Development of decision support system «BPsim3»: Multi-service telecommunication networks design and modeling application

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***Abstract*—The paper describes development of intelligent system, based on integration of simulation, expert, situational and multi-agent simulation, as well as object oriented approach. The developed decision support system was applied for multi-service telecommunication networks design and telecommunication services area business processes dynamic simulation. Paper starts with prerequisites for development, presents research data for multi-service network requirements, focuses on deployment and explains advantages of new system.**

I. Introduction

At the present time most telecommunication carriers (including cellular telecommunication) come to necessity of common multi-purpose services transportation and commutation environment establishment. Multi-service network (MSN) forms common information and telecommunication structure, supporting all types of communication traffic (data, voice, and video) and provides all types of services (incl. conventional and new, basic and optional) at any location, any point in time, in any combination and quantity, of guaranteed differentiated quality, and at a reasonable cost, satisfying various end users categories.

MSN provides [1]:

- All data communication services administration, including dedicated lines, Frame Relay, ATM, transparent LAN,
- Traffic aggregation at broadband access level,
- Cellular networks traffic aggregation and traffic consolidation in backbone network,
- New generation telephone communication infrastructure,
- Physical level and data level convergence in tasks of optical backbone node (core node) construction,
- Backbone/edge IP-routers traffic aggregation. MSN is designed on the basis of multi-purpose telecommunication environment, universal network protocols and technologies, which provide networks convergence and services integration.

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II. MSN Feasibility Study and Analysis Problem

MSN engineering includes the following procedures: Primary data acquisition, Network structure definition, Network architecture and topology choice, Access network establishment, Hardware choice, Applied synchronization systems engineering, Monitoring and control, Services assurance technologies choice, Technical and economical network performance factors estimation.

Primary data for MSN engineering includes: Information and telecommunication services customers number, Initial network availability, Telephone networks number capacity, Coalescing telecommunication nodes location and count, Central and peripheral nodes PC and server count, Free SDH transport network resources in form of E1 digital bit stream, Free transport network resources in form of available optical fibers, Offer of services (telephone communication, dedicated and dial-up channel data communication, IP Telephony, Internet, videoconference communication, etc.), Information system, Reliability requirements, Synchronization requirements.

III. System Approach to Intelligent Telecommunication Networks (ITN)

According to system approach enterprise activity can be decomposed into several tiers; each tier has models with certain level of details. On the basis of key parameters business processes structure is defined and hierarchical decomposition is performed. According to ITU-T 1.312/Q. 1201 recommendation, an abstract conceptual model INCM (Intelligent Network Conceptual Model) is a standard in intelligent telecommunication systems area.

The model consists of four surfaces: Service (services or business processes tier), Global functional surface, Distributed functional surface, Physical surface.

Model distinguishes aspects, related to services, and aspects, related to networking, which allows services and information system capabilities definition regardless of backbone network, over which an intelligent add-on is designed [2]. Surfaces 2-4 are comprehensively covered in literature [1-2], so this section focuses on services surface in more detail.

Services surface definition includes design of models, such as market model, service clients (consumers) and suppliers (carriers and providers) models, hardware suppliers (vendors) models, as well as main processes definition (fig. 1). Control systems model definition includes mission and goals declaration, performance indicators determination, business processes design, definition of resources, information telecommunication technologies-based services, and decision making processes.

Reference model eTOM [3] can be utilized for telecommunication company business processes definition allowing detection of processes with the same functionality, duplication removal, and faster definition of new processed. Business processes cost and performance parameters can be estimated either. Company business processes analysis data can be used for re-engineering, relations optimization with suppliers and partners, collaboration development with new services providers. This solution allows a fully concern of customers oriented strategy determination, which is one of the key success factors on glutted market. An eTOM model example, designed in simulation tool ARIS, is set in [3].

Use of only static visual (graphical) descriptive models is insufficient for business processes analysis and modeling problem solving. Simulation modeling and situational management methods need to be involved allowing time factor (processes dynamics, finiteness, and stochasticity) as well as cause-and-effect relations consideration. Resource conversion processes (RCP) relate to business processes as well, their peculiarities can be reflected in artificial intelligence models and methods.

IV. MSN LEVEL OF AUTOMATION

The following information system classes, used for MSN engineering, analysis and operation, can be differentiated:

- Resources monitoring and stock-taking,
- Business and operational support,
- Billing,
- Failsafe operation,
- Income assurance,
- Services and quality management,
- Network elements registration,
- Traffic optimization,
- MSN engineering and modeling,
- Business processes modeling,
- Security and data protection,
- Decision support.

