

RESEARCH ARTICLE

REVISED Sustainable development of smart cities and smart territories based on the model of minimizing externalities [version 2; peer review: 3 approved, 1 approved with reservations]

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Abstract

The development of conceptual models of a digital city poses numerous challenges for developers. The public sector concept model has become one of the most difficult models to use. When developing algorithms to find a solution, the multidirectional interests of businesses and public institutions are combined. This type of model reflects the most acute and urgent problems faced by megapolises with regard to combining numerous localized services provided to the community in a limited territory. The administrations of both cities and regions (the scale of the smart territories) must make decisions concerning overcoming the barriers existing between the profits of commercial structures, the negative externalities generated by their activities, and the social benefits to the population in the territory under their control. It is necessary to solve this problem to achieve the effective management of enterprises belonging to the segment of long-term participants in various business activities, interacting with the surrounding social and business environment in a complex. This study takes into account the complex structures of the economic processes characteristic of megacities. The periodicity of economic processes is also taken into account. When choosing an optimization

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criterion, functions reflecting the level of internalization of responsibility for external effects were considered. The authors propose a mathematical model that can be used as part of the management decision support systems software, aiming at taking into account the externalities of a wide range of national, institutional, business, and social activities.

Keywords

Smart Cities, Digital Platforms, Sustainable Development, Digital Interactions, Smart Territories, Agglomeration, Satellite-Cities.

Aksaray, Turkey

Any reports and responses or comments on the article can be found at the end of the article.



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REVISED Amendments from Version 1

The author restructured the abstract. Sentences were shortened in accordance with the recommendation that the authors consider revising them to no more than two sentences. The updated version of the abstract included the background, methodology, findings, and conclusion. The externalities are very important concepts in the research, and the mentioning of the externalities is reflected in the first sentence of the abstract. Here, by investigation, the authors explained this term in the introduction in the revised version in order to clarify the confusion. The researchers explained the impacts of externalities on the sustainable development of smart cities and territories. The explanation was disclosed with more details in the introduction. The authors provided clarification of what they mean by "The consequences of a social nature are much wider and deeper." The first paragraphs in the Methods section were moved to the Introduction. The introduction started from the second paragraph — The authors expanded the discussion on the methods once the first paragraph was deleted, enabling them to discuss the methods in detail. The references were extended by new recommended sources. The paper's novelty was revealed in Section 1. The authors suppose that market uncertainty affects the sustainable development of smart cities and territories. The requested changes are made accordingly in the revised version. The authors explained the mathematical model as part of management decision support. According to the experts, formalisation principles serve as the foundation for a mathematical model employed in the construction of smart areas. The results section's first two paragraphs were relocated to the techniques section. The results section contains the derivatives of what was proposed in the methods section. The final statement of the result analysis, explaining that computations were performed using Microsoft Excel, was relocated to the Methods section.

Any further responses from the reviewers can be found at the end of the article

Introduction

Several possible actions from a comprehensive perspective could be significant in Post-COVID recovery.¹⁻⁴ The state as a whole, from the point of view of the economy, is a set of enterprises, both institutional and commercial. When studying economic processes at the top level, profits, common interests, and obligations must be taken into account.^{5,6} Additionally, it is important to introduce formalisms for the effect of externalities, which occur everywhere. Besides entrepreneurial activity, state institutions of the defense department, medicine, transport, education, etc., operate in each country. The authors define externalities as a cost or benefit that is imposed onto a third party that is not incorporated into the final cost (<https://boycewire.com/externalities-definition/#Externalities-Definition>). When modeling externalities, it is essential to consider both their positive (positive externalities) and negative (negative externalities) aspects based on the activities of all market entities. Positive externalities create a benefit to a third party. On the contrary, negative externalities generate a cost to a third party. For example, the digital transformation of smart cities and smart territories could positively affect achieving sustainable development's environmental and social goals improving ecology and healthcare (two of ESG goals). The smart city concept enables the development of culture and society, the social inclusion of different kinds of urban residents in public services, and sustainability.

Any reaction can be the genesis in the general case. Therefore, considering the larger scale, it is necessary to not be limited to the field of ecology in smart cities and in the smart territories.⁷ The consequences of a social nature are much wider and more profound.⁸ Authors suggest including the indicators such as pollution, waste generation and consumption of water and energy. The authors consider the smart cities and territories concept as an efficient, green, socially inclusive socio-economic system using digital transformation to avoid a whole range of damage to a sustainable society. Such damage to society will first be taken into account when monitoring the economic indicators of the current activities of any market participants. Authors suspend that market uncertainty affects the sustainable development of smart cities and territories by forcing economic agents to reduce social responsibility's expenditures.

As a rule, the analysis of market indicators uses the methods of surrogate markets. In turn, this direction, which is usually referred to as an indirect market method or proxy market, is divided into several pricing principles.

Authors suppose that, at present, there is no definitive methodology able to cover the problem in general. The researchers consider the novelty of the article applying the holistic approach with the dependencies of externalities in the form of a function and concerning the arguments as the characteristics of economic activity.⁹ An additional circumstance complicating any activity is the uncertainty of market conditions. Here, the stochastic process theory methods are used, making it possible to form adequate mathematical models.¹⁰ However, it must be taken into account that the indicators of distribution functions are not static. In solving the problem, a set of algorithms are defined, and the economic criteria used is justified. When evaluating a set of planned calculation results, special attention should be paid to finding a balance between the additional burden on the enterprise—i.e., on internalization and the profitability indicators of its activities. Based on this set of conditions, the formalisms of the mathematical model should be built. Similarly, non-commercial activities must be accounted for. This is necessary to assess the social factor in the activities of state institutions themselves in terms of their social and economic efficiency.

