SYSTEM MODEL OF E-SERVICES FOR SUBURBAN AREA MANAGEMENT

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Abstract. Nowadays, smart cities are a prominent research field with practical implementation. Many prominent economically developed city governments and institutions are working on the implementation of large software, hardware, and IoT systems to help make cities more convenient to manage and comfortable to live in. At the same time, few acknowledge that rural and specific rural suburban areas can benefit from smart system implementation. In this paper the authors present the system model concept of e-services that can be used by local government bodies to manage their settlements. We focus our attention on the case of sub-urban areas for the case study. For data management and system development concept evaluation, the authors have used information from several rural settlements in the Kyiv region (country of Ukraine). The suburban areas management system model is based on the concept of digital e-services, which are often used in the case of smart city and land management solutions. Information systems are vital for effective processing and decision support in the case of large data and complex system management. In addition to information systems rural settlement requires a web portal and notification modules. The presented research work can be used as a substantial foundation for further studies and case implementation for each specific statement, considering local area specifics. In the future, the authors plan to add GIS and land management system modules to the list of e-services, besides researching a way to connect smart city management solutions with the presented suburban areas management digital service.

Keywords: system modelling, urban economics, rural development, information systems, smart city.

Introduction

The main roadway of the last decades in national economics of many countries is directed to sustainable development (SD), which has [1] "three principal dimensions: economic growth, social equity and protection of the environment" and grounds on the five principals – "(1) country ownership and commitment; (2) integrated economic, social and environmental policy across sectors, territories, and generations; (3) broad participation and effective partnerships; (4) development of the necessary capacity and enabling environment; and (5) focus on outcomes and means of implementation." The innovative approaches for the automation systems of all human activity spheres must realize these peculiarities. This goal also needs new models of information processing and data representation. There is no unified system concept nor there is a smart city-level software platform for rural areas and small towns [2-8]. Existing solutions focus on land management [2; 6; 8-12] or smart city platforms for larger agglomerations [7; 13]. Without a doubt not all small towns and rural areas need such a system, they have local information software applications [14]. New technological advancement, namely Industry 4.0 and IoT devices add a new layer of complexity and possibilities for areas management [15]. Today, there are no full-fledged digital systems for small settlements and towns in Ukraine (they are available only in a few large cities – Kyiv and Lviv). Within the scope of our research, we focus on small towns in the vicinity of large cities. Such cities have better funding and larger population, but at the same time, they have many persistent issues (social, economic, etc.) due to the close proximity of a larger city. The developed software, hardware, and system models consider the scale of the necessary system, real-world social-economic and land data, as well as procedures and policies used by local governments of small towns and rural agglomerations. The resulting system design is abstract enough to be used for various smart management systems as well as for various land/urban-system modelling research.

Materials and methods

There is no standard definition that defines an urban area or urban population, and how it differs from suburban or neighbouring rural settlements. Most, if not all, countries have their definition of a city and an urban conglomeration. As a result, statistics can often mislead us, or we can misinterpret them. Based on the above facts, it is difficult to have a realistic view of the percentage of urbanized population and settlements without first working out all the terminology regarding the processes associated with urbanization and providing them with clear definitions [8]. An urban area is defined by one or more types of data: administrative criteria or administrative boundaries (e.g. an area within the jurisdiction of a municipality or city council), population limits (where the minimum for an urban settlement is generally 2,000 people, although this figure varies worldwide from 200 to 50,000 people), population density, economic function (e.g. where a large majority of the population is not primarily engaged in agriculture, or where there is a surplus of employment) or the presence of characteristic features of the city (e.g. paved streets, electric lighting, sewerage, etc.) [9; 10].

For the study, we picked Kyiv city and small towns in its vicinity (Figure 1). Kyiv has been divided into two zones – Central Business District and City. The neighbouring cities are classified as the rural zone. The rural zone is more focused around the south of Kyiv due to social and economic factors, towns, and villages in the south are more populated, have a larger concentration of roads, number of industrial zones. As a result, those areas are more likely to benefit from e-service implementation, have appropriate financial resources, and demand to develop and use area management service. While the area to the north of Kyiv is more residential and private farming focused and should be studied, classified separately.

