A research article Choice of a Strategy of Regional ICT-management. Cognitive Paradigm

Robert A. Karayev

Institute of Cybernetics of National Academy of Sciences, Baku, Azerbaijan
karayevr@rambler.ru

ABSTRACT

One of the topical problems of post-industrial (information) economy, the problem of the choosing a strategy of regional ICT-management is considered. We note the difficulties in solving of the problem caused by its complex ill-structured character that limit possibilities of applying the known methods of economic-mathematical modeling and decision-making. Methodology of cognitive support that opens up new possibilities for overcoming these difficulties is proposed.

KEYWORDS:

Regional ICT-management, Strategy, Cognitive Paradigm

1. Introduction

The modern concept of post-industrial economy puts information and communications technology (ICT)[1] among the major factors stimulating economic growth of a country as a whole and its separate entities, first of all, regional level entities [16, 17]. However, in actual practice, this theoretical proposition is faced with numerous difficulties caused by real conditions and real capacity of specific regions [13], such as lack of developed ICT infrastructure, lack of ICT management skills in the management of enterprises (mainly, small and medium-sized enterprises), unfavorable investment policy of regional authorities in the field of ICT, insufficient reliability and safety of ICT infrastructure, poorly predictable dynamics of macroeconomic environment, etc.

Therefore, the problem of the adequate choice of a regional ICT management (RIM) strategy that takes into account a region's characteristics in terms of strategic priorities and goals of regional development (GDP and labor productivity growth, increases in a region's competitiveness, quality of life of its population, etc.) has a great practical importance.
Scientific support of the problem in the present extremely complicated conditions is commonly faced with the problem of ambiguity (incomplete and unreliable statistics, hyperturbulent macro-environment, globalization of economy, multifactor and non-linear nature of economic impact of ICT, etc.) that practically rules out the possibility of using the known methods of economic-mathematic modeling and decision-making [7].

Cognitive modeling methodology, which is being developed actively in the theory of management of complex ill-structured systems, opens new prospects for solving the problem [4, 18].

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2. Cognitive modeling methodology

Cognitive modeling methodology is based on explication and formalization of expert subjective representations (mental models [11, 18]) of a controlled problem situation (PS) and includes:

(a) methods for cognitive-targeted structuring of expert knowledge of PS,

(b) tools for formalized representation of expert knowledge in the form of a cognitive map of PS,

(c) methods for cognitive map analysis (modeling experimentation on the cognitive map) aimed at solving practical problems of PS management.

A classical cognitive map is a directed graph *(F, W)*, where *F* is the vertex set of essential (basic) factors of the controlled PS (target factors, controllable and uncontrollable factors of PS, external environment), *W* is the arc set of cause-and-effect relationship between situation factors. At that, the ordered set of linguistic values *Z* and a scale representing these values at a points of the numerical axis are specified for each factor of *F*, $\varphi : Z_i \rightarrow F_i$.

Diversity of cognitive maps is defined by various methods of assignment of factor scores and cause-and-effect relationship between them. The following types of cognitive maps are distinguished based on these criteria: sign cognitive maps, weighted cognitive maps, rule based cognitive maps (RBCM).

Cognitive maps serve as a tool for structuring and formalization of PS and a tool for their applied analysis. At present, there are the following basic analysis methods:

- impact analysis methods aimed at determining the sign and impact force between any pair of factors,
- methods for prediction of PS states in the self-development mode (the situation develops by itself, following the course of the current trends, without control actions),
- methods for prediction of PS states in the controlled development mode,
- methods for searching the optimal (in one way or another) strategy of PS management.

Methods of analysis allow one to conduct modeling experiments on a cognitive map for the purpose of solving applied management problems, specifically, the priority problem of the modern management practice – the problem of forming the strategy of PS management. This problem is investigated in detailed in the paper [1] by the members of the Institute of Management Problems, the leading scientific research institute of the Russian Academy of Sciences in the field of cognitive technologies. The authors propose a general method for forming the strategy of cognitive management of social-economic systems constituting a wide class of ill-structured systems.

