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The Relevance of Systems Methodologies in the Development of Organizational Systems

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The relationship between systems development and systems methodologies is discussed in this paper. As the measure of system development on the macro level, Gross Domestic Product (GDP) is assumed to be the consequence of systems Research and Development (R&D), which is estimated indirectly by the number of published articles in the last 40 years. It was supposed that profit and governmental organizations are systems comprised of Production, Management and Information Systems (IS), and that their quality performance is related with its income generation, which in the future would impact the overall GDP of a country. Under such view, we also assume that such organizational processes are qualitatively improved by the application of knowledge generated by research publications, and in this study, we research for the specific case of the Systems Approach (SA), Systems Engineering (SE), Operational Research (OR), Information Systems Development (ISD) and Simulation, as the research topics for coping with organizational improvement. We looked for the articles containing the afore-mentioned variables as topic keywords, which indicate sufficient correlations with GDP and carrying information on sustainable development. We found a positive trend in the evolution of research methodologies, such as SE, ISD and OR, towards a Systems Approach and Simulation as a holistic methodology. As a result, we have proved the dynamic hypothesis of a high correlation between GDP of Top 10 + Slovenia and R&D expressed by the above-mentioned variables.

Keywords: Systems methodologies, simulation, information systems, management, R&D

1 Introduction

The fact that "complex systems" is one of more frequently-used terms in scientific literature indicates its importance. Our goal is to analyze the proportion of methodology and process aspect devoted to this subject in scientific journals. This is library research based on Web of Science WoS publications over the last 40 years. The aim is to clarify both the relevance of R&D as well as the methodologies that contributed to the development of complex systems. From the research point of view, human activity in order to gather new knowledge can be considered from two aspects: the subject of the research itself (process) and the methodology with different methods, tools and techniques for process analyses (Mingers, 2008).

With a conception of complex systems, we understood a system within which a complexity of interaction among system elements plays a main role. One of the most complex systems is human-made organizations. Organizational systems are complex because production, information, management as well as psychological, social, material, financial, and energetic relations interplay between subsystems and their surroundings. The goal and interests enforce characteristics and activities that condition system behavior and its development. Decision making is the main force for organization on harmonious development. It comprises different activities of R&D and management process in order to control desired behavior as well as anticipate future behavior. A decision-making problem is a complex one since we have to deal with complex information and "… the capacity of the human mind for formulating and solving complex problems is very small compared with the size of the problem"(Simon, 1957). For this reason, systems methodology and IS for decision assessment of complex problems should play a central role (Kljajić, 2000). It is supposed that quality of new goods is the consequence of market-driven R&D that, as a consequence, results in income as well as in published articles in relevant journals and conferences. We looked for articles that included topics such as: Production, Management, Information systems (IS), Simulation, Systems Approach (SA), Systems Engineering SE, Operational Research (OR), which sufficiently depict correlations with GDP and carrying information on sustainable development. It was supposed that Production, Management and Information Systems are the main representative of quality of organizational process and GDP is their consequence, while SA, SE, OR, ISD and Simulation represent well-established methodologies for coping with complex organizational process. The argument for this can, in part, be found in the paper (Hosman et al., 2008), in which the

relations between investment in IS and its impact on GDP were analyzed. More detail about the meaning and definition of above-mentioned variables could be found for example in the papers (Mora et al., 2008; Petkov et al. 2008). In (Kljajić and Farr, 2008) it was found that Simulation and SA are far more dominant than other methods. In the same paper, the deep relationship among different methodological disciplines for complex systems development and maintenance is also discussed in depth. For example, SE is understood as a composition of SA and engineering of solutions for systems problems independent of type of process. However, a SA can be also considered as an enhanced SE for complex problem solving, taking into accounts not only stakeholders' requirements but also the environment's requirements. That means considering a complex system from all relevant points of view in its environment during developing, maintaining and functioning. The reason for similarities and differences of methodology titles were discussed in Lazanski and Kljajić (2006). The role of the simulation methodology in the understanding of systems is constantly evolving and increasing. Today in modern organizations two words are dominant: change and learning, from which are derived "change management" and "learning management". Human knowledge, the simulation model and decision methodology, combined in an integral information, system offer a new standard of quality in management problem solving (Simon, 1967). The simulation model is used as an explanatory tool for a better understanding of the decision process and/or for defining and understanding learning processes. An extensive study on using the simulation method in enterprises can be found in Gopinath and Sawyer (1999). Information systems and decision support is an important area in Management Information Systems (MIS), as a part of complex SE (Mora et al., 2008).

The main intention of this paper is to study the relevance of systems methodology for decision assessment and the relationship between development and systems methodologies. For this purpose, library-oriented research based on the Web of Science database (WoS) has been done. The aim was to clarify, indirectly, the relevance of R&D and systems methodologies to organization development. As the measure of system development on the macro level, we presume GDP as a consequence of Research and Development, not only in process innovation and invention but also in methodology disciplines. While GDP can be found easily in IMF statistics, R&D has been estimated indirectly by the number of published articles in last 40 years (although such data can be estimated directly by fraction of investment from GDP).

2 Method

2.1 Problem definition and hypothesis

For the purposes of this research, the relevance of articles is understood by the number of publications per year in Journal Citation Reports JCR (WOS EXPANDED, 2008). It is quite natural that frequency of use of some variables over time indicates the importance of the process described by those variables and its impact on other research areas.

For searching proposes, we looked in the database for the papers that contain characteristic keywords for certain variables, including: Production, Management, Information System, Simulation etc. Such a definition is rather broad but convenient for the supposition that keywords reflect the main content of the articles. For example**,** if someone does research in nanotechnology with reference to production or if somebody studies the production of honey, it will be detected as a paper devoted to variable production. Similar reasoning can be applied to each variable. We think that such definition is natural because gathering any new knowledge through research contributes to the welfare of society.