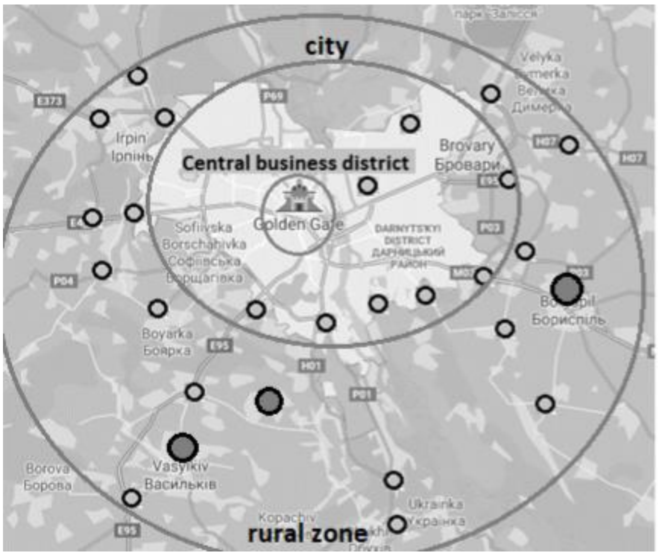

Fig. 1. **Map of research area divided into zones – CBD (Kyiv), Kyiv city and rural area zone**

To get a better understanding of the existing differences between CBD, the city zone, and rural zone, we study the main social, economic, and financial data. A summary of the research results is presented in Table 1, divided into three area types.

Table 1

Research area data by zones – CBD (Kyiv), Kyiv city and rural area zone (pre-2022 data)

Data	CBD (Kyiv)	Kyiv city	Rural zone
Total area population, people	253000	2910195	800000
Area, sq. km	33.6	839	2761
Drive distance to CBD, km.	-	14.6	45
Areas covered by constriction and industrial buildings, %	53	29	5
The workforce employed out of the total population, %	37 (out of Kyiv)	63	58
Average yearly salary, USD per year	8929	5765	5431
Average market land price, USD per sq.m.	879	83.2	14.2
Average market real estate price, USD per sq.m.	3085	1200	480
Total investments (non-resident investors) per annum, USD	no data	70653272	1875040

Results and discussion

The SMART Cities information systems have a strong hierarchical structure and functional division (Figure 2). We can also point to the software and hardware layers related to each other (sensor network

– data sources, data centres – e-services and portals, DBs with data integration and APIs – at the middle layers). However, the base model of the high-level data and information representation is decentralized and distributed with a mesh structure. In the IoT conception, each of this mesh nodes at different times may have different roles – at some time it will be the data source, and at other times is the information system. For example, for the flat owner his home automation software is an information system with a flexible set of features. At the same time, for the management company or community level systems, it will be a plain data source point with a fixed characteristic set.

