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Simulation Based Decision Support

Guest editors: Miroljub Kljajić, Andrej Škraba

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Mobile Agents and XML for Distributed Simulation Support

This paper presents the use of mobile agents and XML for the connection of simulation models and data resources over a communication network. We have developed two types of agents: a mobile agent that functions as a mobile server for on-demand queries in SQL and transformation of results into XML compliant documents and a stationary agent functioning as a client for query forwarding and conversion of resulting XML documents into CSV files. We have established that software agents can be used to connect distributed simulation models, developed with different general purpose simulation tools and databases, thus improving the connectivity and usability of simulation models in distributed information systems.

Keywords: software agents, Java, XML, middleware, distributed simulation

Uroš Breskvar , Miroljub Kljajić

How to Perform a Simulation Project - An Example of Scheduling with Genetic Algorithms and Visual Event Simulation Model

To have useful information has always been an advantage against competition. Simulation can be used as a tool to predict events in the future or to analyze and explain events that occurred in the past. "What will happen if I do that and/or that?" has always been the question of many people. Simulation can give an answer to this question. With computer and software development, simulation has become widespread and user-friendly tool. Simulation is also more and more used in optimization of production systems. But many problems occur in attempt to use simulation in production companies. In this article we

will try to point out these problems and to stress the benefits of simulation. As the case of simulation project performance, scheduling problem by means of VIM and GA is demonstrated.

Keywords: Simulation, manufacture, optimisation, scheduling, genetic algorithms, discrete simulation, visualization

Miroljub Kljajić,
Carlos A. Legna Verna,
Andrej Škraba

System Dynamics Model of The Canary Islands for Strategic Public Decisions Support

The present paper centers on the problems of decision making and decision support related to strategic public decisions. A methodological approach was developed to support decision-making where decision-makers are confronted with unexpected events. The methodology considers the fact that strategic decisions involve a large breadth of variables, qualitative and quantitative; and that they imply distributed and remote interaction between different actors. The approach is based on the building of qualitative models and the application of system dynamics for the development of a simulation model. Variables were identified which affect the sustainable improvement of the quality of life in the Canary Islands. The relationships between the variables are expressed as an influence square Matrix M with dimension n = 53. Each element of M may take values between 0 and 3. If a_{ij} =0, changes in variable Vi do not affect V_j. If aij takes a value between 1 and 3, it means that the changes in variable "i" produce changes in "j" proportional to prescribed gain. We used two methods to address the problem: the analysis of the driving- dependent forces and systems dynamics.

Key words: qualitative modeling, system dynamics, strategic public decisions

Miroljub Kljajić,
Carlos A. Legna Verna,
Andrej Škraba

Development of Simulation Model of the Canary Islands for Strategic Decision Making

This paper deals with the system dynamics model for decision-making, related to strategic decisions for the development of the Canary Islands. The quantitative model incorporates relevant variables, which affect the sustainable development of the quality of life on the Canary Islands. The relationship between the variables was formalized in the influence matrix. The influence diagram defines the connection between the elements of the matrix. The Following submodels were considered: Population, Tourism market, Agriculture, Environment, and GDP. The program package Powersim was used to build the simulation model. Several strategic scenarios are described and their dynamic response was analyzed. Presently the model is in the validation phase. The initial results are promising according to the positive validation results.

Key words: system dynamics, simulation, model, decision support system, sustainable development, tourism

Carlos A. Legna Verna,
Carina S. González

An Intelligent Decision Support System (IDSS) for Public Decisions Using System Dynamics and Case Based Reasoning (CBR)

This paper presents the design of an IDSS that allows the decision makers to identify key issues that matter for the future of a social system and helps them to improve the policy-making processes. The implementation is in process, so this paper presents the achievements up to the present. It combines IA techniques with qualitative models and Systems Dynamic Simulation. The selection of strategies and policies for complex social systems needs to take into account non-quantifiable variables. For this reason, we build models that allow the treatment of these kinds of variables. We propose a methodology divided into three phases. In the first one we build a model and simulate dynamic systems of particular scenarios, using this module as an analysis tool. This phase allows the detection of issues that matters. The results obtained by simulation are stored in a database and are used as entries in the reasoning process. So, they are the start point of the second phase. For this phase we use the CBR (Case Based Reasoning) technique, where each case is defined by a set of norms (common attributes), cases and indexes (attributes for discriminating cases), problem, solution and explanation. Different values of these attributes will be new cases. The last phase produces different solutions, giving to the decision maker explanations about pros and cons of these alternatives. In the case that none of these alternatives are accepted by the users of the IDSS, they can incorporate a new solution explaining that, for them, it is the best alternative to follow. It is important to emphasize that the IDSS is an instrument to promote and facilitate the attainment of a coherence and consensus between the decision makers.

Key words: Decision Support System, Case Based Reasoning, Public Decision, strategic decision making

Robert Leskovar,
Neja Zupan

Simulation with Cellular Automata - Diffusion of Electronic Commerce in Small Organizations

This paper describes the cellular automata-based simulation model of electronic commerce diffusion in small organizations. The model and method is verified with historical data. The focus and purpose of the research was to study long-term influences on electronic commerce caused by organisational characteristics in small organisations. Five maturity levels of electronic commerce were defined. The study found that the most influential factor of diffusion is “management support”. The dynamics of electronic commerce introduction and usage in non-innovator organisations were significantly influenced by the verbalisation process through business partners. The greatest progress toward upper maturity levels were detected when internal factors strongly predominated over external factors. The developed methodology shows new approaches for cellular automata usage in the study of organisational systems.

Key words: small organization, cellular automata, electronic commerce, innovation diffusion

Milan Nikolić, Zvonko Sajfert, Branka Nikolić

An Alternative Criteria Research Methodology for Selecting a New Product

This paper presents the methodology used in the research of a complex problem in business decision-making: determining the relative importance of criteria when selecting a new product. It facilitates obtaining recommendations for defining the relative importance of criteria and sub-criteria for selecting a new product depending on the current situation in the company (which is selecting the new product) and its setting. By applying this methodology, dependence of the criteria-relative importance for selecting a new product on the company’s degree of success can be determined. For that reason, the whole procedure has a dynamic character, and can be applied in different situations and at different times of observation. The recommendations obtained represent the input data and support for subsequent multicriteria ranking of alternatives for new products.

The methodology is confirmed in practice; however this paper does not give ample details related to this, because of the aim of stressing the research procedure of criteria for selecting a new product, as well as its importance. Also, the applied procedure has importance because of its universality, given that it can also be applied to the research of the criteria for other decision-making issues, with or without adequate adaptations.

Key words: methodology, research, criteria for selecting a new product.

Editorial 9/2005

Fast progress in the information technology fostered new ways of organizing enterprises, but at the same time demand changes in management as well as in decision-making. Business process becomes complex and e-global. In such turbulent environments the e-decision paradigm represents the prevalent force of development. Efficient computer systems and program languages in e-environments make possible the integration of a large variety of new simulation paradigm and artificial intelligence in an integral system for decision making support and mastering of organizational processes.

The aim of the special issue is to present a part of research activity of Cybernetics and Decision Support Laboratory at the University of Maribor, Faculty of Organizational Sciences in the field of complex systems modeling and simulation. The special issue includes papers that deal with the development of methodology, modeling tools and practice for decision assessment in regional planning, production planning, control and optimization, social dynamics research and living laboratory development.

First paper entitled: "System Dynamics Model of The Canary Islands for Strategic Public Decisions Support" centers on the problems of decision making and decision support related to strategic public decisions. The methodology considers the fact that strategic decisions involve a large breadth of variables, qualitative and quantitative; and that they imply distributed and remote interaction between different actors. The causal loop diagram expressed as directed graph was explored in the building of qualitative models preceding system dynamics for the development of a simulation model. Variables were identified which affect the sustainable improvement of the quality of life in the Canary Islands. The problem addressed considered the analysis of the driving- dependent forces and systems dynamics.