Now we can post Hypothesis H:

H: New goods as the consequence of market driven R&D and Management have results in GDP, which is correlated with publication in JCR.

In order to answer the posted problem and test the hypotesis **H** we defined next variables:

Independent: (papers which contains in topics keywords) Production, Management and IS; synonym for Process and Simulation, SA, SE, OR and ISD; synonym for Methodology.

Dependent: GDP

We can write the equation $GDP = f(P, M)$, where P represents a set of variables describing Process and M a set of variables signifies methodology.

2.2 Systems view on management and development

In order to clarify the previously-stated hypothesis and defined variables, we will consider our problem from a very general point of view, yet specific enough for further discussion.

In the nature, three basic elements Energy, Matter and Information are supposed to be universal. In organizational systems, Production (process), Management and Information can also be considered to be universal. Production is defined as the transformation process (in space and time) from elementary to complex products with new added values. Management represents a way of control of transformation processes according prescribed tasks and goals, by means of Information (feedback and feed forward), and Information Systems metaphorically represents the central nervous systems of any organization that provides information for management. A cybernetic view of organizational systems is shown in Figure 1.

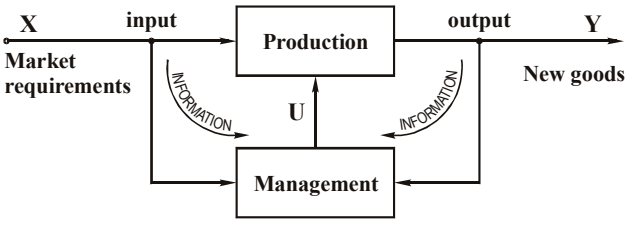

Figure 1: Cybernetic view of organizational process

Figure 1 is self-evident: the production process results in new goods with the new added value, the information from output management represents feedback for control of pre-

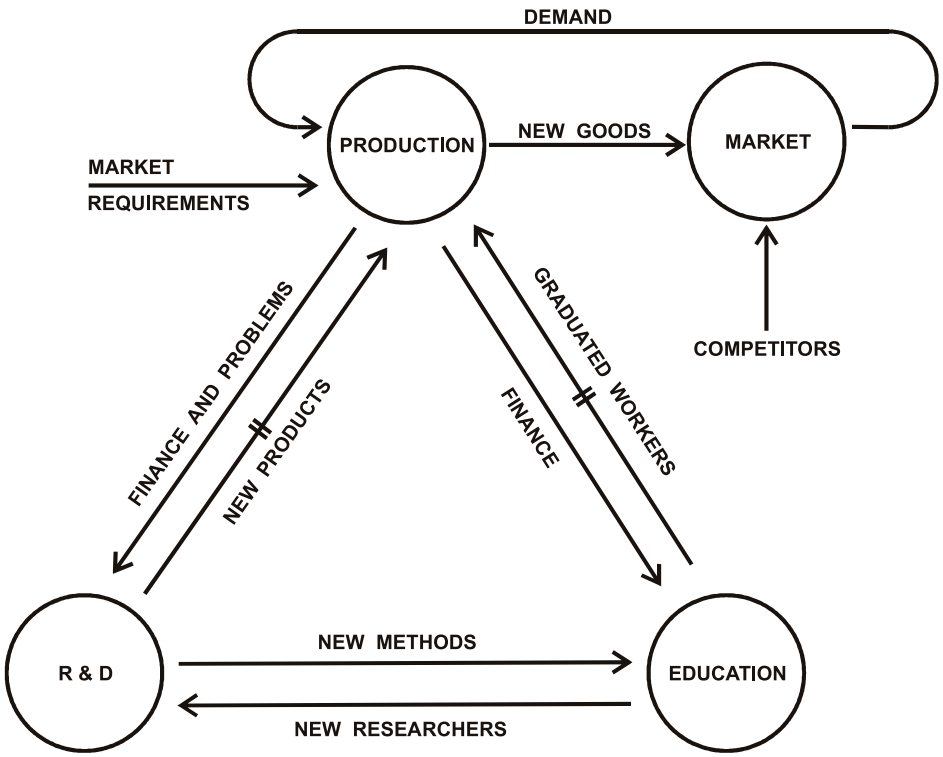

Figure 2:Model of growth: CLD diagram of relationship among Production, R&D and Education

scribed and achieved performance of the goods, while information from input requirements to management represents anticipation of the future behaviors of market. From the control point of view, organizational processes can be described by (1) and (2)

$$P: X \times U \rightarrow Y \quad (1)$$
$$M: X \times Y \rightarrow U \quad (2)$$

Where Process P is the mapping of Cartesian products of input X (Market Demands) and control U (Managerial Decision) into output Y new goods and M (Managerial Decision) represents the mapping of Cartesian products based on information about Market requirements (anticipative information) X and achieved output Y (feedback).

There is no doubt that the innovation of one product and its advantage on market is proportional to R&D capacity and holistic organization and invention as consequence of that. That is especially important if we wish to adjust classical production to a more sustainable one. In order to test dynamic hypothesis H about the functional dependence between R&D and the welfare of one society in Figure 2, a simplified causal loop diagram (CLD) among Gross Domestic Product (GDP), R&D and Education is shown. It is supposed that GDP is proportional to the successfully realized Production on a market.

From Figure 2, on the macro level it is supposed that investment in research and education directly influence new added value of production and so to GDP. This analogy can be deduced *mutatis mutandis* at lover levels on an actual company. The explanation is trivial: from government or firms' management, the R&D department gets money for the problem to be solved. However, R&D sends back, after a delay, new ideas and knowledge for new products. This means more money for the R&D department, allowing it to employ more new researchers, investigate new projects and equipment; consequently innovations and new knowledge can be delivered to the corporation. Similarly, we can explain all other interactions on Figure 2, which mainly represent a positive loop characteristic for growth and development.

It is supposed that the quality of new goods as the consequence of market driven R&D had results in income as well as in publication.

It is important that the researchers publish their discoveries and inventions. According to Figures 1 and 2, it is supposed that articles covered by the topics of Production, Management and Information are the main representative of quality of organizational process and that GDP is their consequence, while SA, SE, OR, ISD and Simulation represent well established methodologies for coping with complex organizational process. In this way, we can logically establish Hypothesis H.

3 Results

We analyzed the number of articles of afore-mentioned variables published in the Web of Science database. WOS represents only articles from JCR and represents publications with strong international review. In fact, we used Keywords in our research. It means that the articles that used words "Production" in the topic are expected to deal with the context of production. We did not analyze for cross correlation

among variables. This aspect was partly treated in by Kljajić and Farr (2008). Figure 3 shows the number of articles from 1970 to 2006: PROD=Production, MAN=Management and IS=Information Systems represent organization growth, while SIM=Simulation, SA, SE, OR and ISD variables represent methodology.

It is obvious that Production and Management have the largest numbers/year of articles and almost the same distribution while Information systems are considerable lower. It is clear that Simulation is close to the Production and Management and more than two times higher that SA, which is considerably higher than the remaining variables. A slow, almost linear growth of all variables can be observed with a significant jump from 1990 to 1991 and then continues with growth but with a much higher gradient. Table 1 shows this dynamics of linear trends with the jump in the years 1990-91.

We suppose this change of gradient is the consequence of internet maturation and the emergence of e-business. It is obvious that Simulation and SA are far more dominant among other variables denoting methodology. This finding is in good agreement with the previous research (Kljajić and Farr, 2008). Now Hypothesis H will be tested regarding correlation between GDP and number of published articles as defined in Section 2.

In Figure 4, the GDP of the Top10 most developed countries + Slovenia for 2006 expressed in % of total world GDP and Simulation and SA for the same countries also expressed in % of total world publication. It is an obvious constant relative value of all three variables. We found very high correlation between GDP and number of articles of Simulation and SA of these countries r= 0.93 and 0.95, respectively. With this, we have indirectly proved the dynamic hypothesis that the above-mentioned variables are good representatives for R&D. These findings were explained by a model of growth expressed by causal loop diagram CLD among GDP, R&D and Education (Figure 2) as well as general control schemata of organizational systems (Figure 1). All this will be considered in light of sustainability growth. The correlation coefficient between GDP and System approach can explain Production as well as Simulation in 2006 by investigation into Research and Development. From Figure 4, a similar pattern can be observed among variables with the exception of China, which has a relatively higher portion of Simulation in comparison to other countries. Such results can be interpreted as the Chinese effort to become a developed country. It is well known that using simulation for testing performance of complex systems can reduce costs and foster development.

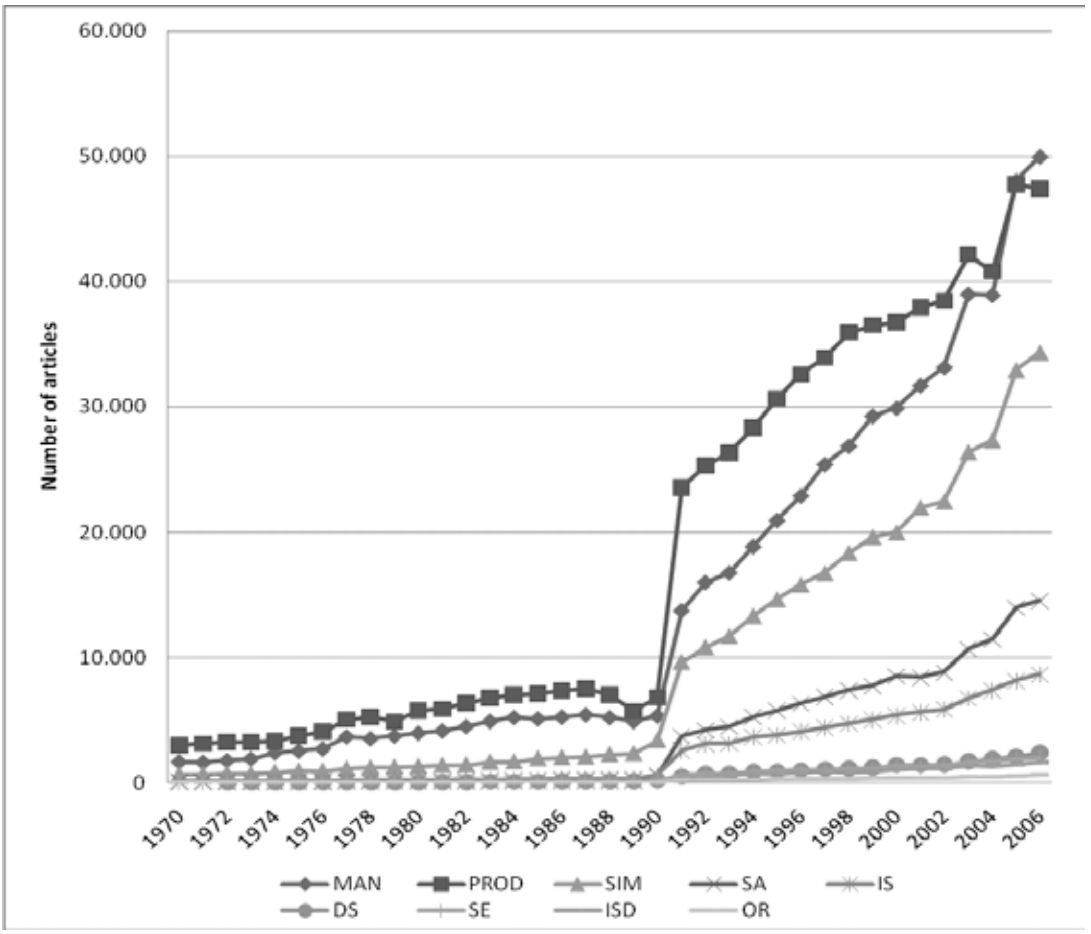

Figure 3: Time course of number of articles: PROD=Production, MAN=Management, IS, SIM=Simulation, SA, SE, OR and ISD, Source WOS (2008).

Table 1: Number of articles/year in the period from 1970 to 2006.

	Number of articles / year in the period		
Name of variable	1970-1990	1990-1991	1991-2006
PROD	191	16760	1592
MAN	183	8396	2416
IS	22	1973	407
SIM	136	6256	1648
SA	24	3199	722
SE	8	526	91
ISD	0.3	435	80

4 Discussion

In order to explain growth of the above-mentioned variables from broader aspect (from all articles in the database), we will analyze their relative changes defined as ratio of certain variables at time with all articles in data base, expressed by Equation 3.

$$r_j(k) = X_j(k) / \sum_{i=1}^{m} X_i(k),\ k = 1,2,...n \qquad (3)$$

The results are shown on Figure 5, where we select only most relevant variables. The shape of Figs. 5 and 4 are similar, indicating that high growth of number of variables per year is also higher when comparing the whole DB, especially after 1991. Another view of Figure 5 as the cumulative function defined by Equation 5 is shown in Figure 6.

$$R_j(k) = \sum_{1}^{k} X_j(k) / \sum_{1}^{k}\sum_{i=1}^{m} X_i(k),\ k = 1,2,...n \qquad (5)$$

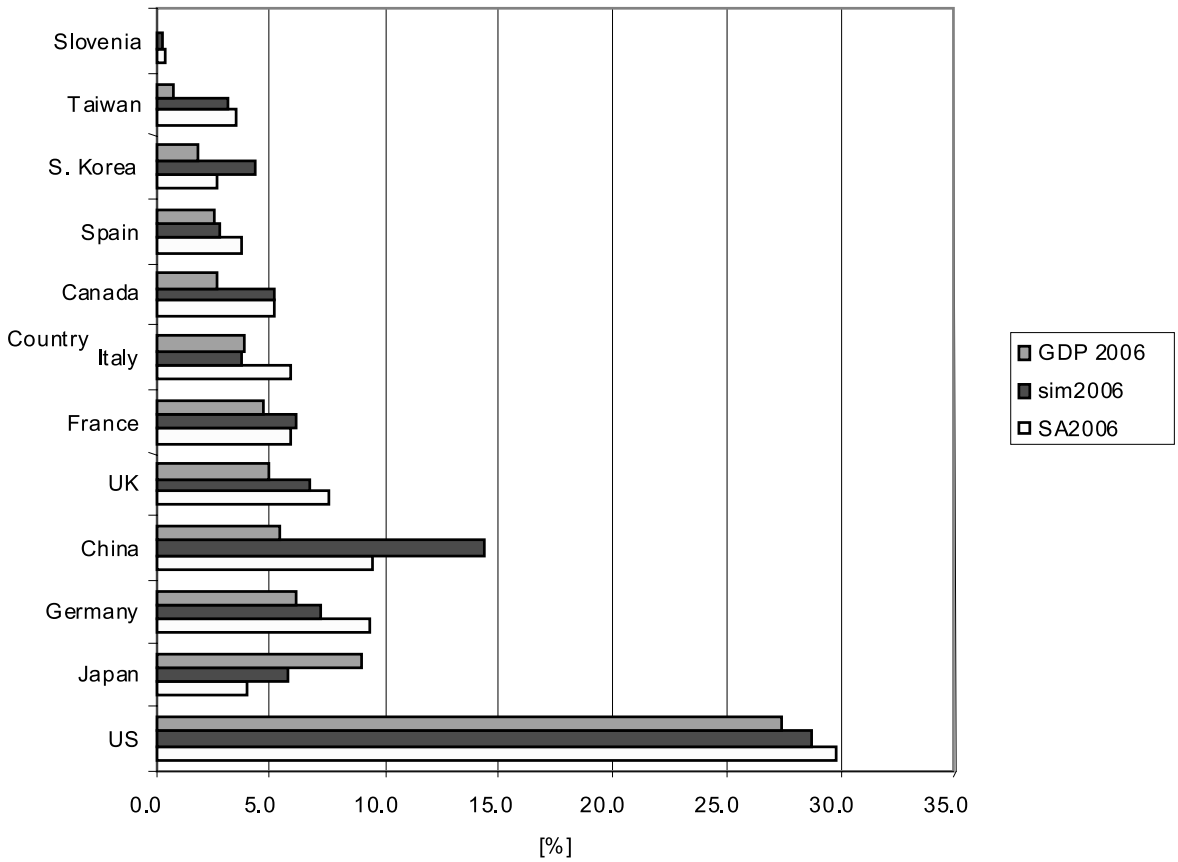

Figure 4:Relative value of GDP of Top10 most developed countries + Slovenia for 2006 expressed in % of total word GDP and Simulation and SA for the same countries expressed in % of total world publication for 2006.

Equation 5 represents the ratio of cumulative value of variable Xj and the cumulative value of all variables from the DB. This ratio of cumulative functions clearly shows that, in the period from 1970 to 1991, all considered variables have an almost constant value with different coefficients. It means that all variables in the nominator and denominator had the same proportion of growth. However, after a jump in 1991, all considered variables have positive linear increase in time with respect to all data. This means that all considered variables became more active in comparison to the whole DB.

Without the intention of studying the rapid growth of all considered variables in detail, we presume in the Results section that this change of gradient with jump is the consequence of internet maturation, the emergence of e-business and the importance of systems methodologies for complex systems development.

It is known that microprocessor-antecedent internet development and the internet itself is condition for radical change in IS, organization, society, ecology and also methodology development. The first two papers on the microprocessor were published in Journal from JCR in 1970 (Hornbuck and Ancona, 1970; Cook and Flynn, 1970) and in the following four years the next 14 articles came. Eighteen years after first publication on microprocessors, two papers in Journal from JCR was published on the topic of the Internet (Abdelwahab, Guan and Nievergel, 1988; Anon, 1988) and continue with next years with seven articles.

On Figure 7, we plotted the variables Microprocessor, Simulation & Management, Simulation & production, Internet & Simulation, Internet & Production and Internet & Management. It is obvious from Figure 7 that Simulation and Management, Simulation and Production as well as Microprocessor have characteristic Jump from 1990 to 1991 but first two continue to grow exponentially while Microprocessors remain constant. The first articles associated with the Internet (Internet & Management, Internet & Production and Internet & Simulation) were published in 1989 (Lu and Sundareshan, 1989; Tolcher, 1989), 1992 (Storm and Kalinoski, 1992) and 1993 (Schwartz, 1993, George and Schlecht, 1993; Mishra, Sanghi and Tripathi, 1993); papers on this subject continue to grow exponentially.

Next, Figure 8 shows once again the variables from Figure 7 where Microprocessor was substituted with Internet i.e.; Internet, Simulation & Management, Simulation & Production, Internet & Simulation, Internet & Production and Internet & Management in order to show the impact of the Internet in 1991 on the change of growth of our variables.

Again, papers on the internet starting in 1988 with Abdelwahab & Guan and Nievergelt, (1988), and Anon, (1988) had continuing exponential growth without a jump. Besides microprocessors, we also analyzed other well-established research topics where we found its cumulative function rather saturated. With this, we factually established that Simulation and the System Approach are really, according our definition of relevance, very important nowadays in the research of complex systems. The reason for this was discussed in depth in the paper (Kljajić and Farr, 2008). Let us briefly repeat those findings in the light of present findings.

"All classical methods initially developed for specific problems and processes converge with the development of IT and society into one holistic methodology colored with specific problems (context) and user preferences. A common name for SE or ISD can be SA or more precisely SA to SE and

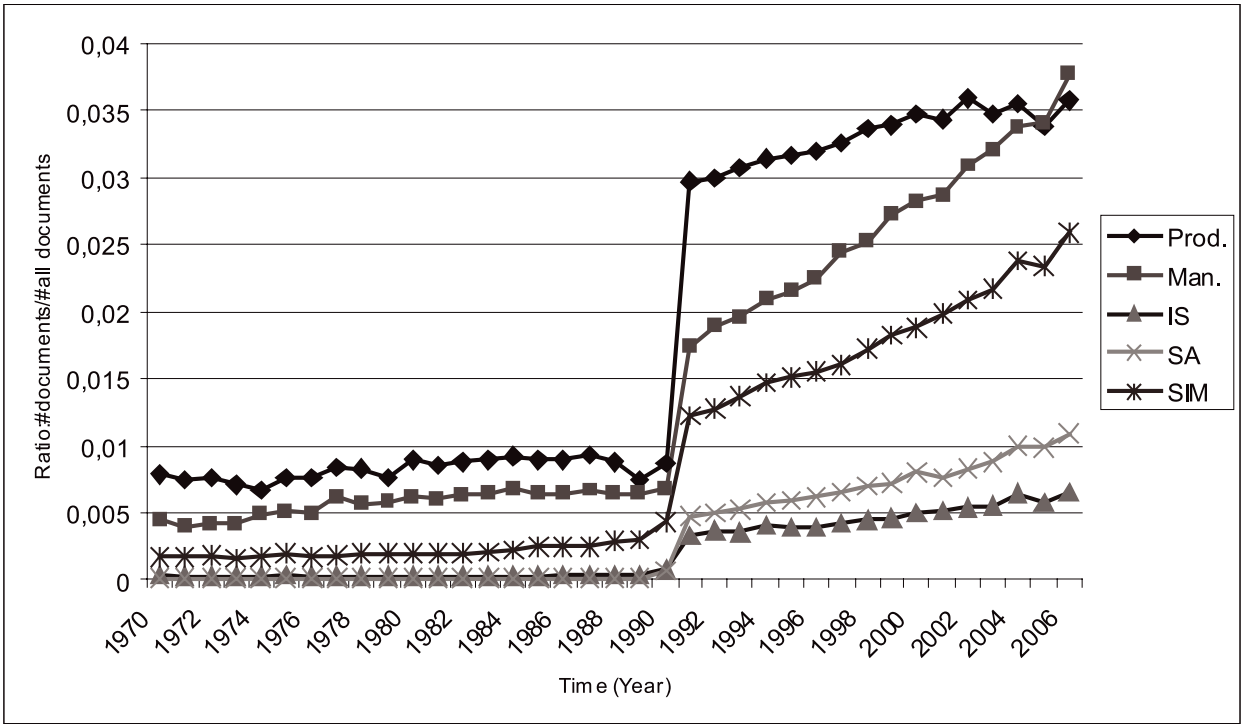

Figure 5: Ratio of number of variable Xi and all variables per year.

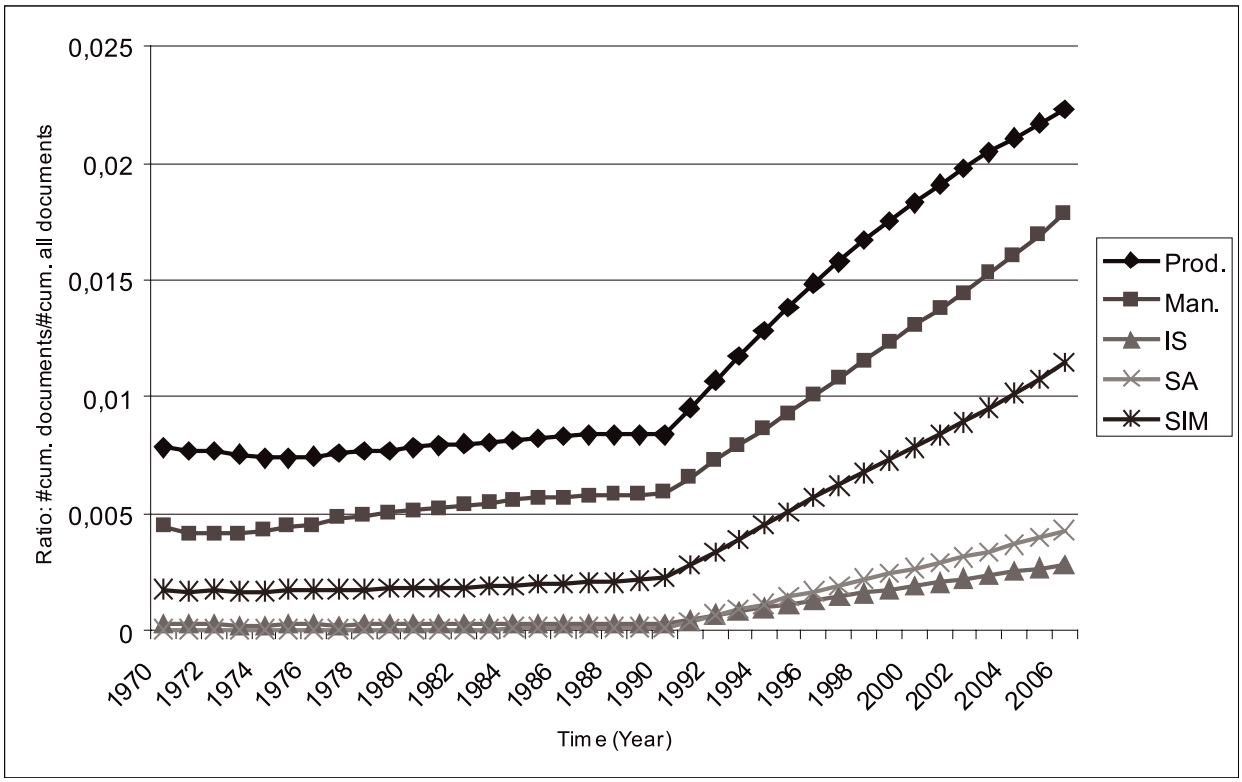

Figure 6: Cumulative ratio of number of variable Xi and all variables per year.

SE with SA as a holistic methodology for complex problem solving as we discussed in (Kljajić and Farr, 2008)".

A backbone for the development of all these methods is IS based on the Internet. One cannot imagine how to test reliability, stability, functioning and behavior of global (complex) systems, without SA methodology combined with systems simulation. Systems simulation is associated with two methodologies: Systems Approach and Simulation. Simulation always involves a computer for experimentation with kinds of systems methodologies, while the Systems Approach is a more abstract paradigm not necessarily dependant on a computer for simulation. To demonstrate this statement we will briefly compare their methodologies.

The Systems Approach paradigm can be defined as holistic methodology consisting of next interrelated steps:

- State the problem,
- Investigate alternatives
- Model the system,
- Integrate,
- Launch the system,
- Assess performance,
- Re-evaluate

Which is in (Bahill & Gissing, 1998) was named with the acronym **SIMILAR.**

The Modeling paradigm in Computer Simulation can be stated (Forrester, 1994, Kljajić, 1994):

- Problem definition
- Goal
- Research design
- Mathematical model (block building)
- Computer program (any general or block-oriented language)
- Model validation
- Experiment set up (scenario preparation)
- Simulation and analysis

Obviously, the two paradigms are almost the same; a small difference could be observed only on the executive level.

A more general Simulation Model SM can be defined on the set:$SM \subseteq (P,C,T,G,M)$, where P,C,G,M,T denote Problem, Context , Goal, Theory and Model; or functionally by Expression (4)

$$T : P \times C \times G \times M \rightarrow SM \tag{4}$$

This means that SM is defined as the systems on the Cartesian product of the Problem, Goal, and Context within certain Theory. In other words, SM is the model implemented on a computer convenient for experimentation under different conditions and assumptions within a certain theory.

The advantage of the simulation model as a part of SA is in the fact that a problem defined in natural language can be easily transformed into a directed graph convenient for qualitative and quantitative analysis in computer program. In this case, the user can always check the validity of the stated problem within a certain theory and further its translation to computer programming. This is important especially in cases of complex problems where feedback loops, stochastic relations and nonlinearity are present, regardless of the process being a continuous or discrete event. Big picture presentations and 3D animation of simulated process make this technique flexible and transparent for testing systems performance of

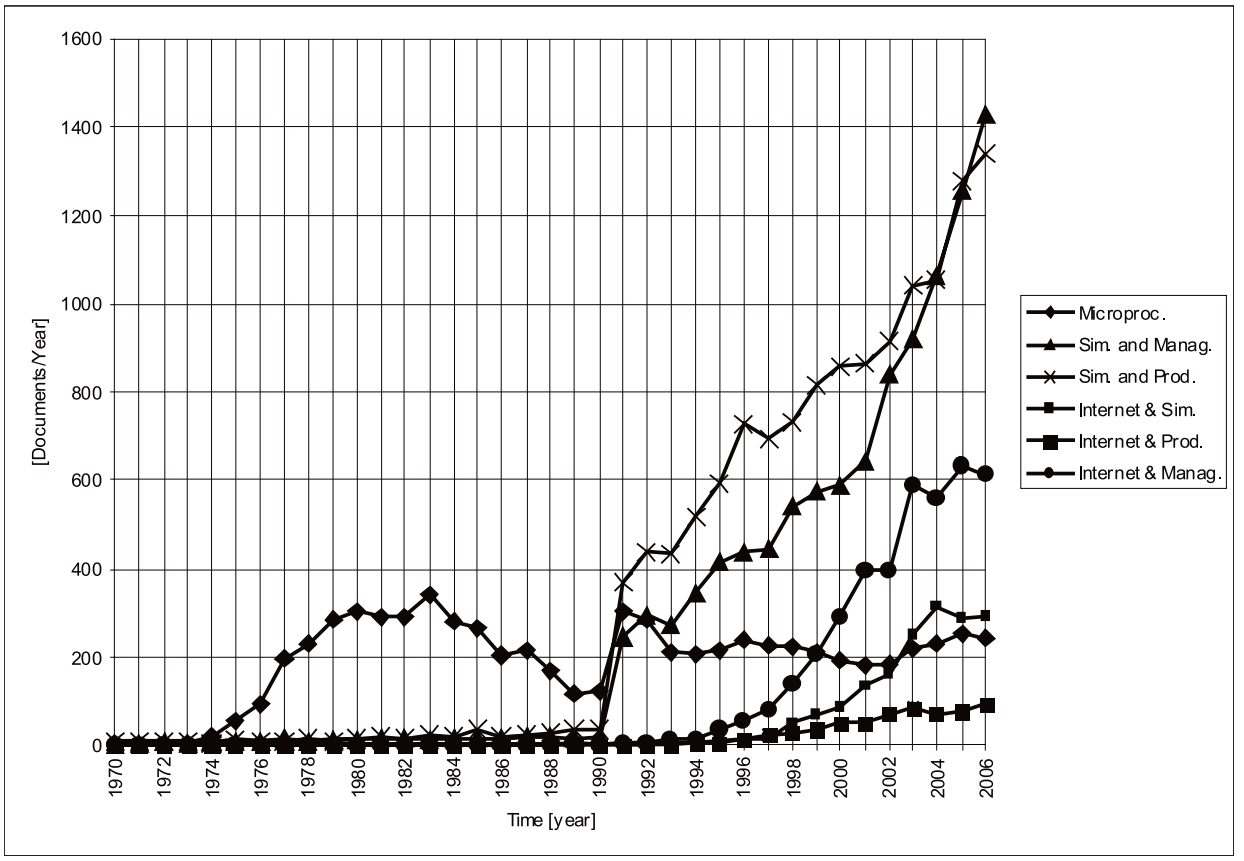

Figure 7: Time course of variables/year of: Microprocessor, Simulation and Management, Simulation and Production, Internet and Simulation, Internet and Production as well as Internet and Management.