In this case, optimization is carried out by searching for the extrema of functionality, considering the inclusion of externalities in the market mechanism for evaluating performance. The results obtained may be a set of regulatory measures using institutional tools. These include dispositive, strategic, restrictive, and stimulating components that form the basis of administrative management and legislative acts that are implemented in both the concepts of preventive behavior and prevention of damage, as well as in the more general ideas of the preservation and development of the social environment.¹¹

Improving the smart city concept is essential to meet the demand of growing urban conglomerates to maintain comfort¹² and improve the quality of urbanization.^{13,14} Regulation of the internal flows of megacities is the main focus of maintaining the quality of urbanization.¹⁵ Ignoring environmental requirements to reduce landscape characteristics, which will occur without striving to maintain the structure and functions of the regional ecological system.¹⁶ Urbanization policy is closely related to a wide range of objectives, including transport policy, the provision of public infrastructure, and the provision of modern security and management facilities.¹⁷ Urbanization affects the condition and viability of green infrastructure and its maintenance as a source of ecosystem services, which will allow the development of effective policies for land use, sustainable urban development and infrastructure management.¹⁸ A recent study suggested the sustainable development of smart cities as a complex structure of interconnected organizations that influence the level of everyday life of the population.¹⁹

Methods

The authors developed a formalized description to solve the problem at hand. The methods presented in the literature operate, as a rule, with the tools of correlation and regression analysis.²⁰ To find the optimal solution under the conditions of market uncertainty and to apply the optimization methods correctly, a more complex mathematical model is needed.

Since the processes of economic activity have some duration in terms of time and also have a complex nature based on changes in seasonal indicators, the authors used a combination of methods.²¹ Among them, we note the theory of the calculus of variations, methods for solving differential equations, the theory of mathematical games, and the main provisions^{5,6} of methods used for finding optimal control.^{22,23}

In order to describe the processes under study, we introduce a number of parameters that describe business and government activities. The mathematical model we propose is based on the application of methods for finding optimal solutions.

We introduce the concept of the number (*N*) of enterprises. All of them work in this limited area. Let us take into account the fact that these enterprises have negative externalities as an external influence. In the case of additional costs for each enterprise, the effect of negative externalities can be reduced.

All calculations were implemented using Microsoft Excel (Microsoft, 2022) (RRID:SCR_016137).

Results

We denote $\bar{P} = (p_1, p_2, \dots, p_N)$ as the vector of searching for the optimal equilibrium solution. Searching for options for such solutions is carried out inside an *N*-dimensional cube of economic situations. We make the calculation specific for *N* = 3, since in this case the result can be visualized. Let us enter the value of additional expenses ω . This amount reflects the need to spend additional money when planning work aimed at minimizing damage from the externalities produced.

Next, we take into account the possible differences in the scale of enterprises, such as the differences in damage ψ^* and ψ . We summarize the calculation model and data in [Table 1](#).

To calculate, we assume that $\bar{p}_i = 1 - p_i, \forall i$ and calculate the product of the vector below:

$$(\bar{p}_1\bar{p}_2\bar{p}_3, \bar{p}_1\bar{p}_2p_3, \bar{p}_1p_2\bar{p}_3, \bar{p}_1p_2p_3, p_1\bar{p}_2\bar{p}_3, p_1\bar{p}_2p_3, p_1p_2\bar{p}_3, p_1p_2p_3) \tag{1}$$

using the corresponding vectors in [Table 1](#). We write these out in the following form:

$$(\omega, \omega, \omega, \psi^* + \omega, 0, \psi, \psi, \psi^*); (\omega, \omega, 0, \psi^*, \omega, \psi + \omega, \psi, \psi^*); (\omega, 0, \omega, \psi^*, \omega, \psi, \psi + \omega, \psi^*).$$

Table 1. Variants of situations and the calculation model.

Option	Enterprise			Calculation
	I	II	III	Element value
	Expenses			
0,0,0	ω	ω	ω	$(1-p_1)(1-p_2)(1-p_3)$
0,0,1	ω	ω	0	$(1-p_1)(1-p_2)p_3$
0,1,0	ω	0	ω	$(1-p_1)p_2(1-p_3)$
0,1,1	$\psi^* + \omega$	ψ^*	ψ^*	$(1-p_1)p_2p_3$
1,0,0	0	ω	ω	$p_1(1-p_2)(1-p_3)$
1,0,1	ψ	$\psi + \omega$	ψ	$p_1(1-p_2)p_3$
1,1,0	ψ	ψ	$\psi + \omega$	$p_1p_2(1-p_3)$
1,1,1	ψ^*	ψ^*	ψ^*	$p_1p_2p_3$

By applying the solution-finding rule²⁴ to the formulated conditions, we obtain two inequalities. The calculated ratios reflect possible market equilibrium conditions. First, we need to define the conditions for the lower bound:

$$-\omega(1-p_1)(1-p_2)(1-p_3) - \omega(1-p_1)(1-p_2)p_3 - \omega(1-p_1)p_2(1-p_3) - (\psi^* + \omega)(1-p_1)p_2p_3 - \psi p_1(1-p_2)p_3 - \psi p_1p_2(1-p_3) - \psi^* p_1p_2p_3 \geq -\omega(1-p_2)(1-p_3) - \omega p_2(1-p_3) - \omega(1-p_2)p_3 - (\psi^* + \omega)p_2p_3.$$

The next calculation step allows us to determine the upper limit:

$$-\omega(1-p_1)(1-p_2)(1-p_3) - \omega(1-p_1)(1-p_2)p_3 - \omega(1-p_1)p_2(1-p_3) - (\psi^* + \omega)(1-p_1)p_2p_3 - \psi p_1(1-p_2)p_3 - \psi p_1p_2(1-p_3) - \psi^* p_1p_2p_3 \geq -\psi p_2(1-p_3) - \psi(1-p_2)p_3 - \psi^* p_2p_3.$$

We then carry out simple transformations and obtain the system:

$$\left. \begin{aligned} \omega p_1 - \psi p_1 p_2 - \psi p_1 p_3 + 2\psi p_1 p_2 p_3 &\geq 0 \\ -\omega(1-p_1) + \psi(p_2 + p_3)(1-p_1) - 2\psi p_2 p_3(1-p_1) &\geq 0 \end{aligned} \right\} \quad (2)$$

The calculation process used for each enterprise is similar. As a result, one obtains a system of equations for calculating the boundaries necessary for making decisions:

$$\left. \begin{aligned} \omega p_2 - \psi^* p_2 p_3 - \psi p_1 p_2 + 2\psi p_1 p_2 p_3 &\geq 0 \\ \omega(1-p_2) - \psi^*(1-p_2)p_3 - \psi p_1(1-p_2) + 2\psi p_1(1-p_2)p_3 &\geq 0 \\ \omega p_3 - \psi^* p_2 p_3 - \psi p_1 p_3 + 2\psi p_1 p_2 p_3 &\geq 0 \\ \omega(1-p_3) - \psi^*(1-p_3)p_2 - \psi p_1(1-p_3) + 2\psi p_1(1-p_3)p_2 &\geq 0 \end{aligned} \right\} \quad (3)$$

All possible solutions are limited within the multidimensional cube of situations. The term of the multidimensional cube of situations means the visualization of several impacts on environmental and social goals considered as dimensions. Such visualization is applicable to the three-dimensional case considered in this example and is used solely for clarity. In the case of $N = 3$, this can be visualized in Figure 1. At the cube corners, the economic indicators associated with externalities are marked.

