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Original article

Budget Optimization Model for the Digital Transformation of Moscow into a Smart City

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Abstract
The main directions of Moscow's strategy "Smart City – 2030" are defined in the Decree of the Government of Moscow. At the same time, the following objectives should be achieved:
- ensuring sustainable growth in the quality of life of Muscovites and favorable conditions for doing business and other activities;
- centralized, end-to-end and transparent city management;
- improving the efficiency of public spending, including through the introduction of public-private partnerships.
The implementation of this strategy of Moscow's digital transformation into a smart city largely depends on the volume and effective allocation of budget funds for solving the goals and objectives set in it. To distribute the budget across the 6 main areas of the strategy, a hierarchical model is proposed, with the use of which the integral indicator of digital transformation would become the maximum. To solve this task, for example, data from the budget allocated for the digital transformation of Moscow in 2022 were used. The presented integrated model has shown its operability and the possibility of further development, taking into account the indications of urban automated systems and new risks in an interactive mode. The effects of external and internal risks on the implementation of the tasks set in the Strategy were studied and considered by conditional experts, whose assessments were summarized in a Bayesian trust network, the structure of which is similar to the hierarchical model.

Keywords: Smart City, budget, hierarchical model, risks, Bayesian trust network

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Оригинальная статья

Оптимизация распределения бюджета стратегии цифровой трансформации Москвы в умный город

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Аннотация
Основные направления стратегии Москвы «Умный город – 2030» определены в Постановлении Правительства г. Москвы. При этом должны быть достигнуты следующие ее цели:
- обеспечение устойчивого роста качества жизни москвичей и благоприятных условий ведения предпринимательской и иной деятельности;
- централизованное, сквозное и прозрачное управление городом;
- повышение эффективности государственных расходов, в том числе за счет внедрения государственно-частного партнерства.

Реализация данной стратегии цифровой трансформации Москвы в умный город во многом зависит от объема и эффективного распределения бюджетных средств на решение поставленных в ней целях и задач.
Для распределения бюджета по 6 основным направлениям стратегии предлагается иерархическая модель, с применением которой интегральный показатель цифровой трансформации стал бы максимальным. Для решения поставленной задачи, в качестве примера, были использованы данные бюджета, выделенного на цифровую трансформацию г. Москвы в 2022 году. Представленная интегрированная модель показала свою работоспособность и возможность в дальнейшем развиваться, учитывая в интерактивном режиме показания городских автоматизированных систем и новых рисков. Влияния же внешних и внутренних рисков на реализацию поставленных в Стратегии задач изучались и рассматривались условными экспертами, чьи оценки сводились в сеть доверия Байеса, структура которой аналогична иерархической модели. Данное обстоятельство позволяет вносить изменения в иерархическую модель для постатейного распределения бюджета, основанные на оценке рисков.

Ключевые слова: умный город, бюджет, иерархическая модель, риски, сеть доверия Байеса

Конфликт интересов: авторы заявляют об отсутствии конфликта интересов.

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Introduction

Monitoring and forecasting of the state of megacities of the world and Moscow is carried out in order to implement their development strategies determined by the global trend of solving the problems of large cities, improving the environment and the quality of life of the population in them. At the heart of these strategies is the digital transformation of cities, as an important part of the digital transformation strategy of the entire society. The effectiveness of the implementation of this strategy largely depends on the optimal allocation of the budget to achieve the goals of the digital transformation of the city.

Main part

In terms of technology, digital transformation of cities is based on several areas of its development - social communications, big data and predictive analytics, cloud technologies, artificial intelligence, mobility, the Internet of Things, cybersecurity, digital platforms. The listed technologies are key for the entire range of solutions of "smart" cities. The development of megacities in accordance with the concept of a "smart city" has become a global trend [1-11].

The strategy of digital transformation of Moscow is also developing in accordance with this concept, as well as on the basis of regulatory documents of the Government of the Russian Federation and Moscow[1].