Paper entitled: "Development of Simulation Model of the Canary Islands for Strategic Decision Making" deals with the application of system dynamics model for decision-making, related to strategic decisions for the development of the Canary Islands. The quantitative model incorporates relevant variables, which affect the sustainable development of the quality of life on the Canary Islands. The Following sub-models were considered: Population, Tourism market, Agriculture, Environment, and GDP. The program package Powersim was used to build the simulation model. Several strategic scenarios are described and their dynamic response was analyzed. Presently the model is in the validation phase. The initial results are promising according to the positive validation results.

Paper entitled: "An Intelligent Decision Support System (IDSS) for Public Decisions using System Dynamics and Case Based Reasoning (CBR)" presents the design of an IDSS that allows the decision makers to identify key issues that matter for the future of a social system and helps them to improve the policy-making processes. It combines IA techniques with qualitative models and Systems Dynamic Simulation. Authors propose a methodology divided into three phases covering a) modelling and simulation of dynamical system, b) application of CBR (Case Based Reasoning) technique, where each case is defined by a set of norms, cases and indexes, problem, solution and explanation and c) determination, explanation and presentation of different solutions to the decision makers. Important finding of the authors is that the IDSS is an instrument to promote and facilitate the attainment of a coherence and consensus between the decision makers.

Paper entitled: "Simulation with cellular automata - diffusion of electronic commerce in small organizations" the cellular automata based simulation model of electronic commerce diffusion in small organizations is described. The focus and purpose of this research was to study long-term influences on the electronic commerce caused by organisational characteristics in small organisations. The study founded that the most influential factor of diffusion is »management support«. The dynamics of electronic commerce introduction and usage in non-innovator organisations were influenced significantly by the verbalisation process through business partners. The developed methodology shows new approaches for cellular automata usage in organisational systems study.

Paper entitled: "Mobile agents and xml for distributed simulation support" mobile agents and XML for the connection of simulation models and data resources over a communication network are presented. Authors have developed two types of agents: a mobile agent that functions as a mobile server for on-demand queries in SQL and transformation of results into XML compliant documents and a stationary agent functioning as a client for query forwarding and conversion of resulting XML documents into CSV files. Authos have established that software agents can be used to connect distributed simulation models, developed with different general purpose simulation tools and databases, thus improving the connectivity and usability of simulation models in distributed information systems.

Paper entitled: "How to Perform a Simulation Project -An Example of Scheduling with genetic algorithms and visual event simulation model" describes the application of simulation methodology in the connection to the artificial intelligence. Authors emphasize that by computer and software development, simulation has become widespread and user-friendly tool that should be applied at solving complex organizational problems. The case of simulation application is described where optimization of production system was conducted. In this article authors will point out the problems that occur at simulation methodology implementation and stress the benefits of simulation. As the case of simulation project performance, scheduling problem by means of VIM and GA is demonstrated.

Last paper of this issue: "Presentation of an alternative criteria research methodology for selecting a new product" presents the methodology used in the research of a complex problem in business decision-making: determining the relative importance of criteria when selecting a new product. It facilitates getting recommendations for defining the relative importance of criteria and subcriteria for selecting a new product depending on the current situation in the company. By applying proposed methodology, dependence of the criteria relative importance for selecting a new product on the company's degree of success can be determined.Applied procedure has importance because of its universality, given that it can also be applied to the research of the criteria for similar decision-making issues, with or without adequate adaptations.

Guest editors:
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Mobile Agents and XML for Distributed Simulation Support

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Podpora distribuirani simulaciji z mobilnimi agenti in XML

V članku je predstavljena uporaba programskih agentov in XML za povezovanje simulacijskih modelov in podatkovnih virov preko komunikacijskega omrežja. Razviti in preizkušeni sta dve vrsti programskih agentov: mobilni agent, ki deluje kot mobilni strežnik za izvajanje poizvedb v SQL (Structured Query Language) in pretvorbo rezultatov v XML (eXtensible Markup Language) format in stacionarni agent, ki deluje kot odjemalec za posredovanje poizvedb in pretvorbo podatkov iz XML formata v CSV (Comma Separated Values) datoteke. V raziskavi smo ugotovili, da je s programskimi agenti možno povezati različne geografsko ločene simulacijske modele in podatkovne baze in tako izboljšati povezljivost in uporabnost različnih simulacijskih modelov v distribuiranih informacijskih sistemih.

Ključne besede: programski agenti, Java, XML, middleware, distribuirana simulacija

1 Introduction

Recent years have seen an increase of research interest in distributed information systems. The main reason is probably the fast growth of the best-known distributed information system today - the Internet. The possibility of accessing a multitude of data and processing resources is also very attractive for simulation purposes, and so the area of distributed simulation systems is gaining attention. In the past, simulation was mostly used to develop stand-alone solutions with a limited scope and lifetime (Harrell & Hicks, 1998). However, the penetration of computer simulation into various areas of business processes has resulted in the need to connect the simulation models used in different parts of an organization (Kljajić et al., 2000). Also, the trend in simulation development has shifted from purely analytical and optimisation oriented models to integrating simulation models into decision support tools to be used recurrently.

However, setting up the connections between distributed simulation models and other data sources can be a demanding task, especially if there are both continuous and discrete event simulation (DES) models present or if the models run within dissimilar simulation tools or on different platforms. There is a clear need for solutions that would simplify the exchange of data between simulations and other applications over the communication network. We have identified the following problems that we would like to address:

- Lack of a common data format understandable to all simulation tools, decision support tools, databases, etc.
- High amount of data exchanged by the components of a simulation system.
- Security threats in non-private networks.
- Lacking control of remote components.

The demands of distributed simulation are different than those of conventional simulation. Distributed simulation is deployed on a broader scale and relies heavily on shared data. The developers focus is shifting from the "all in one" simulation environments with integrated graphical model building, animation and analyses tools towards "barebone" simulation engines with comprehensive application programming interfaces (API). Models can be embedded as a component of the distributed simulation systems and dynamically built by procedures using databases. However, due to less flexibility and user interaction in model building and use, embedded and dynamically built models are only appropriate for specific problem domains. One of the recent developments in the area of distributed simulation is web-based simulation. But its weaknesses are the lack of interoperability with conventional simulation tools, difficult handling and a lack of real advantages over more conventional methods of building distributed simulation systems (Kuljis & Paul 2001). HLA (High Level Architecture) is a well-publicised framework for the construction of distributed simulation systems (Dahmann et al. 1998). The main force behind the development of HLA is the US Department of Defense, thus the development of HLA is closely tailored to the needs of military simulation (Carson 2000). HLA is very highly specified and standardized (IEEE Standard 1516); however it's also too complex for general use. Complex specifications mean difficult development of models and nearly impossible integration of non-HLA simulations (Szymanski & Chen 2000). Another problem is the large consumption of bandwidth due to system overhead (Wayne & Gerald 1999). The CORBA architecture (Common Object Request Broker Architecture) (Buss & Jackson 1998, OMG 2005) is similar to HLA, but more general in its scope. Its aim is the interoperability of distributed systems, however it is difficult to use with legacy applications that do not implement it and suffers from similar complexity problems as the HLA.

Mobile agents are a technology that has gained a lot of attention recently. One of the more popular uses for mobile agents is in the development of distributed systems (White 1996). Agents can reduce network traffic, encapsulate protocols, execute asynchronously and autonomously, adapt to their environment and can be used to build robust, failure resistant systems (Lange & Oshima 1999). The term "software agents" comes from the field of artificial intelligence, and in its broadest sense means an entity that engages in an activity in the name of another entity - either a human being or another piece of software. In the software community the term has come to stand for programmes that have a certain degree of intelligence and adaptability, being able to operate without constant supervision or reducing the necessary user input (e.g. setup wizards). Mobile agents add another degree of autonomy - the ability to move between computer systems. Naturally, this requires an infrastructure that allows for transfer and execution of code.

