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Analysis of Methods and Information Technologies for Dynamic Planning of Smart City Development

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ABSTRACT

The review and analysis of methods and information technologies for the dynamic development planning of the Smart City was carried out. It is shown that the existing methods and information technologies for dynamic planning of the development of complex systems, which can certainly be attributed to Smart city, are not without certain disadvantages. Analysis of the technologies of dynamic planning and decision-making on the development of the Smart City showed the presence of unsolved problems. These problems include the lack of a general theory and methodology for solving the problems of dynamic planning and decision-making on the development of the Smart City, taking into account the uncertainties and risks of various types. New research is also needed to develop adequate methods and information technologies for modeling various, complex types of knowledge and processes required at different stages of building a dynamic Smart city development plan. The necessity to develop adaptive methods and information technologies of forecasting, necessary for building an effective dynamic plan and making decisions on the development of Smart city, is justified. Thus, it is shown that the problems of effective solution of problems of dynamic planning and decision-making, as a new tool of modern information technologies of planning and forecasting, for the development of Smart city, as well as the insufficient level of scientific and methodological research of these issues, make it relevant to conduct new in-depth research in this area.

Key words: Smart City, dynamic planning, methods, models, risks.

1. INTRODUCTION

Conceptually, the idea of creating and developing smart cities (hereinafter referred to as Smart cities) was actively discussed more than 15 years ago. Rare forums that were devoted to urban themes and prospects for its development using new information technologies (IT), did not discuss advanced technologies in Smart City [1], [2]. Many players in the investment market, as well as public institutions, began to consider Smart City in the context of the prospects of urbanism and the creation of new zones for cooperation of producers of high-tech products for the needs of urban economy [3], [4]. The city authorities in many large cities, especially at the municipal level, have announced strategies for investing in Smart City projects. This was dictated by the desire to improve the status of the city, as well as the ability to attract long- term investment. The idea of localizing high-tech businesses within the city infrastructure has also become very promising. At the same time, the companies faced challenges aimed at solving local urban problems, including water and energy supply, transport and logistics, environmental, as well as information security of residents, etc. [5]-[7].

Note that such projects are characterized by a high degree of uncertainty and risk. At the same time, the effective development of complex dynamic systems of various types (socio-economic, political, military, and technical) depends on the definition of goals to be achieved [8], [9]. This fully applies to the development of Smart city. In particular, for large projects in the field of urbanism, success often depends on planning and optimal choice of strategies for the development of urban infrastructure, taking into account all factors that affect the system, as well as taking into account and overcoming various kinds of uncertainties and risks. The main direction of effective solution of these tasks is dynamic planning (DP) of Smart city development. The basis of DP is the systematic use of different types of mathematical models, methods for analyzing situations and making decisions, as well as it, focused on use in conditions of risk and uncertainty. Rapid structural changes in the external environment and in various elements of the Smart city are also taken into account for building development plans and forecasts, as well as for solving strategic planning and management tasks. Planning and forecasting the development of Smart city and various types of processes is associated with overcoming various kinds of uncertainties, non-linearities and risks generated by the system itself and the external environment in which Smart city functions. The presence of various types of uncertainties, such as situational uncertainty, inaccuracy and uncertainty of various parameters of the system and the external environment, insufficient information about the system, non-linearity of processes occurring both in the Smart city and in the external environment, as well as a large number of risks - all these signs make the problem of solving problems of dynamic planning of the Smart city infrastructure poorly structured and difficult to formalize [1], [2]. Currently, the scientific and applied field of dynamic planning Smart city accumulates the latest achievements of the majority of scientific, econometric and information industries and refers to innovative technologies. At the same time, it is an effective tool for planning and forecasting the development of complex dynamic systems at various hierarchical levels. The need for effective planning for Smart cities is growing every year and requires information support in the form of creating information and analytical systems that can effectively solve the problems of research and analysis of Smart cities by optimizing their structure, identifying and determining the main risks and building effective dynamic plans to select the most likely and appropriate ways of their functioning, development and management.

All this leads to the need to create effective tools for research, analysis, decision-making and forecasting of Smart city development. The results of their application should make it possible to create dynamic plans that build strategies for the development, behavior and management of Smart cities based on the most likely and optimal solutions for the main areas of development of complex urban systems.

Since solving the problems of the Smart city DP is a science-intensive process that requires the systematic application of various approaches and methodologies, and which is impossible without the use of modern methods of mathematical modeling, methods, algorithms and software to develop adequate models and make decisions based on them, the topic of research in this article seems to us very relevant.

2. LITERATURE REVIEW

Historically, DP arose in the 50s of the XX century as an alternative to univariate forecasts when building plans for the future development of individual companies and forecasts for the development of individual situations [10], [11].

Single-variant forecasts, as a rule, quite rigidly set the only way for the future development of the system or situation, and in practice, especially in a rapidly changing environment, they very often turned out to be false. It is obvious that it is inefficient to develop strategic plans based on a single probabilistic forecast when there are risks of significant external uncertainty and rapid changes in the external environment [12]-[14].