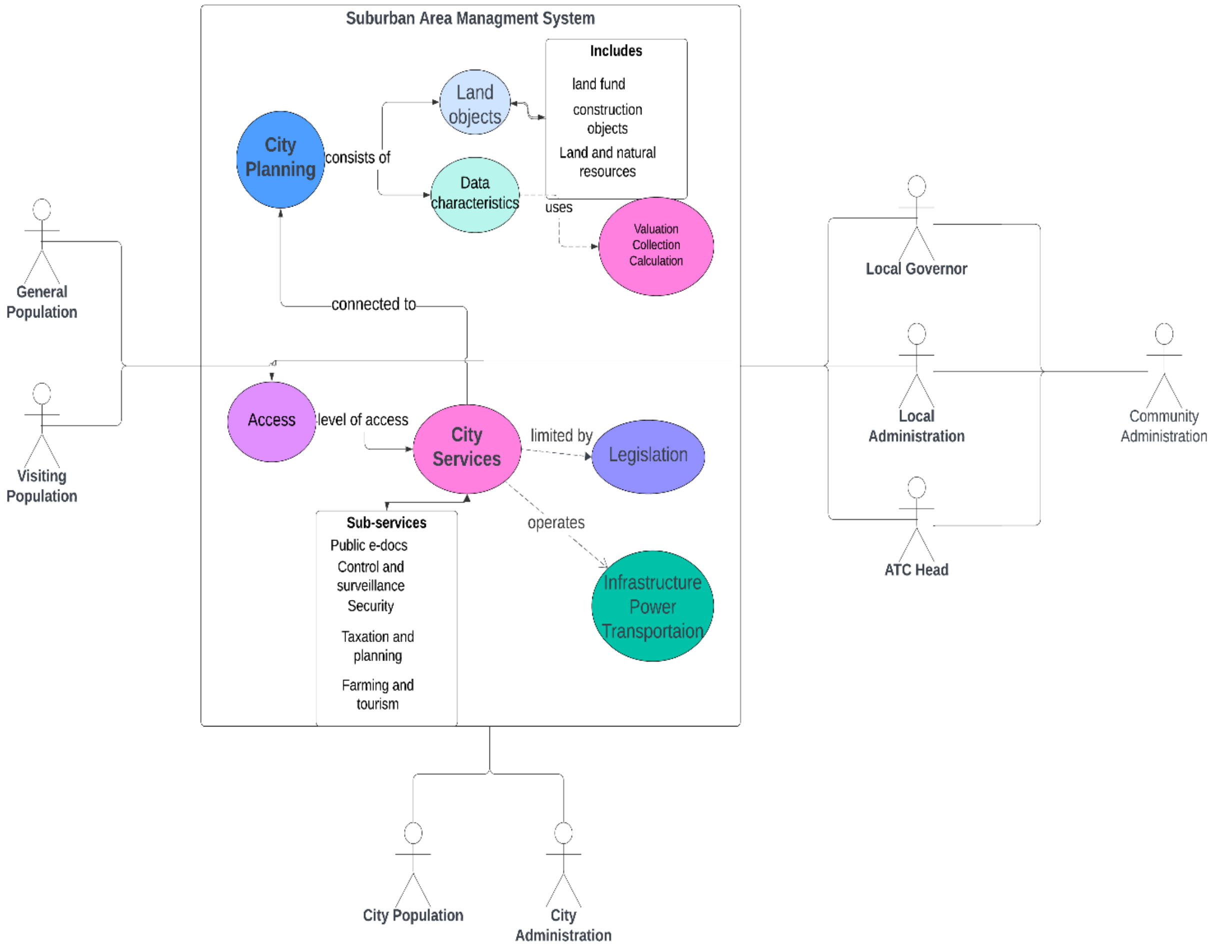

Fig. 2. **Suburban Area Management System, list of main components and types of users**

The standard workflow policies in the city government's peculiarity justify the possibility and need for the use of computerized means on all levels of the SMART City automation system (Figure 3). On the other side, it makes it possible to create information systems with dynamic heterogeneous structures. This way it is possible to move some functions from the high-level information systems to the low-level components – sensor networks or middle-level fog systems. At first, these functions of the sensor data transformation and local control. Next - the unified data representation for the upper-level systems. At the present moment, local rural government institutions use a number of official digital services and software solutions, mostly for official reports, documents submissions and financial accounting. The proposed management system is not meant to replace them but be used together with official national services. This system has its own local databases and service, while it provides GUI panel for end-users and API connectors, data-processing microservices to connect and send requests to existing e-services. In addition, the proposed system requires a special middleware platform to connect and process input/output signals from existing/new digital devices (such as cameras, sensors, alarms, to name a few). The SD targets lead to including such new components as "Social group" or "Environment" with active roles opposite to their roles of the passive monitoring objects as earlier. This causes the emergence of new relations or changes from unidirectional relations to bidirectional ones. Any object (or Node) in the common system becomes active and dynamic and realizes its self-specific behaviour (or the certain e-service). The system as a complex becomes distributed and multiagent with an Ad-hoc mesh structure.

The "Environment" and "Land areas" ("Steads") components, as the object of getting and generating influences, have such characteristics as spatial location described by coordinates. Objects that have an information connection with them (really - all) must have this characteristic (coordinates), also. One of the difficulties today is the unclear meaning of spatial distribution and relation of the great amount of atmosphere, soil, and water processes and characteristics. The solution to this problem can be found with these characteristics' behaviour analyses by AI use.