Why should Moscow become a "smart city"? There are the following reasons for this:

1. Global Mega Trends;
2. Predictions of futurologists;
3. Expectations of Muscovites;
4. Opinions of the expert community.

Goals of the Strategy Moscow "Smart City -2030":

S1. Ensuring sustainable growth in the quality of life and favorable conditions for doing business and other activities;

S2. Centralized, end-to-end and transparent city management;

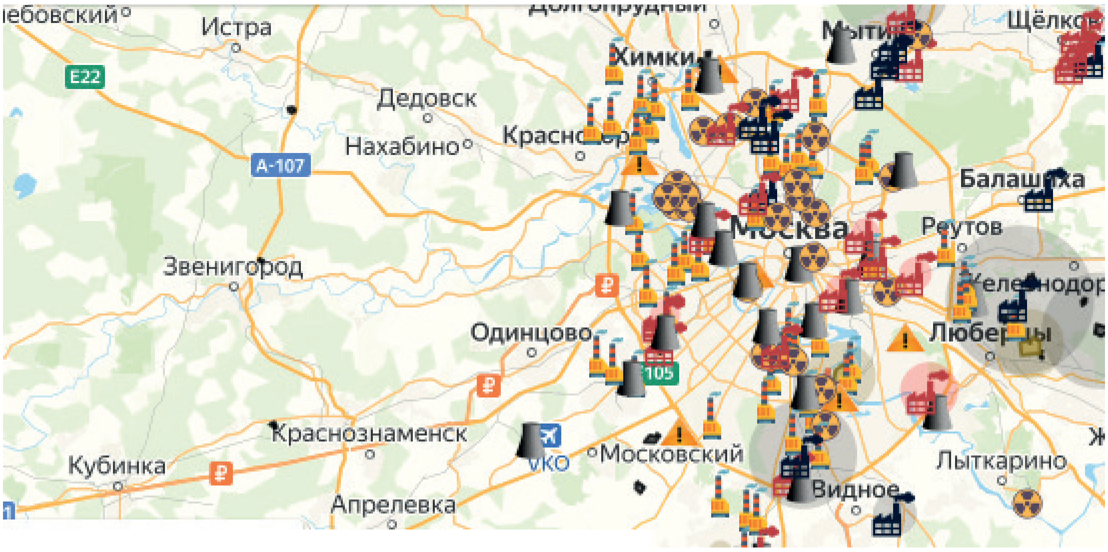
S3. Improving the efficiency of public spending, including through the introduction of public-private partnerships.

Among the basic characteristics of "smart cities" are sustainability and environmental friendliness, public participation in management, efficient use of data, the desire to improve the quality of services and living standards.

A smart city is a balanced, convenient, safe and "green" metropolis. Infrastructure elements and residents in such a city are included in a single information network, the purpose of which is to optimize the consumption of natural, economic and social resources. The heart of the city is information and communication technologies: the Internet of Things, broadband wireless access, cloud computing and analytics [12-17].

Already, special sensors inform drivers about free parking spaces, charging stations available for electric vehicles. Traffic lights flexibly control traffic flow and prevent traffic jams, and smart barriers extend when a bus or cyclist needs a lane. In the event of an accident, an alarm is instantly sent. Remote monitoring updates information about the incident every minute, and drivers receive a GPS warning and smart road boards.

Recycling companies receive real-time signals from smart containers if they are overflowing. Lights on the streets are equipped with motion sensors and light up when someone passes nearby. The state of ecology of Moscow regions is also monitored interactively (Fig. 1).

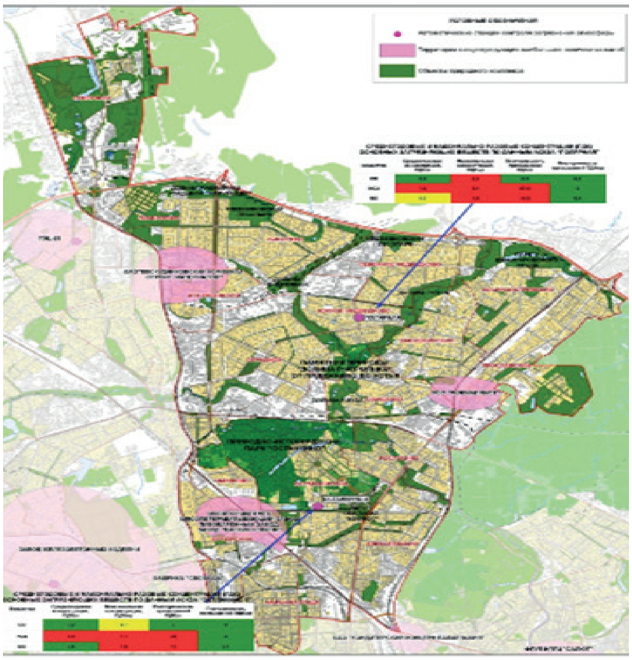


F i g. 1. Ecological map of Moscow districts

Source: https://mwmoskva.ru/ekologicheskaya-karta-moskvy.html

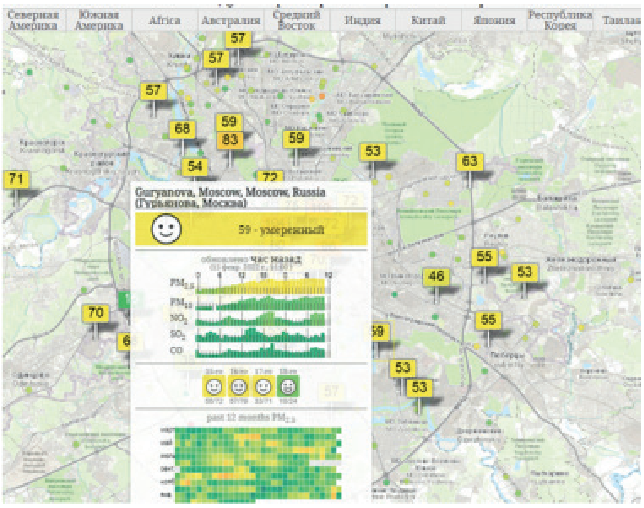
[1] Moscow "Smart City – 2030". Text of the strategy [Electronic resource]. Moscow; 2018. 110 p. Available at: https://www.mos.ru/upload/alerts/files/3_Tekststrategii.pdf (accessed 23.08.2022). (In Russ.); Order of the Ministry of Construction of Russia dated September 16, 2020 No. 518/pr "On Amending the Passport of the Departmental Project for the Digitalization of Urban Economy "Smart City", approved by order of the Ministry of Construction and Housing and Communal Services of the Russian Federation dated October 31, 2018 No. 695/pr [Electronic resource]. Available at: https://minstroyrf.gov.ru/docs/120503 (accessed 23.08.2022). (In Russ.); Project of digitalization of urban economy "Smart City" [Electronic resource]. Available at: https://www.minstroyrf.gov.ru/trades/gorodskaya-sreda/proekt-tsifrovizatsii-gorodskogo-khozyaystva-umnyy-gorod (accessed 23.08.2022). (In Russ.)

Information on the level of air pollution (Fig. 2), noise and water levels in the river (Fig. 3) artificial intelligence analyzes and takes the necessary measures, for example, to avoid flooding.



F i g. 2. The condition of water bodies and the collector-river network of the Moscow region

Source: https://mwmoskva.ru/ekologicheskaya-karta-moskvy.html



F i g. 3. Interactive map of air pollution in Moscow

Source: https://mwmoskva.ru/ekologicheskaya-karta-moskvy.html

Existing elements of the System monitor the weather and control the watering of lawns. Water or electricity consumption data are available to every resident in real time. Interaction with the authorities, payment of public services and housing and communal services are as transparent as possible and are available 24/7 online. All of these features increase the number of smart homes that deliver high quality of life. Almost in Moscow, city free Wi-Fi works everywhere.

To solve the goals of the Moscow Smart City-2030 strategy, it is necessary to systematically conduct research aimed at collecting and analyzing objective socio-economic information, data on the state of the city's life support systems, environmental conditions, etc. The main tasks that need to be solved are as follows:

- efficient organization of information collection;
- availability of a unified information platform for data collection and processing;
- availability of analytical tools for monitoring and forecasting the state of Moscow;
- availability of information and economic and mathematical models of data processing;
- an objective assessment of the changes taking place;
- assessment of external and internal risks;
- forecasting the development of socio-economic processes, the consequences of the use of innovative technologies;
- timely development of regulatory impacts aimed at supporting positive and mitigating negative trends.

The solution of the set tasks provides for the initial development of information and economic and mathematical models that determine the content and algorithms of the analytical tools for processing data obtained from various sources. It is also necessary that the information and algorithms used by analytical tools to monitor and predict the state and development of megacities be compatible with each other within a single information and analytical space. The subsystems of this analytical space should also include the budgeting system for the digital transformation of the city [18, 19].

The implementation of the strategy of digital transformation of Moscow into a smart city largely depends on the effective distribution of budget funds to solve the tasks set in this strategy. In this case, the method of analyzing hierarchies by T.L. Saati[2] is suitable for solving the problem [20]. It consists in decomposing the problem into simpler components and further processing the sequence of judgments of an expert in pair comparisons, and serves to justify decision-making in conditions of certainty and multi-criteria. Its procedure is described in sufficient detail in literary sources, including in work [12] when determining the optimal budgeting of the enterprise.

A hierarchical model of budget distribution in 6 main areas of the strategy is proposed, which, in turn, are divided into sub-levels, so that the integral indicator of digital transformation becomes maximum.

The main directions of Moscow's strategy "Smart City – 2030":

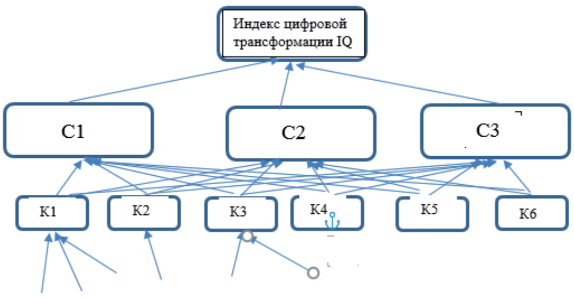
K.1. Urban Environment
1.1. Town planning
1.2. HOUSING AND PUBLIC UTILITIES
1.3. Others
K.2. Digital Mobility
2.1. Transport
2.2. Information Technology and Communications

[2] Hierarchy analysis method – is a method of measuring interdependence in a system, a systematic procedure for hierarchical representation of elements of a dominant, direct or inverse hierarchy that systematically describe the problem.

2.3. Tourism
2.4. Others
K.3. Urban economy
3.1. Finance
3.2. Industry
3.3. Trade and Services
3.4. Innovations
3.5. Others
K.4. Safety and Ecology
4.1. Safety
4.2. Ecology
4.2. Others
K.5. Digital government
5.1. Open government
4.3. Government activities
4.4. Other
K.6. Human and social capital
6.1. Education
6.2. Health care
6.3. Culture
6.4. Social environment
6.5. Other

At the same time, the above goals of the Moscow Smart City – 2030 Strategy should be achieved.

The relationship between the tasks set and the goals of the strategy of turning Moscow into a smart city can be presented in the form of a hierarchical graph (Fig. 4).



F i g. 4. Hierarchical model of the formation of an integral indicator of the assessment of the index of digital transformation of Moscow

The presented hierarchical model can be used to select from various alternatives the optimal distribution of the Moscow budget in order to achieve the maximum value of the IQ index.

As an example of solving this problem, we will use the data on the budget of Moscow, allocated in the amount of 2.9 billion rubles. for the digital transformation of the city in 2022, within the framework of the target state program "Development of the digital environment and innovation"[3]. Based on the wording of the task, these funds should be distributed among the 6 areas presented above (K1,..., K6) based on a pairwise comparison by experts of their impact on the goals of the Strategy (S1, S2, S3). The allocation of funds will be as follows, see Table 1.