3. Methodology for cognitive modeling of regional ICT management strategies

3.1. Key principles.

The first attempts to apply the "general method" in regional informatization projects revealed its significant limitations. Those limitations are mainly caused by the following circumstances:

1. The specifics of the key problem of cognitive modeling – the problem of generation of the cognitive map of RIM that to a large extend defines the authenticity of the modeling procedure. The generally accepted orientation on expert mental models proved to be inefficient in the case of RIM. RIM specifics rule out the possibility of generating a cognitive map only by way of active interaction with regional experts. The correct solving of the problem requires involvement of knowledge not only of local experts but of the entire fund of RIM problem

knowledge accumulated in the international and local practice.

2. F. Roberts's apparatus for linear dynamic systems used in [1] for modeling the dynamics of situation development, unfortunately, does not allow modeling the entire variety of non-linear (non-monotonic) interfactorial relationships that arise in real informatization projects (multiplicative relationships, feedbacks, time-lags, threshold effects, etc.).

3. The mechanism of formation of PS management strategies [1] using the step-by-step "situation-solution" algorithm implements not the strategic management style but the reactive one and cannot be used for generating RIM strategies in real non-monotonic environments. More complex algorithms, such as "situation-strategy-solution" algorithms, are required for this type of environment.

The stated circumstances challenged developing a special version of cognitive modeling methodology based on:

1) a problem-oriented cognitive map for modeling of RIM strategies and
2) an apparatus for modeling of non-linear (non-monotonic) dynamics of that map.

3.2. Cognitive map of RIM strategy.

Ideologically, the developed map is based on the conceptual model of the economic impact of ICT proposed by the analysts of Economic Intelligence Unit (EIU) [12]. The EIU model was developed following the results of the empirical research conducted in 60 countries (26 developed and 34 developing countries), a survey of over 100 senior executives from 18 industries, in-depth interviews with major European politicians, business leaders and prominent academics. The EIU model establishes the conceptual relationship between the economic growth of a region and a number of key (for the time being) informatization problems. The fundamental theses of the EIU model can be represented as follows:

Thesis 1

There is a close connection between ICT and economic growth in the developed countries, while in the developing countries, the impact of ICT is relatively low.

Thesis 2

ICT can facilitate economic growth if business conditions are sufficiently favorable in the region, if the region's economy is open and if the "oil" factor is not dominant in it (the "Dutch disease").

Thesis 3

The impact of ICT on economic growth is of a specific non-linear nature that is illustrated by the chart in Fig. 1. The chart was built after non-ICT growth determinants, such as "quality of business environment" in a region, "management level" in a region, etc., have been controlled for.

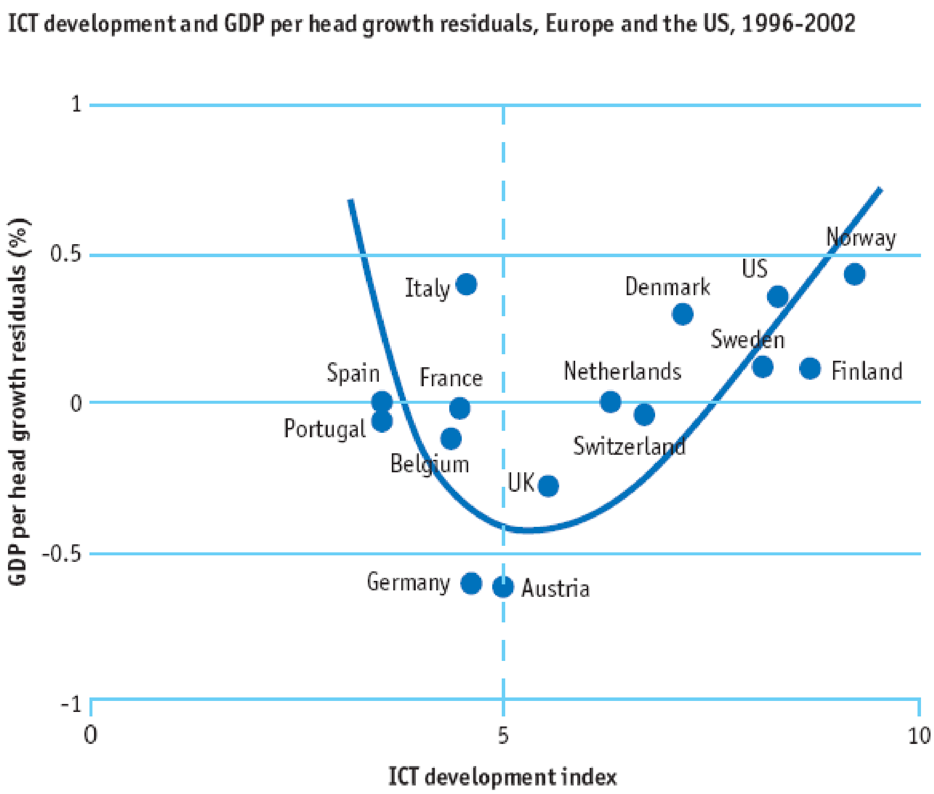


Figure 1. Relationship between ICT development and GDP per capita growth (Europe, US)

Source: EIU

The U-shape of the relationship indicates that:

1) at low levels of ICT development (the downward sloping part of the curve), the various costs and disruptions caused by the introduction of ICT outweigh the benefits – any increases in ICT development level are actually associated with a decline in the GDP per capita growth rate;
2) above a certain level of ICT development (the upward sloping part of the curve), network effects from some minimum mass of ICT in the economy and the experience derived from earlier ICT development mean that the benefits of increasing ICT outweigh the costs – increases in the ICT development index are clearly associated with the increased GDP per capita growth.

Thesis 4

ICT begins to deliver GDP per capita growth only after a certain threshold of development is reached (threshold hypothesis). This threshold is indicated by a dotted line in the chart and corresponds to the ICT development index of 5 (on a 1-10 scale).

Thesis 5

Development and use of ICT begin to influence the economic growth only after a certain adjustment period (the time-lag hypothesis). This assumption of EIU corroborates the popular opinion that there is a certain time-lag before the information factor takes effect.

Thesis 6

GDP per capita growth rate in the upward sloping part of the curve depends on a number of **key factors** (ICT-related factors that manifest themselves to a different extent in different regions) that are most likely to enable fulfilling ICT- potential of a region and, consequently, GDP per capita growth. Those key factors are:

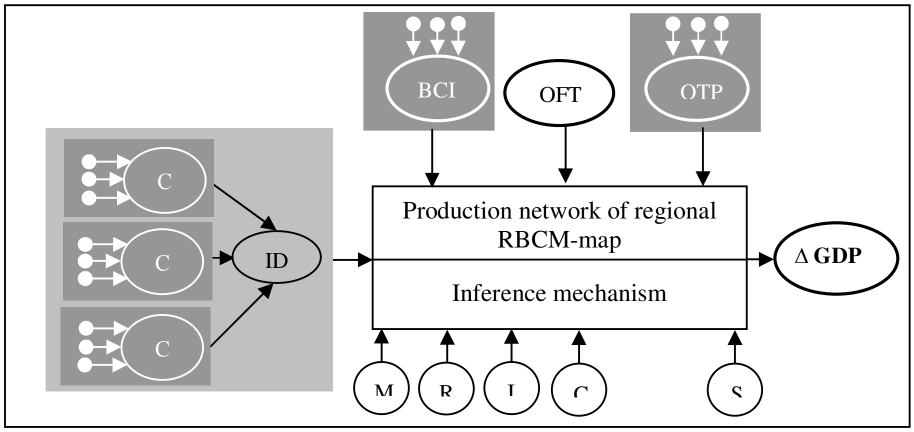
1) affordability of ICT; 2) access to broadband networks; 3) free competition in the telecommunications market; 4) reliability and security of ICT infrastructure; 5) the government's role (financial, customs and tax incentives for ICT, extent of censorship); 6) legislature and law enforcement covering the use of the Internet; 7) ICT skills of managers of enterprises (mainly small and medium-size ones) and the population; 8) a measure of the quality of ICT supporting services.

Obviously, the list of key factors can be modified according to the conditions of specific regions.

In terms of Theses 1-6, the EIU analysts [12] define **regional ICT-management** as management of a region’s key factors aimed at encouragement of the long-term economic impact of ICT. Therefore, the **problem of RIM strategy development** can be interpreted as a search of a mutually agreed sequence of strategic steps providing such management of the named key factors that would deliver the desired economic growth with regard to the structural peculiarities of the EIU model, interfactorial relationship characteristic of the region and the possible dynamics (scenarios) of development of a region’s environment.

Theses 1-6 essentially define the conceptual prerequisites for solving this problem.

We have generated a cognitive map of RIM in the format of a special RBCM representing the non-monotonic logic of interfactorial relationship that arises during the integration of ICT in the economy of regions. The structural scheme of the map is given in Figure 2.



- fragments of RBCM of 1-st level,
- fragments of RBCM of 2-nd level,
- RBCM of RIM (3-rd level)

IDI – ICT Development Index,
C1, C2, C3 – sub-indices of IDI: C1 – ICT access sub-index, C2 – ICT use sub-index, C3 – ICT skills sub-index,
Δ GDP p/c – the share of GDP p/c, caused by impact of ICT,
BCI– business conditions in the region,
OFT– oil factor,
OTP – openness of trade policy in the region (Sachs-Warner index),
M, R, I, C, G, S – controlled factors of RBCM of RIM.

Figure 2. The structural scheme of the RBCM of RIM

3.2.1. The basic factors of the RBCM.

• The target factor: “Regional economic growth index” (EGI); the aggregative “Regional economic development index” that includes a number of primary indicators such as “standard of living”, “employment”, “labor productivity”, etc. can also be used as a target;
• External environment factors: “Business conditions index” (BCI), “Openness of trade policy in the region” (OTP), “Oil factor” (OFT);
• “Regional ICT development index” (IDI);
• Controlled factors (CF) that regulate the impact ICT on the economic growth rate; they are the indicators listed in Tesis 6, requiring regional biding everywhere by inclusion of such factors as “digital crime level”, “education level”, “law efficiency in the field of information”, “digital inequality” of subregions, etc.

EGI, BCI, OTP and IDI can be assessed qualitatively by experts but if the required primary indicators are available, they can be estimated at points in the form of aggregative indices.

Oil factor OFT is a fictitious index assuming value 1 for the regions of major oil exporters and value 0 for other regions.

3.2.2. Production network of the RBCM.

The production network of the RBCM describes the entire set of interfactorial relationships defined by the EIU model, also considering the time-lag in the response of some controlled factors, such as mastering of ICT management skills on the part of an enterprise's executives, development and introduction of tax and regulatory and legal framework of e-commerce, introduction of unified network security standards, etc.

The rule base of the production network includes productions with logical operators: "AND", "OR", "priority AND", "threshold AND", "AND with a time-lag"

3.2.3. Factor values assessment scale and interfactorial relationships.

Values of the factors of the cognitive map, as well as the cause-and-effect relationship characterizing the strength and the sign of impact of some factors on other factors, are assigned by means of the unified linguistic scale given in Table 1.

Table 1. The linguistic scale for assessment of values (activity levels) of *F* factors and the strength of interaction *W* of factors of the cognitive map

F*, *W	**Linguistic values (*Z*)**	**Points**
0	DOES_NOT_CHANGE | DOES_NOT_IMPACT	0
0,1	VERY_LOW | VERY_POOR | VERY_WEAK	0-1
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Notes:

1. For the factors that can be estimated quantitatively, each linguistic value is put in correspondence with the value of a factor from the "object scale", e.g.: "GDP per capita" VERY_LOW – below 500 s.u.(0.1), LOW – from 500 to 1 000 s.u. (0.3), AVERAGE – from 1 000 to 3 000 s.u. (0.5), HIGH – from 3 000 to 7 000 s.u. (0.7), VERY_HIGH – over 7 000 s.u. (0.9).
2. The scale is built for a specific region for a specific period of time (horizon of analysis).

3.3. The mechanism for modeling the RBCM dynamics.

A mechanism for modeling the RBCM dynamics (inference mechanism) based on the arrangement of the multilevel non-monotonic conclusion [10]. Theoretically, the mechanism is based on the fuzzy production dynamics model proposed by Prof. G.S. Osipov (Institute of Systems Analysis, Russian Academy of Sciences) [9]. The situation network, registering the set of hypothetically possible alternative RIM strategies, is built for three alternative development scenarios for the environment – inertial, pessimistic and optimistic, and contains some (probabilistic) metric for assessment of admissible transition of PS from one state into another.
The mechanism allows one to carry out:

(a) dynamic scenario prediction of PS development in the self-development mode and the controlled development mode;

(b) search of the optimal RIM strategy (quasi-optimal strategies) based on the “backward wave” algorithm that implements the basic principle of strategic management – “management from the desired future to the present”.

A “research prototype” (conventional for building knowledge-based models) of the cognitive model of RIM strategy has been developed for the moment.

4. Example

We give the results of solving the demo problem of selecting a RIM strategy as an example.

4.1. The basic characteristics of RBCM of RIM

Basic factors of RBCM (factor semantics according to [13]).

Target factor*:* “GDP per capita” (**GDP p/c**)

External environment factors*:*
BCI. “Business conditions in the region”,
OTP. “Openness of trade policy in the region” (Sachs-Warner index),
OFT. “Oil factor”.
IDI. “ICT development index” ([8]).

Controlled factors:
M. “ICT management skills” at the enterprises of the region.
R. “Improvement of R&D” in the field of ICT.
I. “Innovation culture” (financial and credit support, tax incentives for innovation and entrepreneurship in the field of ICT, access to venture capital).
C. “Competition in the telecommunications market”.
G. “Government’s participation in the introduction of ICT”.
S. “Security of ICT infrastructure” (unified network security standards, efficient standard authentication protocols and technical security of resources of physical and legal entities).

Original state (S_0) of PS (on the linguistic scale in Table 1):
BCI=0.9; IDI = 0.5; OTP = 0.9; OFT = 0.9, M = 0.1; R = 0.3; I = 0.1; C = 0.3; G = 0.5; S = 0.3; GDP p/c = 0.5.

4.2. Problem statement

Scenario.The environment of the region (BCI, IDI, OTP, OFT factors) is favorable for increasing the growth rate of the target factor (GDP p/c) by introducing ICT. S, M and I (established following the results of SWOT&PEST-analysis of the region) are taken as the priority controlled factors that can encourage the impact of ICT on GDP p/c.
The problem of choosing a RIM strategy is to find a sequence of actions on the controlled factors that would allow increasing GDP p/c growth rate from MODERATE (the original value of the target factor is 0.5) to VERY_HIGH (the desired value of the target factor is 0.9).

4.3. Modeling results.

Such management obtained by solving the problem is given in Figure 3.

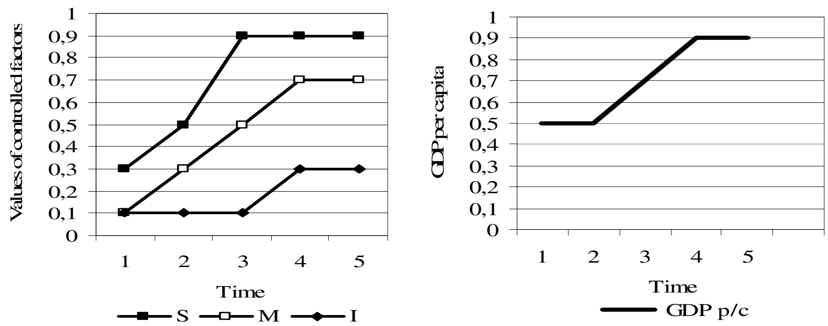

Figure 3. Dynamic scenario analysis cognitive map of RIM.

The left side of Fig. 3 represents the dynamics of activity in the nodes “Security of ICT infrastructure” (**S**), “ICT management skills” (**M**) and “Innovation culture” (**I**), which improve successively with the course of time (activity in those nodes rising). The result of such management is increase in GDP p/c growth rate – from MODERATE (0.5) to VERY_HIGH (0.9) (the right side of Fig. 3). It is clear from Fig. 3 that such increase in GDP p/c growth rate requires raising the intensity of all three controlled factors but **in a different sequence** and **in a different measure.** First of all, “Security of ICT infrastructure” should be significantly increased (for instance, by introducing the unified network security standards, reliable regulatory and legal and technical measures for protection of intellectual property – Internet payment systems, digital identities, digital contracts, etc.). The principal efforts should be aimed at the leading growth of that factor; the increase in its growth rate should be fastest and highest (above 0.9) by the end of imitation period.

The remaining controlled factors are distributed in the following way based on the degree of their impact on the result. The second most significant factor is “*ICT management skills*”. In the beginning of the imitation period, the activity rate of this factor is somewhat inferior to that of “*Security of ICT infrastructure*” but significantly superior to “*Innovation culture*”. To achieve the target result (increase in GDP p/c growth rate), attention should be paid to “*Innovation culture*” no sooner than on the third step of imitation, after the initial GDP p/c growth rate is achieved. Requirements to the activity of “*Innovation culture*” can be brought down again after the fourth step of imitation (after that moment, growth rate of activity of “*ICT management skills*” and “*Innovation culture*” become equal).

5. Experience of cognitive modeling of RIM strategies

The series of modeling experiments was carried out on the RBCM “research prototype”, using the monitoring data [5, 6] obtained for three leading economic regions of the Azerbaijan Republic. The work was conducted with participation of the specialists from the Department for the Information Society Development of the Ministry of Communications and Informational Technologies of the Azerbaijan Republic, employees of the Institute of Cybernetics of the Azerbaijan National Academy of Sciences and a group of experts from the consulting company USTAD LLC.

The development of the cognitive map required extensive and laborious work including the investigation of the local conditions of informatization and overcoming the difficulties associated with the traps of expert knowledge explication [3, 12], which usually stay beyond the model design in most theoretical publications.

In developing the RIM situational network, we used the methods of SWOT&PEST analysis and scenario planning, SMART principles and "Seven Steps" strategy [19].
Cognitive modeling of RIM did not yield trivial or absurd results. In a number of cases, it allows forming unobvious alternative strategies, which usually proved to be better than the strategies proposed by ICT project managers.

Cognitive modeling did not require major computer resources (the minimum resources of a desk calculator can be used) or heavy expenses. The latter did not exceed a small fraction of a percent of regional ICT budgets, which is much less than potential damage associated with the lack of cognitive development of strategies.

6. Conclusion

1. The world practice demonstrates [13, 16] that high rates of investment in ICT and wide application of ICT as such do not secure acceleration of economic growth. According to the OECD estimates [19], in the present conditions of the information boom, regions can invest excessively in ICT either in an effort to compensate the lack of skills or due to the lack of a clear market strategy for informatization. There was no full understanding of the importance of such strategies for solving the problems of post-industrial regional development until the recent years.

2. Cognitive modeling of RIM creates prerequisites for developing strategies in terms of the modern management science and the international experience that formed at the intersection of business analytics, information and communications technology and cognitive technologies.

3. In our opinion, the proposed cognitive RIM model can be regarded as a significantly expanded EIU model that brings strategic analysis closer to the reality of the current economic practice – lack of reliable statistics, interaction of factors of internal and external environment, hyperturbulence of the macro-environment.

4. Academically, cognitive models can apparently be regarded as a new (probably unique) set of DSS-tools that provides support of "nondisjunctive" logic of strategy developers [2, 4], which is impossible for the known models based on conventional ("disjunctive") mathematical calculations, including L. Zadeh's fuzzy logic [2, p. 27, 31, 53].

5. The US National Science Foundation, under whose auspices most of scientific research is carried out in the USA, issued a report [14] in 2006, predicting science development in the next 50 years. The report titled "NBIC Convergence" (N - Nanotechnology, B - Biotechnology, I - Information technology, and C - Cognitive science) defined the principal trends of the world science for decades to come.

The information technology revolution began as early as in the 1960s; the rapid progress of biotechnology unfolded in the 1990s and the progress of nanotechnology in the beginning of this century. Today, cognitive technologies begin to develop rapidly, forming the new "cognitive paradigm" of strategic management, in particular, strategic ICT-management, which we used as an example to demonstrate the applied possibilities of those technologies.

Note

[1] According to the World Bank, ICT consists of the hardware, software, networks, and media for the collection, storage, processing, transmission and presentation of information (voice, data, text, images), as well as related services.
(http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTINFORMATIONANDCOMMUNICATIONANDTECHNOLOGIES/0,,contentMDK:21035032~menuPK:282850~pagePK:210058~piPK:210062~theSitePK:282823~isCURL:Y,00.html#I)

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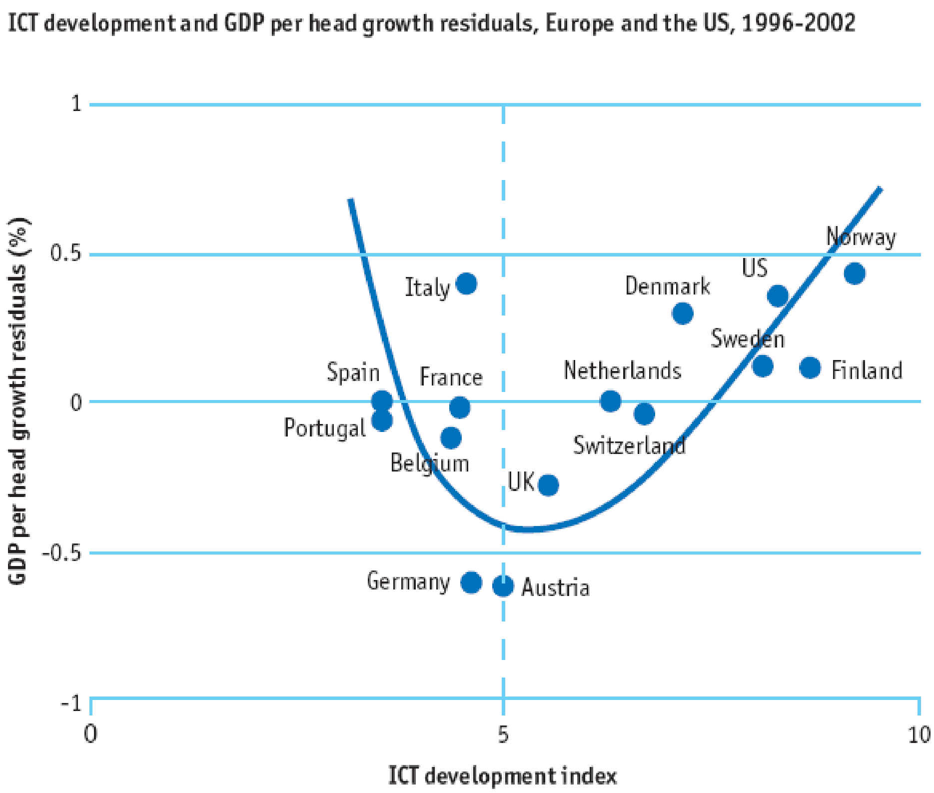
Author

Robert A. Karayev is Professor at the Institute of Cybernetics of National Academy of Sciences of Azerbaijan. His research interests are in information and cognitive technologies. He has more than 190 publications.