We have examined a number of articles in journals describing systems utilizing mobile agents in distributed simulations. A system described by Corbin (1998) utilizes agents to connect military simulation models and allows for remote control of the agents via Java applets in web browsers. The agents use a proprietary method for control and exchange of data, while no mention is made of security mechanisms. Szymanski and Chen (2000) have used the IBM Aglets toolkit to connect two simulations running on very different platforms. Their goal was to improve the usability of component based simulation models of complex systems. The authors compared the execution time of models running within the same shared memory space with a distributed system, where the models were linked over LAN and TCP/IP. They established that the additional networking overhead slowed down the simulation to a quarter of the shared memory system speed. Their conclusion is that the communication link between distributed simulation models is a serious potential bottleneck and effective distribution of components and implementation of data filtering is crucial to distributed simulation system performance. Another interesting example is the ABELS system (Mills-Tettey et al. 2002), which is based on stationary software agents and a broker application that is to allow the connection of various simulation models and other applications into the simulation system. According to available publications the ABELS system is still under development and lacks several necessary components, including the security mechanisms. Conversely, security is the main focus of research by Chunlin and Layuan (2003). The authors have identified mobile agents as a threat to the security of local resources and propose the construction of a distributed system, that would limit access to the resources to communication with available "service agents". The focus of another research (Qi et. al. 2001) is the use of mobile agents for integration and filtering of data in a distributed sensor network. While the traditional approach would gather all available data at a central location, here the agents move from sensor to sensor and locally filter relevant data, reducing the data flow by up to 90%. Jen-Yen and Shih-Wei (2003) describe a system for the connection of different multi-agent systems (MAS). They propose an "Agent Gateway" to act as a MAS protocol converter. As the implementation of an ACL translator for every pair of different ACL's would be uneconomic, the authors propose the construction of an intermediary ACL, based on XML. With this approach, each new ACL would necessitate the development of just two translators - ACL to intermediary ACL and vice versa.

We feel that despite the wealth of research, there is still a need for a lightweight tool that would facilitate the connection of simulation models and data resources over the Internet and provide filtering as well as security. We undertook the construction of a flexible, agent based middleware tool that would allow us to transfer and convert structured data (twodimensional tables) with local filtering, a secure (encrypted) transfer and mobile agent authentication. We decided to develop the software in Java to provide cross-platform mobility and to use standard internet security mechanisms. As there are a number of agent development platforms already available, we tried to find a platform that would provide built-in support for important functionalities such as transport, control and secure communications between distributed components. We have looked at several platforms, including Aglets, Odyssey, Voyager and Grasshopper (Mangina 2002), and decided to utilize the Grasshopper V2.2.4 platform by IKV++ (IKV++ 2003). We have also decided to implement data format translation using basic XML tables as an intermediary format. In contrast with heavyweight solutions such as the HLA or CORBA we decided not to provide explicit support for runtime interface connections, registration and search and synchronization of events. Instead we are aiming for a low cost solution that would connect the simulations at the data resource level, and not at the runtime level. Other advantages of our proposed solution over the existing methods are to include shorter and simpler connection setup procedures, an open-ended structure and the use of security mechanisms with a relatively small impact on adaptability and performance of the system.

2 Methodology

We have used the Grasshopper V2.2.4 agent development platform by IKV++ (IKV++ 2003) to develop the software agents for distributed simulation support. The Grasshopper platform was chosen as it is entirely built in Java and compatible with most computer platforms, because the source code is open and well documented, because of the good implementation of transport, control and security mechanisms, excellent documentation and a free academic license. The central part of the Grasshopper platform is a distributed processing system, which integrates the conventional client/server architecture and the software agents' technology. The Grasshopper system is implemented in Java, version 2 and is one of the first agent platforms to implement MAS interoperability standards such as MASIF (Mobile Agent System Interoperability Facility) (OMG 2005) and FIPA (Foundation for Intelligent Physical Agents) (FIPA 2004).

The Grasshopper platform builds on the concepts of region, place, agency and several types of agents (Figure 1).

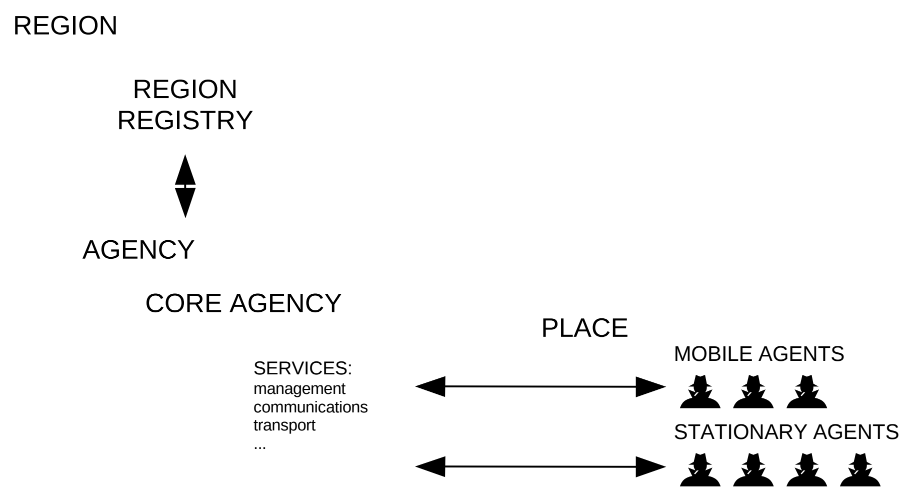

Figure 1: Structure of a Grasshopper based agent system

An agency is an instance of the Grasshopper application that hosts software agents and provides services such as communications, registration, data transfer, security, transport and archiving. Every computer that we want to connect to a distributed multiagent system should be running at least one agency. Every agency contains the so-called core agency and several places where the agents can run. Agencies handle virtually all services related to the lifetime of agents. The concept of place aids the grouping of agents inside agencies according to their purpose or functionalities. Every agency has to contain at least one place on order to host agents. In contrast, the formation of regions is not mandatory, and serves only to simplify the communications between components of a distributed system. A region registry keeps track of all agencies and agents within the region and enables communication with mobile agents regardless of their location. The information on agent states and events is reported to the registry by concerned agencies.

2.1 Prototype system

To test the software agents we needed to develop a distributed system prototype. We have decided to use agents to connect two different simulation models via their data resources. The prototype application used simulation models derived from the models used in a production process reengineering project (Kljajić et al. 2000). In that project we have constructed several simulation models: a continuous simulation model for the financial analysis of investments and several DES models to represent the production line reengineering alternatives. In the prototype we gave the continuous simulation model running in Powersim Studio 2003 (Powersim AS 2004) the role of a data source, while a discrete event simulation model running in ProModel (ProModel Corporation 2002) had the role of a data consumer. Powersim and ProModel are both general purpose simulation tools and are designed for the Microsoft Windows operating system.

Powersim and ProModel cannot be directly connected, as they don't share a common data interface or data format. The only runtime data transfer option in Powersim is the Windows DDE (dynamic data exchange) link to MS Excel files, while the only easily accessible runtime data transfer option runtime data transfer option in ProModel is via text files, for example CSV (comma separated values) files. Therefore the only viable method of connecting Powersim and ProModel is to transfer the data from MS Excel workbooks to text-based CSV (comma separated values) files. While it is possible to save data from MS Excel as CSV files, it is difficult to do remotely. Also, directly translating an MS Excel workbook into a CSV file or files would result in a large amount of poorly structured data that would be very difficult to use in ProModel, therefore data filtering is required. We have also decided to implement data format translation using an intermediary format based on XML to facilitate the addition of new data formats. Intermediary XML data is in the form of an XML table.