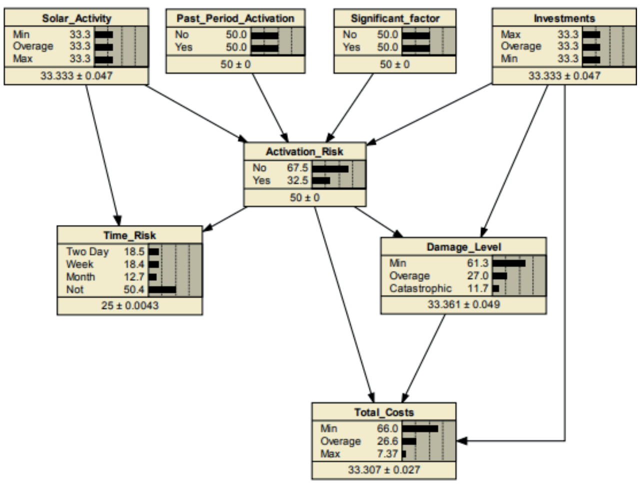
T a b l e 1. **Budget allocation to 6 main areas**

Direction	Relative weight	Budget (bln RUB)
K.1. Urban Wednesday	0,329	0,9541
K.2. Digital Mobility	0,254	0,7366
K.3. Urban economy	0,198	0,5742
K.4. Safety and ecology	0,116	0,3364
K.5. Digital government	0,087	0,2523
K.6. Human and social capital	0,026	0,0754

With such a distribution of funds for the budget item of the state program "Development of the digital environment and innovations," the target will reach the maximum value. Of course, the given example is very conditional, since the model should not be two-level, but include sub-levels of each direction. But this will only slightly complicae computational difficulties [21-24].

The effects of external and internal risks on the implementation of the tasks set in the Strategy were considered by conditional experts, whose assessments were reduced to a Bayes trust network, the structure of which is similar to the hierarchical model presented above.

A more difficult task is to take into account external and internal risks for budget items [13], [14], [25], [26]. For their assessment, experts propose a mutually linked risk network based on the Bayes trust network (Fig. 5).



F i g. 5. Interrelated Risk Trust Network

We will assume that the value of the risks of financing a particular budget item and the level of its financing from the expert's point of view is determined by the type of "indifference curve" (Fig. 6).

[3] Project of digitalization of urban economy "Smart City" [Electronic resource]. Available at: https://www.minstroyrf.gov.ru/trades/gorodskaya-sreda/proekt-tsifrovizatsii-gorodskogo-khozyaystva-umnyy-gorod (accessed 23.08.2022). (In Russ.)

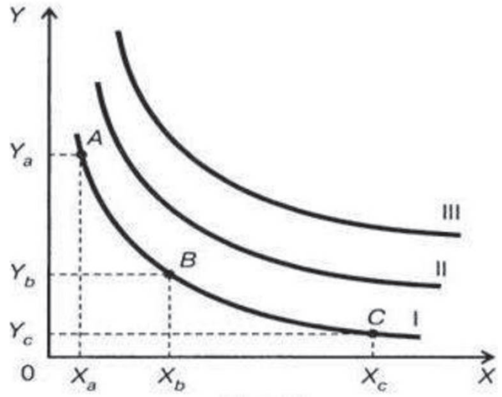


Fig. 6. Indifference curves "risk - budgeting level". Here: X - risk level, Y - budgeting level

Conclusions

The proposed integrated model showed its performance and ability to develop, taking into account the readings of urban automated systems and new risks in interactive mode. A city budget management system that is dynamic and adaptable to internal and external risks, in order to effectively implement the city's digital transformation strategy, should be based both on objective information about the functioning of various city systems, and on subjective assessments and forecasts of specialists and experts. The use of models based on the Hierarchy Analysis Method and Bayesian belief networks included in the budget management system makes it possible to do this.

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All authors have read and approved the final manuscript.

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