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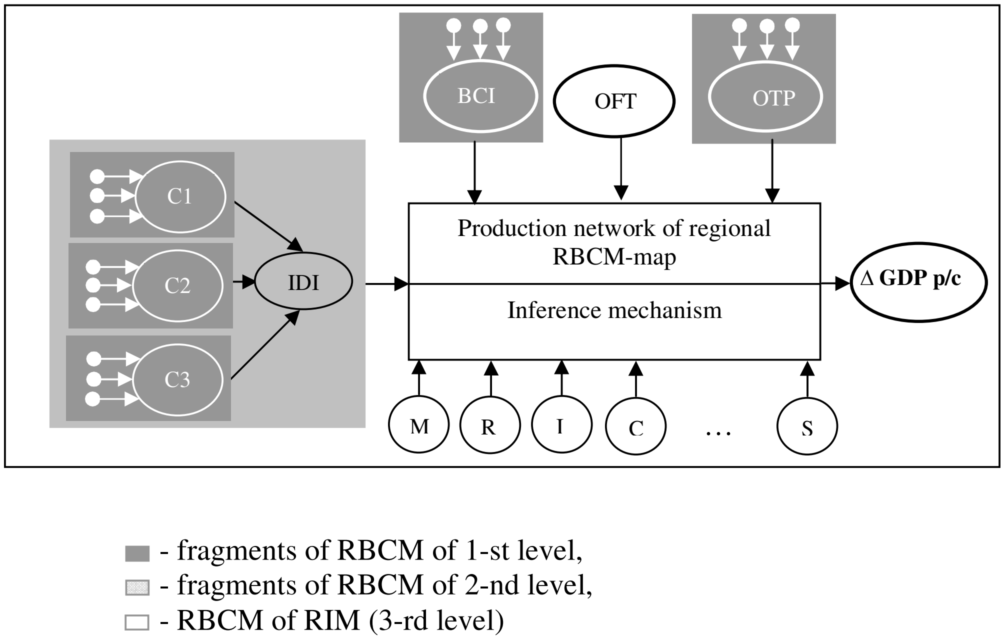

Figure 2. The structural scheme of the RBCM of RIM

IDI – ICT Development Index,
C1, C2, C3 – sub-indices of IDI: C1 – ICT access sub-index, C2 – ICT use sub-index, C3 – ICT skills sub-index,
Δ GDP p/c – the share of GDP p/c, caused by impact of ICT,
BCI– business conditions in the region,
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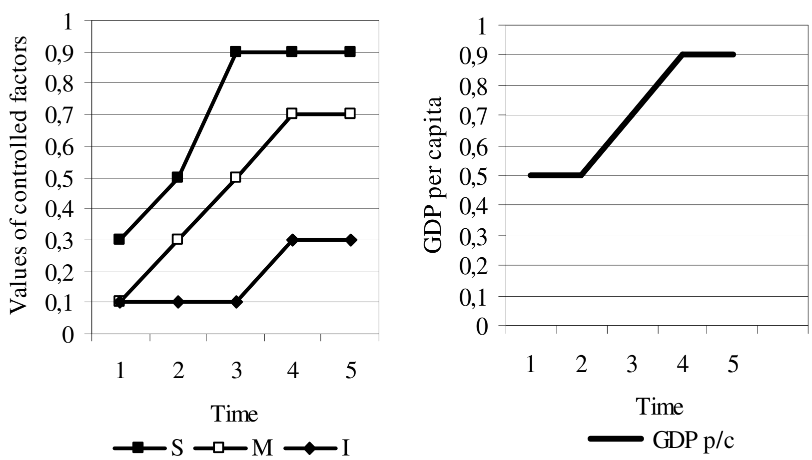
M, R, I, C, G, S – controlled factors of RBCM of RIM.



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Notes:

1. For the factors that can be estimated quantitatively, each linguistic value is put in correspondence with the value of a factor from the “object scale”, e.g.: “GDP per capita” VERY_LOW – below 500 s.u.(0.1), LOW – from 500 to 1 000 s.u. (0.3), AVERAGE – from 1 000 to 3 000 s.u. (0.5), HIGH – from 3 000 to 7 000 s.u. (0.7), VERY_HIGH – over 7 000 s.u. (0.9).

2. The scale is built for a specific region for a specific period of time (horizon of analysis).