Situations in the modern world change quickly and unexpectedly, with abrupt changes in circumstances, sudden events that are impossible to foresee. At the same time, there is always a certain set of possible scenarios for future events that can be foreseen and predicted. Therefore, when implementing the dynamic approach, we began to develop approximately equally plausible, but significantly different versions of the future development of events and the external environment for complex dynamic systems and situations. However, a significant feature of such dynamic plans was that they were tools not only for developing forecasts, but also for developing strategies for the development of complex dynamic systems and processes, including in the development of urban infrastructure.

Dynamic planning includes various methods of processing quantitative and qualitative information, modeling methods, optimization methods and decision-making at different stages of planning, risk and uncertainty assessment [17]-[19]. But the main content of the DP is the construction of well-structured and logically verified dynamic plans, or their elements, different equally plausible and adequate options for the future development plan of the system (in particular, Smart city) and evaluating the effectiveness of these plans [1], [2], [4], [20].

At the same time, the plan under construction must be flexible and effective in order to be able to take into account all changes in the external environment for various options for the future development of the systems under study.

The goals and objectives of the research are to improve the quality of dynamic planning of Smart city development by developing and improving methods, models of information technologies and systems for dynamic planning and decision – making in the presence of uncertainties and risks.

The purpose of the research is to review and analyze existing methods and information systems for solving the problems of forming dynamic development plans for Smart city.

3. MODELS AND METHODS

Dynamic planning today is one of the most effective system tools of modern management and strategic management, analysis and planning of the development of complex systems, in particular, the rapidly developing Smart city. Dynamic planning is an effective method for building and developing a rational socio-economic policy, and is also applicable for in-depth analysis and effective development of innovative technologies or large-scale engineering projects [10], [21].

Dynamic planning has three distinctive features that distinguish it from other types of planning. The first is that the system is considered over time when building a plan, taking into account the presence of risks and various types of uncertainties and taking into account their changes over time. In addition, it is mandatory to make forecasts about the future effectiveness of the plan and take into account any changes in the environment [10]. Therefore, you need to build a flexible plan and adjust it in accordance with current events that affect the results of the development of the system. The second is that planning is of a long-term nature, since not only short-term goals are considered, but also long-term ones. And the third is that the process of building a plan is evolutionary in nature in order to achieve the best results for the current source data [20]-[26].

Building a dynamic plan includes the following elements: defining the goals of a dynamic plan, defining time constraints on planning, selecting the plan structure (defining stages), selecting the structure of each stage of the plan, evaluating uncertainties and risks at each stage of planning, establishing methods for solving the main planning tasks, building models of plans, evaluating forecasts and decision-making, and evaluating the effectiveness of the plan.

The DP task statement may differ in the following ways: whether there are links between tasks, the type of Smart city development plan under construction (operational or early), the presence of various types of uncertainties and risks, the type of target functions and restrictions.

When building a dynamic Smart city development plan at various stages there is a need to solve the following main tasks:

1. Tasks of information analysis. At this stage, the information is analyzed and the goals of building the plan (main and auxiliary) are determined, and their ranking is performed.

2. Tasks for building the structure of a dynamic plan (the composition and number of stages). In addition, the possible plan options are defined in detail, their structure and time limits for the plan.

3. Tasks of determining and accounting for the uncertainties and risks of Smart city development.

4. Dynamic plan modeling tasks. The structure and parameters of the Smart city development plan are modeled.

5. Forecasting the main planning indicators.

6. Making decisions and choosing the best option for the Smart city development plan, taking into account all the criteria and evaluating the effectiveness of the plan.

The General sequence of tasks and stages of the dynamic planning process is shown in Figure 1. At the initial stages of building a dynamic plan, the goals of building a plan and time limits for the entire plan are determined.

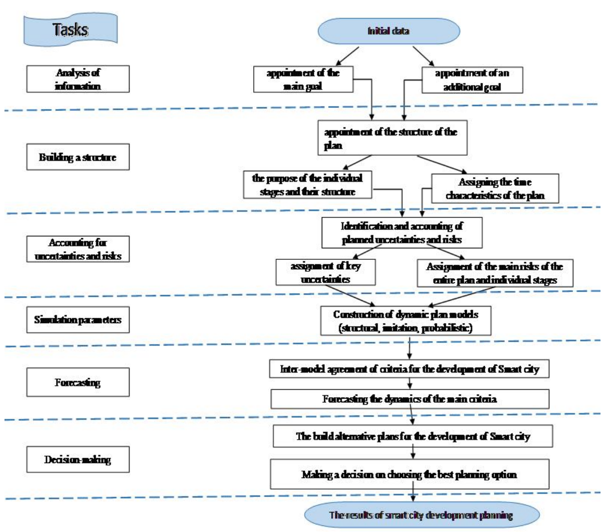


Figure 1: The general sequence of stages and tasks of the dynamic planning process on the example of the development of Smart city

At the next stage, the tasks of constructing the plan structure using graph-theoretic models are solved, and time limits for individual plan variants are determined. Vertexes in models are stages of the plan, and edges are connections of a temporary, logical, and informational type. It is also possible to build alternative versions of the Smart city development plan and select individual areas and technologies according to criteria.

During the synthesis of the dynamic plan structure, the plan structure is selected and optimized. Various approaches to defining and optimizing the construction of dynamic plan structures are possible:

1) dynamic planning is based on the analysis of tasks that are performed or planned at the stages of the plan, based on this, specific stages of the Smart city development plan are determined;

2) the plan is developed in advance, the structure of the plan is adjusted to solve specific tasks;

3) intermediate goals are defined, and the structure of the plan is built in accordance with the achievement of these goals.