As a result of solving the system of equations, we obtain a set of regions for $\{p_1, p_2, p_3\}$. The vector values belong to the multidimensional space of situations that satisfy the Nash equilibrium condition. The obtained data is represented in the simplest way by constructing volumetric diagrams of the solution in any package of mathematical applied programs. An analysis of the obtained equations shows that the domains of admissible solutions belong to the intersection of planes with hyperbolic surfaces.

The calculation results for the two participants in production activities are shown in Figures 2 and 3.³⁸ The third solution differs only in terms of the orthogonal rotation of the axes in which the diagram is built.

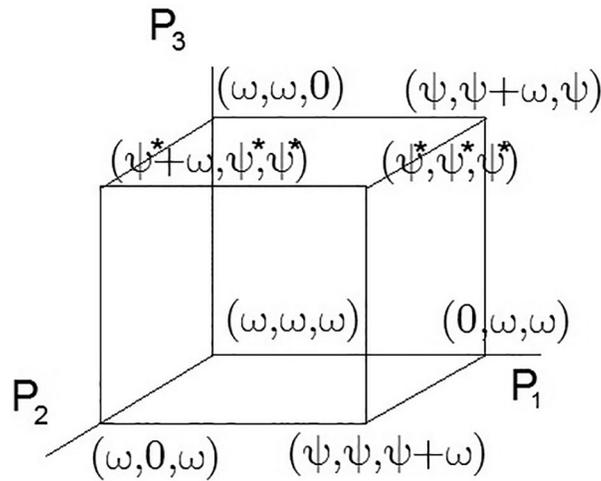


Figure 1. A 3D set of admissible solutions. Source: own study.

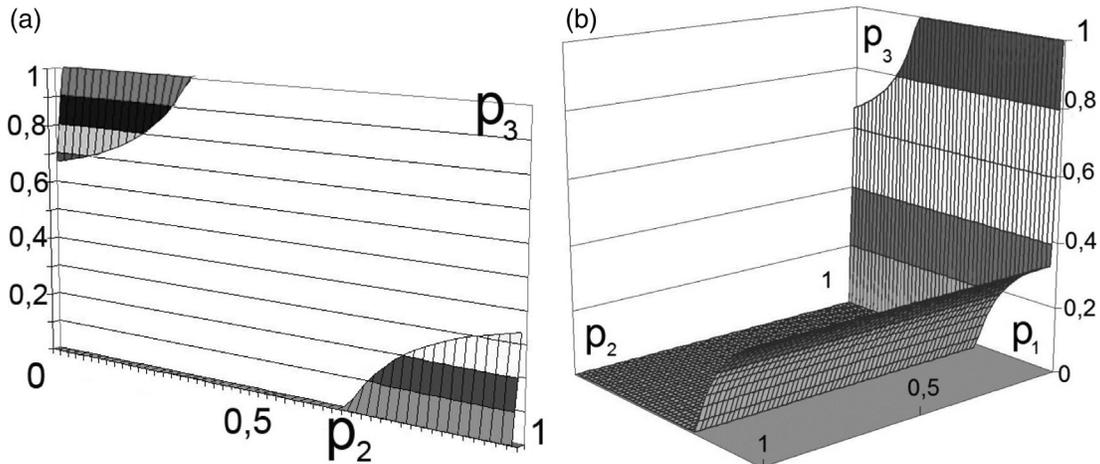


Figure 2. a) Boundary solution areas. b) Set of solutions for Equation (2). Source: own study.

Note that the equations are hyperbolic surfaces, with several intersection points giving the desired solution. To do this, it is sufficient, for example, to transform Equations (2) and (3) to the following form:

$$P_2 \geq \frac{1}{2} - \frac{\psi(2\omega/\psi - 1)}{\psi P_3 - \psi/2}.$$

In this case, the variation in the boundaries forms multidimensional dependencies, as presented in Figures 2 and 3.

The first version of the result reflects a trivial solution $(\bar{p}_1 \bar{p}_2 \bar{p}_3) = 0$. In addition to this case, it is possible to obtain stable states in two more variants. The calculation of the second vector makes it possible to determine the components that satisfy the equilibrium conditions:

$$\left\{ \frac{\omega - \psi \frac{\psi + \sqrt{\psi^2 - 2\omega\psi}}{2\psi} + 2\psi \left[\frac{\psi + \sqrt{\psi^2 - 2\omega\psi}}{2\psi} \right]^2}{\psi \left[\left(\psi + \sqrt{\psi^2 - 2\omega\psi} \right) / 2\psi \right]^2}, \frac{\psi + \sqrt{\psi^2 - 2\omega\psi}}{2\psi}, \frac{\psi + \sqrt{\psi^2 - 2\omega\psi}}{2\psi} \right\}$$