Leading cellular carriers in Russian region (such as Uralsvyazinform, Megafon, Mobile Telesystems, BeeLine) engineers polling revealed, that carriers' development departments use their own experimental knowledge base when engineering data-communication networks, while data-communication implementation engineering solutions are foisted by hardware vendors. No operator either makes use of data-communication networks automated design aids, or models various designed/existing network behavior situations when developing new regions, introducing new services or modifying data-communication network topology.

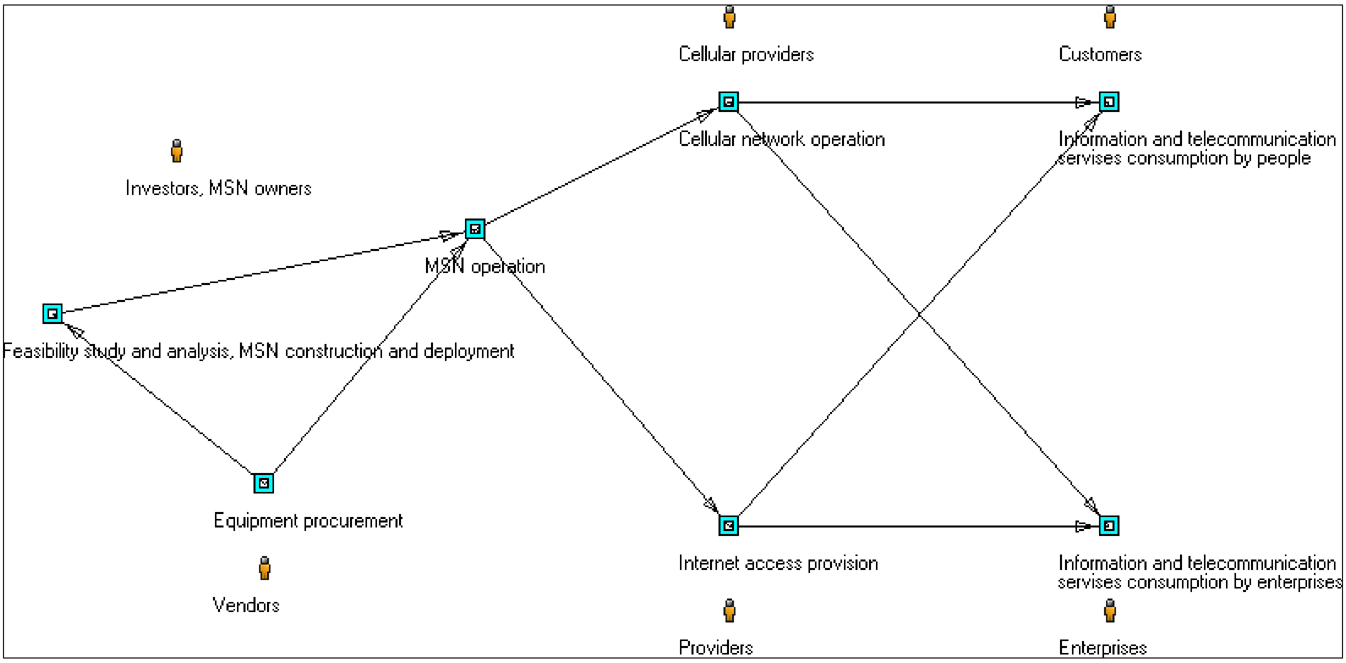

Fig. 1. Information telecommunication technologies-based services market main processes and players

V. Theory of MSN Engineering and Information Telecommunication Services Market Modeling

Development of automated design and modeling methods and aids requires large quantity of primary data for qualitative MSN technical and economical engineering, which includes: telecommunication hardware and technologies types and parameters; engineers, economists, project managers, marketers, and lawyers' level of knowledge.

Decision support systems fit most for MSN technical and economical engineering problem solution. Decision support systems can make use of simulation, expert and situational modeling [4]. Decision support systems development and deployment within cellular communication operators is a pressing and needed problem.

The following mathematical methods are used in MSN and business processes modeling, analysis and synthesis tasks: teletraffic theory may be used on all MSN levels except services level; simulation, situational and expert modeling methods are used for business processes analysis and synthesis tasks. Expert and situational modeling methods, neural networks, multi-agent and evolutionary modeling methods can be used in RCP formalization.

