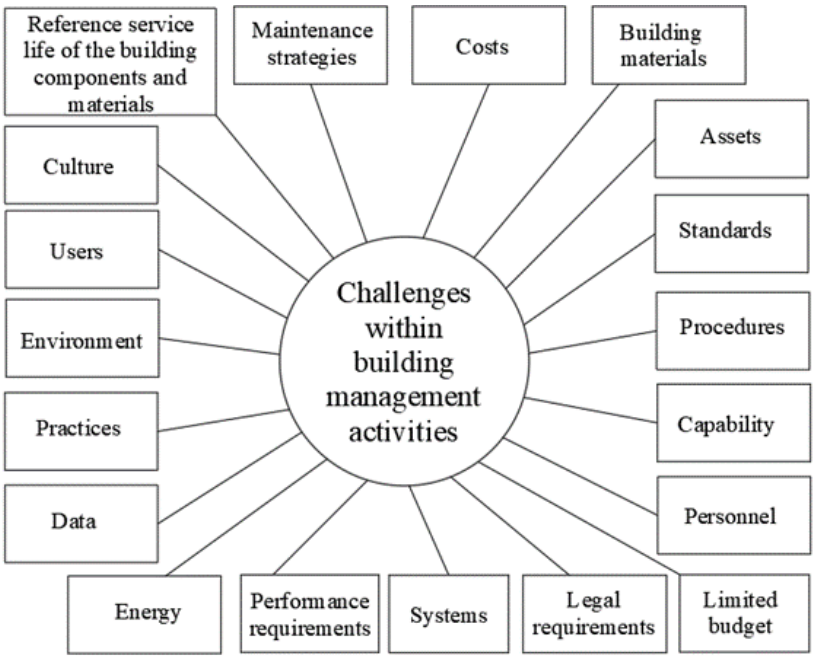

Figure 2. Challenges within building management activities (according to [6])

When it comes to building management, one can see more requirements that need to be met. There are requirements of a limited budget, it is necessary to meet certain standards and there is an increasing number of legal regulations as well as the degree of public acceptance [7]. The impact of construction on the environment takes place throughout the entire life cycle of the building, which includes execution (production of building materials and their installation), use of the building (use and maintenance), and the end of the life cycle (removal of the building) [8]. Buildings play an important role in the energy consumption all over the world. The building sector has a significant influence on the total natural resource consumption and the emissions released [9].

Effective use of natural surfaces, water, energy and materials should be considered in the design process in accordance with the principles of ecologically sustainable design. Economic difficulties should be considered through the effective use of resources and cost analysis in the context of economically viable design. On the other hand, the quality of life in interior spaces should be increased, and innovative ideas and applications should be applied to a greater extent within the framework of socio-culturally sustainable design [10]. All this leads to the need for sustainable design of buildings and their sustainable maintenance. This issue will be presented in greater detail as we move further along.

2. SUSTAINABLE DESIGN OF BUILDINGS

A sustainable building is a building that incorporates environmentally responsible and resource-efficient practices from planning to design and construction, operation, and demolition to provide a long-term comfortable, healthy, and productive environment for its occupants bringing the negative impact on the surrounding environment to the minimum [11].

By looking at a full life-cycle of a building we can characterize it more specifically. For example, during planning, every impact on the environment should be considered in order to minimize the eventual harmful impact. During the design process architects should make an effort and consider using natural lighting, ventilation, window placement, and all other factors that could save up energy. The construction phase is another good example where we can use natural resources as well as limit energy consumption and proper waste disposal that includes recycling everything that can be recycled. Maintenance is also very important. If the planning is done right, cost of maintenance, energy, and water cost should be very low and used efficiently. Especially by using renewable energy and other resources to operate as a net producer, not just as a net consumer. Demolition is the final stage of the building life cycle. But it's not the least important. After demolition, it is important to dispose, recycle and handle all materials so they don't make a negative impact on the environment [11]. The building life cycle is shown in figure 3.

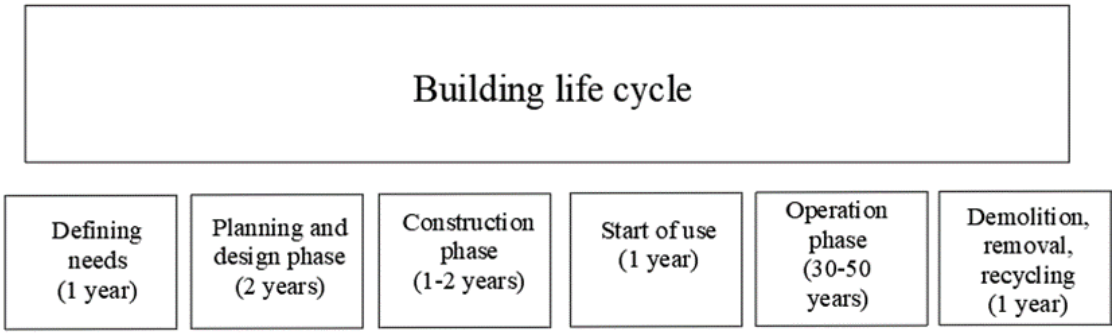

Figure 3. Building life cycle [12]

Sustainable design principles include the ability to:

- Optimize site potential;
- Minimize non-renewable energy consumption;
- Use environmentally preferable products;
- Protect and conserve water;
- Enhance indoor environmental quality;
- Optimize operational and maintenance practices [13].

By knowing all of the above, we can reduce a sustainable design definition by saying that sustainable design not only seeks to reduce a negative impact on the environment, but also to assure the health and comfort of building occupants.

We cannot stress enough how important is good early planning and good building design because it has a major impact on reducing all sorts of costs, pollution and energy used. The sooner sustainable construction is inplemented into the planning, the better. Building Research Establishment Environmental Assessment Method - BREEAM is the world's longest-running method of assessing, rating, and certifying the sustainability of a building. The BREEAM Assessment investigates different categories such as materials, transport, water, energy, and waste [14].

Five of the green systems that are being utilized in building engineering are radiant floors, gray water recycling, solar power, geothermal systems, and energy-efficient window systems. These systems working together can achieve an owner's energy and water conservation goals while also reducing utility bills. Sustainable buildings create a win for the environment, the building owner, and its occupants. Radiant floors are an excellent way to efficiently heat a space with less energy. They can contain water tubing that is heated by solar panels that collect solar energy and deliver it to the tubing in the form of heat. Gray water is the water that runs off from condensation from air conditioning units and other equipment that uses water. Unlike wastewater, however, gray water can be reused to fuel boilers, hydronic cooling equipment, and even irrigate plants. With the price of solar panels dropping, solar energy is becoming one of the most cost-effective, as well as practical ways to install a renewable energy source on a commercial building. Geothermal systems are one of the best ways to efficiently heat or cool a building with a renewable source. It uses the naturally cool temperatures below ground to cool water in pipes and then runs it through chilled water coils, just like a chilled water system. It can also be used for heating by a similar process. Windows are responsible for 25% of the heat gain and loss in a building, typically from heat flow through window panels and around poorly sealed frames. Energy-efficient windows provide glazing in the form of double panes and triple panes that are designed to inhibit the heat flow. The right window placement is also important for letting in enough light throughout the day to reduce electricity use [15].

And finally, sustainable materials can be explained as materials that have no direct impact on the environment and do not use non-renewable resources [14]. So, by using these materials you can also save money while not having a bad impact on the environment.

Examples of sustainable buildings materials:

- Timber instead of steel;
- Concrete reinforced with natural fibers;

- Geo-textiles made from crops;
- Straws bales;
- Materials that are accredited as being responsibility sourced such as the FSC timber [14].

After all, it can be categorized into six basic elements (Figure 4) that need to be investigated when planning and building a sustainable building.

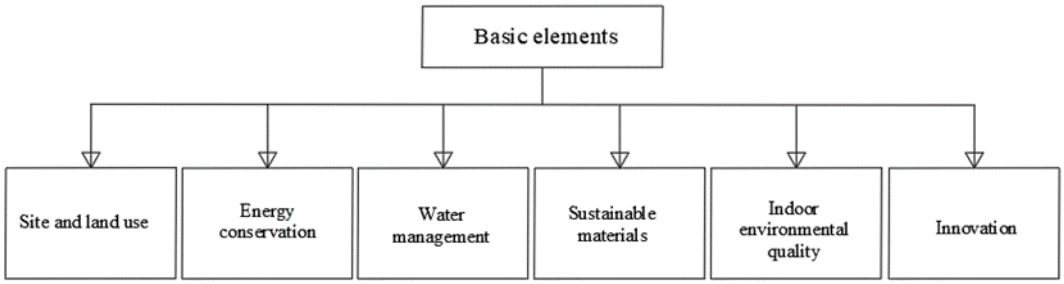

Figure 4. Six basic elements for sustainable building design [16]

Before we start explaining green buildings there is a key difference between sustainable buildings and green buildings. Sustainable buildings operate with all three sustainability pillars in mind (people, planet, and profit), whereas green buildings focus solely on the environment [11].

In green buildings there are four main elements on which it is designed: materials, energy, water, and health to make green building more sustainable [17]. So, materials used for green buildings are always recycled or obtained from natural renewable sources. When talking about energy systems in green building we have to say that the less energy is used the better. The natural daylight is carefully planned so that electricity is reduced to a minimum. Also, carefully planned and placed windows improve people's health and productivity. Speaking of electricity, it is carefully planned to use energy-efficient lighting, low-energy appliances, and renewable energy technologies which can be incorporated by installing wind turbines and solar panels. Even though there are two main differences: passive solar design and passive solar heating. Passive solar design is transforming the sunlight into heat, also the cooling, as well as providing light to a home. Passive solar heating is based on materials in a building that are absorbing heat for later use or keeping the space inside at a comfortable temperature. We cannot forget about water management in green buildings since it is an important part of the building itself. The main thing is installing greywater and rainwater catchment systems that can recycle water that can later be used to flush toilets, for water-efficient appliances, showers, etc. Health components are also very important. It can be accomplished by using non-toxic materials and products that will improve the life of occupants. These materials are emission-free, have low or no volatile organic compounds (VOC) content, and are moisture-resistant to deter molds, spores, and other microbes. Indoor air quality also cannot be forgotten and it is best accomplished by ventilation systems and materials that control humidity [17].

Even though green buildings seem much more appealing than sustainable design, we must mention that green building can be a part of a sustainable building.

By this we mean a green building cannot be built sustainably, and sustainable buildings can operate without green initiatives. Green buildings can be part of sustainable building design but not the other way around since sustainable design has many more things on its to-do list [11]. So, when thinking about how you can take advantage of the opportunities that sustainability and green initiatives bring, here are a few suggestions:

1) Reduce your energy waste: Small steps such as smart meters, switching to LED lighting, and monitoring water usage and CO_2 levels can make a big difference.
2) Improve your buildings', and occupants' health: You can do this with air quality monitoring, to make sure the building and your occupants are operating at their healthiest.
3) Reduce your environmental impact: Solar and other forms of renewable energy can go a long way in lessening your reliance on fossil fuels.
4) Get certified [11].

Operating as a green and sustainable building benefits all parties involved. Not only are you doing your bit for the planet, but you'll be creating an attractive space for occupants to reside, prolonging the life and health of all

those involved [11]. So to sum it all up it can be said that there are "The 7 principles of sustainable construction" (Figure 5).

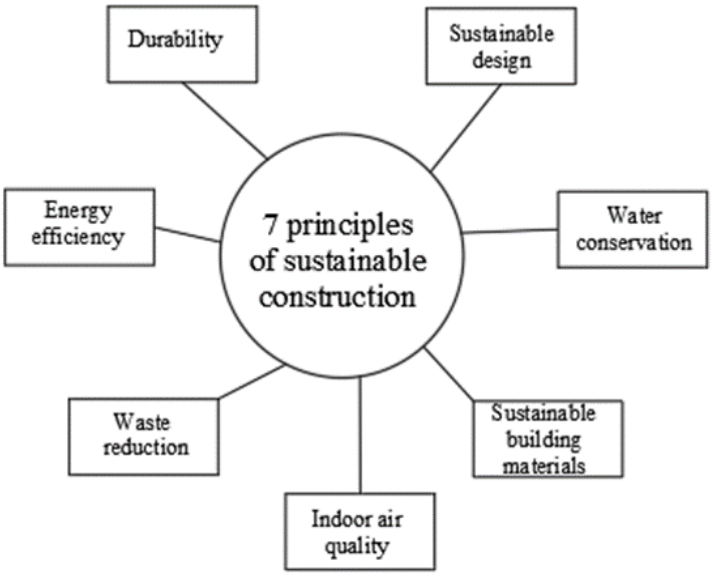

Figure 5. The 7 principles of sustainable construction (according to [14])

For sustainable design, durability, and energy efficiency materials play a big part, prefabricating materials. That is made possible by precutting all materials to the exact length and width in a factory or someplace else. So, when materials are delivered to the construction site there is no additional waste made. Especially because some materials are recyclable on-site. For example, concrete can be crushed and reused for foundations or as aggregate beneath parking lots. The waste made by workers needs can also be reduced efficiently. More and more countries are enforcing the no smoking rule on the site, "walk-off mats" are used to remove dirt, lead, and other potentially dangerous chemicals from their shoes and lunches that are brought in recycling containers for food to decrease organic waste [18].

So not only building is sustainable, but also more and more construction sites are also becoming greener and more nature friendly. The off-site fabrication, improved on-site maintenance, lean practices, landfill avoidance, and green materials acquisition have begun to fundamentally, albeit slowly, transform the way buildings are constructed today as more owners feel a responsibility to build sustainability [18].

3. SUSTAINABLE MAINTENANCE OF BUILDINGS

Building maintenance is an integral part of comprehensive building management. It is defined as undertaking all necessary activities to maintain or improve every part of the building and for the purpose of preserving the value and purpose for which the building or property was built. In order to be able to perform maintenance, it is necessary to analyze the causes of failures, and based on the analysis decide on the measures to be taken to prevent the cause [19].

Although there are many different definitions of building maintenance, the simplest (and probably the shortest) says that building maintenance is ensuring the condition of the building is suitable for use [20]. Of course, it would be very desirable to have a building that does not need to be maintained, but this is difficult to do. To ensure that a building is fit for use, it must be maintained to certain standards. Thus, maintenance costs include all the costs of repairs that occur every day, as well as preventive works and work on improving building elements. These are direct maintenance costs. However, apart from these direct maintenance costs, there are also indirect costs such as fines because the building is not available for use, or it can be a loss of value of the building [20].

The goals of building maintenance are as follows:

- Ensuring the security requirements of the building and associated services;
- Ensuring the suitability of the building for use;

- Ensuring that building requirements are met regarding legal regulations;
- Performance of necessary maintenance work to preserve the value of the property;
- Performing the necessary maintenance work to preserve the quality of the building [21].

It can also be said that building maintenance includes tasks such as cleaning, landscaping, and electrical system maintenance. It is needed to preserve a safe, functional, and comfortable environment for tenants at all times. However, most individuals give little thought to the behind-the-scenes work required to meet these expectations. Maintenance is "out of sight, out of mind" until something goes wrong. Maintenance can be categorized as routine maintenance, preventive and corrective maintenance. Running an effective program can streamline maintenance activities and save costs (using CMMS software for example). Property owners and managers rely on building maintenance to ensure functionality, comfort, and safety for occupants.

4. SUSTAINABLE BUILDING CERTIFICATION SYSTEMS

Assessment and certification systems have been developed to quantify the level of sustainability of buildings. During such evaluation, parameters such as space design, construction, and use are observed, and the certificate itself ultimately provides building owners and users with information about the energy and other ecological properties of the building, depending on the type of certificate. Namely, some certification systems cover only certain criteria of building sustainability, such as energy efficiency, and some cover the entire approach to green building, looking at criteria such as location sustainability, human and environmental health, material selection, ecological quality of the interior, social impact and building economy. For each criterion, there is one or more quality criteria that must be proven in order to receive a certain number of points, i.e. meet the requirements [22].

Rating systems have been developed to measure the sustainability level of Green Buildings and provide best-practice experience at their highest certification level [13]. Federal government agencies in the United States, among other things, requires:

1) Reduce portfolio-wide Scope 1 and 2 greenhouse gas (GHG) emissions (onsite combustion and purchased energy) by 65% by 2030, compared to a 2008 baseline.
2) Use 100% carbon pollution-free electricity on a net annual basis by 2030.
3) Pursue building electrification strategies in conjunction with carbon pollution-free energy, efficiency, and space reduction/consolidation.
4) Design new construction and modernization projects greater to be net zero ready (able to achieve net-zero operational emissions) by 2030.
5) Move toward net-zero emissions from Federal procurement, including through a Buy Clean policy promoting the use of construction materials with lower embodied GHG emissions [13].

The Sustainable Facilities Tool is an online resource to support decision-making regarding sustainable building principles, materials, and systems. The Sustainable Facilities Tool helps users understand and select environmentally preferable solutions for renovations, alterations, and leases [13].

The code for sustainable homes is the national standard for the sustainable design and construction of new homes. It aims to reduce carbon emissions and promote higher standards of sustainable design above the current minimum standards set out by the building regulations. The code provides nine measures of sustainable design: energy/CO_2, water, materials, surface water runoff (flooding and flood prevention), waste, pollution, health and well-being, management and ecology. It uses a 1 to 6-star system to rate the overall sustainability performance of a new home against these nine categories [23].

Table 1. Comparison of different Rating Systems for Sustainable Buildings [24]

Certification systems (Country of origin)	Initiation	Key aspects of assesment	Versions	Level of certification
DGNB (Germany)	2007	- Ecological Quality - Economical Quality - Social Quality - Technical Quality - Process Quality - Site Quality	Offices Existing Buildings Retail Industrial Portfolios Schools	Bronze Silver Gold
LEED (USA)	1998	- Sustainable Sites - Water Efficiency - Energy & Atmosphere - Material & Resources - Indoor Air Quality - Innovation & Design - Management - Health & Well-being	New Construction, Existing Buildings, Commercial Interiors, Core and Shell, Homes, Neighborhood Development, School, Retail	LEED Certified LEED Silver LEED Gold LEED Platinum
BREEAM (Great Britain)	1990	- Energy - Water - Material - Site Ecology - Pollution - Transport - Land consumption	Courts, EcoHomes, Education, Industrial, Healthcare, MultiResidential, Offices, Prisons, Retail	Pass Good Very good Excellent Outstanding
CASBEE (Japan)	2001	Certification on the basis of building environment efficiency factor, BEE=Q/L Q … Quality (Ecological Quality of buildings); L … Loadings (Ecological effects on buildings)	-	C (poor) B B+ A S (excellent)
Mingerie (Switzerland)	1998	4 Building standards are available: (1) Minergie (2) Minergie-P (3) Minergie-Eco (4) Minergie-P-Eco	-	Minergie Minergie-P Minergie-Eco Minergie-P-Eco
Green Star (Australia)	2003	- Management - Indoor Comfort - Energy - Transport - Water - Material - Land Consumption & Ecology - Emissions - Innovations	- Office – Existing Buildings - Office – Interior Design - Office – Design	4 Stars: ‚Best Practice‘ 5 Stars: ‚Australien Excellence‘ 6 Stars: ‚World Leadership‘

5. CONCLUSIONS

Climate change and increasingly rapid urbanization are causing a growing problem, which should be the trigger for a new way of thinking. Integral (sustainable) management is being mentioned more and more in all areas of work and life. Urbanization has reached large proportions. Large-scale urbanization entails various consequences such as increased traffic, air and water pollution, destruction of agricultural land, parks, and open spaces, and increased building construction. An indicator of building construction can be the number of issued building permits (in terms of useful floor area). In the European Union, there is an increase concerning this indicator. The increased construction of buildings also increases the impact of climate change. Buildings play a major role in the total energy consumption, so attention should be paid to choosing a suitable (sustainable) way of supplying energy and water. An example of efficient use of water is net zero water buildings, where such a building collects rainwater and recycles its wastewater for reuse, eliminating the need for water supply from the public water supply and connection to the sewage network.

All available resources must be carefully used when building new buildings, as well as when maintaining the existing ones. Effective use of natural surfaces, water, energy, and materials should be considered in the design process in accordance with the principles of ecologically sustainable design. The same applies to the maintenance of the buildings. Materials used for the maintenance should be environmentally acceptable, and their reuse should be possible. It is important to develop a circular economy model in which the flow of resources and energy is maintained in a closed loop model, aiming the circulation of products in the circular cycle as long as possible. In the circular economy model, among other things, eco-design, advanced technologies, energy efficiency and the use of renewable energy sources stand out. Innovative ideas and applications need to be applied to a greater extent in the case of continuous design and maintenance.

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest.

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Net Zero Water Building

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Abstract

Water is essential for human life, health and overall well-being, i.e. to reduce poverty and hunger. As day after day the earth's population and the need for water are increasing, whereas the amount of water is decreasing, it is becoming increasingly difficult to satisfy people's water needs. Due to the trend of urban population concentration, it can be said without exaggeration that the functioning of cities will also depend on the quantity and quality of management and distribution of water resources within cities. Drinking water from public water supply system is used in households to cover all types of daily water needs. In order to preserve water as much as possible, in terms of its quality and quantity available for human consumption, an integrated approach to water management is needed. Integral water management is essentially water production and consumption management. Zero-use water building is a building that collects rainwater and recycles its wastewater for reuse, eliminating the need for water supply from public water supply and connection to the sewer network. Appropriately collected and stored rainwater can be used multiple times in dwellings, gardens, yards, parks, for washing public areas, etc. The benefits of rainwater use are ecological and financial. A zero-water building is technologically feasible for existing buildings, but costs are quite high, and various other constraints also arise. This approach is most suitable for new buildings, where space for containers, additional pipelines and filtering systems can be set from the beginning. Zero-water buildings aim to reduce total water consumption, maximise the use of alternative water sources and minimise wastewater discharges from buildings. The paper will present the general concept of zero-water buildings and highlight the importance of water conservation.

Key words

Net zero water building, Sustainability, Water, Water consumption

1. INTRODUCTION

Water is considered one of the basic components of life, and the entire history of mankind and civilization is largely related to it. Water is not only included in the composition of human organism and food, but it is also used to produce food and energy, as well as in industry as a raw material or auxiliary material. Due to its importance for the mankind, supply of water to settlements and the population is nowadays considered to be one of the primary branches of water management. Due to the tendencies of people to concentrate their settlements and themselves as consumers around water, and given the available water resources on Earth, the issue of water supply will become even stricter in the future. The rule of water supply, that every drop of water on the catchment is kept for as long as possible for its wider use, is becoming more and more present in our practice [1]. Only 1% of the total water resources on Earth is drinking water, and as much as a third of water consumed in

households goes to flush the toilet that is mixed with faeces to form a substance (mixture) called wastewater [2], [3].

Wastewater is known to be composed of 99.9% water and 0.1% pollution. The primary purpose of wastewater treatment is to prevent infectious diseases and to protect from contamination of groundwater and surface water [4]. The biggest challenge for wastewater treatment is the mixture of human wastewater and factory chemicals with large amounts of water. In combined sewer systems, valuable drinking water is reduced to a carrier of waste substances [5], [6]. One adult is thought to produce about 500 litres of urine [5]–[8] and about 50 kg of faeces [5], [7], [8] over a period of one year. Faeces and urine are resources, not waste, and drainage systems bypass the natural flow of nutrients back into the soil and instead empty nutrients (chemical elements: phosphate, nitrogen, potassium, magnesium, etc.) into the water [6]. Looking at this process in which drinking water is used as means of transporting waste materials [9] from the household, it can be seen that there is a double cost (cost of water used and drainage/treatment of wastewater). This is a linear way of thinking [10]. In view of the above, it is important to preserve, manage and recycle water wherever possible.

A growing global population and economic shift towards more resource-intensive consumption patterns means global freshwater use - that is, freshwater withdrawals for agriculture, industry and municipal uses has increased nearly six-fold since 1900 [11]. This is shown in the Figure 1.

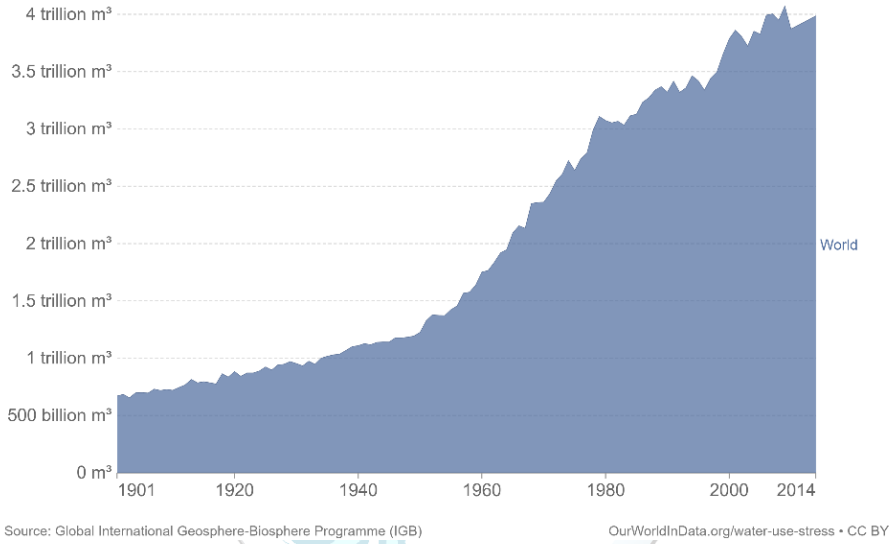

Figure 1. Global freshwater use for agriculture, industry and domestic uses since 1900, measured in cubic metres (m³) per year [11], [12]

People use water for different purposes. It is important to remember that water for different purposes does not have to be potable water. One person per day for survival (drink and food) needs 2.5 to 3 litres, basic hygiene needs 2 to 6 litres, and basic cooking needs 3 to 6 litres leading to a total of 7.5 to 15 litres per person per day for basic emergency needs [13], [14]. Non-drinking water can be replaced by rainwater. So on average, 45 litres of drinking water can be saved each day if replaced by rainwater. Rainwater can be collected on the roof and guided through filters into a container of appropriate size, placed in a suitable place and protected from direct sunlight in order not to start developing algae [15]. The average water consumption in the apartment for one person per day is shown in Table 1.

Table 1. Average daily needs for potable and non-potable water for one person (according to [15])

Potable water		Non-potable water	
Use	**Amount [l]**	**Use**	**Amount [l]**
Shower	35	Toilet flushing	18
Washing dishes	8	Clothes washer	18
Face washing	7	Cleaning	4
Drinking and cooking	3	Watering the garden	5
Total	53	Total	45

The use of water in the household is given in Table 2, and the average daily use of hot water in the household is given in Table 3.