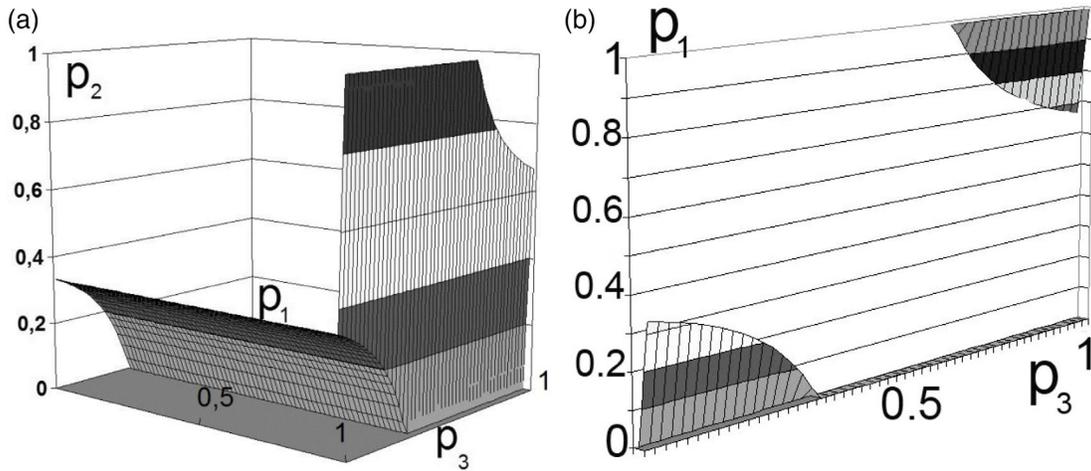


Figure 3. a) Set of solutions for Equation (3). b) Boundary solution areas. Source: own study.

Let us calculate the third case of equilibrium in a similar way. The desired vector is equal to:

$$\left\{ \frac{\omega - \psi \frac{\psi - \sqrt{\psi^2 - 2\omega\psi}}{2\psi} + 2\psi \left[\frac{\psi - \sqrt{\psi^2 - 2\omega\psi}}{2\psi} \right]^2}{\psi \left[\left(\psi - \sqrt{\psi^2 - 2\omega\psi} \right) / 2\psi \right]^2}, \frac{\psi - \sqrt{\psi^2 - 2\omega\psi}}{2\psi}, \frac{\psi - \sqrt{\psi^2 - 2\omega\psi}}{2\psi} \right\}$$

Discussion

Analysis of the results

Each calculated value is applied in different conditions. For the administration of cities and regions, the decision is made in order to overcome a number of barriers. This applies primarily to the disagreement between the profits of commercial structures, the negative externalities generated by their activities, and the social benefit of the population in the controlled territory. In the case of the dispositive method of legal regulation, the first (trivial) solution is applied everywhere.

This decision (presented in Figures 2 and 3) can be interpreted as the unwillingness of the participants in production activities to bear the costs of transforming external effects into internal ones.²⁵

The second equilibrium solution accounts for restrictive measures. This approach requires the application of regulatory standards.

The third result of the decision involves the application of radical measures of restriction.

The listed measures have an economic character. The application of these restrictions obliges economic entities to conduct their activities while taking into account the interests of society. This will also generally affect the state of the entire economic system.^{26–30}

It should be emphasized that the presented equations of the mathematical model reflect the situation for $N = 3$ participants in commercial activities. This is explained by the fact that, in this case, it is possible to visualize the calculation results. The equations developed for the mathematical model can be scaled. At the same time, the number of participants³¹ in economic activities is not limited. In addition, the dependencies describing economic indicators can also have an arbitrary form. This only increases the dimension of the externalities model.

Application of results

Authors' recommendations for authorities and governments include suggestions to use the proposed mathematical model as part of the management decision support. The application of the obtained results in the organization of the life of modern megapolises is especially relevant. Due to the aggravated environmental situation, problems of both a social and economic nature are actively manifested in them. The effective work of the authorities will be based on a scientifically grounded methodology for solving problems related to the economics of the environment. Therefore, the efficient use of

public resources is emphasized as among the major tasks that must be completed. The task of business analysis aimed at developing recommendations for authorities and governments is to take into account multidirectional processes. On the one hand, there is an increased burden on resources and a decrease in the quality indicators of these resources, and it is necessary to evaluate the negative externalities. For the economic indicators of the metropolis, the standard²⁶ of living of the population depends on the activities of all types of businesses and on enterprises that create profit and employment. The results presented by the authors of this paper and the mathematical model^{32,33} make it possible to develop a solution algorithm. Based on this, it is possible to create expert systems. The development of large metropolitan areas and industrial centers is accompanied by data exchange flows. Modern big data technologies and statistical analysis provide operational, economic information for calculations based on mathematical models. Such systems are promising for use in the environmental, social, and corporate management of a smart city at the top level of planning. Also, the researchers propose making urbanization on the basis of sustainable development.

Structure of relationships

Urbanization reflects a global trend. Consolidation into large megapolises is based on a multifaceted process involving the development of society as a whole. Megapolises, alpha cities, and the neighborhoods of such agglomerations, at present, house up to half of the world's population and the majority of industrial enterprises. The smart city concept has no alternative today. The set of expert algorithms within the framework of the smart city conceptual model is intended primarily for decision-makers in each of the sectors of the economy. The authors suppose that the principles of formalization are used as the basis for a mathematical model. As a result, the development of directives for business organizers, systems, and services necessary for a megapolis is carried out based on calculated and economically sound principles. In many ways, the work of the e-government is guided by similar principles. The main principles are still the commitment to sustainable development³⁴ and maintaining the quality of life of the population.^{27,35} High rates of urbanization have caused large-scale shifts in the entire structure of relationships (relationships between business entities operating in a given territory, administration, and the population as a user of public resources). It is necessary for management structures³⁶ or administration bodies to exclude decision-making³⁷ based on heuristic methods. The authors consider the success of smart city development due to the community's acceptance of new technologies.³⁸ COVID-19 seems to be a driver for the digital transformation of ecosystems worldwide.³⁹ The dynamics of the mutual influence of different types of activity have intensified. Over the past decade, the world has come to increasingly rely on scientific and technological achievements. This inevitably entails negative consequences, which, in conditions with a high concentration of population and industry, inevitably create problems of both a social and economic orientation. The nature of these externalities is not determined solely by their impact on the environment. The quality of life, in general, is also negatively affected. The desire of the population to move to megapolises is determined by the high-quality standards of the living environment. If radical measures are not taken to regulate the entire infrastructure, we will see the opposite effect. The functioning of numerous social institutions, public utilities, the service sector, and the industrial sector should be coordinated within smart city digital platforms.