We have divided the distributed system into several components:

- Simulations,
- Data resources and
- Middleware.

The function of middleware is implemented by a multiagent system containing the following components:

- Mobile agents,
- Stationary agents,
- Agent execution platforms (agencies),
- Central registry and control application (region registry).

The prototype of a distributed system contains three computers that host individual components of the system

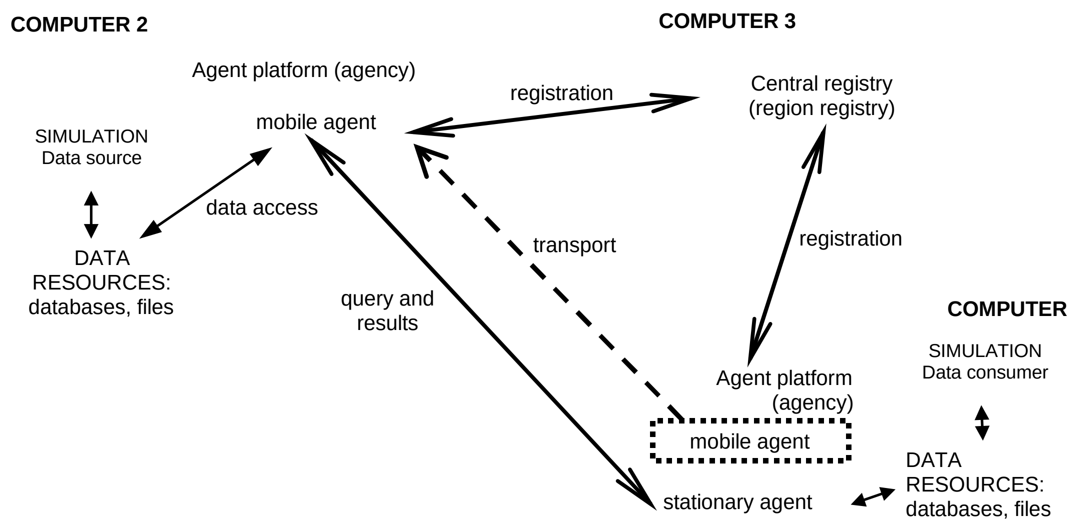

Figure 2: Distributed system prototype schematics

(**Figure 2**). The envisaged scenario has the user of “Computer 1” trying to obtain simulation data from “Computer 2” that is acting as a data source. “Computer 3” has the role of central registry and administration server. The “Computer 1” runs the DES model contains the file used for data transfer (from continuous model to DES model) and an agency hosting a stationary and a mobile agent. The stationary agent is used to forward user queries to the mobile agent and then receive and convert the resulting data from the intermediate XML format to a CSV file. The mobile agent is used to fetch the data according to the user query (applying filtering), convert the data to intermediary XML format and send it to the querying stationary agent. The computer running the continuous simulation model (Computer 2) also contains an MS Excel file used to save and access simulation results and an agency that hosts the mobile agent. Finally, the computer marked “Computer 3” holds the region registry, which is used to control and administrate the agents and agencies. **Figure 2** also displays the connections between components, where continuous lines show communication links, while the dashed line shows the path of mobile agent migration. The agencies are Java applications, running within local instances of Java VM (Java Virtual Machine). It is possible to run several agencies on the same computer, and several agents within every agency. Every agent runs in its separate thread, making the parallel execution of several agents possible without special mechanisms. Every agency implements the following services:

- Creation, execution and removal of agents,
- Reception and execution of mobile agents,
- Control of active agents within the agency,
- Access to information on agents within the agency,
- Access to network and local resources,
- Registration of agents and the agency with the region registry,
- Inter-agent communications, and
- Security mechanisms for communications and agent transport.

The role of the region registry is to enable a centralized overview and control of components in a distributed agent system, i.e. agencies and stationary and mobile agents. The region registry implements the following services:

- Registration of agencies and agents,
- Overview of agent locations,
- Overview of agency and agent properties,
- Removal of agencies and agents from the registry,
- Use of security mechanisms for all communications.

A mobile agent is an executable piece of Java code that can run within an agency and implements the following functionalities and services:

- Migration to the data source,
- Accepting user queries (via the stationary agent),
- Retrieval of data according to the user query (filtering),
- Conversion from original (MS Excel) format to intermediary (XML table) format,
- Transfer of data to the querying stationary agent
- Remote control of life-cycle and
- Use of security mechanisms for communications.

A mobile agent's life cycle (Figure 3) is started by a user that would like to access data on a remote computer that hosts a data source and can accept mobile agents. The initial state ("Awaiting activation") is marked bold. The agent can be started in any agency that is registered with the region registry. Initially, the agent is a passive object (not executing), and has to be activated (with a double-click or via agency GUI). Then the agent initializes itself and asks (via a graphical user interface) what agency the user wants to send it to and what data source it should access there. The user doesn't need to know the exact location of the agency such as the computer name or its IP address, as it is transparently provided by the region registry. The agent then creates a copy of itself and deactivates, becoming a passive object again. This is done to enable the remote control of agent's life cycle - after the user requests the removal of the original agent, the original sends its copy the pass phrase that was randomly generated at the agent's activation (a "shared secret"), and the remote copy stops executing at the first opportunity and removes itself. The copy moves to the target agency, using an encrypted protocol. The transport is performed by the agencies, moving both the execution code and the data (variables). The target agency accepts the mobile agent, provided that it is signed by a known and approved entity. This is done with standard SSL mechanisms and X.509 signatures, i.e. the agent creator's digital signature must be present in the target agency's signature storage. When the mobile agent is allowed to execute in the target agency, it assumes the role of a server and waits for incoming requests. The requests have to include an SQL query and the aforementioned pass phrase to prevent unauthorized data access. The mobile server agent can be removed either remotely by its owner or locally by the owner of the hosting agency. The region registry administrator can delete the agent (in fact any agent or agency) from the registry, thus making it inaccessible to other agents or agencies, but cannot physically remove or deactivate the agent. The xlSQL JDBC driver (NiLOSTEP 2004) was used to access data in MS Excel workbooks.

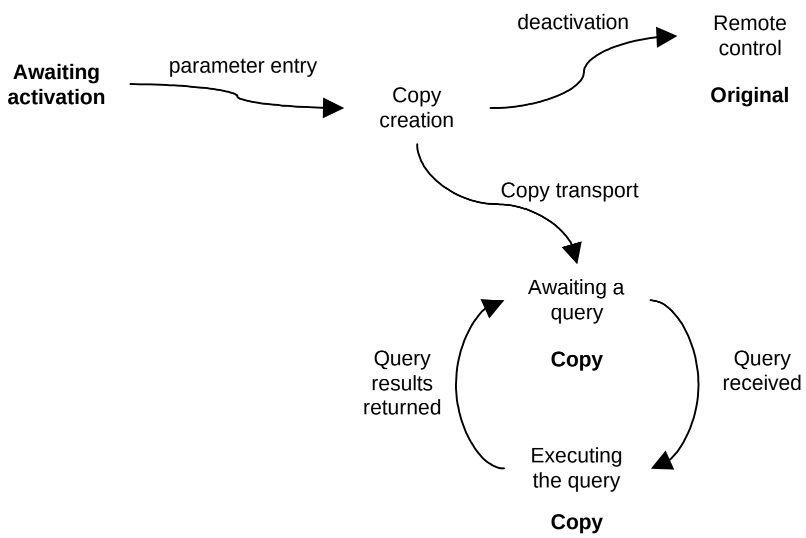

Figure 3: State transition diagram of the mobile agent

The stationary agent has the role of a intermediary between a mobile agent and the data consumer (a user or an application). The stationary agent's functionalities and services are:

- Accepting data queries,
- Forwarding a query to a mobile agent,
- Reception of results and their conversion from XML format to a CSV file, and
- Use of security mechanisms for communications.