Table 2. Indoor household use [16]

Fixture	Use [%]
Toilet	24
Faucet	20
Shower	20
Clothes washer	16
Leak	13
Bath	3
Other	3
Dishwasher	2

Table 3. Average daily hot water use per household [16]

Fixture	Use [%]
Shower	39.1
Faucet	33.8
Clothes washer	9.7
Bath	5.7
Dishwasher	4.8
Leak	4.6
Other	2.0
Toilet	0.0

2. LIVING BUILDING CHALLENGE

Water is an important economic resource and the basis for biodiversity, climate and ecosystem regulation. Protecting aquatic ecosystems from pollution and hydromorphological changes and sustainable use of water are essential to meet the needs of the current and future generations, as well as to maintain political stability at national and regional level. The overarching water policy aims to ensure that sufficient amount of quality water is available in the EU for human and environmental purposes by regulating the main pressures (agriculture, industry, municipal wastewater) and water use (bathing water, groundwater, drinking water) and integrated water management. The vast majority of European citizens have access to basic sanitation services and are connected at least to secondary wastewater treatment. In addition, European citizens have high quality drinking water. However, the pressure from urbanisation, diffuse pollution from agriculture, industry and climate change affect water quality and long-term water security. At a global level, the EU promotes water availability, sustainable water management and sanitation for all through the European consensus on development and EU neighbourhood and enlargement policies [17].

The Living Building Challenge - LBC is a certification program that defines the most advanced measure of sustainability - providing a framework for design, construction and the symbiotic relationship between people

and all aspects of the built environment. It is one of most rigorous performance standards in the industry, as it requires net-zero energy, waste and water by every project. The LBC is comprised of seven performance areas (Figure 2), or "Petals" - Materials, Place, Water, Energy, Health, Equity and Beauty [18].

Figure 2. The Living Building Challenge Petals [19]

The petal Water requires net-zero water use which means all of the water used must come from the site. The intent of the petal is to consider water as a scarce resource and helps us think about questions of waste. 100% of water for drinking, cleaning and gardening is collected and treated on site. Rainwater captured on rooftops is purified using ultraviolet light. Low-flow fixtures and composting toilets minimize water demand and used water is treated in sub-surface wetlands. A monitoring system helps building occupants learn about and adjust consumption [19].

Living Building Challenge rewards facilities that achieve net zero water, where 100% of the facility's water use comes from collected sources or closed loop water systems. The impacts of water runoff on the eco system are being considered and whether they are adequately purified without the use of chemicals. Buildings that achieve sustainable water flow where 100% of rainwater and wastewater from the building is managed on site and integrated into a comprehensive system that meets project requirements are analysed as well. In many important facilities in the world, interesting architectural solutions incorporate elements of rainwater collection systems [20].

3. NET ZERO WATER BUILDING

An important water source for net zero water building is rainwater. A significant condition for adequate reduction of the flow of atmospheric waters is the use of water, either for internal purposes, which slows the flow rate, and the water is eventually returned to the catchment through wastewater, or for irrigation which maximizes local evapotranspiration. In suburban housing zones, acceptable reservoir volumes (ca. 2.5 m^3 per 100 m^2 of roof surface) for rainwater collection, which can later be used for a wide range of indoor and outdoor needs, can reduce the runoff of atmospheric waters to almost natural catchment conditions. In multi-dwelling areas with more population and higher potential water needs per unit roof area, the potential to reduce run-off is even greater [21].

An ideal net zero water building uses on-site alternative water sources to supply all of the building's water needs. All wastewater discharged from the building is treated on-site and returned to the original water source [22]. A net zero water building (Figure 3) is a building that collects rainwater and recycles its wastewater for reuse, eliminating the need for water supply from the public water supply and connection to the sewer network.

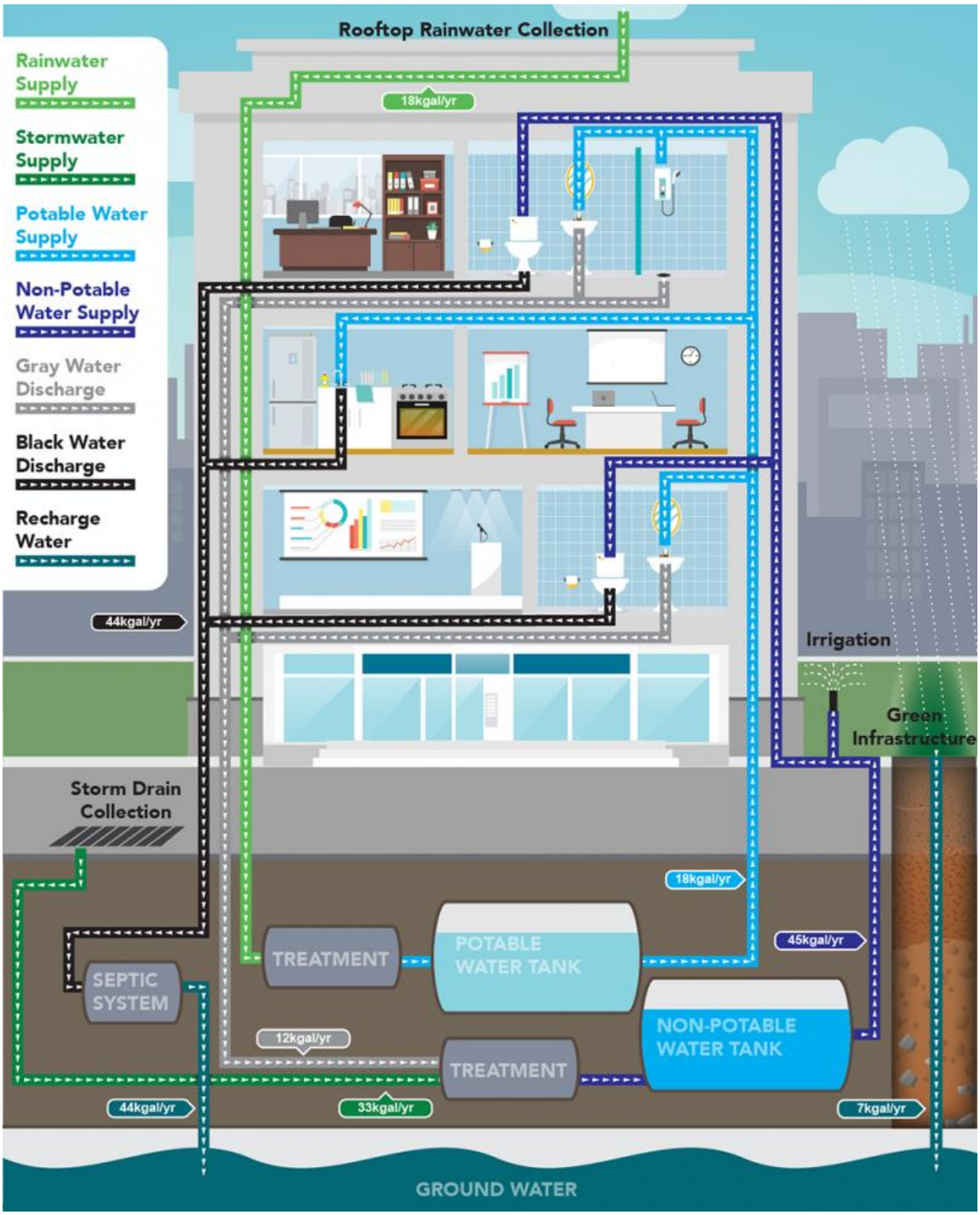

Figure 3. An ideal net zero water building [22]

Net zero water buildings includes the following key design elements:

- Reducing demand by employing innovative technologies that consume less water.
- Producing alternative water sources to offset purchased freshwater.
- Treating wastewater on-site and reuse or inject treated wastewater into the original water supply.
- Implementing green infrastructure by infiltrating stormwater to the original water supply [22].

The goal of net zero water is to preserve the quantity and quality of natural water resources with minimal deterioration, depletion, and rerouting by utilizing potential alternative water sources and water efficiency measures to minimize the use of supplied freshwater. This principle can be expanded to the campus level.

Back in the day, many of the oldest homes could have achieved the net-zero water designations that are cherished today. Rainwater was captured in cisterns, wells provided drinkable water and an outhouse served as a toilet [23].

When talking about net zero water building, it can be achieved gradually, i.e. not every building has to be net zero building, but it is necessary to try to reduce as much water consumption as possible. First, it is necessary to reduce the consumption of water by the householder. In houses, it is necessary to replace old equipment, toilets and appliances that use water, add new toilets that use one quarter of the water of the old ones, and faucets and showers that save water. Water and sewer installations should also be installed in the house to remove leaks, which can be the main source of water loss. All of the above can reduce water consumption by 60% [23].

The next step is to capture rainwater from the roof, just like people did long ago. The rainwater flows into storage tanks – after roof debris is diverted. To make it potable, the water is first filtered, then disinfected by exposure to ultraviolet light. It is ultimately directed to faucets and showerheads within the home [23]. The amount of rainwater that can be collected can be easily calculated. The surface of the roof (flat or pitched) should be calculated and then multiplied by the average annual rainfall. Losses must certainly be taken into account (due to evaporation, absorption, leakage, etc.), leading to a percentage of collected water of 70% to a maximum of 90%.

The most favourable are smooth surfaces, followed by clay covers or shale. Roofs with rough concrete tiles, bitumen cover and so-called green roofs (flat, grass-covered) are inappropriate. Dust and other impurities are preserved in these roofs. If the roof is covered by a metal cover, it must be calculated with a higher metal content in water, which is therefore less suitable for watering gardens [15].

An example of an underground rainwater storage tank is shown in Figure 4.

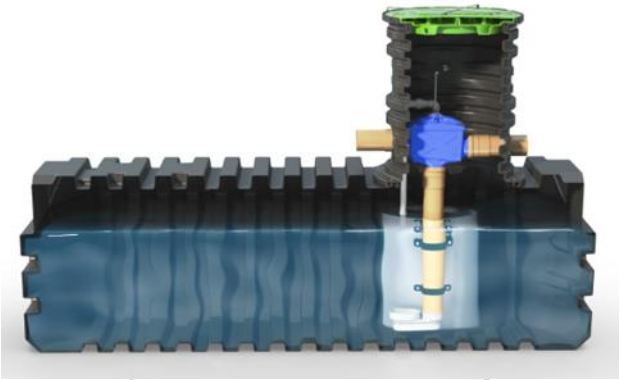

Figure 4. Rainwater harvesting storage tank [24]

Then came analyzing the potential for greywater recycled from sinks and showers to flush toilets. Researchers found that the shower and lavatory would produce slightly more water than the low-flush toilets would need. Extra greywater was dedicated to supplement the needs of the washing machines. One benefit of the greywater system is that potable water from the water company isn't used for toilets, where it isn't really needed. Toilets are the biggest users of water within the home [23].

It is likely that more net zero water homes will only appear in the coming years due to the emergence of a new rigorous certification program, the Living Building Challenge. Unlike green building programs that try to minimize the environmental impact of the house, the Living Building Challenge seeks to eliminate it completely. To earn a certificate, homes must be net-zero in their use of energy and water. Certification is tough because it requires a year's worth of real data, as opposed to a design computation [23].

Certain technologies that can be applied to net zero water building and technologies that can achieve advanced secondary treatment levels to support water reuse or release of less contaminated water back into the environment, taking into account the useful use and appropriate handling of nutrients, are also urine-diversion dehydration toilets - UDDT and urine-diversion flush toilets - UDFT.

Urine can be collected with urinals without water/dry toilets, and the resulting product is natural fertiliser. Faeces can be stabilized by anaerobic method, drying and composting (dry toilets), and biogas and fertilizer are produced as a product. Sanitary water can be purified in wetlands (marshes – artificial/natural), and the resulting water can be used for irrigation. Rainwater does not require any purification and can be directly infiltrated into the soil or collected in containers used for irrigation of agricultural areas [25].

The collection of urine and faeces and water saving can be done in several ways. One way is by using the urine-diverting flush toilet – UDFT (Figure 5). A urine-diverting dry toilet - UDDT is a toilet that operates without water and has a divider so that the user, with little effort, can divert the urine away from the faeces [26].

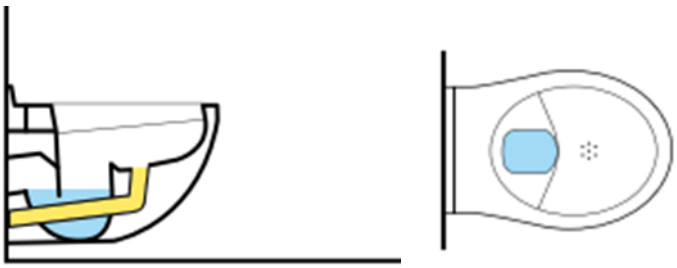

Figure 5. The urine-diverting flush toilet (UDFT) [26]

UDDT toilets are mostly used for family houses, schools (in underdeveloped countries), generally not widely used for multi-apartment buildings. The use of UDDT in multi-dwelling buildings is a major challenge. There are only a few examples of UDDT in multi-dwelling buildings in Germany and Mongolia. Faecal tanks are located in the basement and are dimensioned so that a family of five members can use one tank for about half a year. It is recommended to use ashes to cover the faeces. When the first container is filled, the second container shall be used so that the faeces can be sufficiently dried and ready for use [27]. Such toilets are harder to maintain and clean than ordinary toilets (with flushing). Faeces should be covered with sawdust, lime, dry soil, ash to reduce faecal moisture and increase PH due to pathogen extinction [5].

Composting toilets can be integrated into a building's net zero water strategies with opportunities for maximizing water conservation and reuse. Utilizing composting toilets can result in reduced systems needed for managing a building's remaining wastewater, including fewer pipes and smaller areas needed for on-site treatment [28].

In the case of waterless urinals, maintenance is simple. A urinal is used only for collecting urine. Urine is stored directly in containers and used later. Tanks can be underground or above ground, depending on the construction and location of the urinal in the building and the type of building. For water-based urinals, the water use per flush ranges from less than 2 l in current designs to almost 20 l of flushwater in outdated models [26].

For household urine, the recommended storage time is 1 to 6 months, depending on the storage temperature (below or above 20 °C). However, if urine is used for its own garden, this is not necessary. Storage time of 1 month is recommended for food and crops under cultivation (e.g. cooking). Six months of storage (if temperature > 20 °C) is required for commercial food production and when raw products are consumed. Urine from public places such as schools or restaurants takes 6 months to store. After this storage time, urine may be used to irrigate all crops (if temperature > 20 °C) [7].

Some of the advantages of the above mentioned technologies of separate collection of human urine and feces at the point of their production are: water savings, organic fertilizer production, energy savings since wastewater contains less nutrients and pathogens and less oxygen is needed during biological treatment, and since less water is in the system, less energy is required to pump water [5].

The lack of separation of urine and faecal matter and non-use of water when flushing toilets is the (non) willingness of people to change habits (people are considered not to be "civilized" if they do not have access to flushing toilets), additional maintenance is needed, the initial costs of such investments are higher, urine is less efficient fertilizer than synthetic fertilizers [5].

All of the above - the separation of types of wastewater and waste materials according to the place of their origin - is advocated by the material flow management method – MFM. The term material flow management covers a broad spectrum of methods and approaches in the literature. In general, material flow management refers to the analysis and specific optimization of material and energy flows that arise during manufacturing of products and provision of services. Material flow management can focus on very different levels of consideration [29]. The path of cross-company material flow management is also described as the product line or product lifecycle, from the input of raw materials, manufacturing, distribution and use consumption up to disposal [29], [30].

4. CONCLUSIONS

Water has always been of great importance and always will be. Preserving its quality and sufficient amount of water should be in our best interests. Climate change and the ever-accelerating urbanisation that causes increasing problems should be driver for a new way of thinking. Integral (sustainable) governance has

increasingly been mentioned in all areas of work and life. It is evident that in recent times, much attention has been given to solving the problem of the drainage of atmospheric waters in developed countries, by applying an integral approach to precipitation water planning and management. This is an innovative approach that relies on the environmental principles of drainage planning and design according to the natural way of runoff.

The possibilities of using rainwater in buildings are high. Some of the ways or places where rainwater can be used are to flush toilets, wash clothes, irrigate gardens, etc. The most significant advantage of this approach is its positive influence on the characteristic biophysical features of the urban environment, where the negative effect of rainwater on the urban area is reduced. This approach has many advantages, but is still poorly applied. Changing the existing rainwater drainage systems is quite costly and complex, but nonetheless, the various possibilities and advantages of applying such an approach, its impact on improving the quality of living and housing, improving the protection of space as a whole, and ultimately mitigating the consequences of climate change, are becoming increasingly evident.

Less than 1% of the potable water on Earth is known to be used by humans, among other things (and in large part), to flush toilets. That water is called black water, and actually its only role is to be a transport agent for faeces and urine. Faeces and urine can be used as fertilizer. Of course, certain rules should be observed in such a use. Urine contains most of the nutrients of wastewater, and by volume it accounts for less than 1% of the total amount of wastewater. The separation of urine and faeces, without the use of drinking water as a transport agent, can be done by using water-free urinals, urine-diversion dehydration toilet - UDDT, urine-diversion flush toilet - UDFT where only faeces are rinsed with water and drained and urine is stored in a special tank, etc. A net zero water building (constructed or renovated) is designed to: minimize total water consumption, maximize alternative water sources, minimize wastewater discharge from the building and return water to the original water source. Net zero water creates a water-neutral building where the amount of alternative water used and water returned to the original water source is equal to the building's total water consumption.

The application, i.e. construction of net zero water building, finds many obstacles. Legal barriers - the complexity of managing the regulatory system around such systems at local, state and national level is the biggest obstacle for project teams seeking approval for net zero water projects. Currently, water is regulated in several jurisdictions and agencies. Financial barriers are then emerging as net zero water projects rely on local or distributed water supply and purification systems which are otherwise operated at municipal level by publicly owned utility companies. As such, the burden of costs for supply and processing systems - as well as their current operation, maintenance and replacement needs - is shifted from the utility company to the individual project. Cultural barriers and public perception of the safety of water reuse and on-site management of wastewater pose significant obstacles to net zero water projects. Such fears have roots in our historical management of water and waste and the resulting public health problems that have arisen. Today, education requires convincing the public of the safety of modern decentralised water systems and informing them of their environmental, social and economic benefits.

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest.

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Effect of 6 February 2023 Kahramanmaraş Earthquake on Rural Structures

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Abstract

The 6 February Kahramanmaraş Earthquake was a significant seismic event that occurred in the rural areas of Kahramanmaraş, Turkey. This study aims to evaluate the impact of the earthquake on rural buildings and assess their structural performance. By analyzing the damage patterns and structural vulnerabilities, valuable insights can be gained to enhance the seismic resilience of rural buildings. The research methodology involves comprising visual inspections in the affected regions. The collected visual inspection data includes information about building types, construction materials, structural characteristics, and observed damages. The earthquake damage is categorized based on severity levels, ranging from minor cracks to complete structural failure, allowing for a detailed analysis of the performance of rural buildings. The findings of this study will contribute to the understanding of the seismicity of rural buildings in the Kahramanmaraş region and provide crucial insights for future mitigation and preparedness efforts. The results will help inform the development of appropriate building codes, guidelines, and retrofitting strategies to enhance the resilience of rural communities against future earthquakes. Ultimately, the evaluation of the effect of the 6 February Kahramanmaraş Earthquake on rural buildings will lead to improved seismic safety practices, ensuring the protection of lives and assets in similar rural areas prone to earthquakes. The research outcomes will be valuable for engineers, urban planners, and policymakers involved in disaster risk reduction and seismic resilience initiatives at both regional and national levels.

Key words

Earthquakes, Masonry, Rural area, Rural buildings

1. INTRODUCTION

Turkey is situated on the highly seismically active Anatolian plate, a region that has historically seen large earthquakes. More than 7 earthquakes have occurred in our country since 1900. This brings Turkey to the top of the list of countries damaged by earthquakes. In Turkey, 269 earthquakes resulted in fatalities or property damage between 1900 and 2023. In these earthquakes, the biggest earthquakes in terms of loss of life and heavy damage are the 2023 Kahramanmaraş, 1939 Erzincan, and 1999 Gölcük-centered Marmara Earthquakes, respectively [1].

According to the Turkey Earthquake Hazard Map, which shows Turkey's earthquake hazard most clearly and which was published and entered into force in 2018, a large part of Turkey's lands are located in areas with high earthquake risk. The earthquake Hazard Map of Turkey is shown in Figure 1.

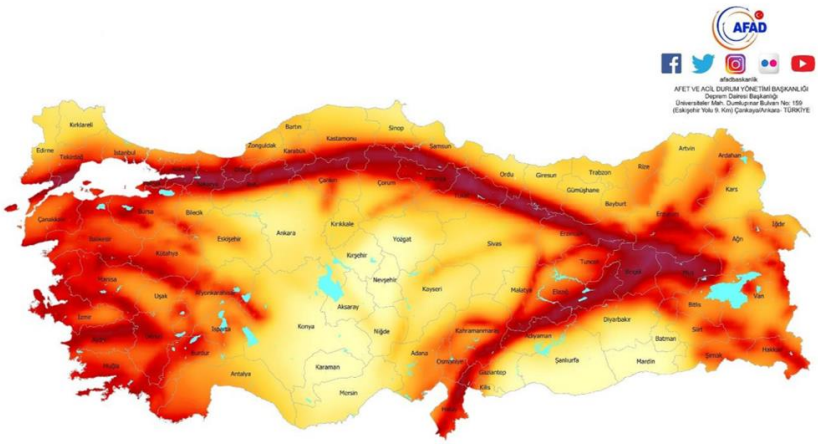


Figure 1. Earthquake Hazard Map of Turkey [2].

2. THE 6 FEBRUARY KAHRAMANMARAŞ EARTHQUAKE: AN OVERVIEW

On February 6th, 2023, a powerful earthquakes struck Kahramanmaraş, a province in southern Turkey. The earthquakes have a magnitude of 7.7 and 7.6 were felt across a wide area, affecting both urban and rural communities. The epicenter of the earthquake was located near the town of Kahramanmaraş, causing significant ground shaking and triggering widespread damage to buildings and infrastructure. Kahramanmaraş Earthquakes details are shown in Figure 2.

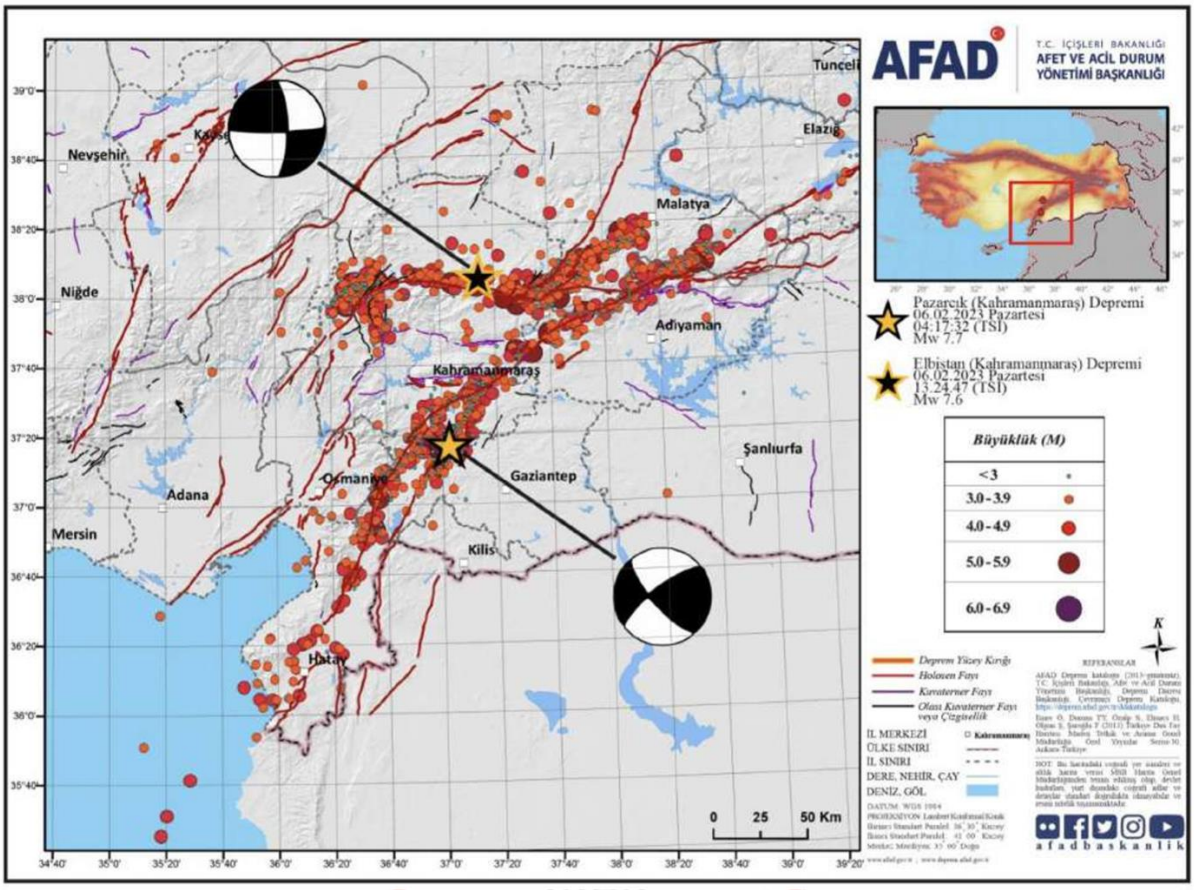


Figure 2. Kahramanmaraş Earthquakes [3]

Total Number of Buildings in the Provinces Affected by the Earthquake is shown in Table 1.

Table 1. Total Number of Buildings in the Provinces Affected by the Earthquake [4]

Province	Residential	Office	Public	Other	Total
Adana	404.502	29.920	8.916	7.779	451.117
Adıyaman	107.242	5.765	.370	3.119	120.496
Diyarbakır	199.138	11.412	11.964	3.165	225.679
Elazığ	106.569	7.221	2.872	7.051	123.713
Gaziantep	269.212	22.829	5.480	8.162	305.683
Hatay	357.467	33.511	10.382	5.489	406.849
Kahramanmaraş	219.351	12.358	6.879	4.565	243.153
Kilis	33.399	1.526	1.651	736	37.312
Malatya	159.896	8.370	6.670	4.051	178.987
Osmaniye	128.163	9.428	3.105	2.384	143.080
Şanlıurfa	347.902	18.847	11.790	4.089	382.628
Total	2.332.841	161.187	74.079	50.590	2.618.697

Number of Buildings with Damage Determined (6 March 2023) is shown in Table 2.