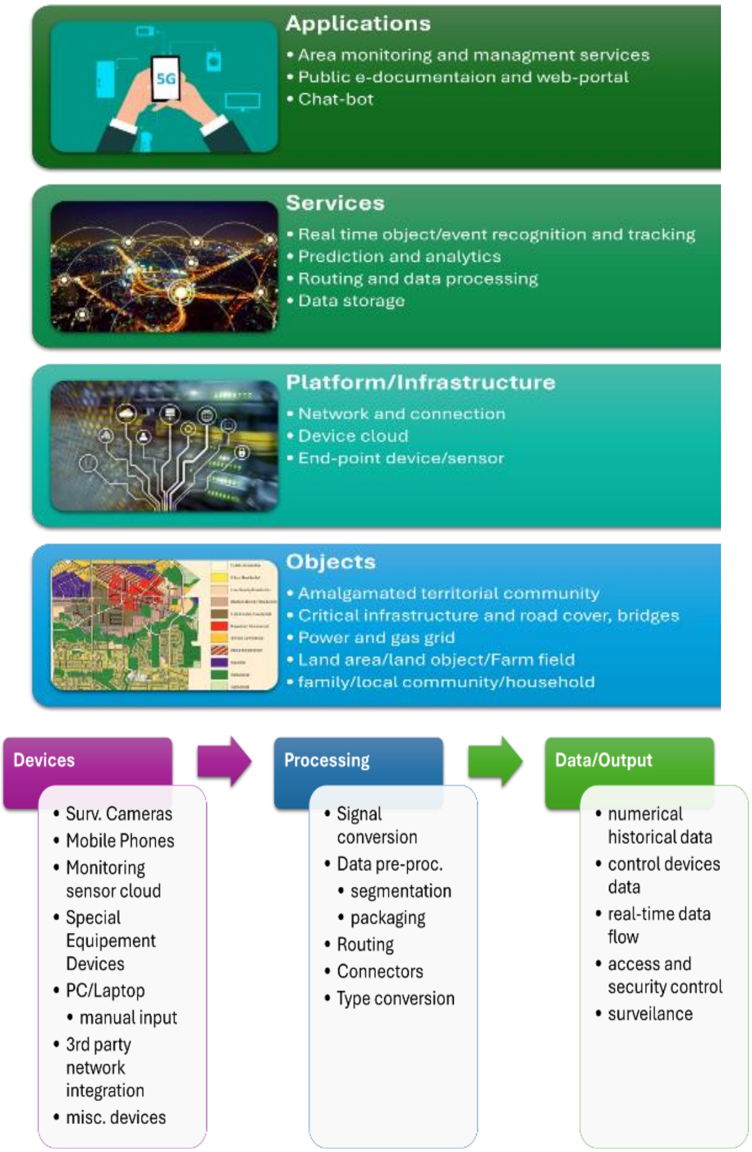

Fig. 3. **IoT Area Management System Model – components and data**

While Figure 3 showcases software and technological components, Table 2 outlines social, economic, and land management parameters that play important roles in research, system design, and development for the IoT Sub-urban area management system.

Table 2

Suburban area management system – list of main components

Objects	Data	Functionality and System Output
Governance - community - City	(un)Employment rate Inflation rate Interest rate Trade balance Local town budget	Financial planning Socio-economic management Land and ecological surveillance Legislation and policies governance Public health and security control

Table 2 (continued)

Objects	Data	Functionality and System Output
Land - commercial - private - municipal	Price, Lease, Rent Location, Area Maintenance price	Land use and zoning Land market Architectural planning Construction planning and surveillance Employment and taxation policies Ecological and environmental monitoring, taxation
Real Estate - private houses - condominium - commercial - municipal		
Industry - processing& manufacturing - resource-based - office-based etc.	Financial and tax Device and sensor data	
Agricultural - farm - land	Location Area Financial and tax	Food and resource Transportation Waste management Taxation and sustainable policies
Infrastructure and road - grid	Device and sensor data Digital Map and spatial	Waste management Grid, road, cover and surveillance
Energy and resources - grid - land area	Numerical Historical Analytical	Resources consumption and recovery management Power and Water supply

The smart management system states and job processing is an important part of the Smart City management e-service (Figure 4). Figure 5 illustrates the city administration dashboard panel, which is one of the key service modules of the management platform (client-application side). Based on the presented system model and its components, it is possible to develop such a system for each individual rural settlement. For its implementation, the system should consist of following components and steps:

- System-related stakeholders research – city council, city residents, tourists and seasonal workers, local/federal government;
- Questionaries and user research – local community survey, service development costs, and time requirements, data mining, list of existing IoT and electronic devices/networks and grids;
- Services and applications – city council website, city governor web service, communication and notification chat-bot application;
- Software Systems – distributed Web Application Service, IoT Middleware Platform, Network, data warehouse or distributed database;
- Deployment and infrastructure – cloud or local hardware (server), data centres and routers, power, and wired/wireless network grid;
- Testing and evaluation – user requirements and testing, software and hardware platform testing, prototype testing, and system concept evaluation.

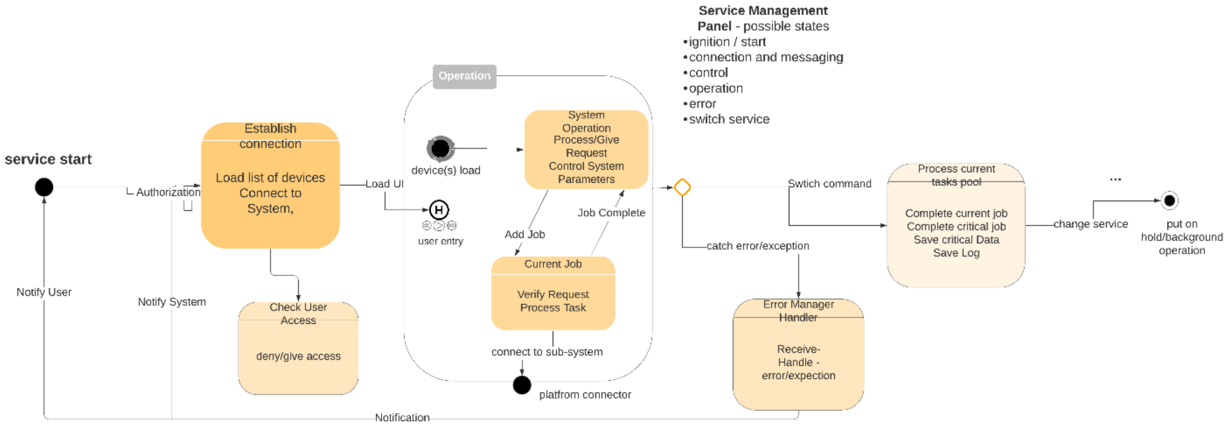

Fig. 4. **Smart management system states and job processing**

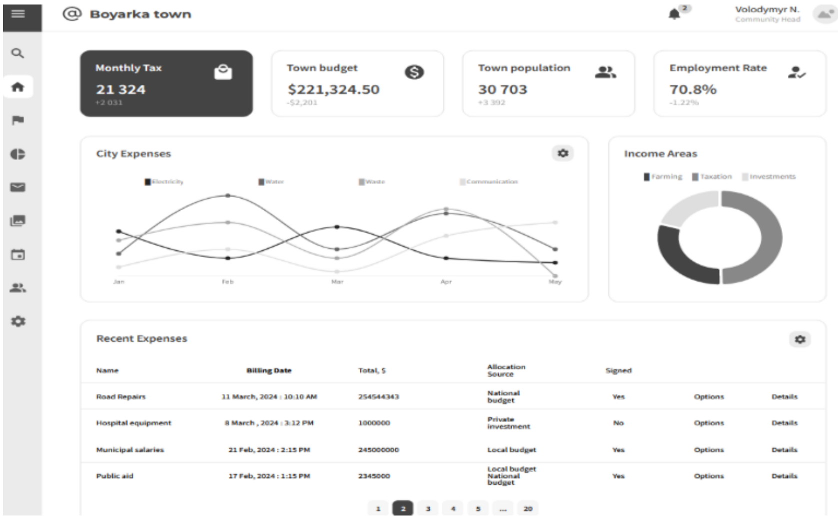

Fig. 5. **Example website page design – city administration dashboard panel**

Conclusions

The authors presented in the paper the Suburban Area Management System, which consists of the main software components with a specific set of user roles. The IoT Area Management System Model is an example of a hardware related part of the main Management System. As a result, a sample website page design for the city administration dashboard panel was designed. The presented e-service concept system design consists of several key components - modules, information system, web portal, smart job and state processing systems, and others. The main modules are used to keep track of resident's inquiries, petitions, special status updates, and notifications in case of a disaster, among other things. The presented concept system can be used to develop a rural-town-specific digital eService governance system. As a summary, it should be noted that for the implementation of e-Services for Suburban Areas Management, the step-by-step actions are as follows:

1. Investment plan - determine the main path of economic growth and development of the territory and macroeconomic planning and develop an investment plan for social security and population growth. Spatial development and zoning - territorial zoning and planning of construction of new facilities, create plans to minimize the negative consequences of the real estate market, social security, and environmental impact. Develop a long-distance and regional agreement - an economic plan for regional development, a Master Plan for the Development, Investment, and Construction of Suburban Areas, a plan for the ecological restoration of territories for conducting a comprehensive study with the involvement of the public and various institutions.
2. Develop information system for accounting data on settlements - the economic activity of the population: income, employment, and expenditure profile, economic statistics, and data on spatial development and land-use in the context of urban development by time intervals, data from environmental monitoring systems, waste management statistics, data of urban life support, and engineering systems, data of the transport, traffic and emergency monitoring system;
3. Suburban Area Management systems - assessment of the dynamics of changes and the state of the financial sector by types of economic activity, key sectors of the economy of territorial communities, monitoring the state of social security and basic services for residents and others, a plan to diversify the source of energy and heat supply to the city, a taxation system for new green technologies, etc.

Author contributions

Conceptualization, V.N.; methodology, V.N. and V.S.; validation, M.M. and B.O.; formal analysis, V.B and B.O.; writing – review and editing, V.N., M.M. and V.S.; visualization, V.N., B.O. All authors have read and agreed to the published version of the manuscript.

References

[1] Alam M. S., Brooks L. Identifying a public sector information system (PSIS) for E-service: a case of land records E-service in Bangladesh. In Electronic Government: 13th IFIP WG 8.5 International Conference, EGOV 2014, Dublin, Ireland, September 1-3, 2014. Proceedings 13 (pp. 106-119). Springer Berlin Heidelberg.

[2] Nazarenko V. System Modeling of the Smart City in Context of Land Management E-Service. Land Science, 3(1), 2021, p. 22.

[3] Enemark S. Understanding the land management paradigm. In Proceedings: Innovative technology for land administration, International Federation of Surveyors, 2006 pp. 17-27.

[4] Yang F., Zeng G., Du C., Tang L., Zhou J., Li Z. Spatial analyzing system for urban land-use management based on GIS and multi-criteria assessment modeling. Progress in Natural Science, 18(10), 2008, pp. 1279-1284.

[5] Darmawan A. K., Siahaan D. O., Susanto T. D., Umam B. A., Bakir B. Exploring Factors Influencing Smart Sustainable City Adoption using E-Government Services Effectiveness Evaluation Framework (E-GEEF). In 2020 3rd International Conference on Information and Communications Technology (ICOIACT), pp. 234-239.

[6] Bennett R. M., Donovan J., Masli E., Riekkinen K. Land Administration As-A-Service: Relevance, Applications, and Models. Land, 12(1), 2023, 241 p.

[7] Khodabakhsh P., Fathi H., Mashayekhi S. Planning for future urban services in the smart city era: Integrating E-services in urban planning process. Armanshahr Architecture & Urban Development, 9(16), 2016, pp. 153-168.

[8] Zitti M., Ferrara C., Perini L., Carlucci M., Salvati L. Long-term urban growth and land use efficiency in Southern Europe: Implications for sustainable land management. Sustainability, 7(3), 2015, pp. 3359-3385.

[9] Pak D. N. B., Kirtiloğlu O. S., Kayalik M., Polat Z. A. The transformation from e-government to e-land administration in Türkiye: A SWOT-based assessment analysis. International Journal of Engineering and Geosciences, 8(3), 2023, pp. 290-300.

[10] Choi H. O. An evolutionary approach to technology innovation of cadastre for smart land management policy. Land, 9(2), 2020, 50 p.

[11] Bokhari S. A. A., Myeong S. Artificial Intelligence-Based Technological-Oriented Knowledge Management, Innovation, and E-Service Delivery in Smart Cities: Moderating Role of E-Governance. Applied Sciences, 12(17), 2022, 8732.

[12] Ameyaw P. D., de Vries W. T. Toward smart land management: land acquisition and the associated challenges in Ghana. A Look into a Blockchain Digital Land Registry for Prospects. Land, 10(3), 2021, 239.

[13] Inkinen T., Merisalo M., Makkonen T. Variations in the adoption and willingness to use e-services in three differentiated urban areas. European Planning Studies, 26(5), 2018, pp. 950-968.

[14] Sharma S. K., Metri B., Dwivedi Y. K., Rana N. P. Challenges common service centers (CSCs) face in delivering e-government services in rural India. Government Information Quarterly, 38(2), 2021, 101573.

[15] Danu D. E. A., Supardi S., Sutanto S. T. J. P., Riko R. S. E-Services: Implementation of Digital-Based Public Services in the 4.0 Era. Athena: Journal of Social, Culture and Society, 1(3), 2023, pp. 87-92.