Approaches and methods for synthesizing the structure of a dynamic Smart city development plan allow us to formalize the choice of the optimal variant of the plan structure for the above options. The main attention is paid to the distribution of tasks by stages of the plan and the construction of a dynamic plan for a separate stage with a given distribution of tasks by stages of the Smart city development plan

The third stage identifies key uncertainties and risks for the implementation of the plan as a whole and for its individual stages. The choice of methods to overcome them is made.

At the fourth stage of the plan, the main criteria and parameters of plans, their cause-and-effect properties are determined, and forecasting is carried out in order to study the dynamic properties of the plan.

At the next stage, alternative versions of the plan and its elements are simulated in order to Refine individual parameters and indicators of the Smart city development plan.

At the sixth stage, the optimal plan option is selected using decision-making methods. Also at the last stage, the effectiveness of the plan is evaluated and the final version of the plan is selected.

Thus, the procedure for building a dynamic Smart city development plan is understood as the process of consistently solving interrelated tasks of dynamic planning and selecting the best option for the plan according to the specified criteria.

Table 1 shows the results of the analysis of the advantages and disadvantages of existing methods and methodologies of dynamic planning - strategic (ST), scenario (SC), intellectual (IN). These methods may also be applicable to solving problems of improving the quality of dynamic development planning for Smart city.

Table 1: Methods of dynamic planning of the development of complex systems (based on the analysis of [1]–[5], [7]–[10], [12]–[17], [20]–[24])

		Methodology	advantages	disadvantages
Dynamic planning of complex systems	ST	SWOT-analysis	1. Applicable in a wide variety of areas of economics and management. 2. Can be adapted to any object of study. 3. Freedom in choosing the analyzed elements. 4. Can be used for strategic planning of the development of Smart city.	1. Does not take into account possible risks. 2. If there is little information, then the results of the analysis are not of great value. 3. Specific activities to achieve the goals are developed separately. 4. Subjectivity. 5. Requires the involvement of a large number of specialists in certain areas.
		Competitive analysis	External factors, such as a competitive environment, are considered in addition to internal factors when developing strategic plans.	1. Concrete measures to achieve the goals must be developed separately. 2. Subjectivity.
		Brainstorm	1. Visibility. 2. A wide range of participants. 3. Analysis of new ideas and alternative solutions. 4. Competitive atmosphere.	1. Perhaps the "loop" on one idea. 2. The risk that part of the group will not participate in the decision. 3. Time limit.
		Goal tree	1. Visibility in the development of a hierarchy of goals. 2. Objective criteria for the results. 3. Feedback.	High costs of time resources.
		Ansoff Model	Visibility and simplicity.	Limited use.
		D. Steiner Method	Visibility and simplicity.	Limited use.
		Method D. Abel	Visibility and simplicity.	Limited use.
	SC	Shaping Factors – Shaping Actors	The disadvantages of the Delphi method have been fixed. Proven Performance	Sophisticated organization of expert groups.
		Methodology GENERON CONSULTING	Simplicity and effectiveness, proven by practice.	Sophisticated organization of expert groups.
		Methodology GLOBAL BUSINESS NETWORK	Performance proven by practice.	Sophisticated organization of expert groups.
		TERRA	Performance proven by practice.	Sophisticated organization of expert groups.
		TAIDA	Simplicity.	Small approbation in practice.
		Methodology ICL.	Visibility.	A limited range of tasks.
	IN	Classic planning	Developed mathematical apparatus and provability of conclusions.	Difficulty for perception.
		Hierarchical Network Planning	Visibility.	Rigidity and complexity of application
		Decision Theory Planning	Performance proven by practice.	The methodological weakness of planning does not take into account reserves, initiative, and the diversity of the micro level.
		Analytical planning	Developed mathematical apparatus and provability of conclusions..	Does not take into account reserves, initiative, micro level diversity.
		Use-Case Planning	Performance proven by practice.	Precedent base required
		Situation Planning	Subjectivity.	Stochastic factors are not taken into account.

Each type of planning is supported by information systems that are designed to implement the methods and algorithms of a certain planning technology, including for tasks related to the development of Smart city. In fig. Figures 2-5 show the interfaces of some software products that are oriented, first of all, to forecasting and modeling of urban infrastructure.

So, Figure 2 shows the main windows of the WireLess software package (PP), which is intended for modeling and planning wireless networks, in particular, used in modern cities. WireLess software, like many similar software products, is highly specialized and focused on solving specific planning problems.