Figure 4 shows the life-cycle of the stationary agent. The agent is started by a user that needs access to remote data. The agent is activated during its initialization and assumes the state "Awaiting query" (marked bold in **Figure 4**). The agent then displays a GUI dialogue requesting the remote mobile agent address, pass phrase, the SQL query and the destination file. The stationary agent can be removed by its creator or the administrator of the hosting agency. The region registry administrator can delete the agent from the registry, thus making it inaccessible to other agents or agencies, but cannot physically remove or deactivate the agent.

3 Results

With the prototype we have managed to build a system that allows us to access a remote data resource, fetch a defined range of data and convert it into the desired format. The software agent based system masks many operations that are necessary to fetch the desired range of data from a remote location and convert it into desired format, and can be seen from the end-user's point of view as a "black box" (Figure 5) that accepts SQL queries and returns CSV format data.

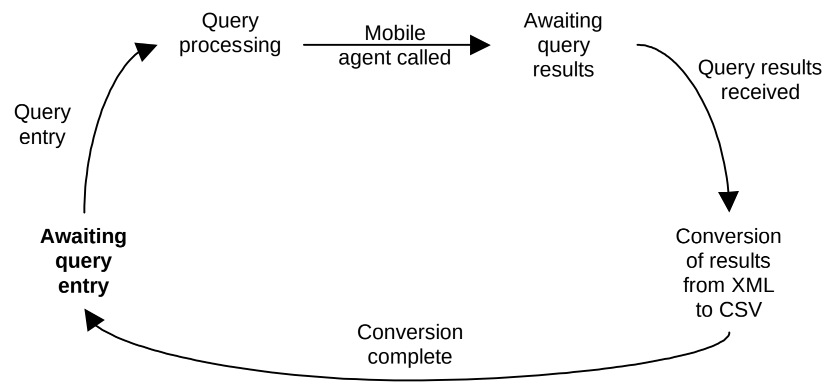

Figure 4: State transition diagram of the stationary agent

Figure 5: The software agents based system from the end-user's point of view

We have tested the operation of the prototype using different sizes of the query results and both with and without security mechanisms. Before the testing took place, we have checked the operation of individual computers and their components: central processor units, hard drives and network adapters. Hard drive defragmentation was performed afterwards. All computers were rebooted between individual tests and the system page file initialized. As the prototype was operating on Faculty's computers the tests were conducted outside office hours to minimize undesired network traffic.

We aimed to find out how the system responds to different communication protocols (sockets and SSL) and data package sizes in order to establish the suitability of the system for different types of distributed simulation systems and hardware configurations. We were especially curious as to what would be the impact of security mechanisms on system performance.

The test environment contained three IBM PC compatible network workstations. The region registry was operating on a DELL Inspiron 8100 laptop with a Pentium 3 mobile CPU running at 1GHz and a 20Gb, 4200RPM hard drive and 512Mb of 133Mhz SDRAM (COMPUTER 3 on **Figure 2**). The mobile and stationary agents were installed on a IBM Thinkpad r50p laptop with a Pentium M mobile CPU running at 1.7GHz and a 60Gb, 7200RPM hard drive and 512Mb of 333Mhz DDR SDRAM (COMPUTER 1 on **Figure 2**). The role of remote data source (COMPUTER 2 on **Figure 2**) was given to a machine with a Athlon 64 3000+ CPU running at 2GHz and a 160Gb, 7200RPM hard drive and 1Gb of 433Mhz DDR SDRAM. All computers were connected to the local area network at the Faculty of Organisational Sciences via Fast Ethernet (100Mbps) network adapters and 100Mbps switches.

We have measured the following parameters:

- Time needed for the transfer of a mobile agent between two agencies, depending on the communication protocol and sequence of transfer,
- Time needed to establish the connection between xlSQL JDBC driver and the data source (MS Excel workbook) depending on the MS Excel workbook size,
- xlSQL JDBC driver's usage of memory depending on MS Excel workbook size,
- Time needed for xlSQL to return a data range depending on the query result (data range) size,
- Time needed for the conversion of a returned data range to XML data depending on the query result (cell range) size,
- Time needed for the conversion of received XML data to a CSV file depending on the query result (cell range) size,
- Time needed for the completion of a SQL query (from the entry of query to the writing of a CSV file) depending on the query result (cell range) size.

The MS Excel workbook contained a table with three columns, containing the record index, decimal value and the time of record creation. We have used tables that ranged in size from 100 to 65.500 rows (maximum supported size in the MS Excel in MS Office 2000). The stationary agent used an SQL query that returned a range of cells at a randomly selected position in the table. The queries were one hundred times to provide better accuracy of results. An example of a query that returned one hundred records is as follows:

select idx,val from 'table.sheet1' where idx>100 and idx<201

An individual record returned contained two pieces of data: the record index (64 bits) and record value (64 bits). The Y7 version of the xlSQL JDBC driver was used. The times were measured using the system clock in the Java Virtual Machine.

In the following part of the paper we present some of the more interesting results of prototype testing. The results of all tests are available in the doctoral thesis (Rodič 2004). Figure 10 shows the dependence of system performance on the size of cell range that a query returns. The performance is expressed as throughput - the average number of records processed per second. We have measured the performance at the client agent side by measuring the duration of processing from the entry of an SQL query to the writing of a CSV file. The processing includes the transfer of the SQL query to the mobile agent acting as a server, querying using the JDBC driver, conversion of the resulting data range to XML, sending XML back to the client agent and conversion to a CSV file. We have established that the system performance is proportional to the query result size and grows in a logarithmic fashion, and that the use of secure mechanisms for communications reduced the system performance by approximately 20 percent.

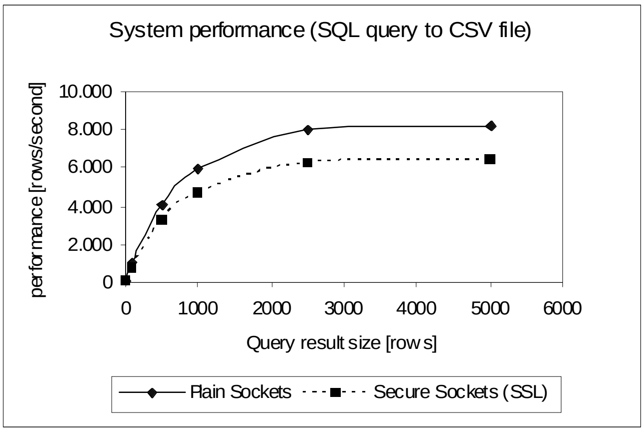

Figure 6: System performance depending on the query result size

Figure 7 shows the average duration of tasks of the mobile server agent, i.e. the execution of the received SQL query and the conversion of the resulting data range into an XML table. The accuracy of results was limited due to the limited resolution of the system clock (10 ms). It is evident that the duration of SQL queries is not seriously affected by the query result size; however the duration of conversion of the data set to XML seems to be linearly dependent on the size of query results. The query response time or latency of the mobile agent is limited by the duration of SQL query using the xlSQL JDBC driver, which was at least 60 ms during our tests.

Our results show that the system performance is affected by both query result size and the use of security mechanisms, as we have expected. The system throughput was highest when the size of query results was several thousand rows. The latency of the mobile server agent is affected by the duration of SQL query. The minimal latency we have achieved with the mobile agent during our test was in the order of 60 ms and the smallest total time of service (SQL query to CSV file) achieved was approximately 100 ms, which translates to about 10 transactions per second. That speed is unsatisfactory for a real-time application of the system but may be adequate for decision support systems.