Multi-agent resource conversion processes theory [4-5] can be applied for MSN definition from decision support point of view.

VI. Hierarchical Models of Control Systems

Conceptual analysis or knowledge structuring phase is usually bottleneck in intelligent systems design lifecycle. Structuring methodology is close to large-scale systems [6] or complex systems theory [7], where engineering process is traditionally emphasized [8-9]. A major contribution to this theory was made by object-oriented analysis classics [10]. System analysis is closely interwoven with system theory and includes a set of complicated systems (technical, economical, ecological, etc.) oriented research and modeling methods [11].

Hierarchical approach [12] is traditionally used as a methodological approach for formal system definition decomposition into tiers (or blocks/modules) in complex systems engineering and structuring methods. Top hierarchy tiers are populated with the least detailed views, reflecting only the most common features and characteristics of designed system. Detail level increases on lower hierarchy tiers, while the system is no longer regarded as a whole, but in separate blocks [11].

Each tier introduces own views on the system and its elements. K-th tier element is considered a system for (k-1)-th tier. Tier-to-tier advancement is severely directional and is defined by engineering strategy – deductive descending «top-down» or inductive ascending «bottom-up» [11].

In relation to processes formalization deductive descending engineering strategy is used in IDEF0, IDEF3, DFD, EPC notations, as well as in dynamic processes hierarchical models design (aggregates, Petri nets, extended Petri nets). Inductive ascending strategy is used in high-level integration system graphs.

High-level integration system graphs [13] are used for multi-agent resource conversion processes hierarchical structure definition [4].

From dynamic simulation point of view, only those elements are simulated which were not decomposed at system analysis phase. When using system graphs apparatus all data required for simulation is obtained on first step of dynamic system model design (0-level integration).

VII. Object-structural Approach to Control Systems Models Design

Object-structural approach, offered by T. A. Gavrilova [14], allowed consolidation of these two, traditionally anticipated, engineering strategies. Strategies synthesis, as well as introduction of iterative returns to previous decomposition tiers, allowed a dual concept, offering wide capabilities at knowledge structuring phase to analysts, together for subject area conceptual and functional structure definition.

Figure 2 illustrates this concept applied to functional structure engineering of an expert system for assistance in MSN development.

VIII. Intelligent MSN Engineering and Modeling System BPsim3

Existing MSN engineering and business modeling tools (Route Explorer, VistaInsight, RiverStone Management Center, CajunView, Engine, NetCracker, AnyLogic, ARIS, G2) do not satisfy all requirements for intelligent MSN engineering and modeling system. Dynamic multi-agent resource conversion processes modeling system BPsim2 [4-5] became a basis for intelligent MSN engineering and modeling system development.

Frame-concept and conceptual graphs based approach, offered by A. N. Shvetsov [15] and implemented with regard to industrial DBMS Microsoft SQL Server in form of «Frame systems constructor» expert system shell (FSC) [4], is used as a means of knowledge formalization. A frame-based semantic network, representing feasible relations between frame-concepts, is defined in form of extended UML classes diagram, at the stage of system analysis.

UML sequence diagram is used for visual FSC output mechanism builder implementation. This approach allows visual (in form of flowchart) problem solution flow definition, when solution turns into a sequence of procedure (method/daemon) calls from one frame to another. Hereby, this approach allowed visual object-oriented ontology and knowledge-based output mechanism constructor implementation in form of decision search diagrams (fig. 2).

This constructor, provided that being filled with MSN subject area knowledge and technical and economical engineering rules, represents an intelligent MSN automated engineering system (Intelligent MSN CAD, figure 3).