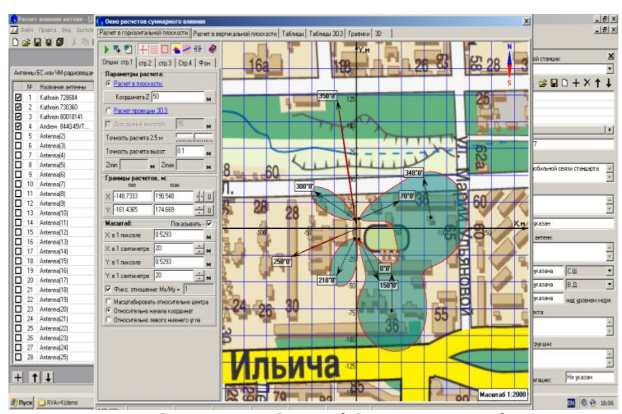


Figure 2: The main windows of the WireLess software

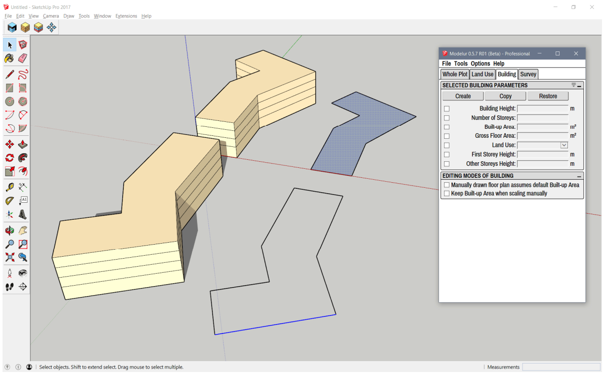


Figure 3: The main windows of the MODELUR software (Urban Design Extension)

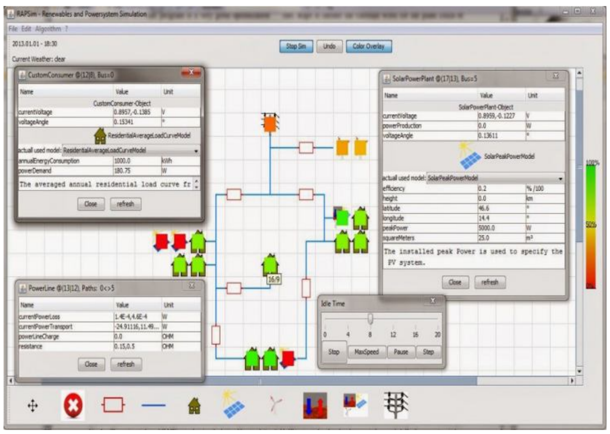
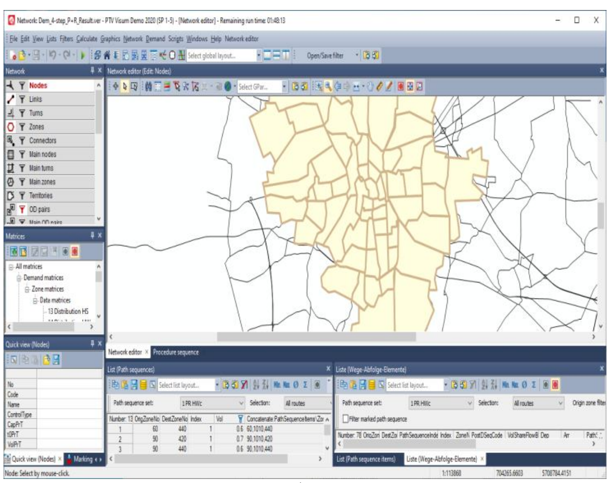
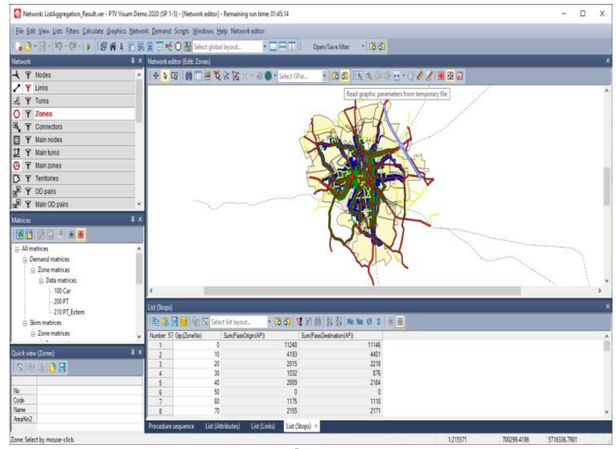


Figure 4: Main windows of RAPSim software for modeling and planning Smart grid



a)



b)

Figure 5: The main windows of the PTV Visum software for modeling and planning urban infrastructure

Table 2 presents the main types of planning and the corresponding IPs that support a certain type of planning.

Table 2 : The main types of planning and related IPs that support a certain type of planning

№	Type of planning	Methodology	IS that implement the methodology
1	Target Planning (TP).	STRIPS	Strips [15], Warplan [23], Interplan, WireLess, RAPSim, PTV Visum, WireLess, MODELUR (Urban Design Extension)
2	Partially ordered planning (POP). TP	NOAH	Noah [21], Nonlin [20], Tweak [17], Ucpop [19], ПП PTV Visum
3	Planning Count (PC). POP. TP.	GRAPHPLAN	Graphplan, Ipp [15]
4	Hierarchical planning.	O – PLAN	O–Plan, Planers-1 [18], Optimum.Aiv [22]
5	Time Based Planning. POP.	DEVISER	Deviser [23], Ixtet [20], Deskarte [20]
6	Time Based Planning. POP. Linear programming (LP).	ZENO	Zeno [24]
7	LP	LPSAT	Lpsat [25],Satplan [26], Maxplan [27]
8	Markov processes. Dynamic programming. Planning Count.	PGRAPHPLAN	Pgraphplan [28], Tgraphplan [28], Spi [29]
9	Situational modeling. Situation Planning.	ROBOCUP	Robocup [30], Copycat [30]

Table 3. discusses the advantages and disadvantages of IP, which support a certain type of DP complex systems. The analysis was carried out based on the general formulation of the research problem.