The highest achieved throughput is approximately eight thousand records per second, where each record contained two numbers in the *double* format (double accuracy floating point number) with the size of 64 bits each. This speed is in our opinion adequate to link business simulation models and other applications, but not appropriate to conduct real-time data transfer between complex natural science simulation models or applica-

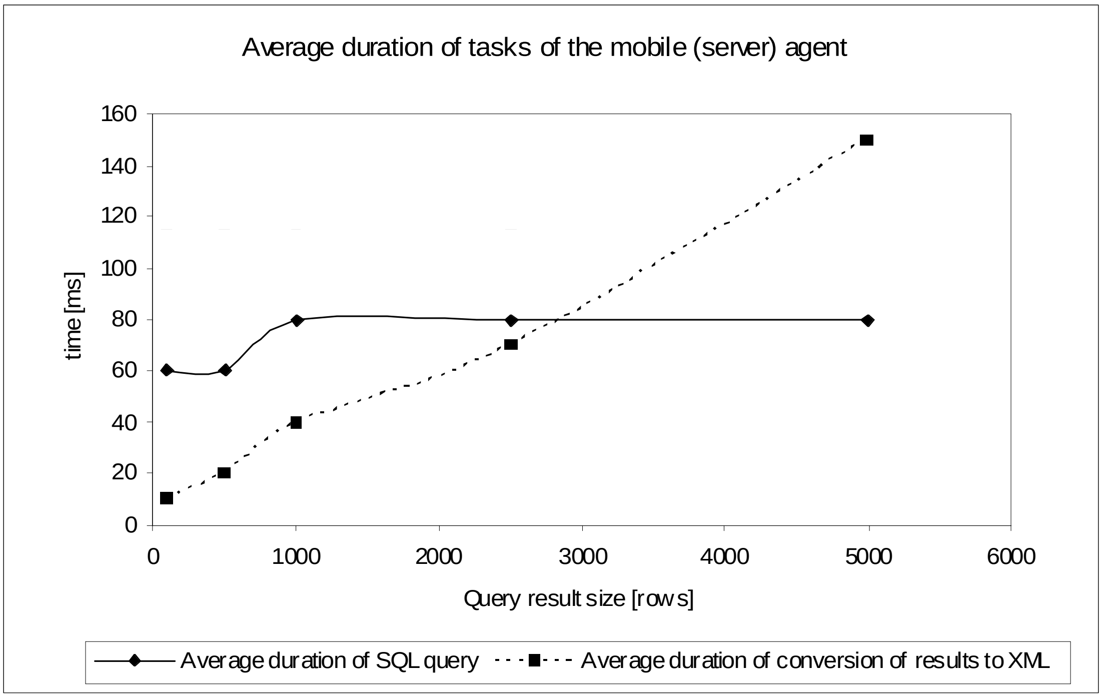

Figure 7: Average duration of tasks of the mobile agent

tions with intensive communication between components. That can be expected as Java applications still tend to be relatively slow compared to compiled native applications. Also, MS Excel workbooks are not intended for the storage of large amounts of data and cannot compete with relational databases for speed of access. Given these limitations, we conclude that the achieved throughput is satisfactory.

The use of security mechanisms in data transfer has a notable negative effect on the system performance due to increased communication setup and data transfer overhead of secure protocols. Establishing a connection using SSL has several additional steps compared to plain Sockets, and some of these steps are computationally intensive (encryption and key generation). SSL also requires some additional resources on the computer (key storage). As all transferred data is encrypted using strong encryption, the overhead is significant during the entire communication. Our tests show that the use of security mechanisms slows the system performance down by 20 to 25 percent. We believe that although significant, the security-performance trade-off is acceptable as the use of SSL makes the system considerably more resistant to eaves-dropping, impersonation, unauthorized modification of data and “rogue” (malicious) agents.

4 Conclusion

The results of our research show that software agents can be used to connect distributed simulation models, developed with different general purpose simulation tools and databases, thus improving the connectivity and usability of simulation models in distributed information systems. The use of standard security mechanisms provide authentication, confidentiality and integrity of information and contribute to the safety of the entire distributed system without a major negative impact on system performance.

We have developed two types of agents: a mobile agent that functions as a mobile server for on-demand queries in SQL and transformation of results into XML compliant documents and a stationary agent functioning as a client for query forwarding and conversion of resulting XML documents into CSV files. The mobile agent implements the methods for migration between agencies, remote control, accepting and processing of queries from remote client agents and conversion of query results to intermediary XML format (a two-dimensional table). The stationary agent acting as a client implements the methods for connecting to a mobile server agent, query forwarding and conversion of results from the XML format to CSV files. The use of an intermediary XML format for data conversion facilitates the addition of new data formats and integration with modern business information systems. By using an intermediary format we only need to develop two converters for every new data format, i.e. converters for conversion between different data formats. Without an intermediary format, converters are necessary. The use of Java, XML and a well documented agent platform facilitated the development of an open ended and expandable system. The use of XML also facilitates data processing, as XML documents can be converted to Java software objects and then modified and processed with Java code. We have used this feature to convert the XML documents to a text string and write it into a CSV file.

While the server side of the system (the computer hosting the data resource and mobile server agents) has to provide an agent platform and an appropriate JDBC driver to access data, the client side needs only the agent platform for full functionality. Therefore any computer that can run the Grasshopper agent platform (therefore most systems that support Java) can be used to easily access remote MS Excel data with simple yet powerful SQL queries. This significantly facilitates the integration of different simulation models and applications from various platforms into a distributed information system.

Acknowledgments

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Miroljub Kljajić - rec biography on page 518.

How to Perform a Simulation Project - An Example of Scheduling with Genetic Algorithms and Visual Event Simulation Model

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Kako izvesti simulacijski projekt – primer razvrščanja z genetskimi algoritmi in vizualnim dogodkovnim modelom

Posedovanje koristnih informacij je vedno predstavljalo prednost pred konkurenco. Simulacijo lahko uporabimo kot orodje za napovedovanje dogodkov v prihodnosti ali za analizo in razlago preteklih dogodkov. »Kaj se bo zgodilo če naredim ali to?« je vedno bilo vprašanje mnogih ljudi. Simulacija nam lahko ponudi odgovor na to vprašanje. Z razvojem računalnikov in programske opreme je simulacija postala razširjeno in do uporabnika prijazno orodje. Simulacijo se prav tako čedalje več uporablja za optimizacijo proizvodnih sistemov. Vendar se pri uporabi simulacije v proizvodnih podjetjih pojavljajo določeni problemi. V tem članku bomo predstavili te probleme in poudarili prednosti simulacije. Prav tako bomo predstavili primer uporabe simulacije z VIM in GA za razporejanje naročil.

Ključne besede: simulacija, proizvodnja, optimizacija, razporejanje, genetski algoritmi, dogodkovna simulacija, vizualizacija

1 Introduction

With the appearance of globalization, causing a more fierce competition, companies have to make choices as close to optimal as possible, because every wrong decision can prove lethal to company's existence. Counselling has been widely recognized as support in decision making process and outside counsellors are usually used, because companies need counselling only occasionally. Financial counselling is used mostly, followed closely by legal counselling. Production companies neglect counselling at their primary activity – product manufacture and production process optimization respectively. Usually they have lots of reserve at cost reductions or at their whole production process organization. Production optimization does not get the necessary attention and resources (Harell & Kerim, 1995). Production organizers/planners have to rely on their inventiveness, experience and clumsy tools. Companies are not aware that planners and other production organizers are faced with problems that practically cannot be solved by any man. One of possible methods to improve production process is simulation (Hoover & Ronald, 1990).

First simulation models were not friendly towards their users or programmers, because they used only text representation. With computer development, simulation software packages have become more progressive and cheaper. Many simulation packages known today can represent simulation in two or three dimensions and are adapted to production processes. Several successful simulation applications in production were shown (Fehnker, 1999; Saltzman, 1997). The field of simulation use is practically unlimited – scheduling, production analysis etc (Tumay, 1993). But simulation is still a much unknown field for most companies. Most of them take simulation as a redundant cost or fear of job cuts. Instead, simulation should be taken as a decision support tool (Law, 1991). The following chapters describe where the simulation should be used, how the simulation project is executed and what the pitfalls in simulation project are.

2 Before starting a simulation project

Simulation models intended for production are rarely built by experts who work inside the production company, because buying simulation building software package and employee training usually represents a big cost for the company. Models are built by people who are not familiar with the problems faced in that particular company and for that reason; a constructive dialogue has to be established between company's employees and people who will build the model. Before the actual building of the simulation model, the following questions have to be answered:

- Why is the simulation being performed?
- Who will be using the model?
- To whom will the results of the simulation be presented?
- What information is expected from the model?
- Is this a "throw-away" model?
- How important is the decision being made?

Answers to the questions above can help in establishing the initial frames of the model. An approximate assessment of time consumption and the price for building the model can also be made.

3 Simulation project

Many simulation projects are from the outset doomed to failure due to poor planning. Undefined objectives, unrealistic expectations and a general lack of understanding of requirements frequently result in frustration and disappointment. If a simulation project is to be successful, a plan must be developed that is realistic, clearly communicated and closely followed. Planning a simulation study involves the following sub tasks:

1. Plan the study
2. Define the system
3. Build the model
4. Run experiments
5. Analyze the output
6. Report results

It can be noticed that building a model is only the third task. The first two tasks are usually skipped, which leads to dispersion of expectations and actual results. Planning the study and defining the system has to go along with close cooperation between people who build the model and people who will use it and/or are familiar with the objectives, that must be achieved with the model. To stress the importance of planning the study and defining the model, both these tasks are described in detail in the following chapters.

3.1 Planning the study

Planning a simulation study involves the following sub tasks:

- **Defining Objectives:** With a basic understanding of the system operation and an awareness of the issues of concern or interest, one or more objectives can be defined for the study. Simulation should only be used if an objective can be clearly defined and if it is determined that simulation is the most suitable tool for achieving the objective. Defining an objective does not necessarily mean that there needs to be a problem to solve. A perfectly valid objective can be to see if there are, in fact, any unforeseen problems. Common types of objectives for a simulation study include the following:
  - Performance Analysis: How well does the system perform under a given set of circumstances in all measures of significance (utilization, throughput, waiting times, etc.)?
  - Capacity Analysis: What is the maximum processing or production capacity of the system?
  - Capability Analysis: Is the system capable of meeting specific performance requirements (throughput, waiting times, etc.) and, if not, what changes (added resources, improved methods etc.) are recommended for making it capable?
  - Comparison Study: How well does one system configuration or design variation perform compared to another?
  - Sensitivity Analysis: Which decision variables are the most influential on one or more performance measures, and how influential are they?
  - Optimization Study: What combination of feasible values for a given set of decision variables best achieves desired performance objectives?
  - Decision/Response Analysis: What are the relationships between the values of one or more decision variables and the system response to those changes?
  - Constraint Analysis: Where are the constraints or bottlenecks in the system and what are workable solutions for either reducing or eliminating those constraints?
  - Communication Effectiveness: What variables and graphic representations can be used to most effectively depict the dynamic behaviour or operation of the system?

  Defining the objective should take into account what the ultimate intended use of the model will be (Thesen, 1992). Some models are built as "throw-away" models to be used only once and then discarded. Other models are built to be used on an ongoing basis for continued "what-if" analyses. Some models need only to provide a quantitative answer. Others require a realistic animation to convince a sceptical customer. Some models are intended for analyst's use only. Other models are intended for use by managers with little simulation background and must be therefore easy to use. Some models are used to make decisions of minor consequence. Other models are relied upon to make major financial decisions.
- **Identifying Constraints** Equally important as defining objectives is identifying the constraints under which the study must be conducted. It does little good if simulation solves a problem if the time to do the simulation extends beyond the deadline for applying the solution, or if the cost to find the solution exceeds the benefit derived. When identifying constraints for a simulation study specific questions to ask include the following:
  - What is the budget for doing the study?
  - What is the deadline for making the decision?
  - What are the skills of those doing the study?
  - How accessible is the input data?
  - What computers will be used for the study?
- **Preparing a Simulation Specification** With clearly defined objectives and constraints, the simulation requi-

rements can be specified. Defining a specification for the simulation is essential for projecting the time and cost needed to complete the study. It also guides the study and helps set expectations by clarifying to others exactly what the simulation will include or exclude. A specification is especially important if the simulation is being performed by an outside consultant so that you will know exactly what you are getting for your money. Aspects of the simulation project to be contained in the specification include the following (Knepell & Deborah, 1993):

- □ **Scope** The scope refers to the breadth of the model or how much of the system the model will encompass (Fig. 1). Determining the scope of the model should be based on how much bearing or impact a particular activity has on achieving the objectives of the simulation. A common tendency is to model the entire system, even when the problem area and all relevant variables are actually isolated within a smaller subsystem.
- □ **Level of Detail** Unlike the model scope which affects only the size of the model, the level of detail affects model complexity as well as the model size. Determining the appropriate level of detail is an important decision. Too much detail makes it difficult and time consuming to develop a valid model. Too little detail may make the model too unrealistic by excluding critical variables. The Fig. 2 below illustrates how the time to develop a model is affected by the level of detail. It also highlights the importance of including only enough detail to meet the objectives of the study.

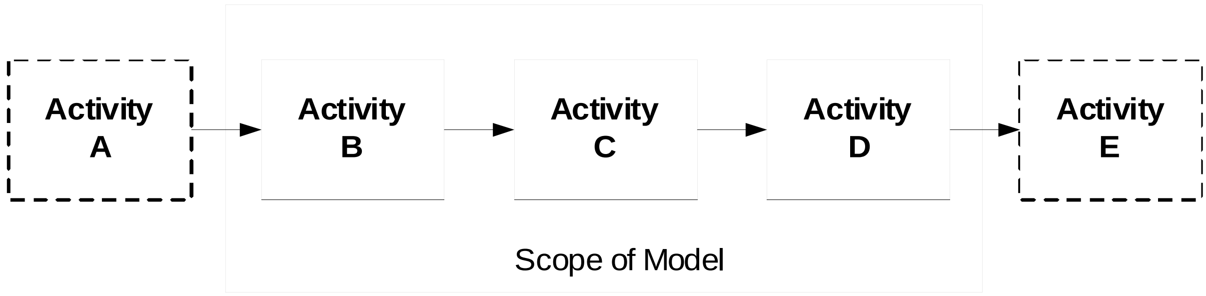


Figure 1: Confirming the scope to impacting activities

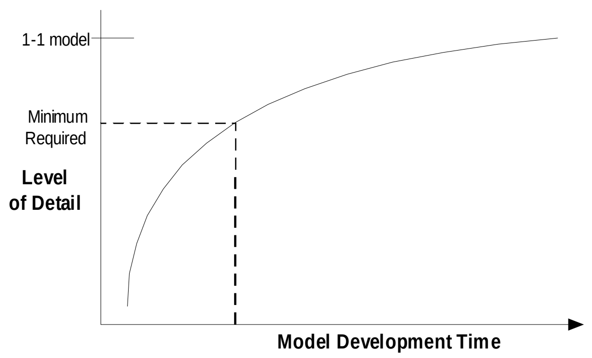


Figure 2. Effect of level of detail on model development time

- □ **Degree of Accuracy** The degree of accuracy pertains to the correctness of data being used. For some models or activities, the information need not be as accurate or exact as it does for others. The required degree of accuracy is determined by the objectives of the study. If the decision is important or a comparison is close, greater accuracy may be required. Accuracy sometimes has to be sacrificed if reliable information is simply unavailable such as when modelling a completely new system.

- ■ **Developing a Budget and Schedule** Defining financial means and deadlines is the usual problem faced with building a simulation project. Time schedule of the project has to be based on realistic assumption – defining system and objectives usually takes up to 50% of the time intended to execute the simulation project. System definition phase is usually skipped, which leads to the simulation model that does not meet the expectations or does not allow the testing of desired simulation scenarios. Crucial discussions are in progress in this phase between the company's employees and people performing the simulation project. When composing time schedule, the following can be taken into consideration:
  - □ Defining the system to be modelled can take up to 50% of the project time.
  - □ Model building usually takes the least amount of time (10 to 20%).
  - □ Once a base model is built, it can take several weeks to conduct all of the desired experiments, especially if alternative designs are being compared.

3.2 Defining the System

With clearly defined objectives and a well organized plan for the study, the system that will be simulated can begin to be defined in detail. This can be viewed as the development of a conceptual model on which the simulation model will be based. The process of gathering and validating system information can be overwhelming when faced with the stacks of uncorrelated data to sort through (Carson, 1986). Data is crucial for good model performance. In this case we can rely on a saying: «Garbage input, garbage output!» Many data gathering efforts end up with lots of data but very little useful information.

Data gathering should never be performed without a purpose. There are several guidelines to keep in mind when gathering data:

- **Identify cause-and-effect relationships** It is important to correctly identify the causes or conditions under which activities are performed. In gathering downtime data, for example, it is helpful to distinguish between downtimes due to failure, planned downtimes for breaks, tool change, etc., and downtimes that are actually idle periods due to unavailability of stock. Once the causes have been established and analyzed, activities can be properly categorized.
- **Look for key impact factors** Discrimination should be used when gathering data to avoid wasting time examining factors that have little or no impact on system performance. If, for example, an operator is dedicated to a particular machine and, therefore, is never a cause of production delay, there is no need to include the operator in the model. Likewise, extremely rare downtimes, negligible move times, on-the-fly inspections and other insignificant or irrelevant activities that have no appreciable effect on routine system performance may be safely ignored.
- **Distinguish between time and condition dependent activities** Time-dependent activities are those that take a predictable amount of time to complete, such as inspection time. Condition-dependent activities can only be completed when certain defined conditions within the system are satisfied. Because condition-dependent activities are uncontrollable, they are unpredictable. An example of a condition-dependent activity might be filling a customer order or performing an assembly operation that requires component parts to become available.
- **Separate input variables from response variables** Input variables in a model define how the system works (e.g., activity times, routing sequences, etc.). Response variables describe how the system responds to a given set of input variables (e.g., work-in-process, idle times, resource utilization, etc.). Input variables should be the focus of data gathering since they are used to define the model. Response variables, on the other hand, are the output of a simulation. Consequently, response variables should only be gathered to help validate the model once it is built and run.

To help organize the process of gathering data for defining the system, the following steps are recommended:

- □ **Determining Data Requirements** The first step in gathering system data is to determine what data is required for building a model. This should be dictated primarily by the scope and level of detail required to achieve the model objectives as described earlier. It is best to go from general to specific in gathering system data. The initial focus should be on defining the overall process flow to provide a skeletal framework for attaching more detailed information. Detailed information can then be added gradually as it becomes available (e.g., resource requirements, processing times, etc.). Starting with the overall process flow not only provides an orderly approach to data gathering, but also enables the model building process to get started which reduces the amount of time to build and debug the model later. Often, missing data becomes more apparent as the model is being built.
- □ **Making Assumptions** Not long after data gathering has started, you may realize certain information is unavailable or perhaps unreliable. Complete, accurate and up-to-date data for all the information needed is rarely obtainable, especially when modelling a new system of which very little is known. For system elements of which little is known, assumptions must be made. There is nothing wrong with assumptions as long as they can be agreed upon, and it is recognized that they are only assumptions. Any design effort must utilize assumptions where complete or accurate information is lacking.
- □ **Documenting and Approving the Data** When it is felt that all relevant information has been gathered and organized into a usable form, it is advisable to document the information in the form of data tables, relational diagrams and assumption lists. Sources of data should also be noted. This document should then be reviewed by others who are in a position to evaluate the validity of the data and to approve the assumptions made. This document will later be helpful if you need to make modifications to the model or look for why the actual system ends up working differently from what was modelled.

Experience in gathering data shows a big difference between companies. It is shown quickly if companies invest in data gathering and data analysis about the behaviour of their systems. They can be roughly divided in two major groups: companies with huge amount of detailed data and companies without any data. The latter need to gather all data before proceeding to the next phase.

Model building can be started only now. It needs to be stressed that during the construction of the model, there is always a possibility that the project plan needs to be corrected and system redefined. In the phases mentioned above, it is crucial to notice that people constructing the model need to cooperate with people working in the actual system. Management's full support is needed and the rest of the employees have to realize that simulation can give them support in decision making process.

4 Pitfalls in Simulation

As any other project, project of building and using simulation is frequently met with several risks which can lead to project failure. Typical reasons why simulation projects fail include the following (Law & David, 1991):

- Failure to state clear objectives at the outset
- Failure to involve individuals affected by outcome
- Being to technical and detailed in presenting the results to management
- Basing decision on a single run observation
- Failure to verify and validate the model
- Including more detail than is needed
- Failure to document and get a consensus on input data
- Overrunning budget and time constraints

If the steps that have been outlined are followed, the chances of performing a successful simulation project are very good.

5 The case of production scheduling applying VIM and GA

In order to demonstrate described procedure of above described methodology of how to design problem solving with simulation, we will demonstrate it on the concrete example. Although technically problem was perfectly solved, model validated, last steps of transferring it in praxis weren't realized due to the lack of proper communication between the methodology and users team and because of unfinished process of transition in ownership.

Scheduling problem is a very important practical problem (Fang, Ross & Corne, 1993). Good scheduling method is crucial for assuring quality and profit (Gary & Johnson, 1979). In general is the scheduling problem in order industry is well known as NP-hard problem. NP is a set or a property of problems which can be solved by the known polynomial-time algorithm. In other words, problem can be solved with classical linear methods, but with large time consumption. A lot of effort has already been put into solving this problem, but there is still room for further improvement of presently existent methods. Good scheduling technique must find the optimum solution in reasonable time (Caseau & Laburthe, 1995). Hugh M. Cartwight says that genetic algorithms are made for solving scheduling problems (Cartwright, 1994).

In 1963 Muth and Thompson were the first to tried solving the scheduling problem. They tried to solve a simple problem, composed of 6 different machines and 6 orders (6X6). This model is still used today - like benchmark problem to test scheduling method quality (Fang, Ross & Corne, 1993). Their goal was to make schedule order that would take as little production time as to make. Total time was used for fitness function. There are other ways for measuring scheduling quality, like optimal warehouse space usage, respecting due dates for product delivery. The mentioned method of measuring total time is simple and most common (Vaessens, Aarts & Lenstra, 1992).

Three main steps in actual scheduling orders case:

- First step: the orders are arranged by confirmed date (the first column in table) and by status (second column in table). Orders with higher status and lower confirmation date are first in scheduling. Individual logical orders are marked with different colors.
- Step two: with GA help and simulation event model scheduling is created, to best satisfy chosen criteria – criteria is idle time on machines. Making order is registered in the last colon of the table.
- