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INTELLIGENT INFORMATION SYSTEM OF THE CITY'S SOCIO-ECONOMIC INFRASTRUCTURE

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Abstract. Urban development is an important problem that can be solved with the help of intelligent information systems. Such systems ensure efficient management of the city's diverse infrastructure. The researchers developed a concept of such an information system based on a conceptual model and using data flow for intelligent decision-making. The system was tested for 1460 days in the city of Ternopil. The modelling results showed that the city's central area is stable, with 50% of enterprises in the "growing" state and 70% of people in the "satisfactory" state. People often move to the northeastern and western zones due to higher levels of comfort and more affordable housing. However, the total distance of car trips has increased by 249%, negatively impacting the environment. The condition of enterprises in other zones is less stable with lower "growth" indicators, but there are zones with "stable" and "satisfactory" conditions.

Keywords: modelling, information system, socioeconomic infrastructure, city.

INTRODUCTION

In recent years, studies of economic infrastructure at various levels of the country's socio-economic system have been actively conducted. These studies have led to the synthesis and systematization of knowledge about the economic infrastructure of states, regions and enterprises. This allowed us to reveal its essence and explain the patterns and cause-and-effect relationships at different levels of the economic system.

Recognition of the importance of the social component in the economic infrastructure of the state and regions led to the introduction of the category "socio-economic infrastructure". This is because the growth of activity and efficiency of economic entities is not the main goal, but should contribute to improving the welfare of the population through increased wages, social assistance and improved quality of social services.

Socio-economic infrastructure is a prerequisite for the stability and efficiency of the socio-economic system at any level. In particular, cities play an important role in the country's economy due to their industrial, scientific and technical potential, financial and commodity markets, and the formation of decisions that determine the vectors of socio-economic development of regions and the state.

Therefore, it is necessary to develop an intelligent information system of the city's socio-economic infrastructure to automate optimal decisions on the development of the city's socio-economic infrastructure. In addition, such a system will provide an opportunity to monitor the state of the city's infrastructure online, respond quickly to problems and ensure their effective resolution.

ANALYSIS OF LITERATURE SOURCES

Article [1] explains the lexical and economic meaning of the term economic security. To assess [2] the level of economic infrastructure, an integrated approach is proposed, which consists in combining a number of indicators into a single integral indicator that summarizes data on the level of sustainable development of an enterprise, which allows it to be used both in operational management and in strategy. A resource-functional model of security (consisting of partial indicators and components of economic security of business) was developed [3] and a resource-functional approach to calculations was also applied. A quantitative assessment of the level of financial solvency of countries based on the use of multidimensional methodological tools for assessing financial indicators of the country's development was carried out [4], which leads to the construction of appropriate integral security indices. Unlike other methods of assessing the level of security, the proposed approach makes it possible to determine not only the integrated level of the financial component of economic security, but also to calculate the quantitative thresholds of financial indicators aggregated in the integral index (foreign exchange reserves, external debt per capita, changes in the official exchange rate of the local currency, budget deficit/surplus to GDP); going beyond the thresholds is a signal of increased risk and lack of solvency.

The article [5] investigates the problems of organizing an intelligent system for managing complex socio-economic processes, defines its levels of intellectual development, proposes stages of intellectualization, and demonstrates the effectiveness of applying these solutions in practical tasks.

The article [6] assessed user satisfaction with the electronic social security system (SSES) as a widely used system in Iran. In [7], the Hans-Böckler-Stiftung and its research unit "Future Jobs" present a revised plan for Enzo Weber's DSS model. DSS addresses the problem of serious gaps in social security for platform workers. The model envisages that platforms around the world implement a digital mechanism to transfer a certain proportion of each agreed remuneration to a global DSS account for the platform worker. The DSS account collects the contributions generated globally and transfers them on a regular basis to the social security system of the country where the platform worker is located. Article [8] discusses the principles of building intelligent decision support systems of situational type for innovative development of megacities' infrastructure.