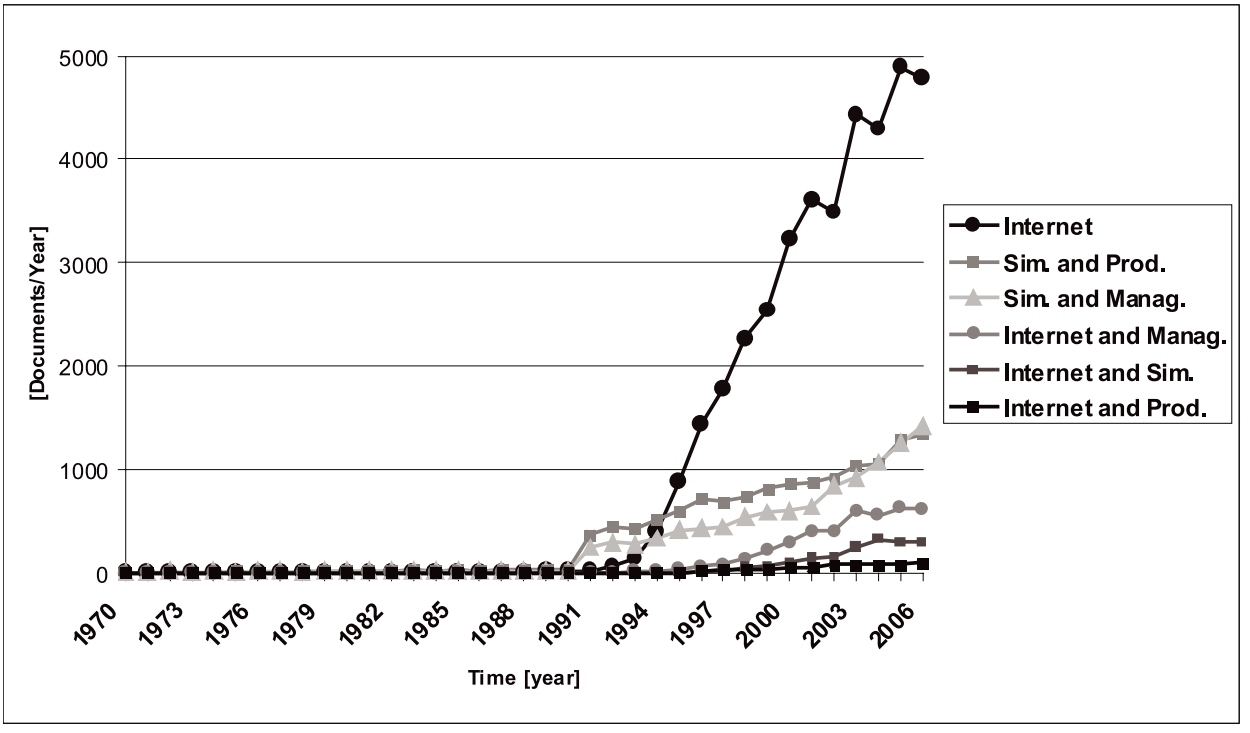

Figure 8: Time course of variables/year of: Internet, Simulation and Management, Simulation and Production, Internet and Simulation, Internet and Production and Internet and Management.

all phases of system design and deployment. With progress in ICT visual interactive modeling (VIM) and animation, modeling and simulation (M&S) have become ever more central to the development of modern systems. This has made it possible to examine the projected performance of systems over wide excursions of design and environmental assumptions very early in the development process when key resources are committed. Today's M&S tools make it possible to perform extensive enterprise and other process simulations and evaluate alternate architectures at reasonable cost and early enough to make a difference.

5 Conclusion

In this paper, the relevance of systems methodologies on the development of complex systems was studied. For relevance, we investigated the number of publications per year. For a resource, we looked in data base in WoS over the last 40 years for the papers which contains in their keywords topics characteristic for certain variables. The relationship between GDP and R&D expressed indirectly with the number of articles published in JCR such as: Production, Management and Information systems representing organizational processes as well as Simulation, SA, SE, OR, and ISD as methodologies was discussed. It was found that Production and Management have the largest numbers/year of articles and almost the same levels. Simulation is close to the Production and Management and more than two times greater than SA, which is considerably higher than remaining considered variables. A slow, almost liner growth of all variables can be observed with significant jump from 1990 to 1991 and then a continual rise but with a much higher gradient. This impact was attributed to the information systems based on the internet.

It was found that Simulation and SA are greatly dominant among methodologies, which is in good agreement with previous research (Kljajić and Farr, 2008). A very high correlation was found between GDP of the Top 10 most developed countries + Slovenia and the number of articles of Simulation and SA of these countries was r= 0.93 and 0.95, respectively. With this, we indirectly prove the dynamic hypothesis that the above-mentioned variables are good representatives for investigation in R&D and Education. These findings were explained by CLD model of growth among GDP, R&D and Education and, consequently, publication of these findings. In the discussion, we have highlighted such findings, which mainly were anticipated in previous paper (Kljajić and Farr, 2008).

The advantage of the simulation model as a part of SA is in the fact that a problem defined in natural language can be easily transformed into directed graph convenient for qualitative and quantitative analysis in computer program. In this case, the user can always check the validity of the stated problem within a certain theory and further its translation to computer programming. This is important especially in cases of complex problems where feedback loops and stochastic relations are present, regardless of the process being a continuous or discrete event. Big picture presentations and 3D animation of simulated process make this technique flexible and transparent for testing systems performance of all phases of system design and deployment.

This has made it possible to examine the projected performance of systems over wide excursions of design and environmental assumptions very early in the development process when key resources are committed. Simulation together with the Systems Approach has become ever more central to the development of complex systems. Human knowledge and the simulation methodology combined in decision a support system offers new quality in decision making and research. In the near future, we expect that the methodologies of Simulation and System Approach should be more intensively fused into one holistic methodology the Systems Simulation methodo-logy.

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Pomembnost sistemskih metodologij za razvoj organizacijskih sistemov

V članku razpravljamo o odnosu med razvitostjo sistemov in sistemskimi metodologijami. Kot merilo razvitosti na makro nivoju smo vzeli BDP, kar je posledica raziskav in razvoja (R&R), katerega smo ocenili indirektno preko števila publikacij v revijah WoS v zadnjih 40 let. Predpostavili smo, da razvitost gospodarskih organizacij lahko dobro opišemo s proizvodnjo, managementom in informacijskimi sistemi, kjer njihova kvaliteta vpliva na dobiček in posledično na BDP države. Poleg tega predpostavljamo, da so organizacijski procesi kvalitativno odvisni z ustvarjanjem novega znanja, ki ga generirajo raziskave in posledično objave v raziskovalnih časopisih. V prispevku so nas predvsem zanimala metodološka področja kot so: sistemski pristop, sistemski inžinering, operacijske raziskave, razvoj informacijskih sistemov in simulacije. Raziskovali smo članke, ki v ključnih besedah vsebujejo atribute povezane z BDP, in vsebujejo informacijo o trajnostnem razvoju. Ugotovili smo pozitivni trend v razvoju raziskovalnih metodologij, kot so sistemski inžinering, operacijske raziskave, razvoj informacijskih sistemov, v smeri sistemskega pristopa in simulacije, kot celovitih sistemskih metodologij. Potrdili smo dinamično hipotezo visoke korelacije med BDPjem desetih najrazvitejših držav vključno s Slovenijo in R&R izraženim preko prej navedenih spremenljivk.

Ključne besede: sistemske metodologije, simulacija, informacijski sistemi, management, R&R