Conclusion

The development of algorithms for making intelligent decisions is only possible today by combining digital data flows, big data technologies, and information communications into a single system. Decision criteria can be multifaceted. Science-based accounting of the balance between profit affecting the welfare and minimizing the negative impact of industrial urbanization is needed. The solution to socio-territorial problems depends on the quality of management decision-making algorithms. These should be based on mathematical models that are close to reality and methods for finding optimal solutions.

The authors propose a complex approach to consider the socially-oriented combination of ICT (information and communication technology) tools for the rational use of resources to improve life quality indicators. The authors attempt to develop a smart city concept considering the public sector concept model (PSCM). The authors' recommendations are aimed at organizations that provide services and manage data in cities. The proposed approach addresses the interoperability of systems and data-sharing so that information from different sources can be normalized, classified, shared, and understood, with data derivation linked back to previous layers and the impact of decisions observable in operational data. The stated principles of formalization are the basis for developing a mathematical model. The use of the decision algorithm serves as a rationale for making several management decisions. At present, the concentration of business and cultural activity on a limited territorial scale dominates. This gives rise to the need to determine the feasibility of internalizing the numerous effects of business or governmental activities. The presented technique makes it possible to formalize these according to the externalities principle and apply a multidimensional balance calculation to minimize the potential damage caused. It is necessary to carry out the analysis on a verified, scientifically based calculation. The result of mathematical modeling will be the optimization of the amount of expenses that various members of the business community must bear. It should be noted that today, in the decision-making process, dynamic analyses of the situation in

the economy using digital twins are not carried out, and methods for finding optimal solutions are not applied. All of these shortcomings occur for many reasons. These include the imperfection of methods and the complexity of taking into account many factors. We would also point to the lack of correct theoretical models and digital twins of processes in megacities based on accounting for economic indicators.

Data availability

Underlying data

Figshare: Figures.xls <https://doi.org/10.6084/m9.figshare.19692205.v1>⁴⁰

This project contains the following underlying data:

- Figures.xls (This is the data used for the calculations shown in this research paper). The EXCEL application contains the visualization of calculations according to the formulas presented in the work.

Data are available under the terms of the [Creative Commons Attribution 4.0 International license](#) (CC-BY 4.0).

Ethical approval

Not applicable (No use of individual human data in this article).

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[Publisher Full Text](#)

Open Peer Review

Current Peer Review Status:    

Version 2

Reviewer Report 07 June 2022

<https://doi.org/10.5256/f1000research.134552.r139693>

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Mui Yee Cheok

Universiti Tun Abdul Razak Kuala Lumpur, Kuala Lumpur, Malaysia

Suggestions have been done.

Competing Interests: No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 07 June 2022

<https://doi.org/10.5256/f1000research.134552.r139690>

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Jakub Kubiczek

Department of Economic and Financial Analysis, University of Economics in Katowice, Katowice, Poland

Dear Authors,

Thank you very much for the responses to my remarks, which were my only ones. The revised version is definitely better.

Best regards,
Jakub Kubiczek

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Decision making, Corporate Social Responsibility, Sustainable Development

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 06 June 2022

<https://doi.org/10.5256/f1000research.134552.r139692>

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Bilal Khalid 

KMITL Business School, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand

I am very satisfied with the improvements and present paper quality. Strongly support the paper's indexing.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Smart Cities, Sustainable Practices, De-carbonization, Immigrant Entrepreneurship, Global Value Chains, Industry 4.0, Digital Transformations, Technology Adoption, Consumer behavior, Public Policy,

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Version 1

Reviewer Report 24 May 2022

<https://doi.org/10.5256/f1000research.126380.r137830>

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Esra Sipahi Dongul 

Faculty of Health Sciences, Department of Social Work, Aksaray University, Aksaray, Turkey

The authors talk about smart cities. Please elaborate with some concrete example not more than a

paragraph.

- Please provide more detail about all of the methods used.
- Please specify what you mean when you use the term of the multidimensional cube of situations.
- Are the economic indicators associated marked with externalities?
- What is the sense of the expression 3? This need to be elaborated well.
- Please explain with concrete examples the theoretical base of the the mathematical model.
- Light up the term “green infrastructure”.

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Yes

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Business, management, organizational behavior

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 28 May 2022

Guldana Kuandykovna Suyendikova, L.N. Gumilyov Eurasian National University, Nur-Sultan, Kazakhstan

Dear Esra Sipahi Dongul

Thank you for your precious comments on our manuscript '*Sustainable development of smart*

cities and smart territories based on the model of minimizing externalities' Your recommendations helped polished the manuscript, and we also appreciate your full consideration to our paper.

As per your instructions, we have included all of your comments points by point individually, indicating exactly how we addressed each concern or problem and describing the changes we have made. The revised manuscript was formatted according to the journal formatting criteria. We hope the revised manuscript will better suit F1000Research but are happy to consider further revisions if any, and we thank you for your interest in our research.

REVIEWER COMMENTS, AUTHOR RESPONSES AND MANUSCRIPT CHANGES

Comment 1: Please provide more detail about all of the methods used.

Response: Thank You! We have clarified the methods in the revised version.

Comment 2: Please specify what you mean when you use the term of multidimensional cube of situations.

Response: Thank you for your comment. We described the meaning of the multidimensional cube of situations.

Comment 3: Are the economic indicators associated marked with externalities?

Response: Thank You for highlighting this confusion. This confusion was removed and we described the logical connection between the economic indicators and externalities.

Comment 4: What is the sense of the expression 3? This need to be elaborated well.

Response: We elaborated the revised version in order to clarify the confusion.

Comment 5: Please explain with concrete examples the theoretical base of the mathematical model.

Response: Thank you so much. We agreed with these Comments and duly explained the theoretical base of the mathematical model.

Comment 6: Light up the term "green infrastructure".

Response: Thank you so much for this suggestion. We followed the comments accordingly in the revised version.

Competing Interests: The authors declare no competing interests.

Reviewer Report 23 May 2022

<https://doi.org/10.5256/f1000research.126380.r137831>

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**Mui Yee Cheok**

Universiti Tun Abdul Razak Kuala Lumpur, Kuala Lumpur, Malaysia

After reviewing the research paper and other reviewers' comments I agree with the reviewers and especially many important points raised by reviewer 1, However, the following are the comments and suggestions from my side to the authors. The authors should incorporate the following suggestions and revise the manuscript.