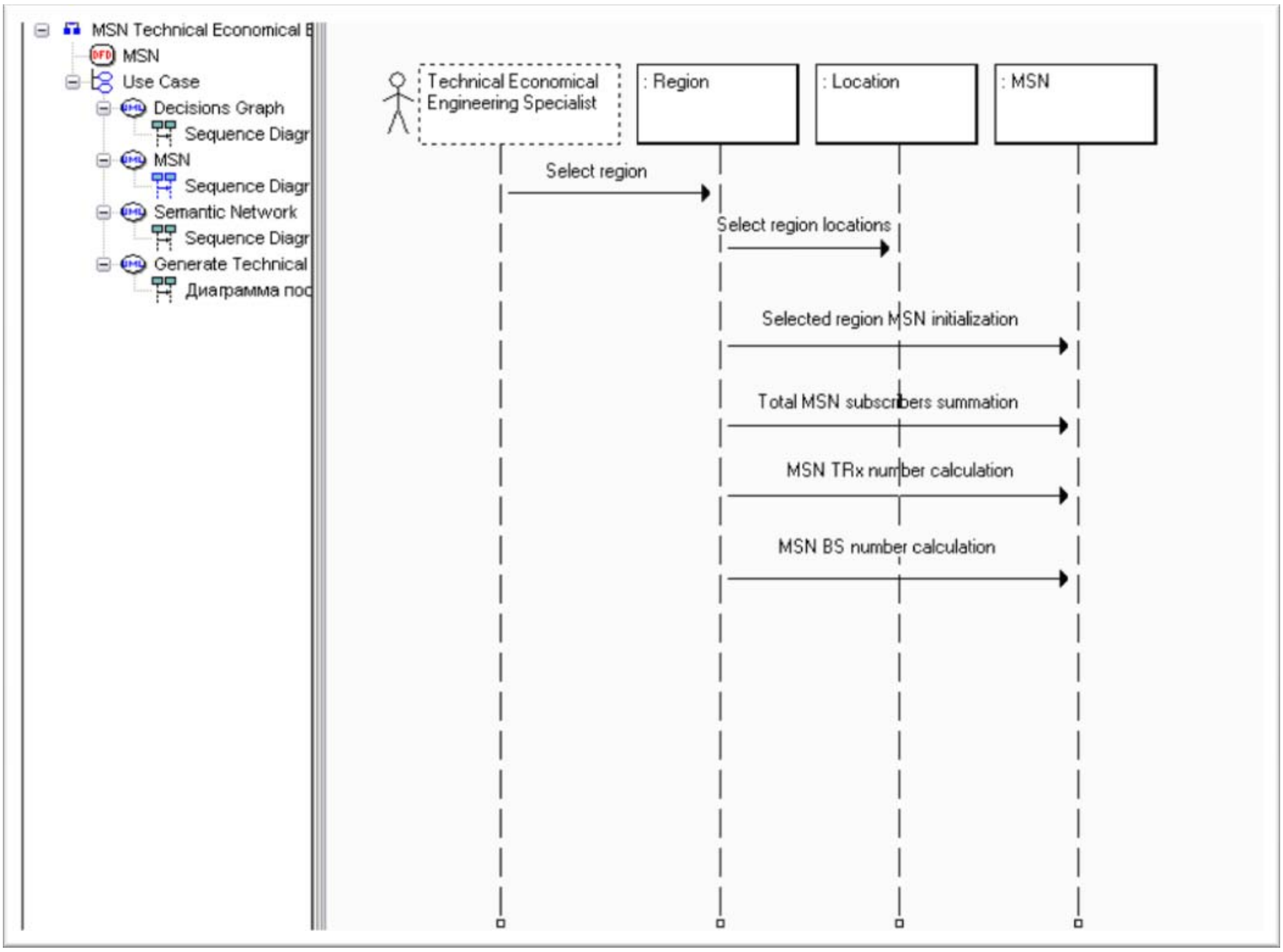

Fig. 2. Visual FSC output mechanism builder

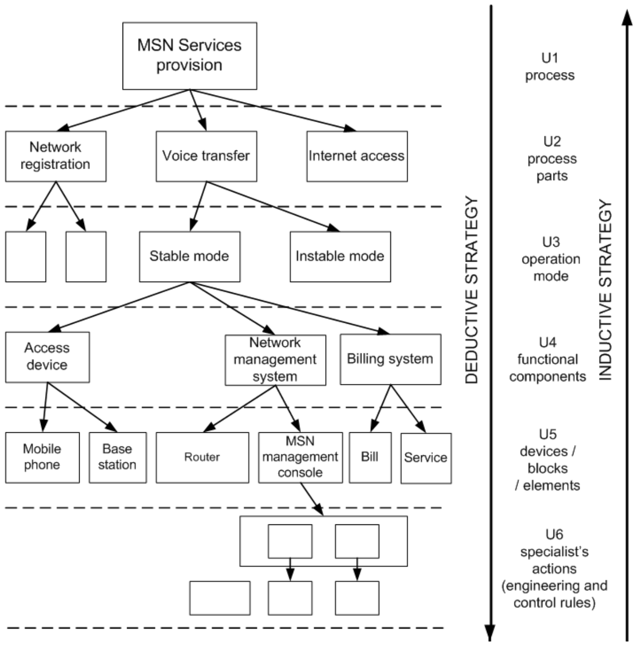

Fig. 3. Dual engineering strategy

Transition from engineering to simulation modeling is implemented by semantic match making between FSC and multi-agent RCP elements. BPsim3 system from the object-structure analysis (OSA) [14] point of view is presented in Table 1.

TABLE 1
ENGINEERING AND SIMULATION SYSTEM BPSIM3 FROM OSA POINT OF VIEW

Stratum	Knowledge type	Stratum levels *[BPsim3 functionality]*
s_1	WHAT FOR-knowledge	Strategic analysis: system purpose and functions *[Mission, vision, strategies, goals, indicators]*
s_2	WHO-knowledge	Organizational analysis: system project team *[Experts, analysts, decision-making people (agents)]*
s_3	WHAT-knowledge	Conceptual analysis: main concepts, conceptual structure

		[FSC (hardware, technologies, MSN, services, processes, etc.)]
s_4	HOW-knowledge	Functional analysis: hypotheses and decision-making models *[Agents' behavioral models (scenarios)]*
s_5	WHERE-knowledge	Tridimensional analysis: environment, hardware, telecommunications *[Geographic information system (regional geographic characteristics)]*
s_6	WHEN-knowledge	Time analysis: time parameters and limitations *[Simulation modeling (limitations in payback period, MSN deployment period, etc.)]*
s_7	WHY-knowledge	Causal analysis: system explanation system engineering *[Expert systems, knowledge and agent-rules bases, output mechanizm]*
s_8	HOW MUCH-knowledge	Economic analysis: resources, expenses, profits, payback *[Solution (MSN technical and economical project)]*

Intelligent MSN automated engineering and modeling system BPsim3 is used for MSN technical and economical engineering problem solution.

IX. BPSIM3 APPLICATION

BPsim3 was applied for MSN technical economical engineering in Ural region, covering metropolis Ekaterinburg and several surrounding towns. Designed model is shown on Figure 4.

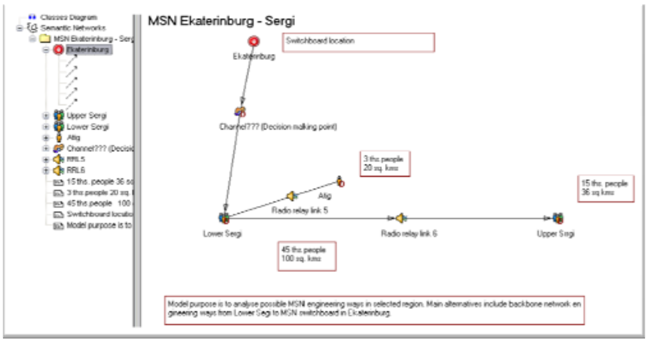

Fig. 4. MSN model view

Graphical implementation of the model is presented on Figure 5. Model allows switching on and off Base Stations (BS) and Transport Networks (TR), as well as changing elements parameters and allowing to select from options of renting or constructing a specific element.

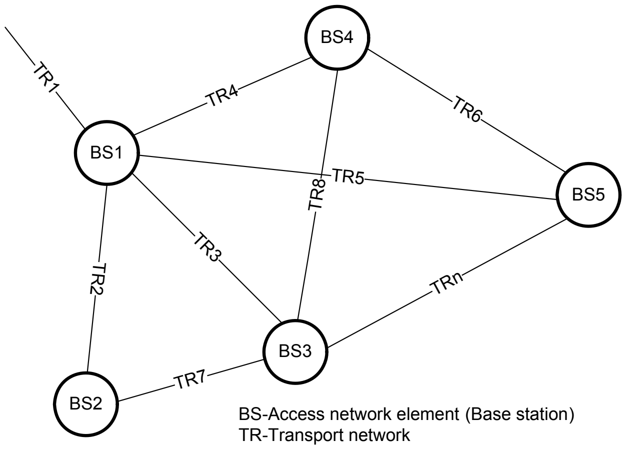

Fig. 5. Modeled MSN graphical model

The model is designed with a main purpose of MSN technical economical engineering with a center in the metropolis and covering surrounding towns. Main goal is to estimate available MSN deployment options for provision of cellular and data transfer services.