Table 3: The advantages and disadvantages of IP, which support a certain type of DP complex systems

Comparison criteria	IS that implement a specific methodology								
	Methodology								
	STRIPS	NOAH	GRAPH-PLAN	O – PLAN	DEVISER	ZENO	LPSAT	PGRAPH-PLAN	ROBO-CUP
	IS and application software packages								
	Strips [15], Warplan [23], Interplan, WireLess, RAPSim, PTV Visum, WireLess, MODELUR (Urban Design Extension)	Noah [21], Nonlin [20], Tweak [17], Ucpop [19], PP PTV Visum	Graphplan, Ipp [15]	O–Plan, Planers-1 [18], Optimum. Aiv [22]	Deviser [23], Ixtet [20], Deskarte [20]	Zeno [24]	Lpsat [25], Satplan [26], Maxplan [27]	Pgraphplan [28], Tgraphplan [28], Spi [29]	Robocup [30], Copycat [30]
Calculation of the optimal solution in dynamic mode	-	-	+	+	-	+	+	-	-
Smart City specifics	-	+	+	+	-	-	+	-	-
Resource Allocation Optimization	+	+	-	-	-	+	-	-	+
The difference between positive and negative effects for the development of Smart city	-	+	-	-	-	-	-	-	-

Uncertainties occur in all types of Smart city development planning. In the tasks of dynamic planning of Smart city development, uncertainties are associated with risk.

Risks are inherent in any activity, and with the development of scientific and technological spheres, the number of existing and potential risks increases significantly.

Today risk management is seen as a key area of applied management, considerable attention is paid to the study of risk areas and major risks, the search for effective methods of evaluation, control and monitoring, and the establishment of appropriate systems of risk management.

Risk analysis in various applications is a very broad and rapidly growing field of research. The effectiveness of solving any problem depends mainly on the correctness and validity of decision-making at all stages of solving problems and, regardless of the complexity of the tasks that are being solved, which, in turn, is impossible without taking into account the risks. To manage any process or to solve planning tasks, you need to be able to analyze the risk, assess its degree, anticipate the consequences of the decision and not go beyond the acceptable risk limits. In other words, to effectively solve dynamic planning tasks, it is necessary to show risk, anticipate it, and try to reduce it to the lowest possible level.

The classical definition of risk is given in the work of F. Knight [32]. According to this definition, risk situations are characterized by known probabilities. In this case, the risk is defined as any unpredictable changes in the system state. When building mathematical models of any process or system, there is always a need to evaluate the possibilities and consequences of changing States in the process or system that is being modeled. Therefore, the risk timing is integrated. The existence of risk in systems is directly related to uncertainty. Uncertainty is heterogeneous in form and composition. F. Knight builds the decision-making process by combining the concepts of risk and uncertainty [32].

In [33], [34], the authors define risk as the mathematical expectation of losses through the choice of a particular solution. In [33], the following definition of risk is given: "Risk is the probability of losses or non - receipt of income in comparison with the predicted option." In many studies, it is proposed to evaluate risk as "the probability of error or success of a particular choice in a situation with several alternatives".

In [35], [36], the creation of a General theory of risks is considered. The concept of multi-factor risks is considered in [37], [38].

Most dynamic planning tasks are characterized by incomplete and uncertain information that makes it impossible to build models to solve them. Therefore, risk and uncertainty factors should be taken into account and evaluated when building a dynamic Smart city development plan, or when building its individual stages.

Taking into account all types of risks and uncertainties is the main task of dynamic planning. The effectiveness of solving dynamic planning tasks in General depends on the quality of solving this problem.

In table. 4 presents the types of uncertainties that may arise in the development of Smart city, and their relationship to different types of risks.

As a result of the analysis of various methodologies for building dynamic plans and various PP the main aspects of the use of information technologies for solving the problems of dynamic planning of Smart city development were identified:

- system analysis of an applied planning task and analysis of source data for accurate determination of planning goals;
- build informational and mathematical models for the creation of structures of dynamic plans, evaluation of uncertainties and risks;
- building Smart city development forecasting functions;
- solving decision-making problems based on a multi-model and multi-criteria approach;
- multi-criteria evaluation when building dynamic plans at the creation stage and in the implementation process;
- creation of information and analytical systems for solving problems of dynamic planning of Smart city development.

Table 4: Types of uncertainties that may arise in the development of Smart city, and their relationship with different types of risks. (based on materials [31]-[39])

№	Uncertainties			Uncertainty Risks
	Types	Description	A source	
1	Promising	The system has not been fully explored; unknown factors may appear.	The complexity of the system. Inability to get all the information. Unpredictable external influences.	The risk of a significant deviation of the key parameters from the planned ones, with negative consequences.
2	Retrospective	Complete or partial lack of behavior information systems in the past.	Low efficiency of processing information about the system. Loss of information.	The risk of fluctuations in the parameters of the system (process). Significant temporary deviations.
3	Technical	Insufficient accuracy of analysis tools.	Inefficiency of forecasting methods. Subjectivity.	Technical risks. Inaccuracy of assessment.
4	Situational	The likelihood of a complete or partial change in the situation.	The complexity of the system. The impossibility of predicting change. Unpredictable external influences.	Probabilistic risks. Risk of significant deviation of key parameter values from the planned ones.
5	Stochastic	The probabilistic nature of the studied processes.	Stochastic parameters of a system or processes.	The presence of accidents in the behavior of the system.
6	Uncertainty of the states of the external environment (nature).	Full or partial ignorance of the natural environment when making of decisions	Inability to control the processes of the natural environment.	Environmental and technological risks.
7	Uncertainty targeted countermeasures.	With two-way interaction, complete or partial absence information about the intentions of the parties.	Different goals of the participants. Active and passive resistance.	Different types of risks (economic, environmental, technical, political).
8	Ambiguity of goals	The need to consider several goals, including number of opposites.	The presence of many participants with different goals. Multicriteria.	The risk of reduced process efficiency. Risk of not achieving goals
9	Uncertainty of structure...	Uncertainty in the composition of elements	The complexity of the system or process. A lot of variation.	The risk of inaccurate planning. The risk of negative consequences.
10	Uncertainty criterion	Uncertainty of the criteria by which decision	Inefficiency of the information processing system. Subjectivity.	Risk of inaccurate parameter estimation system (process). The risk of negative consequences.

The mathematical structure of the dynamic planning and decision-making task for the development of Smart city is:

$$\left(M\left(S_t\right), S_D, P_D, \{R_i, i \in N\}, \{f_j, i \in N\}\right) \rightarrow opt, \quad (1)$$

where $M(S_t)-$ is the model of choice; type of structure (models in the form of a graph, differential equations for dynamical systems, forecast models, etc.); S_D- space solutions alternatives. Depending on the type of models, this is a finite space of vectors or a space of vector functions that characterize the solution of the development planning problem of Smart city; P_D- a smart city development dynamic plan; $R_i -$ many relationships that limit the choice in the smart city development planning task. $f_i -$ many relationships of benefits that are given in spase S_D and reflect the requirements for a better choice.

The formalization of the tasks of dynamic planning and decision-making on the development of Smart city is defined in terms of the theory of dynamic systems and the theory of solving problems of choice in order to determine an effective version of the plan.

For a detailed description of the structure of the dynamic plan, a set-theoretical model of the dynamic development plan of the Smart city is used, which has the form:

$$P_D = \{Gp_D, Fp_D, XpCp_D, Sp_D, Ep_D, Rp_D, Up_D, RSp_D, \tau\}, \quad (2)$$

where $Fp_D = \{f_1, f_2, ..., f_n\} -$are many functions that are implemented dynamically; many goals that need to be achieved using a dynamic plan; $Gp_D -$ many parameters of the dynamic plan; $Xp -$ many restrictions on the input and output parameters of the dynamic plan; $Cp_D -$ many states of the dynamic plan; many events of the dynamic plan; $Sp_D -$ many connections between events of the dynamic plan; $Ep_D -$ many uncertainties in creating a dynamic plan; many risks when creating a dynamic plan; $Rp_D -$ many connections between dynamic plan events; $Up_D -$ many uncertainties in creating a dynamic plan; many risks when creating a dynamic plan; $RSp_D -$ many uncertainties in creating a dynamic plan; many risks when creating a dynamic plan; $\tau -$ many uncertainties in creating a dynamic plan; many risks when creating a dynamic plan;

In order to reflect the focused presentation of the dynamic plan Dp two groups of indicators must be defined: goal indicators Gp_D and indicators of criteria for decision making Xp.

In turn, to solve such a problem in modern conditions without information and computer support is extremely difficult, and in many situations it is simply impossible.

Figure 6 presents the structure of information processing in solving dynamic planning problems for the development of Smart city. As can be seen from the figure, the information is processed by groups of experts, analysts and decision makers.

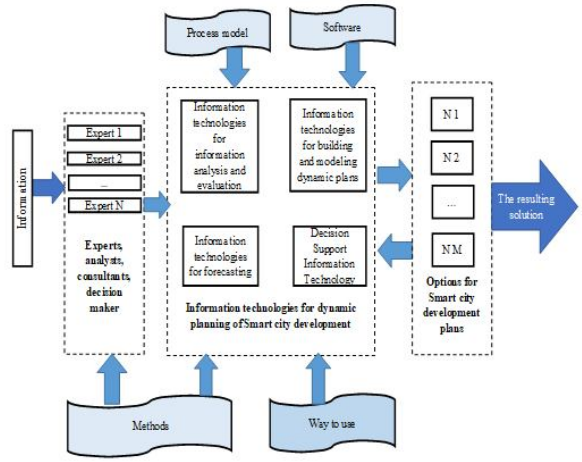


Figure 6: The structure of information processing in solving problems dynamic development planning smart city

Probabilistic statistical methods of data analysis and expert evaluation are used to process data from the "Information" block. This stage is carried out using information technologies for data analysis and evaluation. And at the next stage, models of a dynamic plan are built using information technologies for building and modeling dynamic plans. Then the main planning indicators are predicted and a decision is made on the choice of optimal indicators and the optimal plan as a whole, the ways of using various methods are determined and the necessary software is developed. This is done using information technologies for forecasting and decision-making.

4. DISCUSSION OF THE RESULTS OF ANALYSIS OF METHODS AND INFORMATION TECHNOLOGIES FOR DYNAMIC PLANNING OF SMART CITY DEVELOPMENT

Thus, to solve the problems of dynamic planning in our research, it is necessary to create the following types of information technologies (IT):

IT analysis and evaluation of information;

IT construction and modeling of dynamic Smart city development plans;

IT in the development of Smart city;

IT supports decision-making, for example, at the stage of evaluating investment projects or selecting specific areas for Smart city development.

In fact, the task of dynamic planning of Smart city development is a multi-purpose task. Multi-purpose optimization and decision-making tasks are found in various areas: manufacturing, design, Finance, mobile object management, oil and gas industry, automotive design, etc., or where optimal decisions must be made in the presence of compromises between two or more conflicting goals. The maximization of profit and minimization of product cost; maximum performance and minimization of vehicle fuel consumption are examples of many objective optimization problems.

If a multi-purpose solution is well formed, there should not be a single solution. At the same time, the completeness of each goal is minimized. We are looking for a solution for which each goal will be optimized, and if we try to optimize it further, other goals will suffer as a result.

Finding such a solution is the goal when creating and solving multi-purpose optimization problems and making decisions during the development of Smart city.

5. CONCLUSIONS

As shown in the article, the existing methods and technologies of dynamic planning for the development of complex systems, which can certainly be attributed to Smart city, are not without certain disadvantages. This circumstance allows us to talk about the possibility of improving their work, creating new methods and algorithms. In General, the analysis of dynamic planning and decision-making technologies for the development of Smart city showed the following unsolved problems:

1. Lack of a General theory and methodology for solving problems of dynamic planning and decision-making for Smart city development, taking into account various types of uncertainties and risks.

2. Lack of a theoretical description of the construction (synthesis) of structural elements of dynamic plans for the development of Smart city, taking into account the uncertainties and risks of the external environment.

3. The need to develop adequate methods and information technologies for modeling various, complex types of knowledge and processes required at different stages of building a dynamic Smart city development plan.

4. The need to develop adaptive forecasting methods and information technologies necessary for building an effective dynamic plan and making decisions on the development of Smart city.

5. There is no method for creating information technologies for integration and combined use of data analysis methods, modeling methods, decision-making methods, and forecasting methods for building dynamic Smart city development plans.

6. The need to develop information and analytical systems for solving problems of dynamic planning and decision-making taking into account different types of uncertainties and risks with adaptation to changes in the external environment.

Thus, the problem of effectively solving the problems of dynamic planning and decision-making, as a new tool of modern information technologies for planning and forecasting, for the development of Smart city, as well as the insufficient level of scientific and methodological research on these issues, makes it relevant to conduct new in-depth research in this area.

REFERENCES

1. V. Albino, U. Berardi & R.M. Dangelico, **Smart cities: Definitions, dimensions, performance, and initiatives,** *Journal of Urban Technology,* no. 22(1), pp. 3-21, 2015.
2. M. Angelidou, **Smart cities: A conjuncture of four forces,** *Cities*, no. 47, pp. 95-106, 2015.
3. Amy Glasmeier and Susan Christopherson, **Thinking about smart cities,** pp. 3-12, 2015.
4. A. Zanella, N. Bui, A. Castellani, L. Vangelista & M. Zorzi, **Internet of things for smart cities,** *IEEE Internet of Things journal,* 1(1), pp. 22-32, 2014.
5. S. Paroutis, M. Bennett & L. Heracleous, **A strategic view on smart city technology: The case of IBM Smarter Cities during a recession,** *Technological Forecasting and Social Change*, 89, pp. 262-272, 2014.
6. R.G. Hollands, **Critical interventions into the corporate smart city**, *Cambridge Journal of Regions, Economy and Society*, 8(1), pp. 61-77, 2015.
7. M. Angelidou, **Smart city policies: A spatial approach,** *Cities*, 41, pp. 3-11, 2014.
8. S.L. Blumin, ***Models and methods of decision making in conditions of uncertainty***, Lipetsk: LEGI, 2001, 138 p.
9. A.P. Gozhiy, **Multicriteria evolutionary methods and algorithms in decision-making problems for scenario planning**, *System technologies. Regional interuniversity collection of scientific papers*, Issue No. 2 (79), pp. 20-29, 2012.
10. R.S. de Neufville Dynamic ***Strategic Planning for Technology Policy***, MIT Press, Cambridge, MA, 2008.
11. R.S. de Neufville ***Applied Systems Analysis - Engineering Planning and Technology Management, McGraw-Hill***, New York, NY, 1990.
12. P. Nijkamp ***Interactive multiple goal programming*** – F. University, A. Spronk: Rotterdam Preliminary and Confidential Research Memorandum, 1978.
13. Yu.N. Kucherov, V.V. Bushuev, A.V. Ivanov, D.A. Korev, S.A. Utz & A.V. Shikhina, **Comprehensive development of new technologies for energy supply Smart Cities.** *Environment and Energy Science*, 3, 2019.
14. V.P. Kupriyanovskiy, D.E. Namiot & P.V. Kupriyanovskiy, **Standardization of Smart Cities, Internet of Things and Big Data. Considerations for practical use in Russia.** *International Journal of Open Information Technologies*, 4 (2), 2016.
15. C. Anderson, D.Smith, D.Weld, **Coditional effects in Graphplan**, *In Proc. 4th Int. Conf.AI Planning System.* –1998.
16. R. Fikes, N.Nillsson, **STRIPS: A new approach to the application of theorem proving to problem solving,** *Artificial Intelligence*, vol. 2, pp.189-208, 1971.
17. D. Chapman, **Planning for conjunctive goals**, *Artificial Intelligence*, vol. 32(3), pp.333-377, 1987.
18. J.J.Fuchs, A.Gasquet, B. Olalainty, V.W. Currie, **Plan-ERS.1: An expert planning system for generation spacecraft mission plans**, *In 1st Int. Conf. on Expert Planning Systems*, Brighton. – 1999.
19. J.Penberthy, D.Weld, **UCPOP: A sound, complete, partial order planner for ADL**, *In Proc. 3th Int.*

Conf. on Principles of Knowledge Representation and Reasoning. – 1992, pp. 103-114.
20. A. Tate, **Generating Project Networks,** *In Proc. 5th Int. Joint Conf. on AI.* – 1977, pp. 888-893.
21. E.D. Sacerdoti, **The nonlinear nature of plans**, *In Proc. Of IJCAI Tbillisi, Georgia.* -1975, pp. 208-214.
22. M. Aarup ***OPTIMUM-AIV: A knowledge-based planning and scheduling system for spacecraft,*** AIV: In Fox M. and Zweden M. editors, Knowledge Based Scheduling, Publisher: Morgan Kaufman, San Mateo, California, 1994.
23. S. Vere **Planning in time: windows and durations foe activities and goals**, *Pattern Analysis and Machine Intelligence*, 5, pp. 246-267, 1983.
24. J. Penberthy **Planning with continuos change,** Ph.D. dissertation 93-12-01, *Dept. of Computer Science and Engineering*, U. Washington. – 1993.
25. S.Wolfman, D.Weld, ***Combining Linear Programming and Satisfiability Solving for Resource Planning***.-Knowledge Engineering Review.-1999.
26. D. Weld, **An introduction to least commitment planning,** *In AI Magazine*, 15(4), pp.27-61, 1994.
27. S.M.Majercik, M.L. Littman, ***Contingent planning under umertaninty via stochastic satisfability,*** In AAAI.- 1999.
28. A. Blum, J. Langeford, **Langeford J. Probabilistic planning in the Graphplan framework**, *In AIPS-98 Workshop on Planning as Combinatorial Search*, pp. 8-12, 1998.
29. S.M.Majercik, M.L. Littman, **MAXPLAN: a new approach to probabilistic planning,** *In AIPS*, pp.86-93, 1998.
30. J. Luger, ***Artificial intelligence: strategy and methods for solving complex problems,*** M. Williams, 2003, 864 p.
31. B. Akhmetov, V. Lakhno, V. Malyukov, S. Sarsimbayeva, M. Zhumadilova, T. Kartbayev, **Decision support system about investments in smart city in conditions of incomplete information,** *International Journal of Civil Engineering and Technology*, 10 (2), pp. 661-670, 2019.
32. G. Nicolis, I. Prigogine, ***Self-organization in nonequilibrium structures: trans. from English,*** M.: Mir, 1979. 327 p.
33. Y.Y. Haimes, **Risk modeling, assessment, and management,** *John Wiley & Sons*, Vol. 40, 2005.
34. V. Khodakarami & A. Abdi, **Project cost risk analysis: A Bayesian networks approach for modeling dependencies between cost items**, *International Journal of Project Management*, 32(7), pp. 1233-1245, 2014.
35. J. Grandell, **Aspects of risk theory**, *Springer Science & Business Media*, 2012.
36. C.D. Daykin, T. Pentikainen & M. Pesonen, ***Practical risk theory for actuaries***, Chapman and Hall/CRC, 1993.
37. R. Kaas, M. Goovaerts, J. Dhaene & M. Denuit, **Modern actuarial risk theory: using R**,. *Springer Science & Business Media*, Vol. 128, 2008.
38. Krishna Chaitanya M, Sambasiva Rao G, **Smart Solar Grid integrated PV System with Faulty Permanence Enhancement: For Better Rural Electrification in India,** *International Journal of Advanced Trends in Computer Science and Engineering (IJATCSE),* Vol. 9, No.4, pp.4383-4388 https://doi.org/10.30534/ijatcse/2020/30942020,
39. B.S. Akhmetov, V.A. Lakhno, V.P. Malyukov, A.A. Doszhanova, Zh.K Alimseitova, **Adaptive Model of Cybersecurity Financing with Fuzzy Sets of Threats and Resources at the Protection Side,** *International Journal of Advanced Trends in Computer Science and Engineering (IJATCSE),* Vol. 9, No.4, pp. 5046–5052 https://doi.org/10.30534/ijatcse/2020/124942020,