As of March 6, 2023, damage assessment studies were carried out for 1,712,182 buildings in 11 provinces affected by the earthquake. According to this; It was determined that 35,355 buildings were destroyed, 17,491 buildings needed to be demolished urgently, 179,786 buildings were heavily damaged, 40,228 buildings were moderately damaged, and 431,421 buildings were slightly damaged. Among the destroyed or severely damaged buildings, there are historical and cultural structures, schools, administrative buildings, hospitals, hotels, as well as those used as residences [1].

Table 2. Number of Buildings with Damage Determined [4]

	Number of Buildings	Independent Section
Undamaged	860.006	2.387.163
Slightly damaged	431.421	1.615.817
Moderately damaged	40.228	166.132
Heavily damaged	179.786	494.588
Ruined	35.355	96.100
Will be destroyed immediately	17.491	60.728
not detected	147.895	296.508
Total	1.712.182	5.117.036

3. IMPACT ON RURAL BUILDINGS

Unlike urban areas, rural regions often lack proper building codes and construction standards to withstand seismic events. The rural buildings in Kahramanmaraş were not an exception, and the earthquake revealed the vulnerabilities in their construction.

Building Materials and Techniques: Many rural buildings in Kahramanmaraş were constructed using traditional methods and local materials, which were not designed to withstand seismic forces. The lack of reinforced structures and inadequate foundations made these buildings highly susceptible to damage during the earthquake.

Collapse and Partial Destruction: As a consequence of the earthquake's intensity, several rural buildings collapsed entirely or suffered severe damage, rendering them uninhabitable. The lack of engineering supervision and adherence to modern construction practices exacerbated the severity of the destruction.

Human Loss and Displacement: The earthquake caused a significant human toll, with many rural communities witnessing casualties and injuries. Moreover, the destruction of rural buildings forced numerous families to relocate temporarily to emergency shelters or neighboring towns.

Impact on Livelihoods: In rural areas, buildings often serve as not only living spaces but also shelters for livestock and storage for agricultural produce. The destruction of these structures had a substantial impact on the livelihoods of the local population, disrupting their agricultural activities and economic stability.

3.1. Importance of Seismic Resilience in Rural Buildings

The 6 February Kahramanmaraş earthquake highlighted the urgent need to prioritize seismic resilience in rural building constructions. To mitigate the impact of future earthquakes, the following measures should be considered:

Building Codes and Regulations: Local authorities and policymakers must develop and enforce building codes specifically tailored for rural areas. These regulations should require the use of earthquake-resistant construction techniques and materials.

Public Awareness and Education: Raising awareness among rural communities about earthquake preparedness and safety measures can significantly reduce casualties and damage. Educational programs should be implemented to inform the public about earthquake risks and evacuation procedures.

Retrofitting Existing Buildings: Many rural buildings in Kahramanmaraş can be retrofitted to improve their seismic resilience. This process involves strengthening key structural elements to enhance their ability to withstand seismic forces.

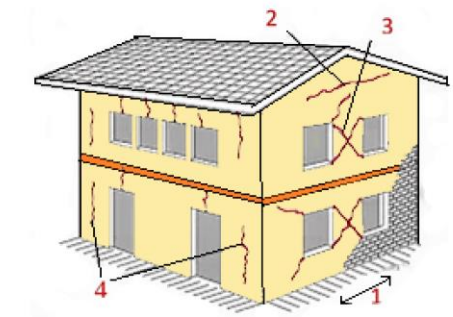
Financial Incentives: Providing financial incentives to rural homeowners and builders who adopt earthquake-resistant construction practices can encourage the widespread implementation of safer building techniques.

4. DAMAGE TYPES OBSERVED IN MASONRY STRUCTURES

When the masonry buildings are examined after the earthquakes of February 6, 2023, most of the damaged and collapsed masonry buildings are located in the village center in rural areas. Types of masonry buildings in TBDY2018 [5]; masonry building without reinforcement, reinforced masonry building, surrounded masonry building and reinforced panel system building. During the field studies, it was observed that the masonry buildings were mostly constructed as unreinforced masonry buildings and adobe, artificial stone, brick, concrete and aerated concrete were used as masonry units [6].

Masonry structures are horizontal and vertical load-bearing structures whose carrier system consists of natural or artificial blocks such as natural stones, bricks or briquettes and formed with a binding mortar. Generally, local materials are used depending on economic conditions. Such structures, which are built without engineering knowledge, are either heavily damaged or demolished in the face of natural disasters such as earthquakes, causing loss of life and property. Damages in masonry structures under the influence of earthquake loads begin with cracks in critical areas. With the increase of the load effect, the cracks become larger. With the opening and closing of the formed roofs, the building absorbs the energy. Depending on the earthquake effect, the structure may reach the collapse mechanism [7].

Damages in masonry structures can be examined under certain headings. These titles are; It can be classified as out-of-plane damages on walls, in-plane damages on walls, damages on minarets, roofs (such as heavy roofs), domes, and arches [8]. Damages in masonry structures are shown in Figure 3, Figure 4, and Figure 5, respectively.



1- Earthquake direction

2- Horizontal cracks in shield walls

3- Diagonal cracks in the solid wall part between the window openings

4- Vertical cracks in the wall

Figure 3. Damages in masonry structures [7], [9]

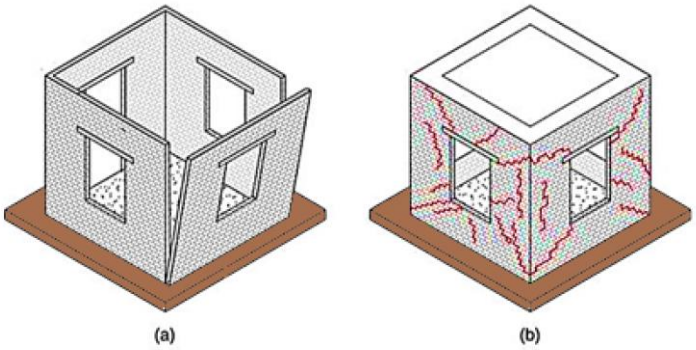


Figure 4. Masonry Structures (a) out-of-plane behavior, (b) in-plane behavior [8]

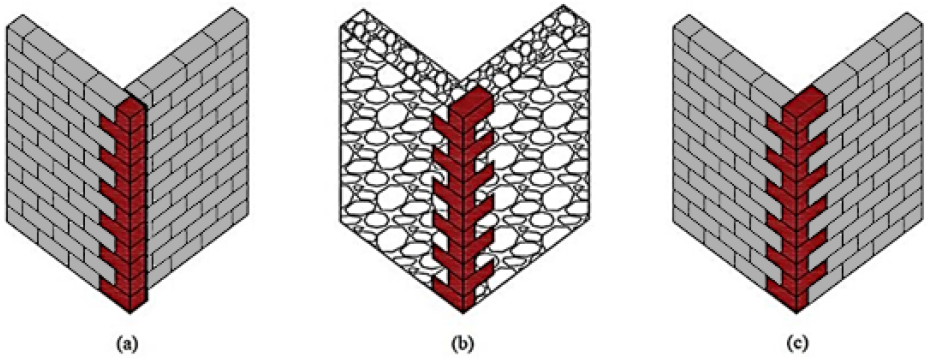


Figure 5. Corner details (a) lack of keystone, (b) insufficient bracing, (c) adequate bonding [8]

Evaluation of damage types according to damage mechanisms is very important for a comprehensive evaluation. For this purpose, lists developed for cataloging mechanisms were used in this section and damage mechanisms are defined. the damage observed in the buildings was classified using the catalogue of damage mechanism, developed by D'Ayala and Speranza [10], [11].

5. PERFORMANCE OF MASONRY BUILDINGS

Masonry is the second largest building type proportionally in the Turkish building stock. Although the proportion of masonry buildings in urban areas is low, it is much more common in rural areas. The masonry building stock in the region, which has not undergone engineering service, was either heavily damaged or completely collapsed under both earthquakes, similar to other buildings. However, the number of completely destroyed 1-3 storey masonry buildings built with relatively high quality masonry materials is less than 8-10 storey reinforced concrete buildings. It has been seen that the height and rigidity of the building play an important role. In addition, many historical masonry buildings were heavily damaged or collapsed due to the strong ground movements they were exposed to [12]. Out-of-plane damages in masonry structures in the earthquake are shown in Figure 6.

Figure 6. out-of-plane damages in masonry structures in the earthquake region [13]

In-plane damages are one of the most important damages that can be seen in masonry structures. These damages occur as a) horizontal cracks caused by shear (b) diagonal tension cracks (c) horizontal cracks caused by bending (d) crushing at the base caused by bending. Some of the in-plane wall damages observed in masonry structures after the earthquake are given in the figure. After the Pazarcık and Elbistan earthquakes, in-plane wall damages have been observed widely in traditionally built single or two-storey masonry structures and historical monuments. In-plane damages in masonry structures in the earthquake region is shown in Figure 7.

Figure 7. In-plane damages in masonry structures in the earthquake region

In masonry structures, not using enough mortar between the stones or not having enough binders in the mortar can also cause the masonry structures to show a tendency to collapse. According to field researchers' observations, the general causes of damage to masonry buildings are generally attributable to architectural qualities, structural properties, poor masonry material properties, and poor craftsmanship. In any case, stone is a readily available material, and the absence of timber forces people to use more stone in construction details. However, due to its unit weight and difficulty in processing, stone is not a good material in earthquake-prone areas. Poor masonry material properties in masonry structures in the earthquake region is shown in Figure 8.

Figure 8. Poor masonry material properties in masonry structures in the earthquake region

6. RESULTS

Earthquakes are natural disasters that can have devastating effects on communities and their infrastructure. In recent years, Turkey has experienced several seismic events, and one such significant earthquake was the 6 February Kahramanmaraş earthquake. This seismic event struck the region with a considerable magnitude, leaving a lasting impact on both urban and rural areas. This article aims to evaluate the effect of the earthquake on rural buildings in Kahramanmaraş and shed light on the importance of seismic resilience in rural constructions.

In this study, the masonry buildings damaged in the Maraş earthquake and the causes of damage to the buildings were examined.

Observations and reports made after the earthquake revealed that masonry buildings were mostly built independently of regulations and devoid of horizontal and vertical beams.

The weak binders and materials used in masonry structures have caused weak load-bearing walls of the structures.

The Maraş earthquake was too strong for the masonry structures, which were not good enough in terms of building materials and binding materials, to withstand. The Maraş earthquake was too strong for the masonry structures, which were not good enough in terms of building materials and binding materials, to withstand. The earthquake acceleration caused in-plane collapses with excessive shear force or out-of-plane collapses by bending or bending,

depending on the aspect ratio of the masonry elements, in unreinforced masonry elements with construction errors. In many weak masonry walls without mortar, diagonal or oblique shear cracks have occurred as a result of cyclic shear forces applied during earthquakes.

The 6 February Kahramanmaraş earthquake had a profound impact on rural buildings in the region, highlighting the urgent need for seismic resilience measures. By implementing building codes, promoting public awareness, retrofitting existing structures, and providing financial incentives, rural communities can better prepare themselves for future seismic events. It is essential to recognize the vulnerability of rural buildings and take proactive steps to ensure the safety and well-being of the inhabitants in earthquake-prone regions.

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest.

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Evaluation Of Construction Wastes After The Earthquake in Terms Of Energy And Sustainability

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Abstract

Evaluation of the construction waste generated after the earthquake in terms of energy and sustainability is very important for effective disaster management and sustainable reconstruction studies. Earthquakes often cause significant damage to infrastructure and create large amounts of construction debris. This study aims to evaluate the energy impacts and sustainability aspects of the management and disposal of construction waste after an earthquake.

In general, a comprehensive assessment of the energy impacts and sustainability considerations associated with the management of construction waste after an earthquake can contribute to existing knowledge on the subject. The findings can guide stakeholders in making informed decisions that minimize environmental impact, optimize resource use, and support sustainable rebuilding practices after earthquakes.

The findings of this study contribute to the development of guidelines and best practices for post-earthquake waste management, emphasizing energy efficiency and sustainability. By promoting waste reduction, reuse and recycling, this research aims to minimize the environmental burden of reconstruction efforts while also highlighting opportunities to use waste as a valuable resource. Ultimately, the energy and sustainability evaluation of construction waste after an earthquake provides a more environmentally friendly and resource-efficient roadmap for post-disaster reconstruction practices.

Key words

Construction waste, Earthquakes, Energy, Sustainability

1. INTRODUCTION

Buildings of various building types in the disaster area show different behavior under the effect of earthquakes. Due to different building types and different design levels and construction management, the damage magnitudes and destructive characteristics of buildings in the entire disaster area are quite different. For this reason, it is very difficult to determine the exact amount of waste that will be released from the buildings. In addition, considering the differences in urban and rural structures and different economic levels for different regions, the amount of waste varies [1].

The creation of waste is steadily rising and turning into a significant environmental issue as a result of earthquakes, natural disasters, wars, the rapid expansion in the world's population, etc. Many buildings are destroyed or damaged, especially following destructive earthquakes. Some of these structures are destroyed during the earthquake, while others are carefully destroyed after it [2], [3].

Natural disasters, such as earthquakes, often leave behind a trail of destruction, with buildings and infrastructure bearing the brunt of their force. While the immediate focus is on rescuing survivors and rebuilding, the management of construction waste generated in the aftermath of an earthquake is equally critical. The evaluation of construction waste, particularly in terms of energy utilization and sustainability, holds immense importance as we strive for more eco-conscious and resource-efficient practices in the field of construction and disaster recovery.

2. EARTHQUAKE

Earthquakes are common worldwide and are caused by nature. Each year, the planet experiences about 3.5 million earthquakes. Only one million of them are detectable, and only about 34,000 are audible. Around the globe, 800 mild earthquakes with a Richter scale of 5.0 to 5.9 per year do only modest damage. Each year, there are about 120 severe earthquakes with a Richter rating of 6.0 to 6.9 that are destructive.Each year, 18 big earthquakes with a Richter scale of 7.0 to 7.9 have the potential to be destructive. A powerful earthquake with a Richter scale value of 8.0 to 8.9 that can be disastrous happens every 10 to 20 years. However, it is impossible to foresee the location and timing of an earthquake in the near future [4].

Unexpected earthquakes can occur at any time. An earthquake is a sudden, intense shaking of the ground brought on by movement of tectonic plates along a fault line in the crust of the earth. Earthquakes can cause landslides, avalanches, fires, liquefaction of the soil, shaking of the ground, and tsunamis. The amount of damage and devastation brought on by an earthquake depends on: magnitüde intensity and duration, the local geology, the time of day that it occurs, building and industrial plant design and materials, the risk-management measures put in place [5].

Even mild earthquakes that do little to no physical harm or destruction can upset individuals emotionally (particularly in locations that are not used to such occurrences). Aftershocks can happen for months after the initial event and can be equally stressful [6].

3. THE IMPACT OF EARTHQUAKES ON CONSTRUCTION WASTE

Earthquakes cause widespread damage to buildings, resulting in rubble, debris, and other forms of construction waste. The diversity of building types, designs, and materials within an earthquake-affected region contributes to the complexity of waste management. Different building materials, ranging from concrete and steel to wood and masonry, pose distinct challenges in terms of recycling and disposal.

These kinds of natural disasters have not only resulted in direct losses in terms of lives and money, but they have also left behind a lot of debris that has contaminated the environment and prevented aid from reaching places that have been destroyed [7].

Earthquakes can also produce large amounts of waste that threatens public health, hinders reconstruction and affects the environment. Asbestos pollution due to collapsed structures poses serious risks to human health and the environment. In researches, it has been stated that the volume of waste generated after disasters such as earthquakes is 5-15 times higher than the annual volume of waste generated [8]-[10].

It is stated that a total of 104.8 million tons of waste was generated in Turkey in 2020. The type of waste that is created suddenly and in large quantities as a result of the earthquake disaster and causes operational obstacles is Construction Demolition Wastes, and it is predicted that 8-16 tons of Construction Demolition Waste is generated per person in the places where the earthquake occurred. Integrated management of non-hazardous and hazardous wastes arising from Construction Demolition Wastes and demolished buildings plays a critical role in reducing the environmental pollution burden and providing disaster management with sustainable economic strategies [11].

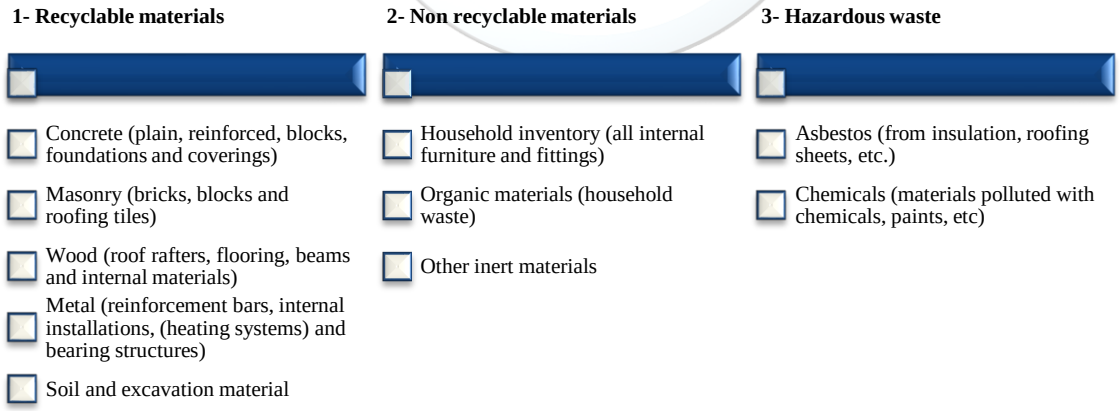
According tothe data of a study conducted in Spain, 6001400 kg of “Excavated Soil, Construction and Demolition Waste” per square meter is produced when an average building is demolished [12].

Over time, there have been countless catastrophic earthquakes that have caused tons of debris to be created [13]. These earthquakes and the amount of waste generated are given in the Table 1.

Table 1. These earthquakes and the amount of waste generated [11], [13]

Date	***Earthquake Name***	***Waste amount***
1994	*ABD-Los Angeles, CA: The Northridge*	*2 million tons*
17 January 1995	*Hyogo-ken Nambu earthquake*	*2000 million tons*
1995	*Japonya-Kobe, Büyük HansinAwaji*	*15 million tons*
September 1999	*Chi-Chi earthquake*	*20 million m3*
1999	*Kosovo earthquake*	*10 million tons*
1999	*Marmara earthquake*	*13 million tons*
2009	*İtalya-L'Aguila*	*2 million tons*
2010	*Haiti earthquake*	*52 million tons*
2011	*Great East Japan Earthquake*	*millions tons*
2008	*Great Sichuan earthquake*	*380 million tons*
2008	*Çin-Siçuan*	*375 million tons*
2017	*Mexico City*	*237.261,50*
2020	*Elazig-Sivrice earthquake*	*millions of tons of waste*
2023	*Kahramanmaras earthquake*	*465 million tons*

The composition of demolition waste has been classified into the following three fractions:



4. ENERGY RECOVERY FROM CONSTRUCTION WASTE

One promising approach to address construction waste after an earthquake is energy recovery. Traditional disposal methods, such as landfilling, not only consume valuable space but also contribute to environmental degradation. Instead, construction waste can be repurposed to harness energy through methods like waste-to-energy (WTE) technologies. By incinerating waste, energy is generated and can be used for various applications, including electricity generation and district heating. This not only reduces the volume of waste but also provides a sustainable energy source.

The granular structures with mineral structure such as gravel and sand, which are mixed with water and cement in the production of materials such as mortar and concrete, are called aggregates. Studies show that CO2 emissions from raw materials that have never been processed before are higher than from the use of recycled aggregate. The use of recycled aggregate in the construction industry provides 16% lower CO2 emissions and 35% lower energy consumption. These structures found in post-disaster debris can be used as filling material for activities such as road construction, drainage system, concrete production or rehabilitation [14].

5. SUSTAINABILITY ASPECTS IN WASTE MANAGEMENT

Recycling is inevitable in order to prevent environmental pollution that may occur and to reduce the consumption of natural resources. The destruction period of the structural wastes that we do not convert is estimated to be 200-300 years for iron, 4000-4500 years for glass, 1000 years for polyurethane foam, 100-300 years for aluminum and +2 million years for styrofoam materials [15]. Recycling of structural wastes, a large amount of which is recyclable, allows the pollution and waste potential that may occur as a result of construction and demolition activities, not being an environmental and economic problem, and turning them into gains with broad effects. Along with the depletion of our natural resources, billions of liras of national wealth are wasted every year. Although the economic and social effects of this situation can be observed quickly in the short term, the capacity of the environment to renew itself and sustainability is destroyed in the relatively long term [16]. Benefits of recycling construction and demolition waste is shown in Figure 1, and Benefits of recycling and sustainability structural waste is shown in Figure 2.

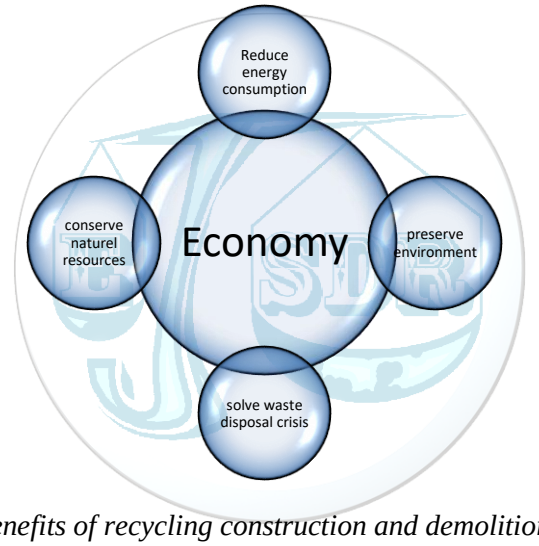


Figure 1. Benefits of recycling construction and demolition waste [17]

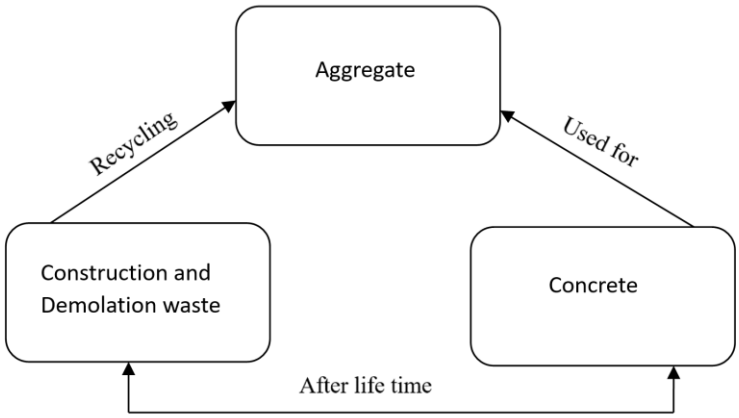


Figure 2. Benefits of recycling and sustainability structural waste [17]

The evaluation of construction waste after an earthquake extends beyond immediate energy recovery. Sustainable waste management practices emphasize minimizing waste generation, maximizing material recovery, and reducing environmental impact. Recycling and upcycling construction materials contribute to the circular economy by extending the life cycle of resources. Moreover, sustainable waste management practices can help reduce greenhouse gas emissions, conserve natural resources, and promote a greener recovery process.

Management of post-earthquake waste; The collection, transportation, reuse, recycling or disposal of waste consists of the response/rescue/first aid and reconstruction/remediation steps of the disaster management cycle [11].

To maintain the sustainability of construction and debris waste, it is necessary to implement measures to regulate disaster waste generation, such as building standards and codes, throughout the mitigation stage of the disaster management cycle. Relationship of disaster management cycle with disaster waste management shown in the Figure 3.

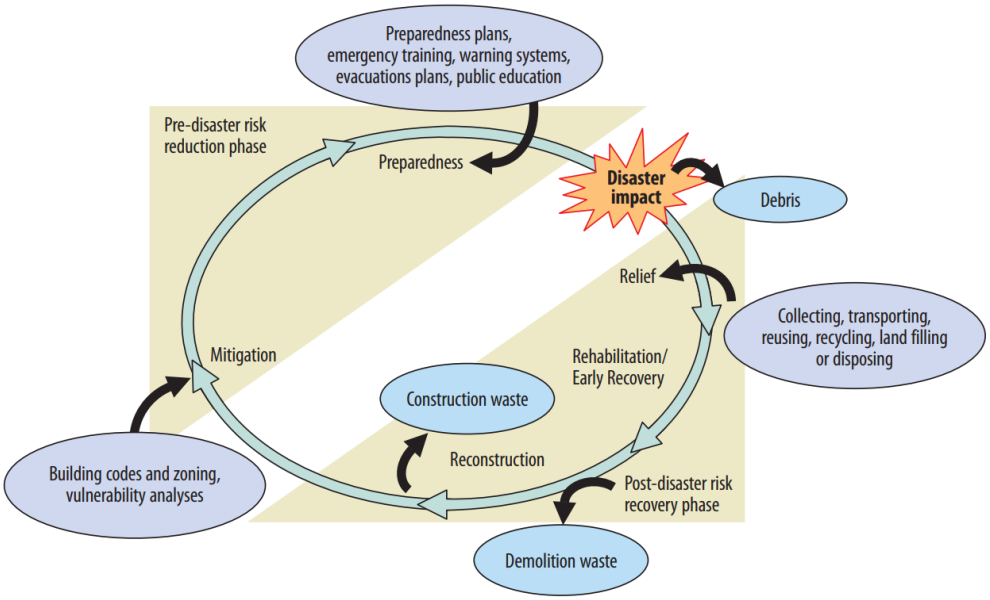


Figure 3. Relationship of disaster management cycle with disaster waste management [18]

Debris management is important during the recovery phase since it needs to be gathered, transported, repurposed, recycled, landfilled, or disposed of due to damaged buildings. According to some literature such as Rafee et al. (2008) [19], one of the major difficulties in a disaster recovery effort is debris management. As a result, at the recovery stage, a proper waste management plan should be devised. Construction waste generated during the reconstruction process is typically clean and relatively uncontaminated, which opens up unique recycling prospects [18].

6. CHALLENGES AND SOLUTIONS

Despite the potential benefits, there are challenges in evaluating construction waste in terms of energy and sustainability after an earthquake. The heterogeneity of waste streams, differing waste management regulations, and lack of efficient sorting facilities can hinder effective resource recovery. To overcome these challenges, a multi-pronged approach is needed:

Integrated Waste Management: Collaborative efforts between government bodies, NGOs, construction companies, and local communities can establish integrated waste management systems tailored to the unique needs of the disaster-stricken area.

Technological Innovation: Advanced sorting and separation technologies can streamline the process of identifying recyclable and recoverable materials from construction waste, making energy recovery and recycling more efficient.

Public Awareness: Raising awareness about the importance of proper waste separation and disposal among citizens can encourage responsible waste management practices

7. CONCLUSION

After reuse and recycling, the residual waste should be appropriately and safely disposed of in landfills. In order to accomplish this in an environmentally friendly way, the amount of debris being disposed of should be reduced to the greatest extent possible by using incineration (controlled open air incineration, air curtain pit incineration, and uncontrolled open air incineration), as well as chipping and grinding (rubber and metal materials) [20], [21].

The problem of waste from disasters is serious and should attract more public attention due to negative effects on water quality, air quality and noise, flora and fauna, visual impacts and socio-economics.

The European Commission has also identified waste management as an important issue to be addressed among the various dimensions of environmental rehabilitation in post-emergency assistance [22].

Proper treatment of building waste and large amount of waste, which takes up a lot of space after the earthquake, and the recycling of building wastes are very important for the region hit by the earthquake.

For this purpose, attention should be paid to studies on building waste to establish or propose methods of recycling and reuse that will help the government formulate relevant policies in order to reduce site clean-up costs and partially meet the demand for reconstruction.

The evaluation of construction waste after an earthquake through the lens of energy utilization and sustainability is crucial for a resilient and eco-conscious recovery process. By focusing on energy recovery, sustainable waste management, and technological innovation, we can mitigate the environmental impact of construction waste while also contributing to the recovery of valuable resources. As we continue to face the challenges posed by natural disasters, a proactive approach to construction waste management will pave the way for a greener and more sustainable future.

The magnitude of construction waste generated after an earthquake cannot be underestimated. It poses environmental hazards, consumes valuable resources, and contributes to greenhouse gas emissions. By embracing sustainable waste management practices, we can drastically reduce the carbon footprint associated with waste disposal, optimize resource utilization, and mitigate the environmental damage caused by reconstruction.

In conclusion, as we confront the aftermath of earthquakes, we must remember that our choices matter. By evaluating construction waste through the lens of energy and sustainability, we can transform challenges into opportunities, disasters into moments of innovation, and adversity into a catalyst for positive change. Let us embrace the imperative of sustainable waste management and energy recovery, working together towards a future where our actions today resonate through generations to come.

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest.

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Evaluation of Disability Standards in Primary Schools: The Case of North Macedonia Gostivar Municipality

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Abstract

This article includes research conducted to evaluate disability standards in primary schools and an evaluation study presented on the example of Gostivar municipality in North Macedonia. Access to the right to education of persons with disabilities and providing appropriate educational environments are essential elements of an inclusive education system.

The aim of the article is to examine the extent to which disability standards are implemented in primary schools. School standards for the disabled aim to meet the physical accessibility, communication opportunities, safety, and learning needs of people with disabilities. In addition, sustainability, engineering principles, and designs for disabled people play an important role in designing school buildings in accordance with disability standards. It is investigating the compliance of primary schools in Gostivar municipality, North Macedonia, with disability standards. Factors such as structural deficiencies, local building materials, and sustainable structures are among the focal points of the assessment. The extent to which disability standards are met and how it affects the safety and learning experiences of students with disabilities is examined in detail.

As a result of this study, it is emphasized that measures should be taken to implement disability standards more effectively in primary schools. Effective implementation of disability standards is of great importance in order to facilitate the participation of disabled students in education and social life. In addition, the importance of engineering and architectural studies for sustainability is emphasized, and it is discussed that factors such as conservation of natural resources, energy efficiency, use of local materials, social participation, economic sustainability, and risk management should be taken into account in order for the studies in this field to be successful. This study also aims to emphasize the importance of engineering and architectural disciplines working together in the process of ensuring sustainability in rural areas.

Key words

School Standards for the Disabled, Designs for the Disabled, Sustainability, Structural Deficiencies, Local Building Materials, Sustainable Buildings

1. INTRODUCTION

Disability refers to a situation that limits the activities of daily living or social interactions as a result of restrictions in the physical, mental, emotional, or social abilities of individuals. Disability can occur at any life stage, from birth or later. The types of disability can be varied. Physical disability includes conditions that limit the body's mobility. Intellectual disability refers to limitations in mental capacity, learning, and cognitive functions. Sensory disability encompasses limitations in the sense organs such as hearing or vision. Psychosocial disability includes caused by mental health, behavioral or emotional problems. Each type of disability has individual differences and can be managed with support and appropriate resources.

The Standards for Schools for the Disabled are criteria set to ensure the right to education of students with disabilities and to ensure that their educational environment is barrier-free. These standards aim to meet the physical accessibility, communication opportunities, safety, and learning needs of people with disabilities. Disabled school standards facilitate the removal of structural, auditory, visual, and tactile barriers and access to learning materials.

The existence of structural deficiencies for people with disabilities can complicate the lives of students with disabilities. For example, the lack of structural measures such as suitable ramps, elevators, or accessible toilets for people with disabilities limits physical accessibility. In addition, the lack of appropriate communication tools and technologies for students with hearing or visual impairments can result in communication barriers. Such deficiencies can adversely affect the safety and learning experience of students with disabilities.

Designs for people with disabilities should be designed to provide ergonomic and comfortable transportation and to meet the needs of students with disabilities in primary schools. It is necessary for students with disabilities to be able to move freely in schools, communicate and meet their learning needs. Accessibility of designs for the disabled: Accessibility measures such as ramps, elevators, and disabled lifts should be available at the entrances to schools for students with disabilities. Safety features such as hand grips and non-slip surfaces should also be provided on stairs. Interior arrangement: Interiors such as classrooms, corridors, and toilets should be designed to facilitate the circulation of students with disabilities. Elements such as wide aisles, flat floors, adequate turning diameters, and appropriate height tables and chairs should be provided. Communication facilities: Appropriate communication tools and technologies should be provided for hearing or visually-impaired students. For example, support such as captioning or sign language interpreting should be provided for students with hearing impairment. Learning materials and equipment: Special equipment, assistive technologies, and appropriate learning materials should be provided to meet the learning needs of students with disabilities. For example, equipment such as magnifying devices, Braille, and special literacy tools may be provided. Barrier-free toilets: It is important to have barrier-free toilets where disabled students can meet their toilet needs. These toilets should have features such as wide doors, grab handles, and a low-level sink. Accessible parking areas: Parking areas should be provided around the school, reserved for students with disabilities and complying with accessibility standards. Focusing on these points will help create an inclusive and supportive educational environment. Sustainability is an approach that supports the efficient use of natural resources, reducing environmental impacts, social balance, and economic development. Sustainability meets the needs of current generations while meeting the needs of future generations.

Sustainable engineering, on the other hand, aims to minimize environmental and social impacts by combining engineering disciplines with sustainability principles. Sustainable engineering aims to use natural resources efficiently in design, production, construction, and operation processes, to promote energy and water savings, to optimize waste management, and to reduce environmental impacts. Sustainable engineering solutions promote the use of renewable energy sources, develop energy and water-efficient designs, improve waste management processes, and use innovative materials and technologies to minimize environmental impacts. At the same time, it should focus on producing socially and economically just solutions by being sensitive to the needs of society. Sustainable engineering contributes to building and operating environmentally friendly and economically sustainable infrastructures. This approach aims for a more sustainable world for future generations, where resources are used effectively, the natural environment is protected, and the welfare of society is increased.

Designs for people with disabilities are of great importance in the context of sustainable engineering. While sustainable engineering aims to reduce environmental and social impacts, it also aims to meet the needs of all members of society. Designs for people with disabilities are important to increase the physical accessibility and quality of life of disabled people. These designs enable individuals with disabilities to carry out their daily activities independently and help to remove obstacles. Structures for people with disabilities, designed with sustainable engineering principles, provide energy and water efficiency, offer effective solutions in waste management and reduce environmental impacts. For example, practices such as making the ramps used for disabled access from natural materials or using energy-efficient lighting systems ensure that sustainability and disability-oriented designs are combined. In this way, sustainable engineering and disability-friendly designs

contribute to the creation of an environmentally friendly and economically sustainable future suitable for all segments of society. The importance of designs for people with disabilities in the context of sustainability forms the basis of an inclusive and sustainable society. Structural deficiencies for persons with disabilities refer to those that limit or hinder the physical accessibility of persons with disabilities. These deficiencies make it difficult for people with disabilities to carry out activities of daily living independently. Access barriers: Lack of ramps or elevators is among the shortcomings that are frequently encountered in those built for people with disabilities. Stairs, narrow corridors, or obstacles restrict access for people with disabilities inside the building or to different floors. Accessible toilets: The lack of suitable toilets that will enable disabled people to meet their toilet needs stands out as a structural deficiency. Barrier-free toilets should have features such as wide doors, grab handles, and a low-level sink. Communication barriers: The absence of appropriate means of communication for hearing or visually-impaired individuals is a structural deficiency. For example, lack of support such as captioning or sign language interpreting for people with hearing impairment causes communication barriers. Roads and streets: There may also be deficiencies in the roads or streets that people with disabilities encounter when reaching building entrances, schools, or other places. Elements such as poor maintenance, uneven floors, obstacles, and insufficient lighting prevent people with disabilities from moving safely and easily.

These structural deficiencies negatively affect the daily life activities, education, and social lives of individuals with disabilities. Structural arrangements should be made in order to ensure the physical accessibility of disabled people and to remove obstacles. This article examines these shortcomings in detail by investigating the compliance of primary schools with disability standards in Gostivar municipality, North Macedonia. There are various local building materials in North Macedonia. These materials reflect the local architectural heritage based on traditional and cultural building techniques. Here are some local building materials commonly used in North Macedonia: Stone: Stone is used as a traditional building material in many regions of North Macedonia. Usually, natural stones are used for walls, foundations, and other building elements. Wood: Wood plays an important role in the construction of traditional houses in North Macedonia. It is used for various building elements such as timber frames, beams, doors, windows, and trim. Lime Plaster: Lime plaster is a widely used material for covering wall surfaces. This plaster is obtained by processing natural limestone or lime rocks and is a characteristic feature of traditional buildings. Title: Tiles, which are often used in roof coverings, are made of a mixture of clay or mud. Tiles are an aesthetic element on the roofs of traditional Macedonian houses with a variety of color and pattern options. Wooden shingles: In some regions, wooden shingles are another local material used for roofing. Shindes, obtained by processing natural wood, are frequently seen on the roofs of traditional houses.

These local building materials give authenticity and identity to the architectural fabric of North Macedonia. The use of traditional and local building materials is also important in preserving and maintaining the region's cultural heritage. However, modern building materials have also increased, and these traditional materials can be replaced over time.

Integrating traditional building materials with sustainability principles and transferring them to future generations is very important. Transfer of Knowledge and Skills: Transfer of knowledge and skills related to traditional building materials and techniques is important. This may include teaching young people by local craftsmen and artisans and promoting apprenticeship systems. Local school and vocational training programs based on traditional building techniques can also be arranged. They are important strategies that can be used to integrate building materials with sustainable buildings and transfer them to future generations. Thus, the unique properties and cultural values of these materials will be preserved, and a sustainable construction industry will be developed.

Civil engineering and architecture play a critical role in sustainable living. Civil engineers consider issues such as energy and resource efficiency, selection of building materials, and waste management to build sustainable structures. Architects, on the other hand, plan environmentally compatible, energy efficient, and disabled-friendly buildings by applying sustainable design principles. In this way, civil engineering and architecture play an active role in the development of environmentally friendly and disabled-accessible structures that support sustainability goals.

The inner experiences of children with disabilities can be emotionally variable and intense. Therefore, different spaces may be needed for these children, depending on their play needs and other needs. Outdoors are environments where children with disabilities can experience their inner world in harmony with the outside world and find encouragement and peace [8].

According to Moore and Wong's (1997) study, disabled school gardens should be designed to increase children's inner curiosity and create the effect of natural formations in the city. These gardens should create a "condensed nature" effect, giving children the opportunity to explore different natural elements.

School gardens are important playgrounds with participatory and creative roles, where children can improve their quality of life by spending time with their friends. For this reason, children often spend most of their time in schoolyards playing games [9].

2. MATERIAL AND METHOD

The region where the study was carried out covers the Municipality of Gostivar in North Macedonia. The areas where primary schools are located form the focal point of the research area. A field study was carried out to collect data suitable for the purpose of the research. The visual data collection method was used to examine disability standards and identify deficiencies. Exterior and interior spaces of school buildings, access roads, school gardens, and facilities for people with disabilities are documented with photographs. Access roads of primary schools, entrance areas to the school garden, and access points to school buildings were measured. Elements such as street widths that provide a return to school, entrance widths to primary school buildings and gardens, stair step heights, and step widths have been examined in detail. The existence of ramps for people with disabilities was investigated, and if any, the ramps were measured, and their compliance with current standards was evaluated. Building materials research was conducted in order to propose solutions in line with the identified deficiencies. An evaluation was made for the integration of traditional building materials used in North Macedonia with modern building materials and solution proposals.

This assessment provides information on identifying suitable building materials to meet disability standards and provide a barrier-free educational environment. The collected data and information from the building materials research were analyzed. The evaluation was made on the extent to which the disability standards were met, what the deficiencies were, and the building materials and solution proposals.

The findings obtained from the research reveal the accessibility of the examined primary schools for disabled students and the effectiveness of their integration with existing building materials. Identifying the deficiencies and problematic points enables the development of solutions to provide a better educational environment for people with disabilities.

Especially the research area, data collection method, measurement and evaluation steps, building materials research, analysis, and results sections contain important details. The information obtained in line with this information is presented in the findings section.

3. RESULTS

The findings of the article reveal that primary schools in North Macedonia generally face some difficulties in meeting disability standards. Issues such as structural deficiencies, accessibility problems, and inadequate communication facilities can negatively affect the educational experience of students with disabilities. It has also been observed that the choices made in terms of local building materials and sustainability also affect the implementation of disability standards.

GOSTIVAR ISMAIL QEMALI PRIMARY SCHOOL		
		
A- Back Entrance to Ismail Qemali Primary School Garden 2. Entrance. ENTRANCE DOOR WIDTH: 150 CM	**B-**The School Building Has Exit Door Opening To The Backyard; There Is No Ramp, and There Is No Stair Railing; the Steps Have Different Heights; the First Step Height Is 30 Cm, and The Upper Steps Are 16cm. Step Width 30 Cm, Stair Width 360cm	**C-** There is no special area for walking and resting in the school garden, walking paths and green areas.
		
D- The School Garden Courtyard Walking Area and Special Areas for the Disabled are not designed.	**E-** The School's Front Garden Entrance Has 1 Pedestrian Entrance, and 1 Sliding Door is Used for Vehicle Vs. Entrance. Since the entrance to the school building is at ground level, there are no stairs and no ramp.	**F-** The Sidewalk Providing Communication and Transportation to the School Garden is not Designed for Disabled Students.

Figure 1. Gostivar İsmail Qemali Primary School

GOSTIVAR BROTHERHOOD AND UNION PRIMARY SCHOOL		
		
A- Sidewalk Width: 190cm. There is no ramp at the entrance to the garden; there is a difference in elevation.	B- There are two entrance doors for pedestrians at the entrance to the schoolyard, and there is a wide door in the middle that can open to both sides at the same time.	C- There is an arrangement with wide cobblestone pavements in the schoolyard, but a special area reserved for people with disabilities has not been designed.
		
D- School Building Entrance Door	E- In Figure B, the View of the Garden Entrance Gate and the Street Image is an Appearance of the Entrance to the School Garden. The ramp is not designed, but a disproportionate amount of concrete is poured, and there is such a design to be used for ramp duty.	**F-** No Ramp Step Height: 15cm Ladder Width: 440 Cm

Figure 2. Gostivar Fraternity and Unity Primary School

GOSTIVAR MUSTAFA KEMAL ATATURK SCHOOL		
		
A- School Building Entrance Has The Same Level As The Ground, and Ramp And Stairs Are Not Available. There Is No Need.	**B-** The School Garden Entrance Has A Wide Entrance Area. The Handicapped Trolley Can Pass, But There Is A Trouble At The First Entrance. Arrangement Must Be Made. Also, There Is No Guidance System For The Visually Impaired.	C- The School Garden Walking Area, The Walking Path Here, Is 120cm. It Is Not Suitable For The Disabled. It is not suitable for wheelchair access, and a walking area suitable for the visually impaired is not designed.

Figure 3. Gostivar Mustafa Kemal Atatürk School

As a result of the examinations, it was determined that the accessibility measures suitable for people with disabilities were insufficient in the three primary schools examined. Problems such as the lack of disabled ramps, the step heights on the stairs not complying with the standards, and the lack of guiding signs were observed. In addition, the lack of discretionary sidewalks, colored road signs, responsive road signs, and Braille signs was also identified as notable shortcomings.

While making accessibility arrangements for people with disabilities, it is of great importance to comply with the local regulations and the accessibility standards of people with disabilities. The deficiencies revealed in the examinations show that compliance with these standards is not achieved. It has also been determined that non-slip floor coverings should be used to facilitate the use of people with disabilities.

In the arrangements to be made in the relevant schools, the design should be at the forefront so that people with disabilities can easily perceive and use it. Arrangements should be made, such as adding disabled ramps, regulating step heights on stairs, placing directional signs, creating discretionary sidewalks, using colorful and responsive road signs, placing Braille signs, and using non-slip floor coverings.

Making these arrangements will enable disabled people to move more easily and safely in school environments and support their active participation in education. In addition, these regulations will support social accessibility principles by complying with local legislation and accessibility standards for people with disabilities.

4. DISCUSSION AND CONCLUSIONS

This study includes an examination conducted in three different primary schools in the municipality of Gostivar, North Macedonia, in order to provide freedom for people with disabilities in a safe environment where they can receive their basic education. The research includes structural solutions and design suggestions that enable students with disabilities to feel safe while studying and be supported in accordance with their needs.

First of all, it is recommended to use discretionary pavements that can be easily perceived by disabled people. A 10 cm high step should be added to these sidewalks, and a platform or border should be created that can enable visually impaired individuals to perceive with their walking sticks. Directions for walking and voice warning systems should be added in disabled crossings. Visually impaired individuals should be able to perceive directions by using embossed or Braille signs on the pavement. It is also important to use visual direction signs and signage.

However, some measures must be followed for structural solutions suitable for people with disabilities. The width of the accessible toilets must be at least 150 cm, and the doors must be at least 90 cm wide. Grab bars should also be available in accessible toilets, and their height should be between 70-75 cm. Doors suitable for disabled users should be at least 90 cm wide and have mechanisms that can be opened and closed easily. The

step height of the stairs should be 10-12 cm, and the step width should be a minimum of 28 cm. The ramp slope should have a slope that disabled wheelchairs can easily climb and should have a preferred slope of 6% to 8%. The ramp width should be a minimum of 120 cm, and there should be flattened areas at the start and end points.

The choice of building materials is also an important factor. For the safety and comfort of students with disabilities, non-slip and easy-to-clean coatings should be preferred on the floors. Anti-slip coatings should also be used on-ramp and stair surfaces. Grab bars and railings should be made of solid and durable materials. Traditional building materials can contribute to the local culture and historical heritage and can be integrated with modern building materials for disability-friendly solutions. Materials such as stone, wood, and adobe can be preferred in this context.

This study also emphasizes planning by considering disabled accessibility. Elements such as building entrances, elevators, corridors, and room arrangements should be designed to provide disabled accessibility. Necessary measures should be taken for disabled individuals to perform their daily living activities independently.

In conclusion, this study aims to provide suitable structural solutions for disabled people in three different primary schools in Gostivar Municipality in North Macedonia. Elements such as discretionary pavements, directions, sound warning systems, dimensions, building materials, and design suggestions ensure that students with disabilities are in a safe and supportive environment while studying. The results of this study can be referenced in other similar projects aimed at providing freedom and equality for people with disabilities.

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The Pilot Implementation of Deposit Return Scheme (DRS) in Turkey for Increasing Recycling Rates

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Abstract

It was conducted an evaluation of the applicability of DRS, which was started to be implemented on a pilot scale in Ankara Province Kızılcahamam District in July 2022 within the scope of the Turkey Deposit Return System Project put into effect by the Ministry of Environment, Urbanization and Climate Change in January 2021, taking into account the domestic waste and zero waste practices based on the 6-month data of the wastes separately collected glass, plastic and metal beverage packaging with DRS. Since 2020, domestic wastes have been separately collected in accordance with zero waste regulation in the region as well. The district was determined as a DRS pilot region in June 2022 as well. The DRS application from July 2022 until the end of December 2022 was found very attractive by the public, and nearly six tons of beverage packaging waste was collected separately in a short period of six months. Considering that organic wastes and construction wastes are included as the recyclable wastes collected separately with the zero-waste application, it is evaluated that the DIS application has had a significant success in a short time.

Key words

Deposit Return Scheme, Zero Waste, Recycling

1. INTRODUCTION

In the solid waste management hierarchy, the most important step after the prevention and reuse step at the source is recycling applications. Recycling is the process of collecting and processing materials that would normally be disposed of as solid waste, transforming them into raw materials and obtaining new products. The collection of waste is seen as the most critical step of the waste management process, but this situation varies greatly according to the development-income level of the countries. While 48% of waste can be collected in urban centers in underdeveloped or developing countries, this rate drops to 26% as one moves towards rural areas. While 96% of waste is collected in developed countries such as Europe and North America, upper-middle-income countries can collect 82%, low-middle-income countries 51%, and low-income countries 39% of their waste [1-2]. In the solid waste management hierarchy, the most important step after the prevention and reuse step at the source is recycling applications. Recycling is the process of collecting and processing materials that would normally be disposed of as solid waste, transforming them into raw materials and obtaining new products.

Recycling provides many benefits such as protection of natural resources, especially economy, combating climate change, energy saving, land efficiency, waste reduction, reducing/preventing pollution of environmental components such as air, water and soil, and creating new job opportunities. Despite its many benefits, recycling rates are still not at the desired levels in many countries. The main reasons for this are that many people do not have clear information about exactly which materials can be recycled, where and how, and the necessary infrastructure cannot be fully established. It is possible with the Deposit Return Scheme (DRS) to make the recycling rates, which cannot be increased with a voluntary and environmentally friendly approach, attractive with the return of cash [3].

The New Circular Economy Action Plan was adopted on 11 March 2020, as the EU approved the European Green Deal in December 2019. This action plan is seen as one of the building blocks of sustainable growth to achieve Europe's 2050 climate neutral goal and halt the loss of biodiversity. The EU's transition to a circular economy will reduce the pressure on natural resources and create sustainable growth and employment (Figure 1). The new action plan aims to promote circular economy processes, promote sustainable consumption and prevent waste and ensure that the resources used are kept in the EU economy for as long as possible. Among the measures to be taken within the scope of the new action plan, it is aimed to make sustainable products the norm in the EU, to ensure less waste generation by focusing on sectors with high resource use and cyclical potential such as packaging, plastics, textiles, food, water and nutrients [4-5].

Figure 1. Circular Economy Model [5]

The circular economy model, which is an economy model in which the value of products, materials and resources is preserved in the economy as long as possible and waste generation is minimized; It has become a necessity against the risks of solid waste management such as inefficient use of resources, greenhouse gas and other emissions, depletion of natural resources, difficulty in accessing raw materials, land use limitations and adverse effects on soil and water pollution [6].

Today, when many countries have adopted the circular economy model and started to implement zero waste policies, DRS is considered as the most effective and sustainable way to increase recycling rates and not to leave waste to the environment (Figure 2).

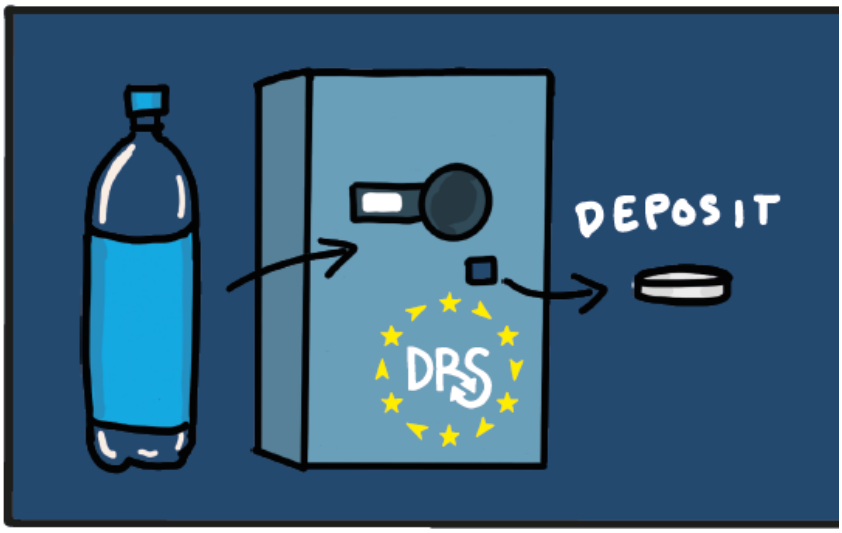

Figure 2. Deposit Return Scheme [7]

DRS is a system in which consumers who purchase a product pay an additional amount of money (deposit) and this amount can be recovered by returning the packaging or product to a collection point. Under DRS, producers and consumers agree as parties to a contract: The consumer buys a product with a package, in which case the package, which is a bottle, remains the property of the producer. The consumer returns the packaging to the owner after using the product content. DRS is an application that helps ensure that the packaging is returned to its owner. DRS is becoming an increasingly attractive application system in the world for various packaging wastes collected through containers placed at any point to ensure their reuse or recycling. DRS is seen as the most important tool to reduce packaging waste, but the system still operates on a packaging production. Some large manufacturers also use the "refill" application within the scope of DRS. According to the system that has just started to become widespread in some European countries, the consumer can buy the product again and unpackaged by refilling the products, especially detergents, in the content of the package, which he bought for the first time, at the filling point [8-9].

Therefore, the pilot implementation of DRS at Kızılcahamam District in Ankara since the last 6 months of 2022 year was investigated in this study. For this purpose, Deposit Return Machines (DRM) have been placed at 5 different points (in front of the National Garden, Zero Waste Garden, Soğuksu National Park Entrance, in front of the Municipality Hall and Cumhuriyet Square) in the district center and, the amount of 6-month packaging waste collected from the DRMs until the end of 2022 were used as study data. In addition, the recyclable wastes collected within the scope of zero waste implementations in the district for the last three years. It was seen that wastes were collected according to zero waste implementations in 2020, 2021 and 2022 in Kızılcahamam District as well.

2. MATERIALS AND METHOD

A pilot scale DRS was first implemented with 4 deposit return machines in the central service building of the the Ministry of Environment, Urbanization and Climate Change in Turkey. Then Kızılcahamam District was chosen second pilot implementation area (Figure 1) for DRS with 5 different public point in order to establish a sustainable, traceable, auditable and controllable system carried out by Turkish Environment Agency before the returnable beverage packages are put on the market (TÜÇA).

Figure 3. The study area

Through these DRM, consumers can bring their packaging wastes for demanding their costs when they pay during the shopping. After taking the empty beverage packages to any DRM and returning them one by one, the machine issues a receipt to the user (Figure 4). Applications called Mobile Application and E-Wallet have been developed for DIS users. With the mobile application installed on the phones from Google Play and AppStore stores, it is possible to log in to the DIS application. When users show the barcode found on this receipt to their phone's camera via the deposit application, they receive "TUCA" points equal to the number of packages they return, and

this score is loaded into their E-Wallet accounts. The earned points can be used for shopping by transferring them to the Ministry Canteen and/or Kızılcahamam Public Transportation Card. Therefore, the data of this pilot project is followed and collected through the deposit information system, and the results are evaluated in this paper before its widespread use.

Figure 4. One of the DRS machines in the Kızılcahamam

3. RESULTS AND DISCUSSION

An evaluation has been made by taking into account the results of zero waste implementation (Table 1). In 2019, the district was selected a zero-waste pilot implementation area and the first recycling applications were started until today. In the second part of 2022, the district was also chosen a pilot area for DRS as well. It is seen that the separate collection rates of recyclable packaging waste remained between 7-10% of all domestic waste during zero waste application period except for the last 6 months of 2022, when the packaging waste was collected according to DRS.

Table 1. Zero waste amount of Kızılcahamam District

KIZILCAHAMAM MUNICIPALITY ZERO WASTE QUANTITIES, kg				
MONTHS	**2019**	**2020**	**2021**	**2022**
JANUARY	-	40,70	49,96	30,44
FEBRUARY	-	42,70	52,52	38,12
MARCH	-	44,54	65,76	62,74
APRIL	-	42,64	50,85	73,74
MAY	-	41,78	62,78	71,32
JUNE	-	62,48	69,40	74,44
JULY	-	78,28	68,00	67,639
AUGUST	-	83,82	79,18	73,227
SEPTEMBER	-	70,52	71,54	75,506
OCTOBER	-	62,50	62,10	80,601
NOVEMBER	8	57,78	50,06	72,287
DECEMBER	23,98	49,52	59,14	71,711
TOTAL	**31,98**	**677,26**	**741,29**	**803,63**

As a first district where the zero-waste application was implemented as a pilot region, 8.000 residences were visited by 170 environmental officers and 15.000 people were directly informed. 70.000 blue waste separation bags and 60.000 cloth bags were distributed and 3.500 students and 350 teachers were informed about zero waste in schools in Kızılcahamam.

As a result of zero-waste implementation that started in the district in November 2019 and continued throughout 2020, 2021 and 2022, and the amount of recyclable waste collected every year increased. The rate of recyclable waste collected separately according to the total amount of EA was 7.3%, 8.7% and 9.8% in 2020, 2021 and 2022, respectively. According to TÜİK 2020 Turkey solid waste statistics, these rates remain very low considering that 38.5% of total domestic waste are recyclable [10]. Atalay (2021) has found why recycling in Turkey could not reach the desired levels that low public awareness about recycling, insufficient training, no habit of separating at the source and difficulties for individuals to reach the separation facilities at the source, the insufficient facilities in terms of number and capacity, not enough licenses for recycling sectors in terms of number. It has also been stated that there are other important factors such as the lack of vehicles with sufficient equipment, lack of adequate measures in terms of legislation, lack of reliable and up-to-date statistical studies, and failure to clarify the recycling model appropriate for the country [11].

Considering these results, recycling habits vary from region to region and city to city in our country. However, although the infrastructure services provided by municipalities have increased significantly over the years through recycling awareness and awareness-raising activities, it is seen that the public's behavior of collecting packaging waste separately has not increased at the same rate. Based on this point, DRS was started to implement in the end of June 2022 in the district as a pilot area. DRS was planned to raise public awareness about the transforming their waste to an economic means or directly money, which is based on the principle of taking the packaging waste of the products purchased by consumers to the sales points for return and receiving a refund for the price they paid for the packaging. During las 6 months of 2022, the packaging waste were collected separately via DRMs in the district. The amount of packaging waste of glass (G), Plastics (P) and Metal (M) collected from DRS machines located at 5 different points in front of the National Garden, Zero Waste Garden, Soğuksu National Park Entrance, in front of the Municipality Hall and Cumhuriyet Square are shown in Table 2 during the pilot implementation period between July 2022 and December 2022. These amounts are direct weight of the individual packaging wastes in the district now total zero-wastes due to organic or other content of zero-wastes.

Table 2. DRS waste amount in Kızılcahamam District

KIZILCAHAMAM MUNICIPALITY DRS WASTE QUANTITIES, kg															
	National Garden			Zero-Waste Garden			Soğuksu National Park			Municipality Hall			Cumhuriyet Square		
MONTH	**G**	**P**	**M**	**G**	**P**	**M**	**G**	**P**	**M**	**G**	**P**	**M**	**G**	**P**	**M**
JUL	0,5	0,03	0,03	-	-	-	-	-	-	-	-	-	-	-	-
AUG	34,75	9,9	0,5	-	-	-	77,5	30	0,5	-	-	-	-	-	-
SEP	110,5	33,7	1,53	107	27	0,735	324,5	153	4,68	4	10,85	0,255	4,5	11,41	0,645
OCT	164	90	3	965	223	12,7	-	-	-	41	39	2,67	52,5	59,3	7
NOV	300	217	15	1452	305	16,8	0,25	4,47	0,015	261	156	9,5	632	190	14
DEC	832	431	18	2664	548	21	6,25	4,86	0,09	363	190	5,5	428	163	4,4
TOTAL	**1441,75**	**781,63**	**38,06**	**5188**	**1103**	**51,235**	**408,5**	**192,33**	**5,285**	**669**	**395,85**	**17,925**	**1117**	**423,71**	**26,045**
G. TOTAL		**2261,44**			**6342,24**			**606.11**			**1082.78**			**1566.76**	

According to Table 2, approximately 2.26 tons of glass, plastic and metal packaging waste were collected at the DRM in front of the National Garden; Approximately 6,34 tons of glass, plastic and metal packaging waste were collected at DRM in the Zero-Waste Garden, 606,11 kg for glass, plastic and metal packaging waste at DRM located at the entrance of Soğuksu National Park, 1,08 tons of glass, plastic and metal packaging waste at the DRM in front of the City Hall, and finally 1,57 tons of packaging waste for glass, plastic and metal packaging waste at the DRM in Cumhuriyet Square.

According to these results, packaging waste collected separately for 6 months according to DRS will have a share of approximately 1,5% in zero-waste, where 0,5 tons in the first month and then increased to 5,67 tons in December 2022. While the rates of waste collected separately according to the zero-waste application have not changed

significantly in the district in the last three years, DRS has shown a significant progress in just 6 months. Considering that the recyclable waste collected separately with the zero-waste application includes organic waste and construction waste, it can be seen that DRS application has caused a significant success in a short time. If DRS becomes widespread, it is expected that the structure of disposal activities such as licensed companies, neighborhood warehouses, municipal collection system, street collectors and landfills will change significantly. DRMs will be placed in many social areas, parks, gardens and store centers, especially in shopping malls, and an important infrastructure system combined with digital technology needs to be established so that consumers can take and return packaging waste to these points as the process developed. Within DRS application zero-waste targets of Turkey can be importantly achieved by increasing the amount of separately collected packaging waste, preventing environmental pollution, municipalities saving on transportation costs, preventing practices such as sorting garbage on the streets, and ensuring effective use of regular landfills. It is expected to make significant contributions to the economy and resource use.

DRS is a system in which consumers are motivated to voluntarily collect plastic packaging, which has become a huge problem in nature, and other packaging, such as glass and metal boxes, by consumers when they return the packaging to the collection points, and both the infrastructure and the consciousness of the people. It is possible to increase the recycling rates considerably after the basic levels of DRS implementation. DRM will be placed in many social areas, parks, gardens and store centers, especially in shopping malls, with DRS, and an important infrastructure system that combines with digital technology should be established so that consumers can take and return packaging waste to these points. With DRS, which is planned to be spread all over the country in 2023, it is aimed to achieve zero waste targets to a large extent, to increase the amount of separately collected packaging waste, to prevent environmental pollution, to save municipalities on transportation costs, to prevent practices such as sorting garbage on the street and to ensure effective use of sanitary landfills. It is expected to make significant contributions to the economy and resource use. The main principles of DRS application; It is necessary to disseminate throughout the country, the material type, size and beverage type of the included returnable beverage packages should be determined correctly and these packages should contain a large part of the total beverage industry, preferably more than 90%.

By the end of 2022, over 50 countries all over the world had DRS for the recycling of single-use drink containers. As a policy tool to manage wastes grown over the past decade, DRS is proven to collect high quantities (over 90%) of recyclable materials that the authorities seek to implement [13]. In addition to high recycling rates, a DRS that is designed and operated by high-performance principles, can create jobs, bring cost savings for municipalities by contributing circular economy, avoid carbon emissions, and reduce plastic wastes which is considered an important threat for oceans in these days.

4. CONCLUSIONS

It is known that every society has its own characteristic structure. For this reason, it is seen that the habits that need to be gained in order to obtain high efficiency from the newly implemented systems should be in accordance with the character structure and behavioral characteristics of the societies. DRS, which is being rapidly implemented by all countries of the world, is inevitable for our country's zero-waste targets. For this reason, social areas, youth centers, libraries, kindergartens and playgrounds, mosques and places of worship, grocery stores, markets and shopping centers, in short, every area where life activities are carried out should be considered to implement for DRS. Raising awareness with various advertisements and public spots in broadcasts with a high audience, it is thought that it will be important both in terms of spreading the practice of DRS and creating zero waste awareness and reducing all other environmental problems.

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CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest.

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Life Cycle Assessment for Sustainable Solid Waste Management in Erzurum City

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Abstract

Waste amount has increased and solid waste management has become an important environmental issue with the increase in population and the change in social living conditions. Therefore, solid waste management is important in terms of controlling environmental impacts. Life Cycle Assessment (LCA) is a method that measures the environmental impact of products or systems throughout their life cycle. Working with a cradle-to-grave approach, LCA starts from raw material supply and continues with production, transportation, consumption and waste generation. Evaluation of products and services throughout their life cycles provides an opportunity to evaluate the environmental impacts of the decisions. The aim of this study is to develop a LCA framework that enables a sustainable solid waste management system for Erzurum city. Thus, it can be developed a road map to reduce environmental pressure caused by solid waste. The solid waste LCA system, which will be implemented for a determined process, consists of the four elements as system boundaries, waste characterization, waste facilities, and environmental impacts.

Key words

Solid Waste, Erzurum Province, Life Cycle Assessment

1. INTRODUCTION

Globalization and industrialization increase the amount of waste all over the world. In addition, the increase in urbanization and industrialization necessitates the management of this increase in the respect of amount of waste. In this way, it is possible to create more livable environments and to ensure sustainability. Solid wastes are defined as solid materials that are intended to be disposed of by the manufacturer and that must be disposed of regularly, especially in terms of environmental protection. It is material, which is not in liquid form, and has no value to the person who is responsible for it [1].

It is necessary to ensure that solid wastes are collected, transported, recovered and disposed without harming the environment. Solid waste management is the one thing just about every city government provides for its residents. In this point, it is necessary to ensure that solid wastes are collected, transported, stored and disposed without harming the environment. So, solid waste management is arguably the most important municipal service [2]. Annually, about 2.01 billion tons of municipal solid waste (MSW) are produced, and that is estimated to reach 3.40 billion in about 30 years. Even though, less than twenty percent of them is recycled, a very big amount are still sent to landfill sites. Waste is also often disposed of at hazardous open dump sites, especially in developing nations [2]. Managing waste properly is essential for building sustainable and livable cities. Effective solid waste management systems require integrated systems that are efficient, sustainable, and socially supported. One of the big challenges that today's growing cities are coping with is the delivery of effective and sustainable waste management, together with a good sanitation [3].

Life cycle assessment (LCA) is an internationally standardised method (ISO 14040/44) for the evaluation of potential environmental impacts that provides to identify environmental hotspot areas allowing LCA to become one of the most accepted environmental performance tools today. LCA is a process of evaluating the effects that

a product has on the environment over the entire period of its life thereby increasing resource-use efficiency and decreasing liabilities. It can be used to study the environmental impact of either a product or the function the product is designed to perform. LCA is commonly referred to as a "cradle-to-grave" analysis. LCA's key elements are: (1) identify and quantify the environmental loads involved; e.g. the energy and raw materials consumed, the emissions and wastes generated; (2) evaluate the potential environmental impacts of these loads; and (3) assess the options available for reducing these environmental impacts. The main areas of the application of LCA within public environmental politics are waste treatment options, means of transport, energy sources, and product's choice [4-5].

LCA studies the environmental aspects and potential impacts from raw material acquisition through production, use and disposal. LCA is a valuable tool for evaluating the total environmental impacts of solid waste management options within a boundary. Many researchers use LCA as a combined tool to evaluate the environmental performance of solid waste management systems such as marine litter [6], urban solid waste [7], municipal solid waste [8] etc. From this point of view, the aim of this study is to develop a LCA framework that enables a sustainable solid waste management system for Erzurum city. The study is structured in two parts: theoretical framework including the background information on life cycle assessment, and the application of solid waste life cycle assessment.

2. THEORETICAL FRAMEWORK

2.1. Life Cycle Assessment

Life Cycle Assessment (LCA) is a method that measures the environmental impact of products or systems throughout their life cycle. Working with a cradle-to-grave approach (Figure 1), LCA starts from raw material supply and continues with production, transportation, consumption and waste generation. LCA is a globally used and accepted method for assessing environmental impacts of a product's life cycle from cradle to grave, including all life cycle phases: production, use, waste. It is a computer-based tool used to assess the environmental burden as well as benefits associated with a product or service.

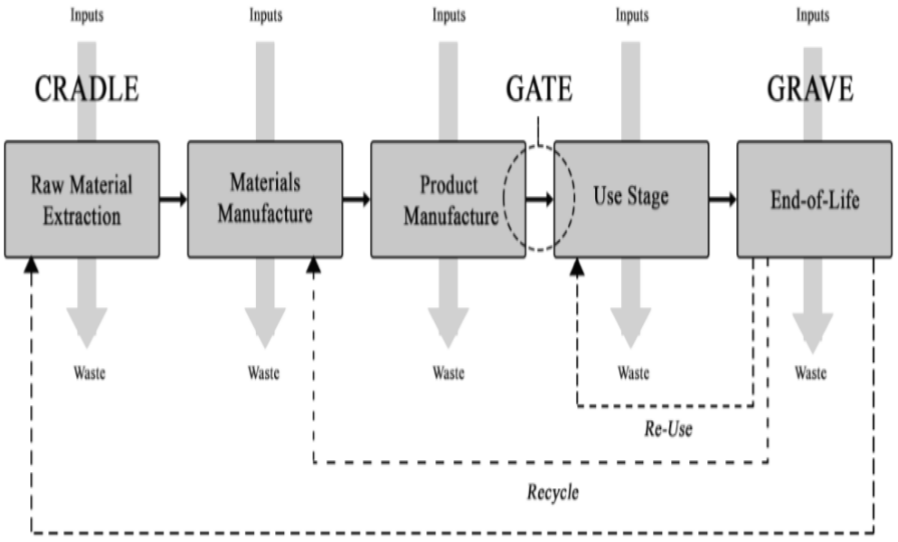

Figure 1. Ecological loop (Cradle-to-Cradle)

LCA has mainly been developed for analyzing material products, but can also be applied to services, e.g. treatment of a particular amount of solid waste [6-7]. LCA can be used for municipal [8-12] and hospital [13-16] solid waste generally.

2.2. Solid Waste Life Cycle Assessment (SWLCA)

Solid waste amount has increased and its management has become an important environmental issue with the increase in population and the change in social living conditions. Planning the waste applications for solid wastes in a way that will not harm the environment is important in terms of managing environmental impacts. Evaluation of products and services throughout their life cycles provides an opportunity to evaluate the environmental impacts of the decisions.

Solid waste life cycle process boundary is the interface between the waste management system and the environment or other product systems as in Figure 2. The life cycle starts once a material or product becomes waste, i.e. its owner discards it in the waste collection bins. Solid waste is collected either via mixed-bags or via separate collection. Each collection method requires its own infrastructure.

The transportation stage follows. In the solid waste management system of developed countries, the mixed bag waste can either go to the landfill, the waste- to-energy facility or to the treatment plant. The source-separated waste, if it is a dry stream, can go to the material reclamation facility or if it is a wet stream can go directly to the biological treatment facility [17-19].

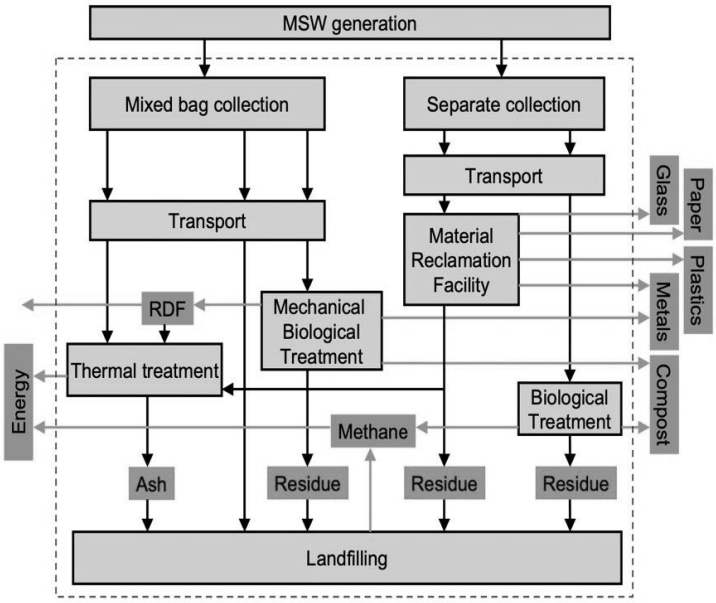

Figure 2. The complete life cycle of municipal solid waste [20]

3. APPLICATION

The SWLCA system, which will be implemented for a determined solid waste management system, consists of the many hierarchical processes. According to it, SWLCA application for solid wastes generated in Erzurum City has been carried out in four elements as *system boundaries, waste characterization, waste facilities,* and *environmental impacts.*

3.1. System Boundaries

The system boundaries of the waste management of Erzurum City determined in the study is shown in Figure 3. According to it, there are five main processes in the application. In the first stage, the produced wastes are collected and transported. There are two alternative ways to transportation of the wastes. In the first of these, the wastes are transferred to the transfer station firstly and then sent to the landfill. In the other alternative, the wastes are sent directly to the landfill. The wastes in the landfill can be sent to the relevant facility for energy production, as well as to the leachate treatment facility.

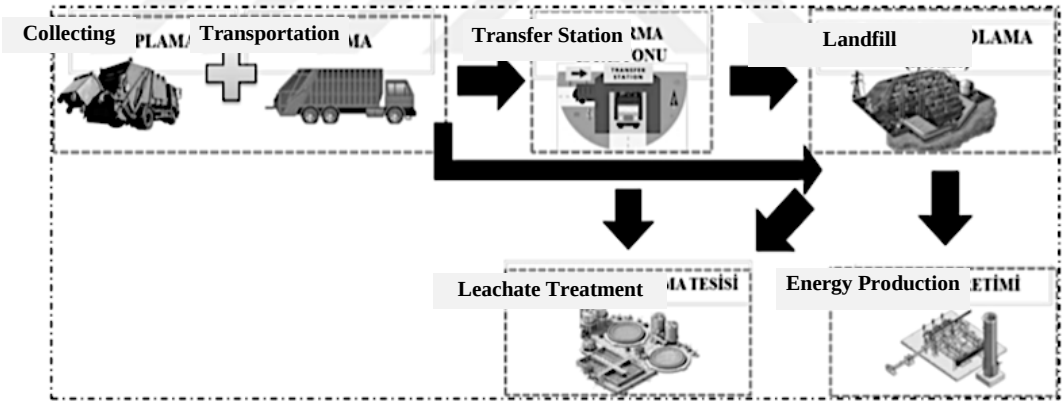

Figure 3. The system boundaries of the waste management of Erzurum city

3.2. Waste Characterization

In order to carry out the SWLCA application, the waste characterization of the relevant city should be determined. In this context, waste characterization of Erzurum City determined in the study can be seen in Table 1. The waste amount in Erzurum city is 21.600 tonnes per mounth.

Table 1. The Waste Characterization of Erzurum City (%)

		Summer	**Winter**
Recyclable Wastes	Glass	2,96	2,96
	Metal	1,31	1,31
	Paper / Cardboard	6,80	6,80
	Plastic	10,69	10,69
Other Wastes	Waste Medicine	0,60	0,60
	Vegetable Waste Oil	0,17	0,17
	Waste Battery	0,32	0,32
	Textile Waste	1,00	3,60
	Electronic Products	1,10	0,11
	Bulky Wastes	17,50	17,50
Biodegradable Wastes		56,94	56,94
Total		**100**	**100**

3.3. Waste Facilities

Another important step in SWLCA implementation is to determine the facilities in the waste management system. According to it, waste facilities of Erzurum city determined in the study can be seen in Table 2.

Table 2. The Waste Facilities in Erzurum City

Facility	**Amount**	**Capacity (tonnes/year)**
Packaging waste collection separation plant	2	34.483
Recycling plant.	2	6.855
Non-hazardous waste collection separation plant.	14	-
Landfill Plant	2	131.400

3.4. Environmental Impacts

It is very important to determine the scope of the calculations within the SWLCA application. Thus, environmental impacts of the wastes need to be revealed. Therefore, environmental impacts arising from waste managed in Erzurum city on the basis of impact categories presented in Table 3.

Table 3. Environmental impacts of solid wastes in Erzurum city

Global Impacts	• Global warming. • Soil moisture loss. • Forest loss/changes and changes in wind. • Ozone depletion. • Consumption of natural resources – Depletion of natural resources for future generations.
Regional Effects	• Photochemical smog. • Acidification.
Local Effects	• Human health, • Terrestrial toxicity. • Aquatic toxicity. • Eutrophication, Land use – Loss of terrestrial habitat necessary for natural life and reduction in landfills. • Water use – Reduction in existing surface and underground water resources.

4. CONCLUSIONS

Solid waste management is the one thing just about every city government provides for its residents. So, solid waste management is arguably the most important municipal service. One of the big challenges that today's growing cities are coping with is the delivery of effective and sustainable waste management, together with a good sanitation. The main goal of this study is to develop a LCA framework that enables a sustainable solid waste management system for Erzurum city.

The SWLCA system, which will be implemented for a determined solid waste management system, consists of the many hierarchical processes. This study indicates that there are four main elements of an effective SWLCA application. They are system boundaries, waste characterization, waste facilities, and environmental impacts.

This study has also some limitations. For instance, no numerical analysis was made within the scope of the study. Therefore, similar studies are needed in different empirical contexts to further validate the process. Moreover, the study also cannot provide an estimation about the effect of a SWLCA to be implemented in Erzurum city. Accordingly, further studies are needed to calculate the estimation of an implemented SWLCA model.

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest.

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Analysis of Bioclimatic Features of Vernacular Architecture – A Case Study of Vernacular Residential Buildings in Sarajevo

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Abstract

The imperative of today's architects and urban planners is to identify and implement sustainable solutions that would increase the overall quality of the urban environment and people's well-being, by maintaining a natural balance and integrity. In this regard, the bioclimatic principles of vernacular architecture can serve as inspiration for designing buildings in a contemporary urban context. This approach can help to gain knowledge about the practices of vernacular architecture, and define solutions that can deal with today's urban challenges, such as urban and environmental pollution, lack of comfort, and low quality of life. This paper presents the analysis of bioclimatic features of three well-preserved vernacular residential buildings, located in Sarajevo, Bosnia and Herzegovina. The research methodology is based on the literature research, photo documentation, and field observation, regarding the presence of bioclimatic design principles, such as building form, orientation, layout, use of local building materials, topography, traditional passive strategies - sun shading, cooling and natural-induced ventilation, natural landscape, and comfortable living environment. The results of this research showed that the selected vernacular buildings fulfill most of the basic bioclimatic principles, which could be transposed into contemporary architecture, not in the context of a pure replication of an old style, but as a modern sustainable architectural design. The analysis also showed that the potentials of passive heating were not exploited in the best possible way, therefore the improvement of the building design will be a necessary step in order to be implemented in the design of sustainable architecture.

Key words

Contemporary architecture, sustainability, vernacular architecture, bioclimatic features

1. INTRODUCTION

In recent decades, a dynamic trend of urban expansion has been noticeable, accompanied by population growth, modifications in the spatial and social forms of cities, and economic prosperity [1], [2]. Urban settlements, which are often viewed as a "complex phenomenon" [3, p.6], contributed to the transformation of the lifestyle and the environment itself, through significant impact on socialization, improvement of living standards, and economic development [4]. Considering that every progress also has its negative impact, the current global situation is the indicator that the outcome of such progress significantly leads to an "environmentally, socially and economically unsustainable" direction [1, p.8]. A significant increase in concerns about environmental conditions, climate change, and energy crises, has "forced" society to reconsider the mistaken belief that nature is only there to satisfy the needs of humanity, providing unlimited availability of natural resources [4], [5]. This situation required the transformation of environmental consciousness, as well as strategies and activities in the context of sustainability, with the aim of reestablishing a balance between man-nature-architecture, and "the need to protect the environment

in order to preserve human welfare“ [4], [5, p. 41]. These sustainable principles are not a new paradigm, as mentioned in the [5, p.35] “the history of architecture tells us that architecture has been sustainable since its birth and that since its very origin, it has satisfied many of the needs that today are no longer met.”

The origins of today’s sustainable architectural principles can be found in the design principles of indigenous architecture, known as vernacular architecture. The tendency of vernacular builders was to design and construct buildings in a way that minimizes their environmental impact and maximizes their social and economic benefits [6]. Design solutions relied on passive bioclimatic strategies that incorporated architecture and the natural environment, through the use of local materials, natural resources, traditional construction techniques, site features (climate, morphology, orientation), building design (layout, form), and passive strategies (cooling, ventilation, solar, water, and vegetation) [5], [7], [8]. Traditional building, in accordance with these principles, "is integrated into the environment and does not harm other elements of the ecosystem" [5, p. 44], providing residents with a healthy and comfortable living environment. Many researchers believe that the benefits of this type of architecture can be used for future sustainable building design, due to its design strategies that use bioclimatic passive principles in the architectural context [9], [10]. But it is necessary to take care that the implementation of sustainable principles of vernacular architecture should not be a mere imitation of the concept in the contemporary design because otherwise, it will represent a risk of “ignoring the lessons of sustainability of local vernacular architecture, without taking into account specific local conditions and materials, based on other vernacular architectures from faraway lands, in other environments and with other basic conditions” [5, p. 36].

In this paper, we will analyze the presence of bioclimatic features in three representative and well-preserved vernacular residential buildings from the Ottoman period, located in Sarajevo, the capital of Bosnia and Herzegovina (B&H). The chosen houses are significant as a cultural heritage and national monuments. The focus of research will be on the analysis of the environmental-social sustainability features – appropriate topography, orientation, and location on the site; building compactness; use of locally available materials and resources; use of non-polluting materials; adequate strategies for passive cooling and natural ventilation; adequate natural lighting and sunshine protection; vegetation and greenery; healthy and comfortable microclimate. The aim is to estimate if such building design can serve as a role model for the integration of traditional and modern design values, with a tendency to achieve modern sustainable buildings, with optimal energy consumption and environmental performance, and enhanced thermal and visual comfort

2. CONCEPT OF TRADITIONAL URBAN SETTLEMENTS IN SARAJEVO

Bosnia and Herzegovina is one of the countries characterized by its rich architectural heritage. Its architecture was mainly created under the influence of the political and social changes of the different development periods, and each period had an authentic impact on the development of cultural diversity and specific architectural expression [11]. The period that had a strong influence on Bosnian architecture, especially through the emphasized relationship of architecture to nature and life, was the Ottoman period. In that period, along with the development of urban planning, urban areas began to emerge and acquire their basic form, the organization which is still noticeable today [11]. Architecture, as well as urbanism, was organized around a series of unwritten laws, which included: human proportions, unobstructed views, geometry, open and flexible spaces, simple furniture, spatial connections with nature, and the use of local and traditional construction methods [11]. Although it seems that the architecture of B&H had the characteristics of Ottoman-oriental architecture, it also had some of its specific characteristics, when domestic builders, neimars, introduced elements of the local traditions. Mahalla was one of the traditional settlements that was significant due to its conceptualization as a residential area of the city, located outside the main traffic arteries. The residential house adapted to the environment by using natural, local materials for construction, respecting climate, and fitting in the terrain due to the exceptional skills of domestic builders. In Sarajevo, houses in mahallas, as peri-urban residential settlements, were placed on the hillside, gradually, with a carefully chosen building site in accordance with the non-written, building law – to respect the right of view and the right to privacy, Figure 1 [12].

Figure 1. Horizontal and vertical displacement of houses – “the right of a view” [12]

Mahallas were connected by alleys or sokaks that were branching off on both sides of the main street, where were entrances to the houses. From the street, the houses blended into the ambiance and formed an integral part of the mahalla, and the houses can be considered as belonging to anyone and for anyone as long as they are all in human proportions [13]. For the visitors, the house is hidden and protected from the outside views by a high white wall,

as a physical boundary between built and unbuilt environment, with a characteristic courtyard door, as a very significant element of housing in functional and decorative terms [13], [14]. As much as the residential complex is separated from the outside world, from the street and the uninvited curiosity of passengers, the house and its layout were so open towards nature, as an integral part of every house in the mahalla. Gardens or avlija provided comfortable and healthy microclimate for living, a source of joy, and the entire complex in the architectural sense represents a harmonious relationship, where nature becomes an element of the composition and nature passes into architecture [13], [15], [16]. There was a strong emphasis on vegetation, and gardens were decorated with a variety of fruit trees, and flowers [12], [13]. The natural environment, according to an unwritten rule, was also enriched by flowing, clean water. The presence of water was important because of two reasons: one is the sanitary needs, to which a lot of attention was paid, and the other is the desire to enjoy the freshness and the noise of that water [12], [17]. The construction of the house was quite simple, characterized by cubic forms, gently sloping roofs, different floor materialization, verandas, courtyards, and doksat on the first floor, overhanging the street. The combination of closed, open, and semi-open spaces, was primarily due to the desire for space, and the desire for nature to be part of the architectural composition, creating a high degree of unity. Houses were built mostly from natural materials, such as stone, wood, and adobe brick [12], [17], [18]. The domestic architecture used mainly adobe bricks because it required less effort and expense for the production, processing, and transportation than stone, which was done near the construction site. Wood retains its natural appearance and structure everywhere, as a constructive element and an architectural decoration [12]. The common use of this construction material was due to the forest wealth of Bosnia and Herzegovina.

3. RESEARCH METHODOLOGY

The aim of this research is to analyze the bioclimatic features of vernacular residential architecture on the example of three well-preserved vernacular town houses, located in Sarajevo, B&H, and to examine if the good architectural principles and practices of vernacular architecture can serve as an inspiration for the design of sustainable contemporary buildings. The performed analysis consists of literature study, photo documentation and field observation. Based on the collected data and layout drawings obtained from the study literature and observation on the site location, a detailed survey was conducted regarding the presence of bioclimatic design principles. The analysis of the various bioclimatic elements of the chosen vernacular houses includes the investigation of the following characteristics:

• Building location and utilization. When planning the integration of bioclimatic elements into the building, it is very important to take into account microclimatic factors, such as climate and landscape, with the aim to find the right location with lots of sun, wind, vegetation, and water in order to create a healthy living microclimate. The influence of these factors is reflected through proper orientation, positioning, form, and materialization of the building [19, p.19]. These natural elements can also be used for passive heating and cooling [7]. Building utilization refers to optimizing the size of the spaces inside the house, without disturbing their comfort, in order to reduce heating and cooling demands.

• Building form and orientation. Considering the orientation of the building in the process of planning and construction of the building, it can have a significant impact on "the energy performance of the building throughout its life cycle" [19, p.18]. That is why the integration of proper design (form, orientation, spatial configuration) and natural resources of the environment [5], [19], can enable diverse solutions that contribute to energy consumption reduction and internal comfort. The openings have to be positioned in a way to make maximum use of daylight and reduce the need for artificial lighting. During the winter it is important to use as much solar heat gains as possible to reduce energy demand for heating.

• Local, natural building materials and construction. The focus should be on using materials that have environmental advantages, such as natural, locally found materials with low environmental impact; recyclable or biodegradable, and with good thermal characteristics [5], [19]. Building construction has to be adapted to the local climate conditions.

• Natural cooling and ventilation. Natural ventilation can be obtained through proper orientation of the building, facade openings (size, disposition, quantity) and sun shading elements that do not obstruct free airflow. Natural vegetation (gardens, courtyards) and the presence of water (water fountains), can be used as additional elements of passive cooling.

4. CASE STUDY – ANALYSIS OF THE BIOCLIMATIC FEATURES OF VERNACULAR RESIDENTIAL BUILDINGS IN SARAJEVO

In this paper, three vernacular houses in Sarajevo from the Ottoman period are analyzed: Alija Đerzelez's house (Figure 2), Sabura's house (Figure 3), and Svrzo's housing complex (Figure 4). Chosen houses were built during the 17th Century and represent the most authentic examples of residential architecture from that period in B&H,

which survived in their original form or have been restored, partially or completely to this day. The Commission to Preserve National Monuments designated these houses as national monuments of Bosnia and Herzegovina. The locations of the buildings were carefully chosen. Houses were built on slopes of the hills, positioned towards the most beautiful views of the city, in a way not to obstruct neighbors' views. These locations are airy with plenty of sunshine. The position of the houses in accordance with the terrain confirms that „buildings exist within an environmental context" [5, p. 43], meaning that achieved livability and building characteristics were influenced by „site's feature, culture and local climate" [5, p.43].

Figure 2. Alija Đerzelez's house [20]

Figure 3. Sabura's house [21]

Figure 4. Svrzo's house (Source: Authors)

Organizationally, each house was divided into four functional units: habitation, leisure and relaxation, utility, and outer spaces with vegetation and water. Conceptually, this included: the fence, which defined the street and separated the private from the public space; the courtyard, which was cobbled; the fountain as a basic part of hygiene before entering the house; the garden; the ground floor, or semi-private space where the family gathered. Kamarija and divanhana, the semi-open spaces on a first floor, which served as transitional spaces from the interior to the exterior, had a private character, and were used mainly for rest and enjoying the view of the bazaar, or the view of nature [11], [15].

The main living rooms in the house called halvat and čardak had a multifunctional character. Flexible use of the rooms was obtained by reducing the furniture to two basic fixed elements and mobile furniture, which was brought into the room when needed. This interior design enabled the reduction of the size of the room to a minimum. This is important from the aspect of energy savings, because large spaces are requiring more energy for heating and cooling.

4.1. Building Form and Orientation

The basic design concept of analyzed houses was the separation of private, family life from noisy, public life on the street. Therefore, houses were oriented towards inner courtyards and gardens. Secondly, there was the division of the houses into winter and summer quarters. Winter quarter is located on the ground floor and summer quarter is located on the first floor. Winter quarters are more compact and closed with few smaller windows. The reason for such design approach was to reduce heat losses during the winter period. Negative aspect of such building design is reflected in limited heat gains from the sun. Additionally, the shadow is created from kamarija and divanhana on the first floor which reduces solar heat gains even more [22]. This is especially emphasized in Sabura's house, where kamarija is on the south side of the main living room. Also, fewer windows and shadows from the first floor are minimizing daylight harvesting and increasing the need for artificial lighting.

Summer quarters, where closed and semi-open spaces intertwine, are playful and more open, with many large windows, oriented mainly towards the south, west, and east. In this way, interiors of the analyzed houses are perceiving a lot of natural light during the day, which is positive from the bioclimatic aspect because it can reduce the need for artificial lighting. Considering that the rooms in summer quarters are accessed through semi-open spaces, they are not exposed to direct sunlight from the south, in order to keep the rooms as cool as possible [22].

4.2 Local Building Materials and Construction

Several different sun-shading elements were used in the summer quarters of the houses for the protection of inner spaces from overheating during the summer. Mušebak is a wooden lattice element that has a double purpose. First, it acts as a vernacular version of a modern double-skin facade. In the space between mušebak and the window, due to the shade and lower temperature, airflow is enabled [22]. Secondly, the semi-transparent structure of the mušebak is reducing solar radiation that enters the room, while providing optimal natural lighting. Beside mušebak, in Alija Đerzelez house, nontransparent wooden shutters, placed on the inner side of the windows were used, Figure 6. In Svrzo's house, on some windows, iron window shutters, placed on the outer side, were used, Figure 7. The main purpose of the iron window shutters was to secure houses from intruders, but they were also used as protection from strong winds and storms, or direct solar radiation during the summer. In all three analyzed houses, the main sun-shading element used on windows was mušebak, Figure 5.

Figure 5. Mušebak on the windows of kamarija [23]

Figure 6. Wooden shutters on windows [24]

Figure 7. Iron window shutters on windows (Authors, 2022)

In all three analyzed houses sun shading of the first floor is additionally provided by roof eaves. The doksat on the first floor is providing sun shading to the rooms on the ground floor, but also an appropriate shading for pedestrians, as the first floor is overhanging the street [22]. All the streets (mahala) are very narrow and surrounded by houses with overhanging first floors. This spatial organization of the residential quarters within the city gives pedestrians a place to hide from the heat during the hot summer days.

Natural ventilation was achieved through a thoughtful building design. Elements used for achieving qualitative natural ventilation of the summer quarters were: semi-open spaces, careful disposition and the size of the windows, the inner spaces organization, and courtyards and gardens.

In the semi-open spaces, divanhana (Figure 8) and kamarija (Figure 9), due to a shade and lower temperature, airflow is established, and solar radiation is reduced, creating a living space with a pleasant climate. Careful disposition and sizing of the windows enable cross ventilation through windows that are open at the same time throughout the house during the summer [22]. In Sabura's house, on the upper part of the walls, above the windows, there are holes which are enabling airflow even when the windows are closed, Figure 10.

The rooms placed in the middle of the house were cross ventilated through the corridor called hajat and the kitchen (mutvak), in which the windows were always opened. Vertically, the ventilation was achieved through the hajat and the kitchen which has ventilation openings in the roof to allow the smoke and steam from cooking to escape. Therefore, the houses are ventilated in both ways, horizontally and vertically.

Figure 8. Divanhana in Sabura house [26]

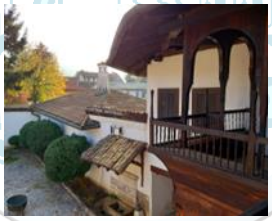


Figure 9. Kamarija in Svrzo's house (Authors, 2022)

Figure 10. Ventilation elements in the walls above windows [27]

The courtyards and gardens contribute significantly to the process of natural cooling of the houses during the summer, Figure 11. Trees, fountains and wells were the key elements of every courtyard. Gardens were enriched with flowers and fruit trees. Planting deciduous trees to shade south, east, and west side of the building is beneficial in the summer by creating a refreshing effect. Dense tree canopies are providing a natural shadow. They also regulate wind mitigation and its direction, which improves natural ventilation. In winter, deciduous trees shed their leaves and allow sunlight to reach the winter quarters of the houses. Therefore, they do not obstruct the utilization of solar heat gains for passive heating.

Figure 11. Integration of the greenery in Svrzo's house complex, small garden - left, Men's courtyard – right [28]

Figure 12. Water fountain in the garden (Sourse: Authors, 2022)

Water elements, in the form of fountains, through the process of evaporation, additionally contribute to lowering the temperature during the hot summer days, Figure 12.

5. DISCUSSION

Examples of analyzed vernacular houses show the importance of proportions, scale, and volume in architecture for users and visitors in creating a personal impression and a pleasant experience of a certain built environment. The conceptual approach that architecture is built from nature and the environment, represents the utilization of bioclimatic elements such as the use of local building materials, simple, cubic forms, adaptability to a specific location and climate, and passive strategies for cooling and natural ventilation (wind, vegetation, local breezes, water). Such design, with a tendency to achieve a balance of aesthetics and function, without comprising nature and needs of people, represents an important basis for reinterpretation of heritage values into contemporary architecture, by improving the sustainable design with continuous progress.

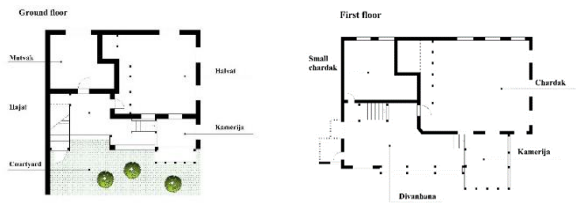
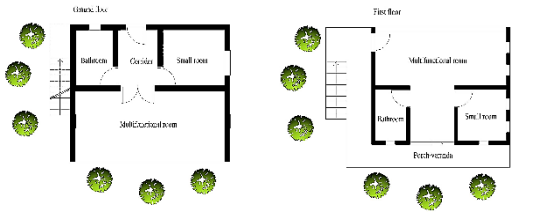
The findings presented in this paper do not propose rejection of modern technological achievements and pure replication of the good vernacular building practices. In order to achieve sustainable built environment, we need new architectural perspective in which valuable traditional knowledge is combined with new industrial innovations and emerging technology. Also, negative aspects of the vernacular building design which are reflected in the use of building materials with thermal characteristics that do not meet today's standards of energy efficient architecture, insufficient use of passive solar heat gains in winter and uncontrolled infiltration losses need to be improved in a contemporary bioclimatic building design. The guidelines for the contemporary bioclimatic building design, based on the positive characteristics found in vernacular architecture, as a model for future, are shown in Table 1. From

the analysis presented in this paper, it can be concluded that the most significant characteristic of vernacular houses from Ottoman period in Sarajevo is the division of the houses in winter and summer quarters and their adaptation to seasonal conditions. Secondly, the multifunctional character of the rooms makes a significant contribution to the overall reduction of required energy for heating and cooling through optimization of the room dimensions without interrupting the comfort of living for the tenants. This can be achieved by introducing multifunctional furniture, which can change its purpose during the day. A schematic floor plan representation of a proposed contemporary house, based on these principles, and based on the guidelines for contemporary building design, is shown in Table 2. Following guidelines were taken into account: multifunctional character of the rooms, division of the house into winter and summer quarters, winter quarter oriented towards south, with large windows, closed towards north, summer quarter opened towards north and east, with large windows, few smaller windows towards south, semi-open spaces in summer quarter in the line of the ground floor, deciduous trees on the west and south side for natural cooling.

Table 1. The guidelines for the contemporary bioclimatic building design, based on vernacular architecture

Vernacular building design	**The guidelines for contemporary building design**
building in a human scale	building in a human scale
multifunctional character of the rooms	multifunctional character of the rooms
division of the house into winter and summer quarters	division of the house into winter and summer quarters
compact and closed winter quarter with fewer windows	winter quarter oriented towards south, with large windows, closed towards north with few smaller windows
playful and open summer quarter with many large windows, oriented towards the south, west, and east	summer quarter opened towards north and east, with large windows, few smaller windows towards south
sun shading elements on windows in summer quarter	sun shading elements on windows in summer quarter
natural cross ventilation in horizontal and vertical direction	natural cross ventilation in horizontal and vertical direction
uncontrolled ventilation, high infiltration losses	controlled ventilation, good air-tightness of building envelope elements
the protruding semi-open spaces in summer quarter on the first floor, creating shadow for the winter quarter on the ground floor	semi-open spaces in summer quarter in the line of the ground floor, without obstructing heat gains from the sun in winter quarter
courtyards and gardens for natural cooling	courtyards and gardens for natural cooling
natural, locally found building materials with low embodied carbon, recyclable	natural, locally found building materials with low embodied carbon, recyclable
high thermal mass of the walls in winter quarter	high thermal mass of the walls in winter quarter
low thermal mass of the walls in summer quarter	low thermal mass of the walls in summer quarter
no thermal insulation in building envelope elements	good thermal insulation of building envelope elements, use of organic, natural insulation materials
single-glazed windows with wooden frame	triple-glazed windows with wooden frame

Table 2. The proposed contemporary building design, based on vernacular architecture

The principles of vernacular building design	The proposed contemporary building design
	
Sabura's house: left – winter quarter, right – summer quarter	*Contemporary model house: left – winter quarter, right – summer quarter*
	
Multifunctional room in Svrzo's house during the day	*Multifunctional room in winter quarter during the day*
	
Multifunctional room in Svrzo's house at night	*Multifunctional room in winter quarter at night*

6. CONCLUSION

Bioclimatic principles recognized in the analyzed vernacular houses from the Ottoman period in Sarajevo can be used as an inspiration for contemporary architecture. These vernacular houses show that in the old times, the approach to urban settlement planning was carefully thought out with great respect toward people's needs on one side and towards nature on the other side. The analysis showed that in vernacular houses, a high standard of living was achieved. Opposite of that holistic approach, Sarajevo today is faced with increased urban development and poor living standard, which is the result of unsustainable urban planning. The right approach to overcome the negative environmental impact of unsustainable urban planning, which is a major problem nowadays, is to learn from the past and to interpret all the good traditional principles through a new contemporary design. Incorporation of bioclimatic principles from the vernacular building into modern building design, such as the use of local and natural building materials, the position of the building with respect to nature, consideration of passive systems for cooling in a design process, integration of greenery, and water, multifunctional spaces that will optimize the room size without degrading the quality of living, and the division of the spaces in winter and summer quarters, can result in the high-quality sustainable modern architecture.

CONFLICT OF INTEREST STATEMENT

The author(s) declare(s) that there is no conflict of interest.

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Importance of Water Supply System for Public Health

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Abstract

It is well known that polluted water is dangerous to health. Pollution of fresh water ecosystems is often the cause of diseases, and therefore a multidisciplinary approach involving hydrology, engineering, urban planning and public health is necessary for a good public health outcome. It has been recognized that a water supply system is connected with the improvement of public health of the population. Can diseases such as diarrhea in isolated rural areas or malaria in Africa be prevented through good water supply management? There is an opinion that water supply management is also public health management and that it is a very good tool in reducing and controlling diseases and will definitely play a big role in the future. Protected drinking water is essential for public health. The most common microorganisms associated with waterborne diseases are: Campylobacter, Legionella, Cryptosporidium, Norovirus, E. coli and Giardia. Legionella has been proven to be one of the most important causes of diseases associated with the water supply systems. Investing in water infrastructure is therefore investing in the safety of drinking water, which is the basis of public health, and its pollution can even lead to a potential epidemic caused by various microorganisms. The paper will present the most common diseases that can potentially be transmitted through the public water supply system, as well as the differences in the infrastructure in different parts of the world, which play a major role in public health of the population. The importance of a good water supply system and the environment in preventing diseases that are potentially spread by contaminated drinking water will be shown. Also, possible dangers of contamination of drinking water that the population uses on a daily basis will be pointed out.

Key words

Polluted water, Public health, Water supply system, Waterborne diseases

1. INTRODUCTION

We collect water for water supply from natural sources; we use it, and return wastewater back to nature. The characteristic feature of today's world is that the heavily polluted wastewater is increasing and the quality water supply is decreasing. In addition to high water pollution levels, losses occurring in the water supply system have a major impact on water supply. Such lost water does not reach the end consumers and is not even charged by the water supply company. All of this is due to the "water crisis", which means that a large part of the population on Earth has no access to drinking water or the basic hygienic living conditions [1].

One of the preconditions for a healthy life of people is access to drinking water through public water supply services and the drainage of contaminated wastewater through public drainage services. UN General Assembly Resolution 64/292 of 2010 affirmed the right to safe and clean drinking water and wastewater drainage as a human right essential for the full enjoyment of life and all human rights [2], [3], [4].

Since the creation of the human community there has been a need to provide conditions for supply of drinking water as well as for other human activities. At the same time, the question of disposal of used wastewater was also raised. These issues have been addressed by civilizations, from ancient times to present, and will continue to be addressed in the future, because these are issues without which there is no normal life on planet Earth [5]. Water is considered to be one of the basic components of life, and the entire history of mankind and civilization is largely related to it. Water is not only included in the composition of human organism and food, but it is also used to produce food and energy, and it is used in industry as a raw or auxiliary material. Due to its importance for humans, the supply of water to settlements and the population is nowadays considered to be one of the primary branches of water management. In the tendencies of concentration of settlements and consumers around water, and given the available water resources on Earth, the issue of water supply will become ever stricter in the future. The rule of water supply that every drop of water on the catchment is kept as long as possible for its wider use, is becoming more and more present in our practice. All the aforesaid affect the emergence of complex water supply and drainage systems [6].

It has already been noted that the investment in sanitary infrastructure and in its development has a significant impact on the reduction of population mortality [7], [8], [9], as authors [8], [9] researched and established in their papers. The area they studied and analysed was England, Wales, Switzerland, Finland and Sweden. The authors of the study [8] deal with the issues and research of the impact of the improvement of sanitary infrastructure on mortality in urban environments. Their special focus was to study the improvement of water supply and the development of efficient sewer systems. These improvements are likely to have the greatest health impact by reducing exposure to diseases transmitted by water and food [8].

Various studies have confirmed that good sanitation in a city has the major impact on public health [10]. The biggest reduction in mortality from waterborne infectious diseases was due to the establishment of improved sanitary conditions [11].

The paper [12] analyses the impact of works on water supply networks and sewer systems in German cities in the period from 1877 to 1913. The results of the research presented in the paper show that safe drinking water reduces mortality, but more importantly investment in sanitary infrastructure that contributes to the reduction of mortality. They also found that the limited impact of only safe-distribution of drinking water through water network on mortality reduction was limited. Greater influence is achieved by combining the construction of water and sewer systems - networks.

The results of the author's second paper [13] support other studies that highlighted the role of public health infrastructure, although it has been shown that the provision of clean drinking water alone has limited effects. In the absence of effective methods for the removal of urban waste, decontamination of water and disease vectors, they neutralise some of the benefits of water from the water supply (i.e. the construction of the water supply network) [13].

2. WATER SUPPLY SYSTEM

The practice of transporting water for human consumption has been around for several millennia. From the first pipes in Crete some 3500 years ago, to today's complex hydraulic models, the history of water distribution technology is quite a story [14].

Water supply and sewer system are the most important services and integral part of urban society and infrastructure. Water infrastructure cannot function well and efficiently without other urban infrastructure, in particular transport and electricity supply. Construction, operation and maintenance of urban infrastructure are a permanent and expensive process. Today, the management of urban water systems faces many problems such as:

1) The need for reliable sources of drinking water.
2) Significant flood damage as a result of the urbanisation of the catchment area and the possession of water inundation.
3) Deterioration of water quality, pollution and depletion of groundwater, and negative impact on residents including the coastal sea into which water is discharged from urban water systems.
4) Health problem caused by pollution of water resources and seas [15].

The most common and user-friendly access to water for human consumption and sanitation is ensured through public water supply and sanitation systems operated by public water service suppliers [16]. Water supply services are provided by means of a water supply system, and drainage services are provided by means of a public drainage system, i.e. a sewer system. Water supply system is a collection of buildings and devices for the supply and distribution of water from the site to the consumer. It covers all necessary system facilities: source, main supply pipeline, water improvement facilities, water supply, main supply pipeline and distribution network.

Fundamentally, a water supply system may be described as consisting of three basic components: the source of supply, the processing or treatment of the water, and the distribution of water to the users [17]. Typical elements of the water supply management system are presented in Table 1.

Table 1. Typical elements of the water supply management system (according to [18])

Component	**Subcomponents**
Water source	Lakes/Rivers
	Reservoir
	Ground water
Treatment plant	Filtration
	Coagulation
	Disinfection
Transmission and distribution	Pipe networks
	Service reservoirs
	Storage tanks
End users	Potable water

The basic roles of the water supply system, regardless of all possible variants and specificities, are:

- Ensuring quality water treatment from the environment to drinking water, the quality of which must comply with legal requirements, both in the processing phase and up to the consumption phase;
- Continuity in water supply 24 hours 365 days a year, all consumers;
- Necessary, sufficient amounts of water for all consumers in the defined area of the system [5].

Ensuring a sufficient quantity of quality water is primarily of great health importance in protecting against various diseases transmitted by water. Sufficient amounts of water in settlements make it possible to increase the general standard of living of man and to regulate his environment. Large quantities of water are needed to satisfy the growing needs of populated places. Water distributed to the public must have a drinking water standard in accordance with the law [15].

In 2020, an estimated 90% of the world population had access to at least basic drinking water services. Access was highest in Europe and North America and Australia and New Zealand, with 100% of both regions having access to at least basic drinking water services. In most regions of the world, 90% of the population has access to at least basic drinking water services. However, just 65% of the population in Sub-Saharan Africa and 57% of the population in Oceania had basic access in 2020 [19].

Estimated share of global population with access to at least basic drinking water services in 2020, by Sustainable Development Goal (SDG) region [19] is shown in the Figure 1.

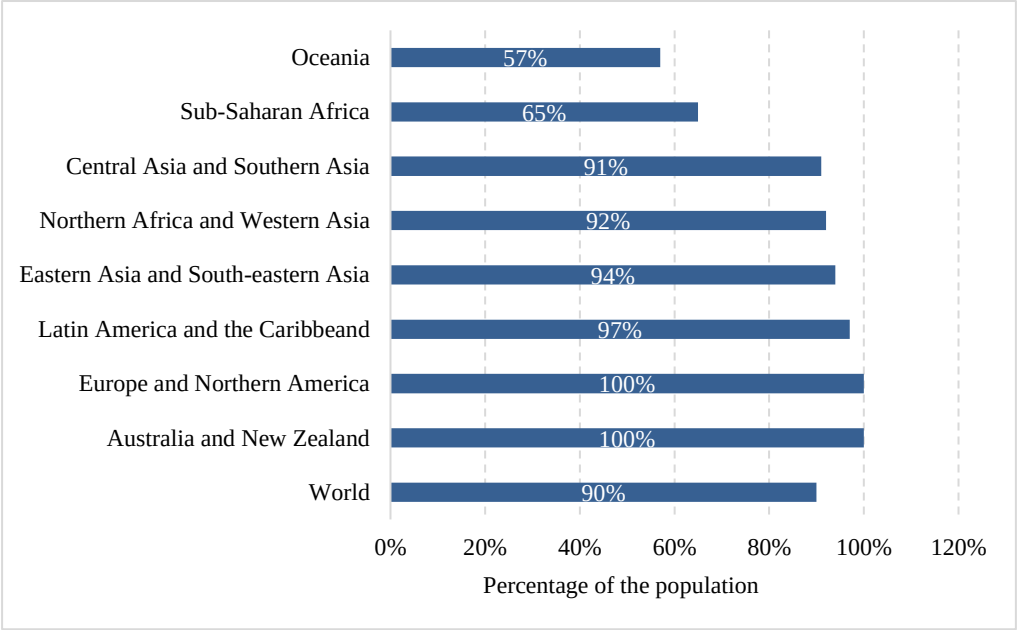

Figure 1. Estimated share of global population with access to at least basic drinking water services in 2020, by SDG region [20]

There are differences in distribution of drinking water in the world. Figure 2 shows the number of people across the world that do not have access to safe drinking water. Safely managed drinking water is defined as an "improved source located on premises, available when needed, and free from microbiological and priority chemical contamination" [21].

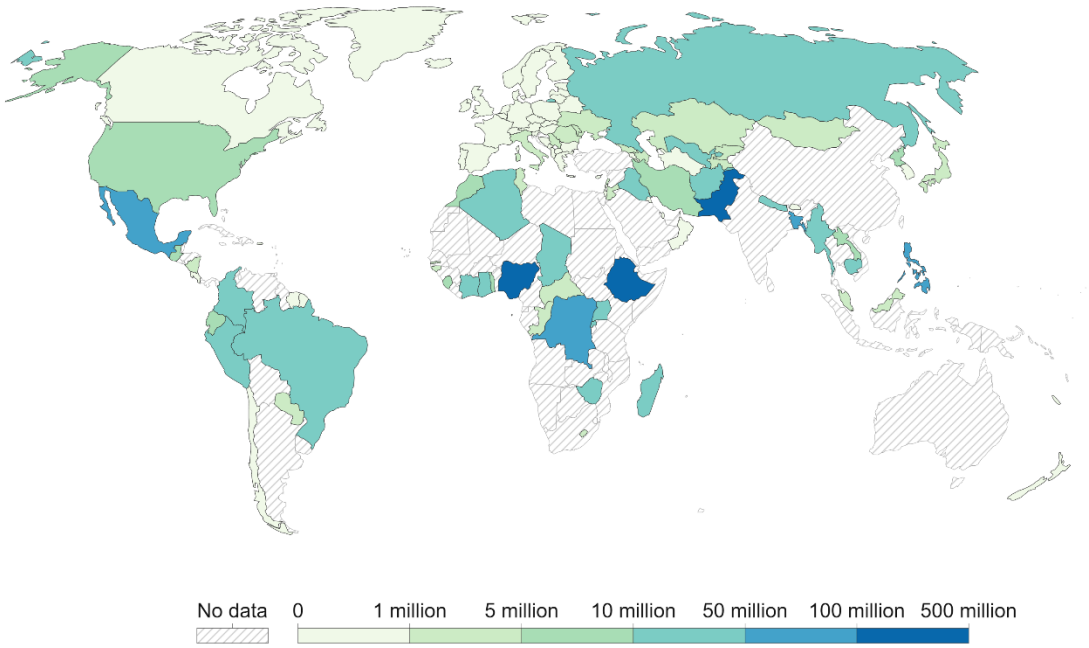

Figure 2. Number of people without access to safe drinking water, 2020 [21], [22]

3. WATERBORNE DISEASES

Clean water is the key factor for public health. Waterborne diseases are one of the most important diseases known as typhoid fever, rotavirus diarrhea, or pandemic cholera disease. Each of the listed in history was one of

the most important causes of death at the time. In 2006, the WHO showed that contaminated water and lack of basic sanitation led to at least 1.6 million deaths in children under 5 years of age in 2004 [23].

The causes of these diseases are different. And they are called pathogenic organisms. They include viruses, bacteria and protozoa [24]. The pathogen is every microorganism that causes the disease. Water contaminated by microorganisms may cause a disease either directly (e.g. drinking such water) or indirectly (consumption of vegetables washed in contaminated water).

Most pathogens causing waterborne diseases are primarily transmitted by faecal contamination. Thus, monitoring faecal pollution by bacteria in water is a necessary and relatively cheaper way of protecting the public health of the population from faecal - transmissible pathogens. Unfortunately, studies in the 1970s have shown that faecal indicators are not always affected by the concentration of pathogens. The scenario that occurred in Ontario is a good example, where the presence of E. coli did not mean the presence of the pathogenic E. coli O157:H7 [25].

The link between the disease and microorganisms was established back in the time of Robert Koch in the 1880s. In 1854, John Snow (Figure 3), the father of epidemiology, linked exposure to contaminated drinking water to cholera transmission, when an English water company supplied residents of London with contaminated drinking water [25], [26]. Insecure water supply, ineffective sanitation, and hygiene can be one of the major causes of diarrhea and the leading cause of death of about 1.58 million people each year. [25], [27].

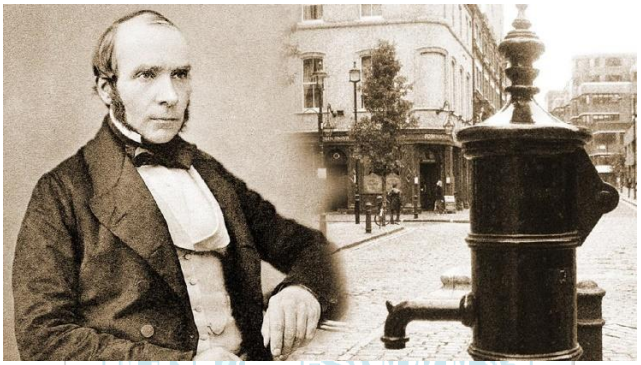

Figure 3. John Snow [28]

Table 2 shows the most common pathogens of waterborne diseases by category and name of microorganisms.

Table 2. Agents of Waterborne or Water-based Disease [24]

Category	Pathogens
Bacteria	*Vibrio cholerae*
	Salmonella spp.
	Shigella spp
	Campylobacter spp.
	Yersinia enterocolitica
	Legionella
	Helicobacter pylori
	Toxigenic *Escherichia coli*
Protozoa	*Giardia lamblia*
	Cryptosporidium parvum
	Entamoeba histolitica
	Isospora belli
	Toxoplasma gondii
	Naegleria fowleri
	Microsporidia
	Ballantidium coli
Viruses	Norovirus
	Sapprovirus
	Poliovirus
	Coxsackievirus
	Enteroviruses 69-91
	Adenovirus
	Hepatitis A
	Reovirus
	Rotavirus
	Coronavirus

Legionella is one of the most common causes of waterborne diseases. Legionella is the major cause of waterborne illness outbreaks in the USA [29], [30], [31]. Large *Legionella* outbreaks receive the most attention given their substantial health impact. However, it is estimated that less than 20% of all reported legionellosis cases are outbreak-related [30], [32], [33]. Worldwide, waterborne *Legionella pneumophila* is the most common cause of cases including outbreaks. *Legionella pneumophila* and related species are commonly found in lakes, rivers, creeks, hot springs and other bodies of water [34].

In Canada, reported rates of legionellosis in 2006–2020 (the latest year for which data have been published) were 0.37–1.75 per 100,000 population [30], [35]. Reported rates from the USA were 1.0–1.89 per 100,000 population in 2006-2016 [36], [37]. As legionellosis is underdiagnosed and underreported, the actual number of cases is expected to be much higher [38].

4. WATERBORNE DISEASES IN THE WORLD

Water pollution is a global problem, according to the World Health Organization (WHO), 2.1 million people do not have access to safe drinking water sources [39]. The WHO said the minimum water requirement per person for one day is about 7.5 to 10 litres [23].

As access to quantities of water increases, the public health risks decrease (see Table 3) [23], [40], [41]. When water is scarce, then people are forced to drink unsafe water, and water cannot be easily spared for hygiene or sanitation.

Table 3. World Health Organization summary of water access, adequacy and level of health concern [23], [40], [41]

Service level	Access measure	Needs met	Health concern
No access <5L/c/day	>1 km; 30 minutes	Consumption not assured; hygiene not possible	Very high
Basic-often<20 L/c/day	100-1000 meters; 5-20 min	Consumption should be assured; hand washing and basic food hygiene; laundry/ bathing no	High
Intermediate~50 L/c/day	Within 100 m, 5 minutes, or by single tap	Consumption, ditto basic personal and food hygiene, laundry/bathing	Low
Optimal >100L/c/day	Supplied by multiple taps	Consumption and hygiene-all needs met	Very low

L/c/day – liters per capita per day

By comparison, in wealthy countries, residents use 200-300 litres per day for drinking, sanitation, cooking, hygiene, not to mention the unnecessary and uncontrolled use of drinking water to wash cars or clean (watering) the garden or watering grass surfaces [23].

Diarrhea, which is closely associated with contaminated drinking water, coupled with poor sanitation, causes many cases of disease. Diarrheal disease is very high, accounting for 1.7 to 5 billion cases per year worldwide. Specifically, diarrheal diseases are associated with an estimated 1.3 million deaths annually, with most occurring in resource-limited countries. Very young children are the most vulnerable, the incidence of severe gastroenteritis being highest in the first 2 years of life. Indeed, up to 25% of deaths in young children in Africa and south-east Asia are attributable to acute gastroenteritis [42], [43]. Waterborne diseases can range from light, self-limiting diseases to serious diseases such as typhoid fever and cholera. Serious cases end in death unless treated.

In Sub-Saharan Africa significant progress has been made in reducing the risk for children under the age of five, but progress is slower for newborns. The region accounts for 38% of global neonatal deaths and has the highest infant mortality rate (34 deaths per 1,000 live births in 2011). There are many causes of such a high mortality rate, but poor hygiene during childbirth could account for up to 15% of neonatal deaths [44], [45]. Lack of access to water and sanitation is linked to neonatal infection and maternal mortality. It is estimated that clean

childbirth practices could avert 6 to 9% of the 1.16 million annual newborn deaths in countries in Sub-Saharan Africa [44], [46].

Many women giving home birth do not have access to clean water and sanitation (less than 10% according to a study examining data from 22 Western and Central African countries) [44], [47]. Even women who attend a health care facility may not be guaranteed acceptable hygiene standards. A WHO survey of health care facilities in a selection of low- and middle-income African states revealed that 42% did not have an improved water source within 500 metres of the facility, 16% did not have improved sanitary facilities and more than 45% lacked adequate handwashing facilities [48].

Diarrhea is particularly dangerous for children and it is the fourth cause of death of children under the age of 5 in poorly developed parts of the world. Effective treatment of drinking water, however, can kill or inactivate the more than 20 waterborne pathogens. Several of these pathogens are already antibiotic resistant and have taken first place on the WHO global pathogen list. So, clean safe water is the first line of defence against serious diseases that will soon become incurable due to antibiotic resistance. Safe water is also needed to prevent diseases that can arise from inhaling contaminated water droplets, or aerosols, associated with air conditioning systems, spas and devices or systems that produce mists or sprays. These include outbreaks caused by the bacteria Legionella, which can be the most significant waterborne pathogen in high-income countries. Safe and sufficient drinking water is also key to maintaining the health of people who are vulnerable to opportunistic infections (e.g., people living with HIV/AIDS) [49]. It is also estimated that 1.8 million people globally are at risk of potential COVID-19 infection through faecal contamination of drinking water [50]. Death rates are much higher in low-income countries [21]. Figure 4 shows estimated annual number of deaths attributed to unsafe water sources per 100,000 people.

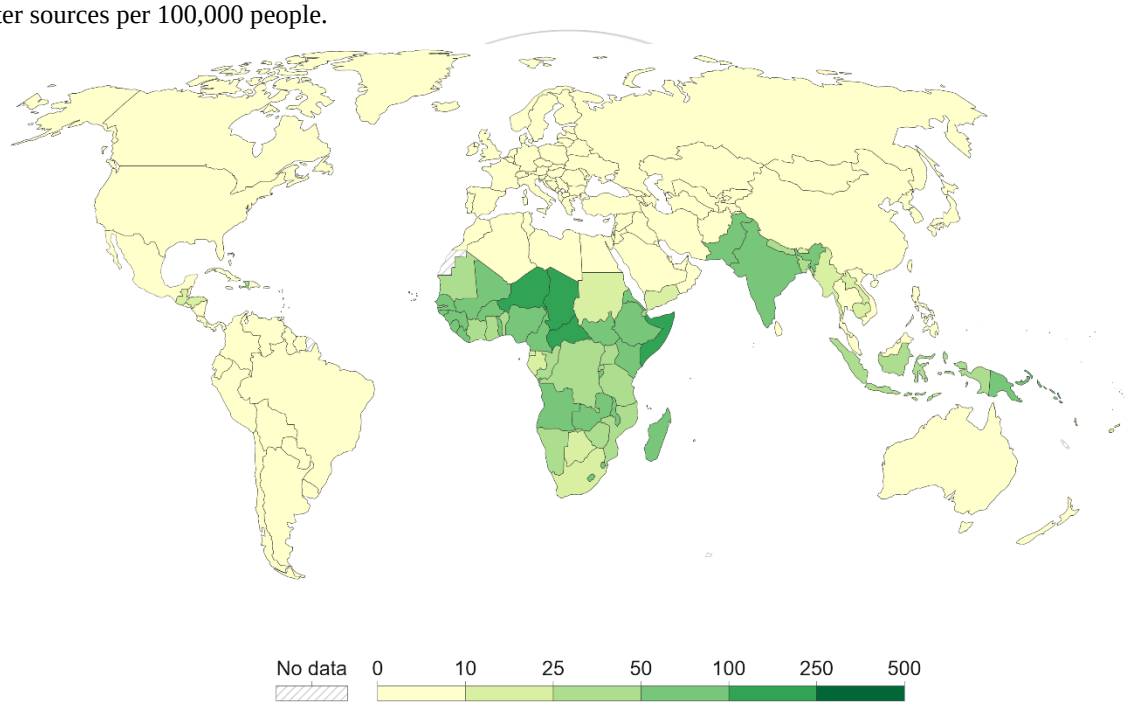

Figure 4. Death rate from unsafe water sources, 2019 [21], [51]

Figure 4 shows large differences in death rates between countries: rates are high in lower-income countries, particularly across Sub-Saharan Africa and Asia. Rates here are often greater than 50 deaths per 100,000 – in the Central African Republic and Chad this was over 100 per 100,000 [21].

5. CONCLUSIONS

Water is essential for people's life and health. Proper sanitation, including proper wastewater management, is essential to ensure human health, a healthy ecosystem, and economic and environmental benefits. Due to its importance for people, the supply of water to settlements and the population is nowadays considered one of the primary branches of water management. Water is distributed to end consumers through the water supply system. The most important roles of the water supply system are ensuring quality water processing from the environment to drinking water, the quality of which must comply with legal regulations, continuous water supply 24 hours a day for all 365 days of the year and sufficient quantities of water for all consumers on the system space. Sufficient quantities of quality and proper drinking water in settlements provide a prerequisite for the protection of the health of residents. This prevents people from becoming infected with diseases transmitted by water.

There is a different availability of drinking water in the world. Thus, in 2020, it is estimated that 90% of the world's population had access to at least basic drinking water services. The biggest access was in Europe, North America, Australia and New Zealand. However, in sub-Saharan Africa only 65% of the population have access and 57% of the population in Oceania. Without water, there is no life, and the health of the body depends largely on the state of the water we bring into it. In case of water contamination from water supply, the intake of such contaminated water into the body can cause disease for a large number of people and animals and can thus lead to a pandemic in a very short period of time. The intake of contaminated water can infect us with various diseases such as: dysentery, typhoid belly, cholera, rotavirus diarrhea, infectious hepatitis, etc. Some of the most common causes of waterborne diseases are bacteria, protozoa, and viruses. Diarrhea, which is closely associated with contaminated drinking water, coupled with poor sanitation, causes many cases of disease. By ensuring sufficient quantities of quality drinking water, it is possible to prevent different diseases transmitted by water, maintain proper health - hygiene conditions and reduce the risk of death associated with inadequate hygiene conditions (due to insufficient quantities of water and its poor quality). Water is the most important and the most used natural resource on Earth, so its health is essential, as well as proper and careful water management.

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest.

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New Opportunities Provided by Marine Communication Systems in Ship Management of Maritime Enterprises

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Abstract

In recent years, developments in communication systems, one of the two basic elements of the IT sector, offer great opportunities in the effective control and supervision of seas and coasts. Especially developments in wireless communication systems offer countries many new opportunities in the effective management of their coasts. While these developments in communication systems lead to problems such as marine pollution in the surrounding seas of countries, safety of life and property in the seas, irregular migration, effective use of maritime transportation, maximum utilization of seafood, they also offer very important opportunities in many areas. As it is known, uncontrolled migration, which has accelerated in recent years and become a major problem even for landlocked countries, is carried out largely by sea, and therefore the security of the coasts has become an international issue. In addition, in our world where natural resources are decreasing, keeping the seas clean and making maximum use of the opportunities offered by the seas has become one of the most important areas of interest for countries. The developments in technology in recent years offer very important opportunities to countries and their administrations in all these matters. Today, new opportunities provided in wireless communication and the use of data communication in these systems also enable the automatic collection and evaluation of many data. In this regard, developments in data communication in marine VHF systems in recent years and the shift of existing VHF channels to data communication have made a significant contribution to the technical infrastructure. As a result, it has become possible for the maritime authorities of the countries to easily monitor the pollution of the surrounding seas and the issues listed above.

Key words

Coastal Management, Communication Systems, Information Systems, Maritime Enterprises, Ship Management

1. INTRODUCTION

Marine communication systems made between ships and ship land are carried out on two different platforms. These are satellite and terrestrial communication systems. The devices used in these systems, which are different from each other as a communication infrastructure, are also completely technologically different. In one of these systems, satellites are used as a relay in communication, while the antennas of the radio devices used in the other system are directly visible or communication on the basis of the reflection of these signals from the ionosphere.

2. MARINE COMMUNICATION SYSTEMS

Marine communication systems are divided into two basic groups as technical infrastructure. These are Satellite and Terrestrial marine communication systems. In marine satellite systems, communication between ship / ship and ship / land is provided via satellites. Inmarsat and Cospas Sarsat satellites are used in this system.

In terrestrial systems, communication between the ship / ship and the ship / land is based on the reflection of electromagnetic waves from the ionosphere or on the basis of the antennas of radio devices directly seeing each other. Short, medium and long-distance wireless systems are used in terrestrial maritime communication systems.

2.1. Marine Satellite Communication Systems

Communication through satellite systems; The searches made from the ship and land are reflected on the satellite. In other words, in communication between the two satellite terminals, satellites function as relay. Currently, two different satellite systems are used for marine communication. These are Inmarsat and Cospas Sarsat satellite systems. The satellites, positions and coverage areas of the Inmarsat system are shown below.

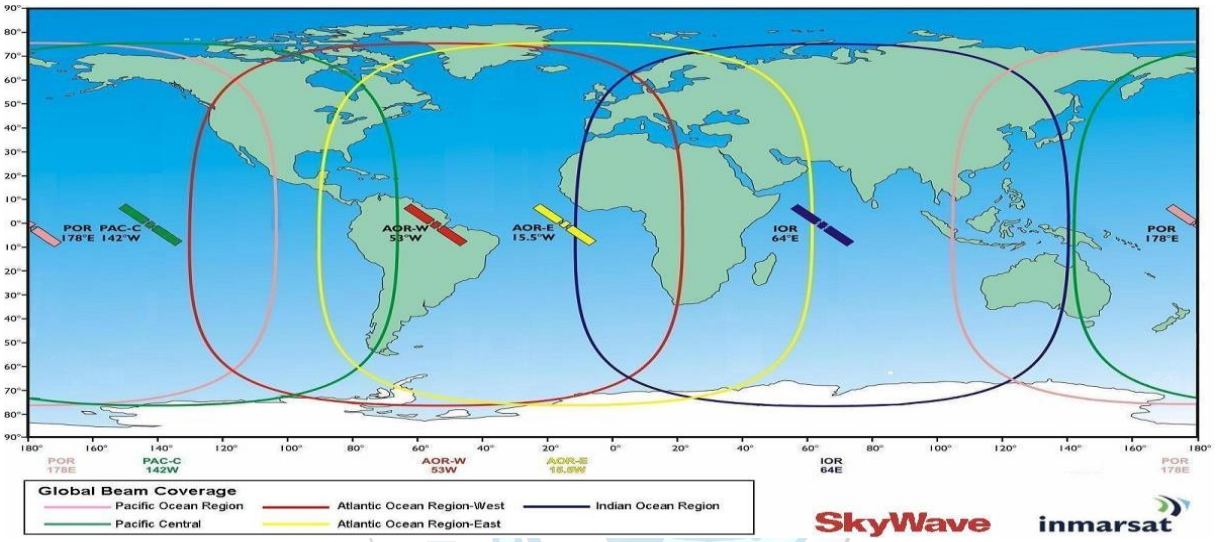

Figure 1: Inmarsat Satellites coverage [1]

Radio telephone, telex and data communications are made between different Inmarsat terminals and ship land and ships. GMDSS (Global Maritime Distress and Safety System - Global Naval Hazard Safety Safety System) system with Inmarsat devices in accordance with both commercial communication and communication on danger/safety communication is established.

On the other hand, commercial communication cannot be made in the cospas satellite system and only danger publications are possible.

In recent years, the marine radio communication, which has been realized through both InMarsat and Cospas Sarsat satellite systems, has started to be done automatically in the type of data communication.

2.2. Terrestrial Marine Communication Systems

Today, the most used devices in maritime communication between ships and land are terrestrial communication systems. VHF (Very High Frequency - Very High Frequency), MF (Medium Frequency - Medium Frequency), HF (High Frequency - High Frequency) and Navtex (Navigational Telex - Written Navigation Warnings) devices are used in terrestrial maritime communication.

These devices are quite different from each other in terms of frequency and distance, and they have similar capabilities in terms of communication modes (telephone, telex, data, etc.).

VHF system is the most commonly used device in maritime communication. In addition, it is the easiest equipment to use and preferred by seafarers of all training levels.

In the VHF system, both the frequency and the power of the transmitter devices used are standard. Since these features will not change according to different devices, the communication distance of VHF systems on two different ships depends on the height of the antennas of these systems from the sea.

Access formula for this;

$l = 4{,}1 \times 10^3 \times [\sqrt{h_1} + \sqrt{h_2}]$ [m] (1)

$l = 2{,}21 \times [\sqrt{h_1} + \sqrt{h_2}]$ nM

In this formula;

l: communication distance

h1 and h2 are the heights of the transmitting and receiving antennas (on 2 different ships) above sea level in meters.

Accordingly, 36 m above sea level. If the communication distance between a ship with a VHF antenna at altitude and a coastal radio station with a VHF antenna at an altitude of 1600 m is calculated according to the above formula;

$l = 2{,}21 \times [\sqrt{h_1} + \sqrt{h_2}]$ (2)

$l = 2{,}21 \times [\sqrt{36} + \sqrt{1600}] = 2{,}21 \times [6 + 40] = 2{,}21 \times 46$ nM

$l = 101{,}66$ nM ~ 100 nM.

According to the figure below; communication distance between a sea craft with a VHF antenna at sea 9 m above sea level and a VHF system at sea with an altitude of 62 m above sea level (for example, a device in a coastal radio station);

$l = 2{,}21 \times [\sqrt{h_1} + \sqrt{h_2}]$ (3)

$l = 2{,}21 \times [\sqrt{9} + \sqrt{62}] = 2{,}21 \times [3 + 3] = 2{,}21 \times 6$ nM

l = 24,045'dir.

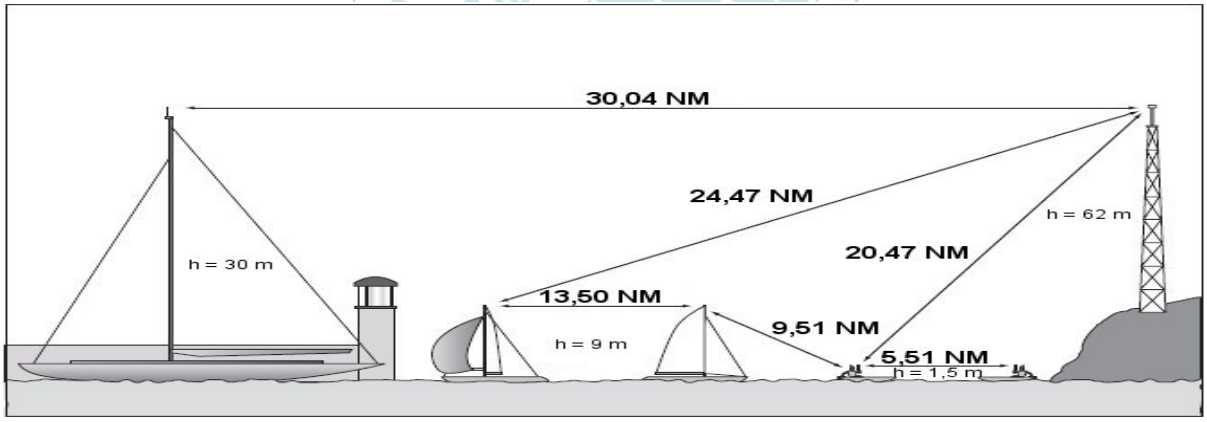

Figure 2: Communication distance between a sea craft with a VHF antenna at sea [1]

Again, the communication distance of these two VHF devices is as shown in the figure above and the antenna lengths are quite low at sea level (if the antennas of the VHF systems of the two sea vehicles are "9 m" above the sea;

$l = 2{,}21 \times [\sqrt{h_1} + \sqrt{h_2}]$ (4)

$l = 2{,}21 \times [\sqrt{9} + \sqrt{9}] = 2{,}21 \times [3 + 3] = 2{,}21 \times 6$ nM

$l = 13{,}26$ nM ~ 13,5 nM nM'dir.

The most important feature of this system, which is also used extensively in on-board communication, is that the antennas of the communicating devices operate on the basis of seeing each other as optical vision. Considering the roundness of the world, it is possible to define the communication distance between two ships as a maximum of 25 nM, when the optical sight distance is considered to be 25 nM (nautical mile) [2].

On the other hand, in the communication between the ship and the land coast radio station (CRS - Coast Radio Station), if the coast radio station is located on a hill or mountain higher than the sea level, as in Turkey, the distance of the communication between the ship and the land will increase, since the optical vision will also increase. will increase accordingly.

The other important equipment of the terrestrial system is the MF. (Medium Frequency) Medium Wave marine radio devices are systems called medium range and used at approximately 300-400 nm from the shore. MF systems, which were used extensively in marine radiotelephony and radiotelex communication, are now mostly preferred for danger/safety communication. In MF systems, the type of communication defined as Ground Wave is used.

The layers in which the ionosphere is effective according to the general broadcasting principle and frequency bands of the HF system are shown in detail in the figure below.

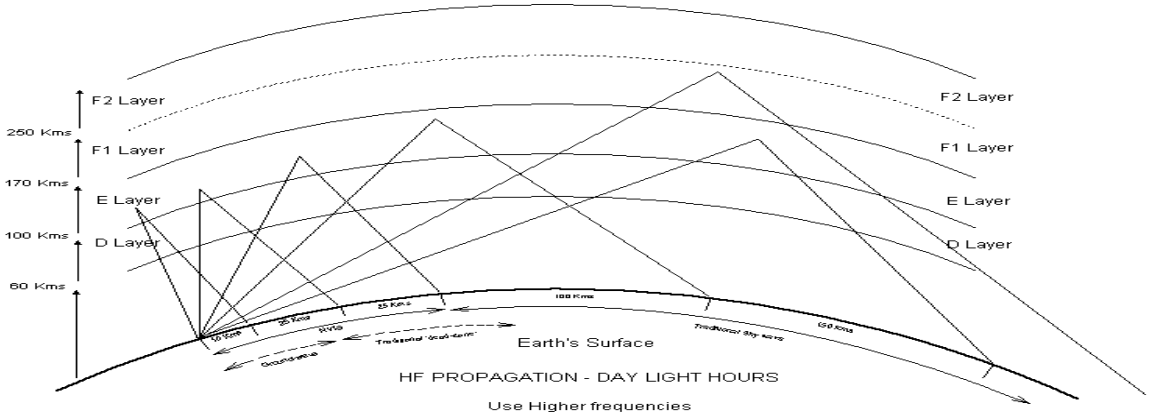

Figure 3: Reflection of HF Waves from Different Layers of the Ionosphere [3]

Long-distance maritime communication systems, also defined as HF (High Frequency), are used in wireless communication with ships located in different parts of the world according to the preferred frequency band. In this system, communication is provided based on the reflection of electromagnetic waves from the ionosphere (sky wave - space wave) used in wireless communication between ships or between the ship / shore radio station. In this respect, it is possible to say that this system is an extremely reliable form of communication from a strategic point of view, since there is no possibility of deterioration or destruction of the reflector (ionosphere) between HF systems.

Navtex broadcasts, one of the most important communication systems used in maritime transport, are also defined as written navigational warnings. Considering the frequencies used, the most important feature of this system, which is operated in the MF band, is that it is one-way broadcasts made by the coast radio stations towards the ships, and the transmitted messages contain very detailed data in the navigational warnings.

2.3. VHF Data Communication

VHF is the most used device in maritime communication systems and the most preferred device by seafarers in their daily functions. The fixed type of these devices are larger in size and are generally installed on the bridge. Antennas of VHF devices have the feature of stick antenna and their length is approximately 1 m.

DSC (Digital Selective Calling - Digital Selective Calling) feature has been added to these devices in accordance with the international communication rules called GMDSS, and automatic call capability has been added to both routine and danger/safety communications made over these devices [4].

DSC devices are technically a data-containing technology and have a feature that allows recordings and calls to be received and sent automatically, even if there is no human being at the device. Therefore, for DSC capable VHF devices, it is correct to use the phrase still the most important and most intensive communication equipment of maritime communications.

A revolutionary decision was taken at the WRC -19 (World Radio Conference - 19) meeting (made in 2019), which is one of the regular meetings held by IMO (International Maritime Organization). According to this decision, all of the duplex channels (channels where the receiving and transmitting frequencies are separate) in the VHF system were allocated to data communication within the determined period [5].

In addition, the channel range has been expanded by combining the close ones of these channels, thus providing the necessary bandwidth for fast data communication over VHF devices.

Data transmission is very important in communication systems. Because nowadays sensors, sensors, etc. Data is the technology used to transport the data obtained from different systems by means of elements and to evaluate and interpret them by the central processing units. For this reason, data communication has become increasingly widespread in the IT sector in recent years, and this development has provided very important audit and evaluation opportunities to different organizations regarding the systems they are responsible for.

In order to make maximum use of these developments in the IT sector in maritime communication, it was first aimed to use data communication extensively in VHF systems. For this purpose, it was decided to use all duplex channels used in the VHF system for data communication as a result of the meeting mentioned above.

This regulation provided the users with the technical infrastructure necessary for the effective inspection of ships, surrounding seas and coasts, and for the instant monitoring and evaluation of the information obtained from the data production sources related to them, and for taking effective decisions.

3. INCREASE IN THE AMOUNT OF DATA AND DATA SOURCES IN RECENT YEARS

Today, developments in technology show the most impact in the information sector. Digital Twin, Metaverse, Blockchain, Cryptocurrencies, Big Data, Data Analytics, Industry 4.0, Internet of Things (IoT), Machine to Machine (M2M), etc. All of the technologies are developments that have emerged in the last 10/15 years. The impact of the said developments in the IT sector was not limited to this sector, but these technologies also affected all sectors to which the information sector is related to different extents. This interaction still continues at an increasing rate. Currently, the most important technological impacts in the IT sector are seen in the data communication infrastructure.

3.1. Systems Used in Data Collection

Data is as valuable as the oil of our age, and its value is increasing. Today, there are many types of data and different sensors are used to collect and process them. Each of these sensors, also called sensors, is used in different types of data sources. In addition, they convert the data produced by these data sources into a binary (binary number system) number system that can be understood by computer systems.

With the developing technology, the sizes of the sensors are getting smaller and it is possible to detect and collect the data produced in this way more easily and quickly.

The usage areas and importance of sensors in the informatics sector are increasing day by day. The data collected through the sensors is transmitted to the systems where this data will be collected and processed, and the form of communication in the form of data is generally used in sending these collected data. Wired systems can also be used in the transmission of data, and wireless access systems are generally preferred. These systems can be mobile communication systems defined as 2G (generation), 3G and 4G, as well as WiFi, Bluetooth etc. There may also be local and local access systems. As a result of the developing technology in recent years, significant increases have been achieved both in the data capacity of the systems used in this communication and in the speed of the transmitted data.

3.2. Wireless Systems Used in Data Communication

IoT (Internet of Things) is one of the most important elements of the IT industry today. While wired transmission systems were used to transmit data from objects to systems where they are processed and evaluated, in recent years, wireless systems have taken the place of this communication.

Although there are many wireless systems, the most used one among them is mobile communication systems, which are defined as generation. Among these, the fourth generation (4G) systems are the most widely used and have the highest data communication speed. Many countries still use the Advanced LTE (LTE Advance) system, which is the advanced version of this generation and is defined as 4.5G in Turkey. The graphic below shows the current mobile communication standards and the development of new wireless technologies in detail.

Figure 4: Current Mobile Communications Standards and Evolution of New Wireless Technologies [6]

Since the data rate in the LTE Advance system has reached very large sizes, the latency in the transmission of the data produced via sensors and objects to the central processing units has been reduced to the level of milliseconds [7]. For this reason, it is possible to say that a breakthrough has been made in data transmission in the IT sector with 4G. The use of this system in almost all countries in the world has led to the widespread establishment of 4G infrastructure. This causes 4G to be the most preferred system in data transmission.

In the last few years, fifth generation systems, defined as 5G, have also started to be used in mobile communication systems. However, since the speed and data capacity targeted with 5G is much higher than that of 4G, it will take a few more years to establish the fiber optic infrastructure required in this system. In addition, since private networks were initially preferred in the establishment of 5G, it is still impossible for this system to become a national network and be used everywhere in data transmission.

In the last decade, there has been a rapid change and development in generations, and after 2018, more than 99% of the mobile network worldwide has turned to the 4G network. As shown in the chart below, the development of the 4G network over the years and its value as CAGR (compound annual growth rate) are given.

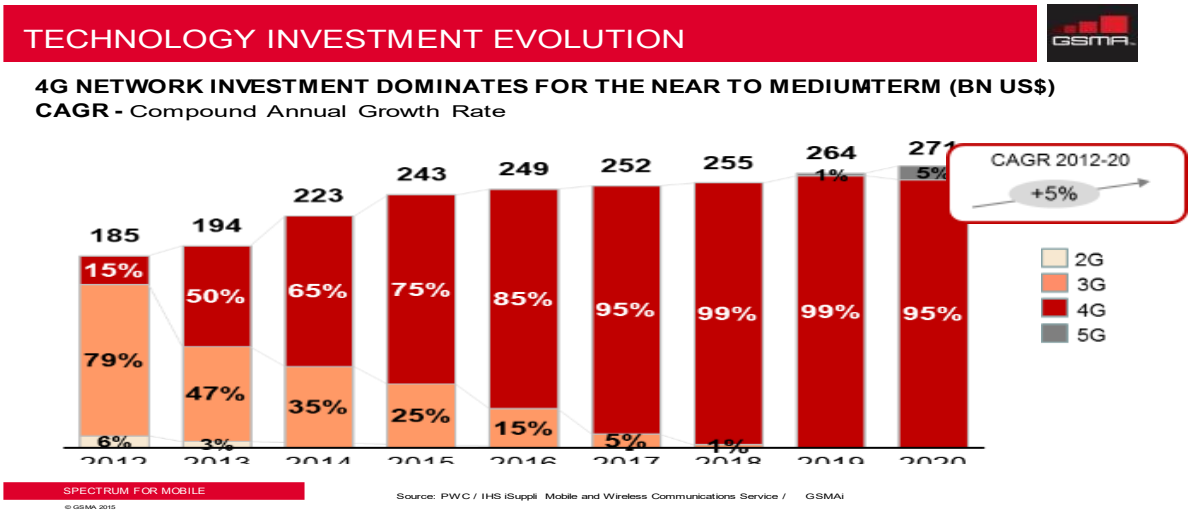

Figure 5: The Development of the 4G Network Over the Years and Its CAGR Value [8]

Today, local-based systems such as WiFi (Wireless Fidelity) are also used in data transmission. These systems, which are also defined as Wireless Local Area Networks (WLAN - Wireless Local Area Network), are not used

in the national dimension and are preferred in some special areas. In addition, since the speed of these systems is much lower than 4G and 5G networks, the use of mobile communication networks, which are also defined as generations in data transmission, has increased in recent years.

One of the systems used in the collection of data, especially at sea, in recent years is Automatic Identification Systems. (AIS – Automatic Identification System) In line with the provisions determined by IMO, it is possible to automatically detect marine vehicles around the ship by means of these devices, which are required to be installed on ships for the purpose of navigational safety. In addition, it is also possible to automatically interrogate ships within VHF range from coastal radio stations and send one-way warning messages to these ships via this system.

In Turkey and some coastal countries, in recent years, control of buoy equipment and buoy positions, measurement of current intensity and direction, wind direction and intensity, detection of sea pollution, etc. For these purposes, the use of AIS systems has started. Since AIS systems operate over the VHF band (AIS1 channel: 161.975 MHz, AIS2 channel 162.025 MHz), the distance of this system from the shore is much longer than mobile communication systems [4].

3.3. Big Data

In recent years, the most important differentiation in the information sector is seen in the increase in the data produced. Because the amount of data produced is increasing day by day and according to statistics, it doubles every two years. It is calculated that the global data traffic, which was 20 ZByte in 2015, will reach 125 ZByte in 2025.

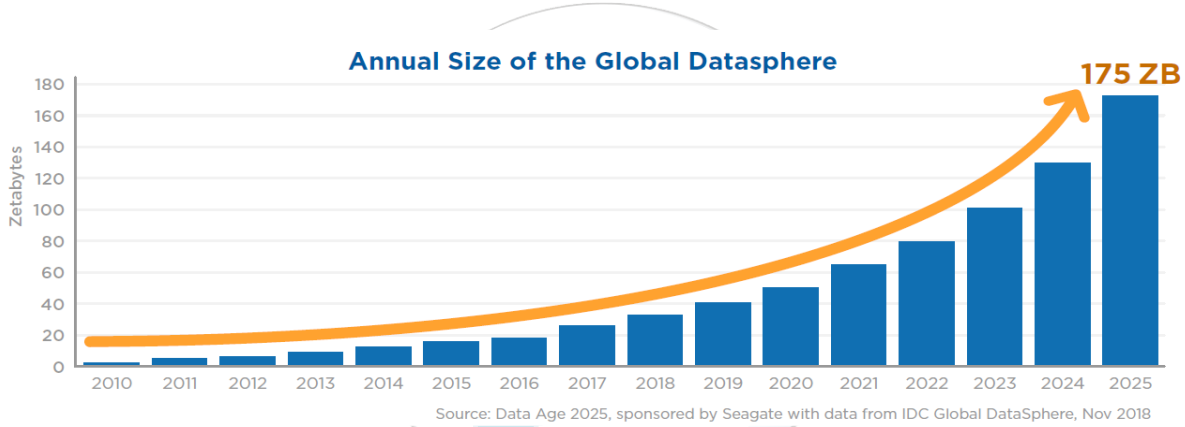

Figure 6: Development of Global Data Over the Years [9]

The most important reason for this is that the sources that produce data, the data produced and the sensors and sensors that detect the data in them are increasing day by day. Since data transmission environments have developed rapidly in recent years, the transmission of the produced data for evaluation is getting easier.

Although it is possible to compress big data into smaller areas with some compression applications (zip), however, due to the increasing amount of data, very large capacity and expensive storage equipment (disks, servers, etc.) is required.

3.4. Data Analysis

Data analysis, also defined as Data Analytics, means the evaluation, interpretation and processing of the collected big data and making it commercially available. This issue, which constitutes perhaps the most important part of the data collection function, has become a very important field of informatics in recent years. Because the data stack that cannot be made sense and therefore not commercialized has no scientific meaning and is only considered as a data stack.

Many advanced programs are still used for data analysis. In addition, the training of software developers in sufficient numbers and skills to be able to perform this analysis also requires special training and expertise.

Today, the most effective tool for data analysis is artificial intelligence. In recent years, the need for this issue has played a very important role in the rapid development of artificial intelligence.

3.5. Artificial Intelligence

Artificial Intelligence (Artificial intelligence) is one of the most popular topics in the IT industry in recent years. “Artificial intelligence” is the engineering or science of making intelligent machines, especially intelligent computer programs [10]. The importance of artificial intelligence has gradually increased in a process where big data is processed and commercialization activities are increasing, especially today, where data is becoming increasingly valuable and is considered the oil of the 21st century. Because artificial intelligence plays a big role in the function of data analysis and then making sense of it. In addition, taking quick decisions about the results obtained according to the collected data and determining the most correct course of action are as important as the collected data. Evaluating the data collected for this purpose, finding the most suitable solution for the targeted purpose is only possible by using advanced software and hardware systems.

Again, one of the important areas of interest in the IT sector in recent years is machine learning. (machine learning) Machine learning should be considered together with artificial intelligence and the fastest evaluation of data should be considered as one of the elements that should be taken into consideration.

4. THE IMPORTANCE OF THE SEA FOR COASTAL MANAGEMENTS

Effective use of the seas is an extremely important issue, especially for the countries that have a coast to the sea. Because countries that make maximum use of the seas provide great advantages both economically and strategically. Today, 85% of the cargoes carried in world trade and 97% of the energy transportation are carried out by sea, approximately 75% of the world population lives in the coastal areas and close to the coast [11]. For this reason, they have been gathered under the following headings, which are important for the effective monitoring of the seas and coasts for the countries with a coastline.

4.1. Marine Pollution Monitoring

Pollution of the seas is the area of interest of many international organizations. Every year, different conferences and meetings are organized on this subject and it is tried to draw the attention of all relevant authorities. This issue is one of the main functions of the international maritime organization, and special working groups have been established within this organization. With many international agreements, serious responsibilities have been brought to the countries that have a coast on the cleaning of the surrounding seas. In order to fulfill these responsibilities, countries establish different observation systems and aim to instantly observe the pollution in the surrounding seas. Because if sea pollution is constantly increasing, it is very difficult and costly to rehabilitate the sea after a certain point [12].

For this purpose, quite different sensors and sensors are used in the installation of these systems. Data on the pollution of the seas are collected through these sensors and these data are sent to data processing centers via different wireless systems. As explained in the previous sections, although different infrastructures can be used as communication systems, the most commonly used systems in this regard are mobile communication systems such as 3G and 4G, and automatic ship identification (AIS) systems, the use of which has been increasing in recent years.

4.2. Life and Property Safety Communication at Sea

Many of the most important regulations of maritime transport have been made regarding the safety of life and property at sea, and regulations on this subject are still in progress. The first regulations regarding the safety of life/property were gathered under the title of SOLAS (Safety Of Life At Sea). The regulations made on this subject in 1974 were gathered under the title of SOLAS-74 and turned into a collection of maritime communications rules [13].

Issues related to the safety of life/property at sea do not only include the safety of seafarers, but also concern the safe navigation of the ship and the cargo on board. For this purpose, coastal countries are obliged to establish different radio systems. Through these systems, countries aim to automatically or manually receive distress/safety broadcasts made with different search methods from ships at different distances from the shore, and then initiate rescue/assistance activities.

Terrestrial systems such as VHF, MF and HF radio devices and satellite systems such as Cospas Sarsat EPIRB and Inmarsat devices can still be used in distress/safety broadcasts made by ships.

The International Maritime Organization (IMO) has been determining the minimum standards required for personnel and ships in order to prevent maritime accidents since its establishment [14]. The most important issue required by the IMO regarding the safety of life/property from the coastal countries is to install automatic or manual radio systems to receive these broadcasts and to initiate the rescue/help function without delay when necessary. Establishment and active operation of such facilities are governed by international agreements, and countries with a coastline are held responsible for these services.

4.3. Effective Use of Seaway in Transportation

The volume of cargo transported by maritime transport is greater than the sum of other modes of transport. Especially in countries with a coastline, the rate of transportation by sea is approaching 90%. Especially in recent years, with the gradual development of container transportation, it is aimed to safely deliver the products that are transported internationally to their relevant buyers without spoiling or being damaged. This issue has increased the attractiveness of sea transportation compared to other transportation modes in recent years.

Another important factor in maritime transportation being the most preferred mode of transportation is that it is cheaper than other transportation modes. Especially in recent years, it has become possible to deliver very large quantities of cargo to their buyers in one go, with ships that have been increasing in size in recent years. This situation causes the unit transportation costs in seaway to be much cheaper than other transportation modes. In the evaluations made, the unit transportation cost of sea transportation is 3 times cheaper than railway, 7 times cheaper than road, and 21 times cheaper than airline [15].

In addition, maritime transport functions are also possible over long distances and between continents, where the speed factor is not very important. For this reason, maritime transportation is an alternative mode of transportation at many transportation points [16].

Apart from this, considering the volume of cargo carried, the safety and accident risk of sea transport is accepted as the safest mode of transport after air transport. For this reason, a large part of the transportation of large volumes of goods in world trade is carried out by sea transportation [17].

4.4. Maximum Utilization of Seafood

In today's world, where the resources in the world are decreasing, the importance of marine products is increasing day by day. In many countries, the income from the export of seafood has become one of the most important export items of those countries. Since the price of these products is increasing day by day, the share of the income obtained from the seas in the total exports will increase even more for the countries.

Products obtained from the sea should not be defined as only fish, etc. products. Because fishing is not only done in a country's own coastal regions, the share of open sea fishing is increasing in total fish production. Even many countries that do not have a coastline still have long-distance fishing activities. Fishing boats of these countries are housed in neighboring countries with the closest coast to the sea and benefit from offshore fishing.

In addition, as a result of the developing technology, there are problems such as deterioration, delay, etc. in the shipment of fish caught by open sea fishing to distant countries. problems are minimized. This situation has made open sea fishing even more attractive for all countries. Today, this issue has become a very important source of income for many countries.

Again in recent years, inland seas such as the Marmara Sea, lakes, dams, streams, seafood farms, etc. Both the production capacities and the total costs of seafood produced in these environments have increased significantly. For this reason, seafood, especially fish etc., which is supplied only from the sea, should not be considered as products, but should be considered as income sources from all fishery products in a wider portfolio.

4.5. Irregular Migration Movements

Today, one of the most important international problems is irregular migration movements. Even if the source of migration is far from the countries, all countries are affected by this process at different rates. This effect is generally greater in developed countries, and all countries on the route from countries of origin to developed countries are exposed to this process to a different extent. The clearest examples of this can be seen very clearly in the migration movements from neighboring countries to Europe in recent years.

There have been many dramatic events related to irregular migration movements until today, and these events still continue. In recent years, serious arrangements have been made to find a solution to this issue, which also causes many international problems.

In this regard, the first thing that is requested from all countries is to take the necessary measures regarding the borders of the country. For this, the establishment of effective surveillance and control mechanisms at the borders is of great importance. In this regard, the weakest link for countries is the seas. Because, despite the fact that today's land borders can be controlled more effectively with the possibilities of developing technology, an irregular migration event by sea is only possible if the coasts are controlled by highly developed systems. For this, it is obligatory to equip the coasts with different systems and systems to control and monitor. For this purpose, it is necessary to establish the necessary systems on the coastlines and to make physical interventions by evaluating these systems instantly.

5. RESULTS AND DİSCUSSİON

Developments in maritime communication systems are of great importance, especially in terms of effective management of coasts. This issue is also extremely important in terms of the successful continuation of the measures taken by many countries regarding the cleaning of the surrounding seas. Marine communication systems are wireless communication systems. For this reason, it is a technical necessity to use wireless systems in transmitting the data collected through the systems to be established in the seas and sea shores to the evaluation center without delay and loss. As a result, the systems that create the radio communication between the sensors and the evaluation centers should be chosen in the most effective and correct way.

Effective control and surveillance of coasts has many benefits in terms of national and international interests of countries. Especially the pollution of the surrounding seas, the safety of life/property of the ships and their contents in these seas, the increasing use of maritime transport today, the unit transport cost of this mode of transport being much lower than other modes of transport, the increasing importance of seafood in the economies of countries with a coast to the sea, prevention of irregular migration movements, which are gaining more and more importance in the international relations of countries, etc. Due to many issues, the establishment of the said inspection and surveillance systems is of great importance for the coastal administrations of the countries.

The most important reflections of the developments in technology in recent years are seen in the information sector and communication systems, which is one of the most important elements of this. Today, mobile communication systems, which are defined as generations, have created many new possibilities in the field of communication as well as in our daily lives. Especially the shifting of mobile communication systems to data communication enables lossless and delay-free communication of data provided through different sensors, especially sensors to be established for this purpose. The increase in the amount and speed of data transmitted in each new generation is one of the other important issues in this regard. Although 5G is seen as the most advanced system in this regard, this system has not yet become locally widespread and an international network has not been established. For this reason, it is still considered that the most suitable system to be used for these studies is the fourth generation mobile communication system.

It has become possible to use some new maritime communication systems, which have started to be used in many countries including Turkey in recent years, to transmit the data to be transferred from the said seashore surveillance and control systems to centers on land. Among these systems, VHF, MF and HF systems, which are considered as terrestrial maritime communication systems, can technically be used for this purpose. The increasing prevalence of data communication in these systems in recent years is also a very important advantage. Especially, data communication has started to develop rapidly in VHF maritime communication systems in recent years, and many arrangements have been made regarding this, and all of the duplex VHF channels have been allocated to maritime data communication. However, a similar process has not yet developed in MF and HF systems to the same extent, and regulation studies regarding these systems are still in progress.

Although it is possible to use Inmarsat devices, which is one of the satellite systems, which is the other type of maritime communication, in data transmission, the installation and operating costs of these systems are much higher than terrestrial systems. This is the most important negative factor preventing the preference of the said system for this purpose. For this reason, if the Inmarsat system is preferred for transmitting the data to be obtained from the inspection and surveillance systems of the coasts, it is beneficial to carefully evaluate the cost of their use.

One of the rapidly developing and widespread wireless communication systems in recent years is AIS. Although these devices are not a direct maritime communication system and their main use is an electronic navigation aid system, they are required to be installed on ships in accordance with IMO legislation. Due to its technical capability, this system has started to be used in many countries in recent years for transmission purposes in the transmission of many sea-related data to land.

The fact that data is transmitted free of charge in the AIS system is another important factor in the widespread use of this system. For this reason, this system should be considered as a serious communication tool in the data transmission of the systems to be established by the coastal administrations.

In addition, since AIS devices operate in the VHF band (156 -174 MHz), the coverage area of this band and therefore AIS devices is much higher than that of mobile communication systems such as 4G and 5G. Therefore, this issue should be taken into account in the evaluations to be made.

In many surveillance and control systems of today, it is a big mistake that the preferred communication systems are not chosen correctly in order to deliver the data produced to the evaluation centers on land. Because if the communication systems are chosen incorrectly, no matter how accurate, high quality and expensive the sensors for different purposes are, there are great difficulties in delivering these data to the central evaluation units on land. This problem even causes the installed systems to be idle after a while. It is possible to see many examples carried out by different organizations in the recent period.

For this reason, it is extremely important to choose the transmission system to be used in data transmission in this system, as well as the technical capabilities of the systems to be preferred for the inspection and surveillance activities of the sea coasts. This issue is considered as an indispensable issue for the successful operation of the system to be established.

In line with these evaluations, the studies carried out so far on the effective control and management of the coasts and the important issues in this regard have been taken into account. For this purpose, the most suitable wireless communication system for transferring the data to be obtained from the sensors planned to be installed on the sea shores; It has been evaluated that there is the AIS system, which is defined as an automatic ship identification system, due to both the installation and operating costs, the coverage area and the very low data loss (almost negligible).

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