Developed model parameters are presented in Table 2.

Synthesized model allows estimation of main investment indicators (IRR, EBI, Payback Period), that are required for substantiated decision making in MSN engineering.

Estimated IRR (Figure 6) shows project #10 as the most attractive (development of 2 base stations, long-distance 2E1 channel rent, lease of BS2 and TR5. Next most attractive experiments are #3 and #4 (access network development, based on own «last miles»). Optic-fiber channel construction (experiment #8) can be mentioned among preferred options targeting MSN development in future, resulting in the best IRR =28.61% and fastest return of investment period of 3.79 yrs among experiments involving channel TR1 construction (Figure 8).

Live, experiment #10 was implemented. Real indicators were close to ones estimated with aid of decision support system BPsim3.

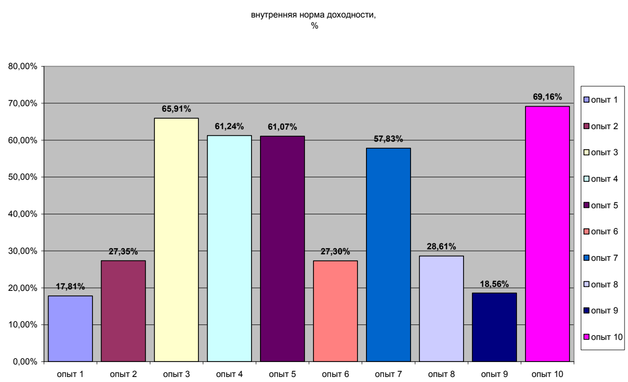

Fig. 6. Internal rate of return (IRR), 10 experiments

TABLE 2
MODEL PARAMETERS

Expenses	Opex	Network channels rent
		Network technical and IT support
		Rent of space and utility charges
		Base stations security
		Technical services for base stations and locations
		Last mile servicing
		Base stations licensing
		Subscribers involvement costs
		Assets tax
	Capex	Engineering, hardware, installation costs
		Additional costs
		Transport network construction cost
		Base stations legalization
Revenue	Marketing forecast	Number of subscribers
		Expected traffic per subscriber
		Revenue from traffic
		Revenue from interconnect
		Other revenue
		Monthly number of subscriber growth
		Average MOU, minutes
		Average APPM, $
		Interconnect cost, $
	Revenue from lease	Channels lease
		Locations lease
		Other

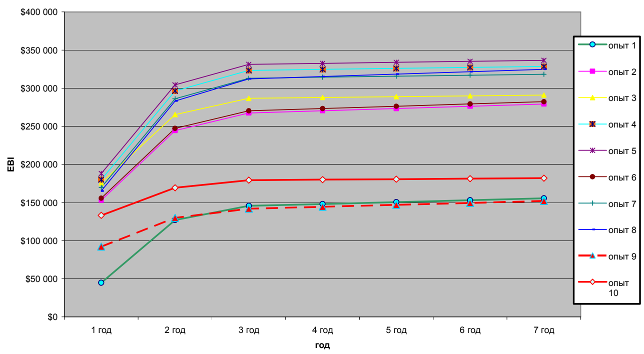

Fig. 7. Earnings before interest (EBI), 10 experiments

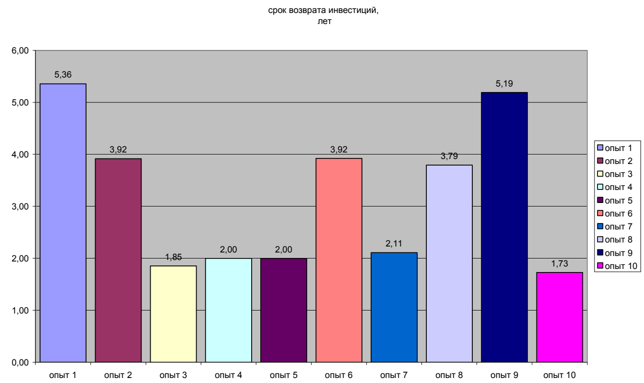

Fig. 8. Return of investment (ROI), 10 experiments

X. CONCLUSION

Integration of simulation, expert, situational and multi-agent simulation, as well as object oriented approach, allowed implementation of intelligent problem-oriented MSN CAD.

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