1. The abstract needs revision and restructuring. The abstract should be revised by adding the objectives, conclusions and future scope of the proposed work.
2. Word "Externalities" is repeatedly used in the title as well as in the abstract it is not defined and the term is required to explain in the introduction
3. Market uncertainty is a wide concept that is required to explain in this paper's context.
4. It is advised to add more literature data in the introduction section to understand the research problem, The research contributions of the present work in the existing body of knowledge should be summarized in the introduction section.
5. Paper novelty & research objectives should be added at the end of section 1 (Introduction).
6. It is advised to explain the findings of Table 1 in the text, similar all figures should be discussed in the discussion section and support some of your important findings with the past studies.

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Partly

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have

significant reservations, as outlined above.

Author Response 28 May 2022

Guldana Kuandykovna Suyendikova, L.N. Gumilyov Eurasian National University, Nur-Sultan, Kazakhstan

Dear Mui Yee Cheok

Thank you for your valuable comments on our manuscript '*Sustainable development of smart cities and smart territories based on the model of minimizing externalities*' Your recommendations have been immensely helpful, and we also appreciate your full consideration to our paper.

As per your instructions, we have included all of your comments point by point individually, indicating exactly how we addressed each concern or problem and describing the changes we have made. The revisions have been approved by all four authors and I have again been chosen as the corresponding author. The revised manuscript was formatted according to the journal formatting criteria. We hope the revised manuscript will better suit F1000Research but are happy to consider further revisions if any, and we thank you for your interest in our research.

REVIEWER COMMENTS, AUTHOR RESPONSES AND MANUSCRIPT CHANGES

Comment 1: The abstract needs revision and restructuring. The abstract should be revised by adding the objectives, conclusions and future scope of the proposed work.

Response: Thank you! We have restructured the abstract in the revised version.

Comment 2: Word "Externalities" is repeatedly used in the title as well as in the abstract it is not defined and the term is required to explain in the introduction.

Response: Thank you for the identification of this confusion. The explanation was provided in the revised version.

Comment 3: Market uncertainty is a wide concept that is required to explain in this paper's context.

Response: Thank you for highlighting this confusion. The explanation was duly provided.

Comment 4: It is advised to add more literature data in the introduction section to understand the research problem, The research contributions of the present work in the existing body of knowledge should be summarized in the introduction section.

Response: Here by investigation, we added the description in the introduction.

Comment 5: Paper novelty & research objectives should be added at the end of section 1 (Introduction).

Response: Thank you so much. We agree to this modification. The novelty was disclosed in the introduction.

Comment 6: It is advised to explain the findings of Table 1 in the text, similar all figures should be discussed in the discussion section and support some of your important findings with the past studies.

Response: Thank you so much for this suggestion. We followed the comments accordingly in the revised version.

Competing Interests: Authors declare no competing interests

Reviewer Report 20 May 2022

<https://doi.org/10.5256/f1000research.126380.r137833>

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Jakub Kubiczek

Department of Economic and Financial Analysis, University of Economics in Katowice, Katowice, Poland

Dear Authors, I am grateful for the opportunity to read and review your text.

In my opinion, there are many approaches to your research problem, but this is the science of finding and proposing new one. I believe that the text is written correctly - although a few adjustments need to be made. I agree with reviewer 1 in many respects, but I believe that these amendments are not too complex and none of them disparages your text. You can find detailed comments below.

Technical issues related to the structure of the article

1. Shorten the abstract to make it more specific. I would remove the introduction to the problem because the abstract should contain the essence itself. At the same time, I would add the most important results of the study.
2. "As a rule, such analysis uses the methods of surrogate markets. In turn, this direction, which is usually referred to as an indirect market method or proxy market, is divided into several pricing principles". You write "usually" - it would be useful to support it with some other article.
3. You have defined the research gap very well and proposed a way to fill it, but there is no clearly defined purpose of the article.
4. In the results section, "the Nash equilibrium condition" appears - it would be nice to mention what it means somewhere.
5. The figures are not signed - "Source: own study."
6. Please, number the patterns continuously - they should all have a number.

7. Please, divide the conclusions into certain sections as this is too chaotic at the moment.

Substantive issues

1. The authors mention the pandemic, but do not detail how it affected the externalities. Which externalities are connected with the post-pandemic situation?
2. The authors should clarify suggesting a mathematical model as part of the management decision support.
3. I miss the justification that the presented model has potential. Therefore, I propose to note the potential of proposed model and its practical implication opportunities.
4. Do the authors mean that the nature of a sustainable development is connected with the smart territories' development. If so, in what way? Please refer it to the proposed model.
5. Are there any recommendations for authorities and governments based on the developed model?
6. Do the researchers propose making urbanization on the basis of sustainable development?
7. Are the principles of formalization used as the basis for a mathematical model?
8. Could the developed model be qualified as the optimization of the amount of expenses that must be borne by various members of the business community?

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Partly

Are sufficient details of methods and analysis provided to allow replication by others?

Partly

If applicable, is the statistical analysis and its interpretation appropriate?

Partly

Are all the source data underlying the results available to ensure full reproducibility?

Partly

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Decision making, Corporate Social Responsibility, Sustainable Development

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 28 May 2022

Guldana Kuandykovna Suyendikova, L.N. Gumilyov Eurasian National University, Nur-Sultan, Kazakhstan

Dear Jakub Kubiczek

Thank you for your important comments on our manuscript '*Sustainable development of smart cities and smart territories based on the model of minimizing externalities*'. Your recommendations have been immensely helpful, and we also appreciate your full consideration to our paper.

As per your instructions, i have included all of your comments point by point individually, indicating exactly how we addressed each concern or problem and describing the changes we have made. The revisions have been approved by all four authors and I have again been chosen as the corresponding author. The revised manuscript was formatted according to the journal formatting criteria. We hope the revised manuscript will better suit F1000Research but are happy to consider further revisions if any, and we thank you for your interest in our research.

REVIEWER COMMENTS, AUTHOR RESPONSES AND MANUSCRIPT CHANGES

Comment 1: Shorten the abstract to make it more specific. I would remove the introduction to the problem because the abstract should contain the essence itself. At the same time, I would add the most important results of the study.

Response: Thank you! We have made the relevant changes in the revised version.

Comment 2: The reviewer asked for the methods of the following:

"As a rule, such analysis uses the methods of surrogate markets. In turn, this direction, which is usually referred to as an indirect market method or proxy market, is divided into several pricing principles ". You write "usually" - it would be useful to support it with some other article.

Response: Thank you for the identification of this confusion. The appropriate explanation was provided in the revised version.

Comment 3: You have defined the research gap very well and proposed a way to fill it, but there is no clearly defined purpose of the article.

Response: Thank You for highlighting this confusion. This confusion was removed and the purpose was written.

Comment 4: In the results section, "the Nash equilibrium condition" appears - it would be nice to mention what it means somewhere.

Response: We described the mentioned approach more precisely.

Comment 5: The figures are not signed - "Source: own study.".

Response: Thank you so much. We agree to this modification. The figures are duly signed.

Comment 6: Please, number the patterns continuously - they should all have a number.

Response: Thank you so much for this suggestion and modification. We followed the comments accordingly in the revised version.

Comment 7: Please, divide the conclusions into certain sections as this is too chaotic at the moment.

Response: Yes by this we mean logical explanation. Changes made accordingly in the revised version.

Comment 8: The authors mention the pandemic, but do not detail how it affected the externalities. Which externalities are connected with the post-pandemic situation?

Response: Thank you. We explained the externalities accordingly.

Comment 9: The authors should clarify suggesting a mathematical model as part of the management decision support.

Response: Thank you. We explained the mathematical model as part of the management decision support.

Comment 10: I miss the justification that the presented model has potential. Therefore, I propose to note the potential of proposed model and its practical implication opportunities.

Response: Thank you so much for identifying this confusion. We had added the potential of the model. The same has been elaborated well in the revised version.

Comment 11: Do the authors mean that the nature of a sustainable development is connected with the smart territories' development. If so, in what way? Please refer it to the proposed model.

Response: We mean that the nature of a sustainable development is connected with the smart territories' development.

Comment 12: Are there any recommendations for authorities and governments based on the developed model?

Response: This has been explained in the revised version.

Comment 13: Do the researchers propose making urbanization on the basis of sustainable development?

Response: Thank you so much for identifying this confusion. We had added the explanation of the model in the revised version.

Comment 14: Are the principles of formalization used as the basis for a mathematical model?

Response: We mean that the principles of formalization are used as the basis for a mathematical model implemented for the development of smart territories.

Comment 15: Could the developed model be qualified as the optimization of the amount of expenses that must be borne by various members of the business community?

Response: This has been explained in the revised version.

Competing Interests: Authors declare no competing interests

Reviewer Report 19 May 2022

<https://doi.org/10.5256/f1000research.126380.r137829>

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Bilal Khalid 

KMITL Business School, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand

Abstract:

- The background section of the abstract is too long, the authors should consider revising it to not more than two sentences. Because of the length of the background, the authors did not provide much information about the study in the abstract. The part above where it says “This study takes into account...” Is ideally where the authors start talking about this study. The other parts above it should be condensed into two sentences.
- The abstract should be written with the following in mind, aim/problem, objective(s), theory, methods, results, discussion, conclusions and limitations. These aspects where applicable should be touched briefly in the abstract.
- Externalities seem to be a very important concept in this study, yet it only appears once towards the end of the abstract. This is part of the problem being studied and should be reflected earlier in the abstract.

Introduction:

- The authors should provide a better explanation for the term “externalities” and how it affects the conceptualization of sustainable development of smart cities and smart territories.
- Cases of the impacts of externalities on the sustainable development of smart cities and territories should be provided if they are available in studies or practical examples.
- The authors should provide clarification of what they mean by “The consequences of a social nature are much wider and deeper.” It is not enough to provide citations, a context should be provided to show the relationship between the statement and the problem to research hopes to address.
- The authors should elaborate on how market uncertainty affects the sustainable development of smart cities and territories.

Methods:

- The first paragraphs in the Methods section should be moved to the Introduction. This section should start from the second paragraph – “The authors developed....” The authors should expand the discussion on the Methods once the first paragraph is deleted, this enables them to discuss the Methods in detail.
- The Methods require further clarification to understand the specific correlation and regression tools to be employed.

Results:

- The first two paragraphs of the results section can be moved to the methods section as it seems to describe actions that will lead to results, not the findings itself. The results should only contain the derivatives from what was proposed in the Methods section.
- The second line of the third paragraph contains a spacing error, kindly correct – “...carried out inside anN- dimension....”
- Authors should present the results and provide a clearer explanation, rather than using statistical jargon and equation.

Discussion:

- The last sentence of the analysis of the result that informs that calculations were implemented using Microsoft Excel should be taken to the Methods section. The discussion is only for the implications of your results.
- The discussion should analyze the implication of the equations and figures presented in the results. How do they affect the sustainable development of smart cities and smart territories? Please also consider citing the following articles:
 - Chaiyasoonthorn, W., Khalid, B., & Chaveesuk, S. (2019, August). Success of Smart Cities Development with Community’s Acceptance of New Technologies. *Proceedings of the 9th International Conference on Information Communication and Management*.¹
 - Khalid, B., & Naumova, E. (2021). Digital transformation of the Russian venture ecosystem under the impact of the COVID-19. In *Global Challenges of Digital Transformation of Markets* (pp. 313–329). Nova Science Publishers, Inc.²
- There is a little linkage between the literature and the results in the discussion section. Try to connect the literature to the discussion to understand how the findings impact smart cities and smart territories.

Conclusion:

- The conclusion should summarize the research, make recommendations and state the limitations of the study if any. Instead, the conclusion seems to be an extension of the discussion. “Megapolises’ appears three times in the conclusion, twice in the discussion, and once in the abstract. Throughout the manuscript, it does not appear in the introduction, methods, and results. It needs to be situated in the introduction section and methods.

References

1. Chaiyasoonthorn W, Khalid B, Chaveesuk S: Success of Smart Cities Development with Community’s Acceptance of New Technologies. *Proceedings of the 9th International Conference on Information Communication and Management*. 2019. 106-111 [Publisher Full Text](#)

2. Khalid B, Naumova E: Digital transformation of the Russian venture ecosystem under the impact of the COVID-19. In: de la Poza E, Barykin S.E. (eds): Global Challenges of Digital Transformation of Markets. *Nova Science Publishers, Inc.* 2021. 313-329

Is the work clearly and accurately presented and does it cite the current literature?

Partly

Is the study design appropriate and is the work technically sound?

Partly

Are sufficient details of methods and analysis provided to allow replication by others?

Partly

If applicable, is the statistical analysis and its interpretation appropriate?

Yes

Are all the source data underlying the results available to ensure full reproducibility?

No

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Smart Cities, Sustainable Practices, De-carbonization, Immigrant Entrepreneurship, Global Value Chains, Industry 4.0, Digital Transformations, Technology Adoption, Consumer behavior, Public Policy,

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 28 May 2022

Guldana Kuandykovna Suyendikova, L.N. Gumilyov Eurasian National University, Nur-Sultan, Kazakhstan

Dear Dr Bilal Khalid

Thank you for your constructive comments on our manuscript '*Sustainable development of smart cities and smart territories based on the model of minimizing externalities*' The suggestions offered by you have been immensely helpful, and we also appreciate your full consideration to our paper.

As per Your instructions, I have included all of Your comments point by point individually, indicating exactly how we addressed each concern or problem and describing the changes we have made. The revisions have been approved by all four authors and I have again been chosen as the corresponding author. The revised manuscript was formatted according to

the journal formatting criteria. We hope the revised manuscript will better suit F1000Research but are happy to consider further revisions if any, and we thank you for your interest in our research.

REVIEWER COMMENTS, AUTHOR RESPONSES AND MANUSCRIPT CHANGES

Comment 1: The background section of the abstract is too long, the authors should consider revising it to not more than two sentences. Because of the length of the background, the authors did not provide much information about the study in the abstract. The part above where it says “This study takes into account...” Is ideally where the authors start talking about this study. The other parts above it should be condensed into two sentences.

Response: Thank you for the identification of this confusion. We have restructured the abstract. The sentences were shortened.

Comment 2: The abstract should be written with the following in mind, aim/problem, objective(s), theory, methods, results, discussion, conclusions and limitations. These aspects where applicable should be touched briefly in the abstract.

Response: Thank you! The aim, methods, results and conclusion were provided in the revised version.

Comment 3: Externalities seem to be a very important concept in this study, yet it only appears once towards the end of the abstract. This is part of the problem being studied and should be reflected earlier in the abstract.

Response: Thank you for highlighting this issue. This confusion was removed and the mentioned term was duly placed in the beginning of the abstract.

Comment 4: The reviewer asked about the following:

The authors should provide a better explanation for the term “externalities” and how it affects the conceptualization of sustainable development of smart cities and smart territories.

Response: Here by investigation we explained this term in the introduction in the revised version in order to clarify the confusion.

Comment 5: Cases of the impacts of externalities on the sustainable development of smart cities and territories should be provided if they are available in studies or practical examples.

Response: Thank you so much. We agree to this modification. The explanation was disclosed with more details in the introduction.

Comment 6: The authors should provide clarification of what they mean by “The consequences of a social nature are much wider and deeper.” It is not enough to provide citations, a context should be provided to show the relationship between the statement and the problem to research hopes to address.

Response: Thank you so much for this suggestion and modification. We followed the comments accordingly in the revised version.

Comment 7: The authors should elaborate on how market uncertainty affects the sustainable development of smart cities and territories.

Response: Yes by this we mean that market uncertainty affects the sustainable development of smart cities and territories. Changes made accordingly in the revised version.

Comment 8: The first paragraphs in the Methods section should be moved to the Introduction. This section should start from the second paragraph – “The authors developed...” The authors should expand the discussion on the Methods once the first paragraph is deleted, this enables them to discuss the Methods in detail.

Response: Thank you. We made the relevant amendments.

Comment 9: The Methods require further clarification to understand the specific correlation and regression tools to be employed.

Response: We changed the manuscript accordingly. It is corrected now and all clarification was provided in the revised version.

Comment 10: The first two paragraphs of the Results section can be moved to the methods section as it seems to describe actions that will lead to results, not the findings themselves. The results should only contain the derivatives from what was proposed in the Methods section.

Response: Thank you so much for identifying this confusion. We had moved this sentence in the revised version.

Comment 11: The second line of the third paragraph contains a spacing error, kindly correct – “...carried out inside anN- dimension....”

Response: Changes made in the revised version.

Comment 12: Authors should present the results and provide a clearer explanation, rather than using statistical jargon and equation.

Response: This has been provided in the revised version.

Comment 13: The last sentence of the analysis of the result that informs that calculations were implemented using Microsoft Excel should be taken to the Methods section. The discussion is only for the implications of your results.

Response: The appropriate changes were made in the revised version.

Comment 14: The discussion should analyze the implication of the equations and figures presented in the results. How do they affect the sustainable development of smart cities and smart territories? Please also consider citing the following articles:

Chaiyasoonthorn, W., Khalid, B., & Chaveesuk, S. (2019, August). Success of Smart Cities Development with Community's Acceptance of New Technologies. Proceedings of the 9th International Conference on Information Communication and Management.1
Khalid, B., & Naumova, E. (2021). Digital transformation of the Russian venture ecosystem under the impact of the COVID-19. In Global Challenges of Digital Transformation of Markets (pp. 313–329). Nova Science Publishers, Inc.

Response: The mentioned sources have been added in the revised manuscript.

Comment 15: There is a little linkage between the literature and the results in the discussion section. Try to connect the literature to the discussion to understand how the findings impact smart cities and smart territories.

Response: We made these changes in the revised version.

Comment 16: The conclusion should summarize the research, make recommendations and state the limitations of the study if any. Instead, the conclusion seems to be an extension of the discussion. "Megapolises" appears three times in the conclusion, twice in the discussion, and once in the abstract. Throughout the manuscript, it does not appear in the introduction, methods, and results. It needs to be situated in the introduction section and methods.

Response: The conclusion was revised by your comments.

Competing Interests: Authors declare no competing interests.

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