The article [9] provides new insights, develops a conceptual framework, and identifies promising research questions by putting local government AI systems under the microscope through the lens of responsible urban innovation.

The article [11] proposes a new conceptual framework for IDSS for disaster management, with a particular focus on forest fires and cold/heat waves. IDSS uses big data collected from APIs and AI to help decision makers make faster and more accurate decisions.

The article [12] explores the impact of governance on sustainability and reflects the impact of ICTs on decision-making by improving policy effectiveness, accountability and transparency in urban systems. The paper also presents conceptual system models of the cognitive city and energy behaviour, including three sub-levels: human-institutional, physical, and data. It proposes integrated conceptual models to improve the efficiency of energy systems in complex and uncertain environments, facilitate the resolution of energy consumption problems, and support capacity development at the individual, social and technical levels to improve future energy management.

The article [13] was based on a synthesized and aggregated literature review to build a new conceptual framework. The literature review revealed additional existing smart city frameworks, including city services (essential services, nonessential services, and complementary services); city resources (superstructure, infrastructure, infostructure); city architecture (enterprises); and city goals (livability, performance, and sustainability). This study contributes to a broader understanding of the smart city reference model for Indonesia and other developing countries.

The above-mentioned works mostly assess economic or social infrastructure as a separate system. Few works consider the socio-economic infrastructure as an information system (analogues).

In this regard, the purpose of this article is to develop the concept of an intelligent information system for the provision of socio-economic infrastructure of the city.

The developed intelligent information system for the provision of socio-economic infrastructure of the city differs from its analogues [5, 7, 8, 9, 12] in that it takes into account qualitative and quantitative indicators. This system can automate the distribution of powers between the state and regional governments in the development of master plans for the development of cities in the country, social programmers and other documents aimed at improving the quality of life of the population. In the future, this intelligent information system can be used as a basis for the development of other systems for similar purposes.

CONCEPT OF AN INTELLIGENT INFORMATION SYSTEM FOR THE CITY'S SOCIAL AND ECONOMIC INFRASTRUCTURE

To ensure the socio-economic infrastructure of a city, an intelligent information system (Fig. 1) should contain at least four main levels of infrastructure: economic, social, environmental, and socio-political. To achieve this goal, it is important to take into account both quantitative and qualitative indicators. Let us consider each level separately.

he social sphere includes people's attitudes towards culture, art, and tourism [18, 19], as well as an assessment of personal safety, the education system and personal education, the healthcare system and personal health, amenities and living conditions [16], and transport.

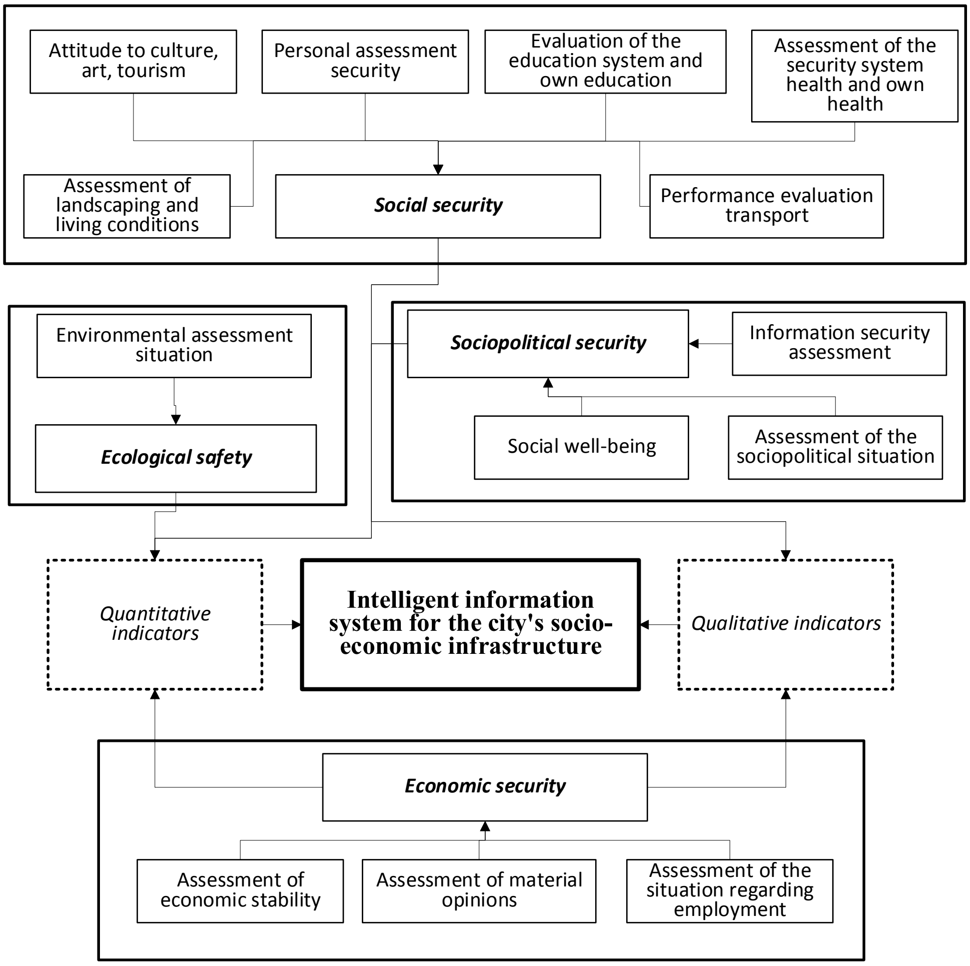


Fig. 1. The concept of an intelligent information system for the city's socio-economic infrastructure

The importance of the environmental sphere for a person is an assessment of the current environmental situation in the city.

As for the economic sphere, a city resident can assess economic stability [17], their financial situation and the employment situation.

Today, during the period of military aggression in Ukraine, socio-political security is becoming important for everyone, and every city resident can assess the socio-political situation, information security and personal social well-being.

Let's take a closer look at the structure of the data flow in the intelligent information system for the city's socio-economic infrastructure (Fig. 2).

Data will be collected based on surveys of residents, as well as on the basis of collected statistical indicators and sensor data. The latter is important for studying the city's environmental infrastructure.

All quantitative data will undergo preliminary processing and will be stored in the relevant databases. In the case of surveys, after collecting data into the database, it needs to be processed using intelligent methods to give it quantitative values.

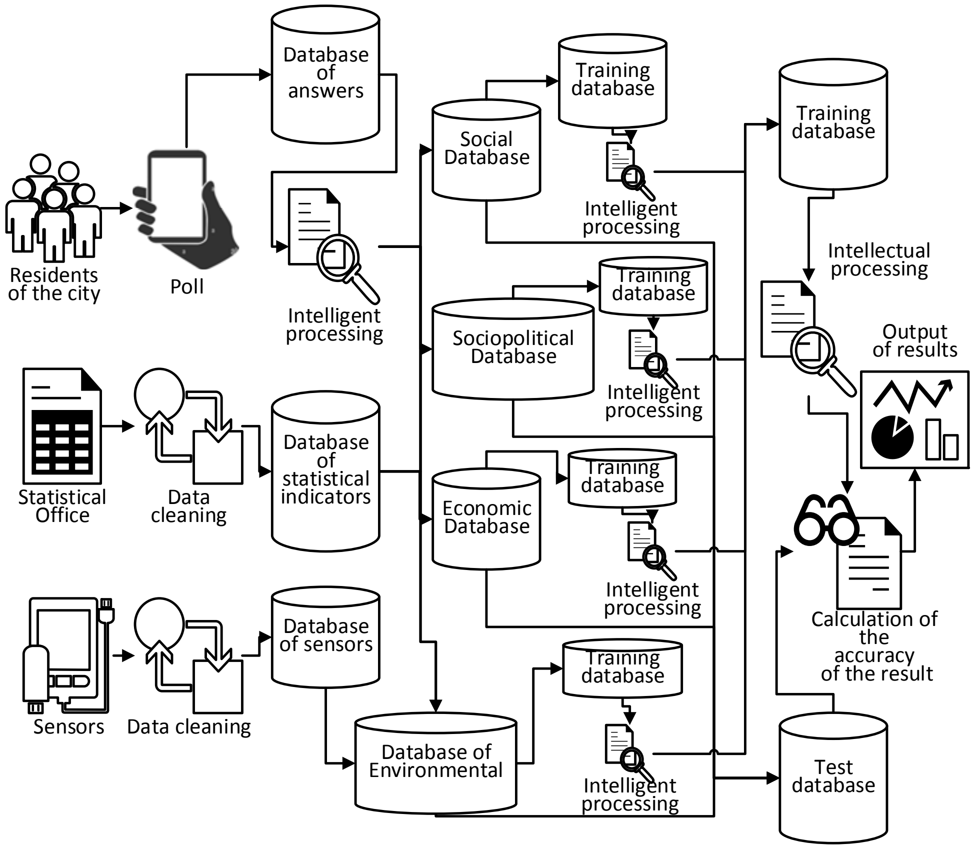


Fig. 2. Data flow in an intelligent information system for the provision of the city's socio-economic infrastructure

All data is then transferred to the databases of the four levels of socio-economic infrastructure. At each level, intelligent data processing is carried out, the results of which are transferred to a common training database. At the same time, data from the databases of the four levels of socio-economic infrastructure are transferred to a common test database.

The main intellectual processing is carried out on the common database, after which the accuracy is calculated relative to the common test database. Finally, the results are displayed.

The presented conceptual model of an intelligent information system for ensuring the socio-economic infrastructure of the city and the structure of the data flow in it makes it possible to monitor threats to society in the context of socio-economic infrastructure in real time. The developed conceptual model can be part of a smart city [10].

EXPERIMENTS AND RESULTS

In general, modelling such a system involves developing a mathematical model, programming and simulating the system on a computer. Next, we will simulate the system's operation and model the city's socio-economic infrastructure.

First of all, the objects to be modelled, the city's socio-economic infrastructure and its components, are identified. In this case, these may include city zones, residential and business units, enterprises and people, and CO_2 emissions.

Next, it is necessary to investigate how these objects will interact with each other, which is described using various algorithms and formulas. In this case, an agent-based model was created, where each agent has its own set of characteristics and interacts with other agents and the external environment.

Thus, the system uses an agent-based transport and dynamic model to simulate the movement of people and businesses in the city and their interaction. Each agent (person or enterprise) has its own properties and can change its state according to the interaction with other agents and changes in the environment. For example, a person can change his or her job, move to another area, or buy a car if he or she has sufficient funds. An enterprise can change its operation or production in response to changes in demand for its products or services.

Data is collected automatically in real time. Traffic information is collected using sensors on roads and vehicles and transmitted to the system for further processing and analysis. CO2 emissions are also collected and accounted for in the system. In addition, the system analyses data on the level of comfort of housing, the number of residential and commercial units in each zone, and other factors that affect the standard of living in the city.

Modelling based on data from a specific city, such as Ternopil, is an important stage in the development of an information system for managing socio-economic infrastructure. It allows to take into account specific features of the city, such as demographic, economic, transport and other characteristics.

Ternopil is a medium-sized city located in the western part of Ukraine. It has a rich history, as well as important economic and cultural significance for the region and the country as a whole. According to the Ukrainian State Statistics Committee, as of 1 January 2022, the population of Ternopil was over 219 thousand people [15]. The age group selected for modelling is 25-54 years, which is 44% of all citizens [14], as this category belongs to the active working age group, people who are potentially able-bodied citizens. This is an important factor for modelling the city's socio-economic infrastructure, as this category of citizens are the main users of transport and other public services, and the functioning of the city's infrastructure depends on their activity.

Based on the Ternopil city model, we will highlight some properties that may be characteristic of certain city zones:

1. The central area of Ternopil is the most commercial and business-oriented zone, with a high level of comfort, but also with high property values.
2. The South-Western zone of the city is a residential zone with a low level of comfort and average property prices.
3. The north-eastern area of the city is more industrial with a large number of factories and plants, and few residential areas.
4. The area on the western edge of the city is a residential area with a high level of comfort and high property prices.
5. The southern edge of the city is a more industrial area with few residential areas and average property prices.

Based on expert data (Table), the values of the system input parameters were formed.

An information system has been developed based on the model [15] and adapted for the city of Ternopil.

According to the results of the modelling carried out for a period of 1460 days, it was found that the largest number of enterprises (Fig. 3) is concentrated in the central, western and southern zones of the city. This is due to the fact that these zones are more developed in terms of economy and the location of the city centre. The largest concentration of population (Fig. 3) is also observed in the central and western zones of the city.

System parameters for the zones of Ternopil city

Zone	Housing capacity	Comfort level	Number of places for enterprises	Road capacity, % of total traffic
Central	600	1	35	20
North-western zone	500	0.7	25	55
North-eastern	1000	0.5	100	85
Western	700	0.9	20	30
South	500	0.6	70	90

a *b*

Fig. 3. Modelling results: *a* — workload of enterprises; *b* — po

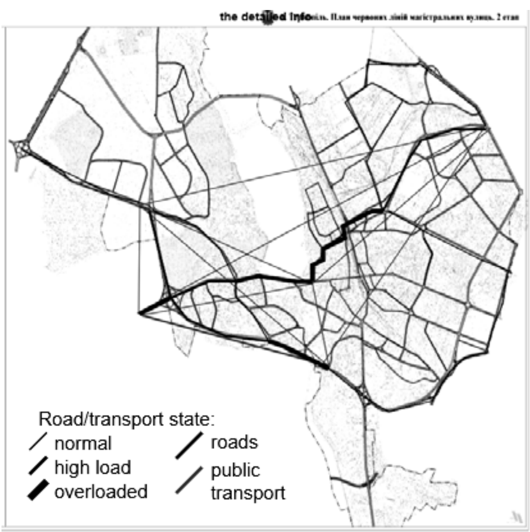


Fig. 4. Road load

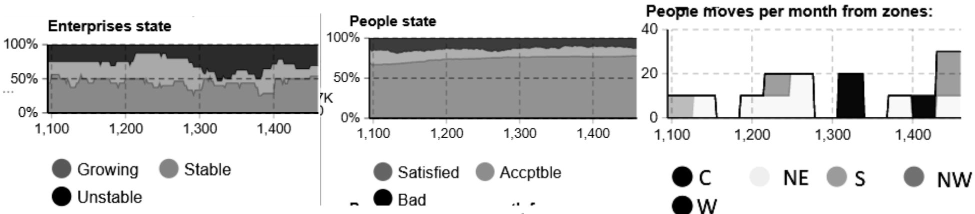
The modelling results showed that the highest road congestion (Fig. 4) in Ternopil is observed on the route from the western zone of the city to the north-eastern zone through the city center. This is because most of the city's residents live in the western and central parts of the city, but work in other parts of the city, particularly in the northeastern part. Thus, this route is key for transporting people and goods in the city.

The following is a more detailed analysis of the indicators for each zone.

First, the state of enterprises

will be analyzed: the data is presented as a time series of three variables for each point in time: growing, stable and unstable. Next, the data on the state of people, this data is a survey where people are asked to assess their condition in relation to their place of residence: satisfactory, acceptable or poor. And lastly, we will analyze the rate of moving from the respective area of the city to another.

So, let’s first look at the central zone indicator (Fig. 5). The state of enterprises is characterized by “growth” at the level of 50%. This may mean that the overall level of economic development in the region is positive, or that there is a certain level of stability in this area. The state of people in a “satisfactory” condition is 70%. This indicates that the majority of the population feels satisfied with their lives, possibly due to economic achievements that allow people to meet their needs. People most often move to the north-eastern zone. This may be due to certain factors, such as job opportunities, infrastructure development, better living conditions or other factors.



a *b* *c*

Fig. 5. Central zone: *a* — the state of enterprises; *b* — human condition; *c* — people move to other zones every month

According to the data, the state of enterprises in the Northwest zone (Fig. 6) is stable on average with a business growth rate of 50%, but there is a certain probability that the state will become “unstable”. The situation of people in this zone is generally satisfactory with a comfort level of 70%. People tend to move to the Western zone, probably because of the higher levels of comfort in this zone. Therefore, the North-Western zone can be an attractive place to live and develop business, provided that the businesses remain stable.

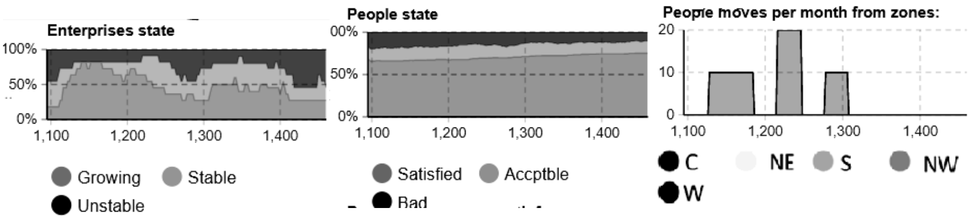
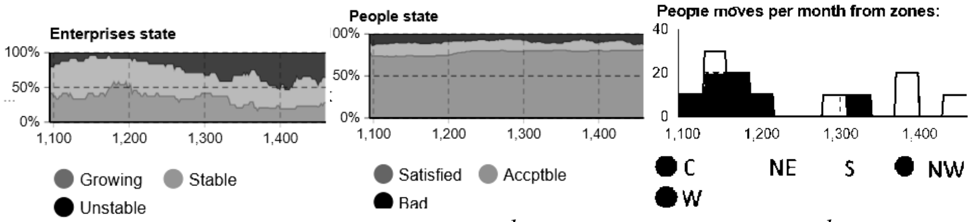


Fig. 6. North-Western zone: *a* — the state of enterprises; *b* — human condition; *c* — people move to other zones every month

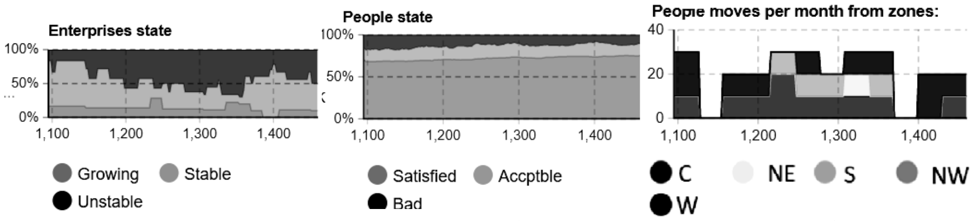
The North-Eastern zone is characterized (Fig. 7) by a less stable state of enterprises compared to other zones. The growth rate is less than 30%, although sometimes it can become unstable and reach 50%. In such periods, enterprises may have problems with maintaining and developing their business. The state of people in this zone is relatively satisfactory, as most people are currently satisfied with their situation. This may be due to the high level of employment in the area, or possibly other social factors that keep people comfortable. Nevertheless, people in the northeastern zone are more likely to move to the western zone, where they have a higher level of comfort. This may be due to fewer career opportunities in the northeastern zone, or to a lower quality of life due to less stable businesses. It is also possible that people are moving to the central zone, where there are more employment and career opportunities.



a *b* *d*

Fig. 7. North-eastern zone: *a* — the state of enterprises; *b* — human condition; *c* — people move to other zones every month

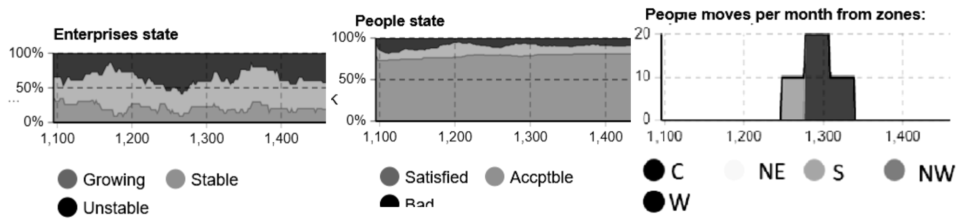
The Western zone is characterized (Fig. 8) by a lower level of economic growth compared to other zones. Most of the enterprises in the zone are in an “unstable” state, which can create difficulties for businesses and investors. However, in most cases, the condition of enterprises is “stable”. People’s perception of the area’s quality of life is fairly high, with a “satisfactory” rating of 85%. People tend to move to the north-western zone, where housing is cheaper, and to the central zone, where there is a higher level of comfort and opportunities for career and business development.



a *b* *d*

Fig. 8. Western zone: *a* — the state of enterprises; *b* — human condition; *c* —people move to other zones every month

In the Southern zone (Fig. 9), the situation of enterprises can be characterized as stable in most cases, although some enterprises may experience instability. In general, the state of enterprises in this zone can be described as “growing” at the level of 25–30%. As for the state of people, they are in a “satisfactory” state at 85%. People are most often moving to the central zone, as it offers a higher level of comfort.



a *b* *d*

Fig. 9. Southern zone: *a* — the state of enterprises; *b* — human condition; *c* — people move to other zones every month

Also, the system has statistics (Fig. 10) that show that the total distance of car trips has increased by 249% or more than three times (the initial distance was 83.661 km and now it is 208.414 km). This has also resulted in an increase in CO_2 emissions by the same amount – 249% of the initial emissions level. This is an indicator of increasing air pollution and can have a negative impact on human health and the environment. This data can be used to evaluate the effectiveness of programmers and policies aimed at reducing car traffic and air pollution.

Statistics

Total car trips distance, % (Km):
+249.326% (208414 Km)
CO2 emissions variation, %
+249.326% of original

Fig. 10. Statistics on CO_2 emissions from motor vehicles

It is also possible to display information on each individual enterprise (Fig. 11) and person (Fig. 12).

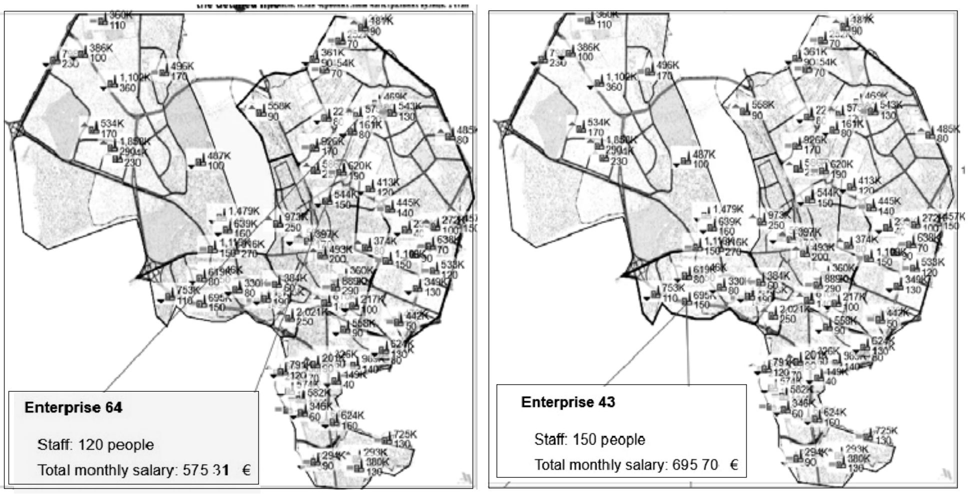


Fig. 11. Display of information on the enterprise

Fig. 12. Displaying information on people

For example, the first 64 enterprises have 120 employees and a total monthly production capacity of 57.5 thousand euros. The state of the enterprise is "growing", which may indicate a successful team and effective business management. The second enterprise 43 has a larger number of employees – 150 people. The total monthly production capacity of this enterprise is 69.5 thousand euros. The company's condition is "stable", which may indicate its long-term sustainability and reliability. Overall, both enterprises have significant potential and can be successful in the market for their respective goods and services. However, their future development depends on how efficiently they use their resources and how well they can adapt to changes in the current business environment.

The first person, 917 (Fig. 12), is 24 years old, lives in the north-western zone and also works in the central zone. According to the status, she also considers her condition to be satisfactory, with an income of €1058 per month. The second person 381 is 39 years old, lives in the southern zone and works in the central zone. According to the status, she considers her situation to be satisfactory. Her income is 892 euros per month.

Thus, during the 1460 days of modelling the socioeconomic infrastructure of Ternopil, it was found that the state of enterprises in different zones has different levels of growth, and the state of people is mostly satisfactory. People tend to move to areas with higher levels of comfort or cheaper housing. The total distance of car journeys has increased by 249%, resulting in CO_2 emissions in line with this increase. The model also provides information about two people – one living in the southern zone and the other in the north-western zone, both working in the center and in good health.

CONCLUSIONS

The concept of an intelligent information system for the provision of the city's socioeconomic infrastructure and the structure of the data flow in it have been developed. This system will automate the distribution of powers between the state and regional governments in the development of master plans for the development of cities in the country, social programmers and other documents aimed at improving the quality of life of the population.

Experimental results of the 1460-day simulation of the intelligent information system for the city's socioeconomic infrastructure show a 50% increase in businesses in the central zone and a 70% increase in people's satisfaction, as well as a move of residents to the north-eastern and western zones due to a higher level of comfort. The total distance of car journeys increased by 249%, and the change in CO_2 emissions also increased by the same percentage, which is negative for the environment. The condition of enterprises in other zones is less stable, with lower "growth" scores, but there are also zones with a stable and "satisfactory" condition.

Further research may include the development of new methods and algorithms for using data from the city's socioeconomic infrastructure in intelligent information systems, analysis of the impact of intelligent information systems on the economic and social development of the city, development of new information technologies for creating intelligent information systems, and research on the impact of an intelligent information system on the environmental sustainability of the city. In addition, the interaction of intelligent information systems with local governments, business and the public, as well as the impact of intelligent information systems on ensuring accessibility and equality of use of the city's socioeconomic infrastructure for all its residents and visitors can be studied.

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INFORMATION ON THE ARTICLE

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ІНТЕЛЕКТУАЛЬНО ІНФОРМАЦІЙНА СИСТЕМА СОЦІАЛЬНО-ЕКОНОМІЧНОЇ ІНФРАСТРУКТУРИ МІСТА / Х.В. Ліп’яніна-Гончаренко, Є.В. Бодянський, А.О. Саченко

Анотація. Розвиток міст є важливою проблемою, яку можна вирішити за допомогою інтелектуальних інформаційних систем. Такі системи забезпечують ефективне управління різноманітною інфраструктурою міста. Дослідники розробили концепцію такої інформаційної системи, яка базується на концептуальній моделі та використовує потік даних для розумного прийняття рішень. Систему протестовано на період 1460 днів у місті Тернопіль. Результати моделювання показали, що центральна зона міста є стабільною зі станом підприємств «зростаючий» на рівні 50% та станом людей у стані «задовільно» на рівні 70%. Люди найчастіше переїжджають у північно-східну та західну зони через вищий рівень комфорту та більш доступне житло, проте загальна відстань автомобільних поїздок збільшилась на 249%, що має негативний вплив на довкілля. Стан підприємств у інших зонах є менш стабільним з нижчими показниками «зростання», але є зони зі «стабільним» станом і станом «задовільно».

Ключові слова: моделювання, інформаційна система, соціально-економічна інфраструктура, місто.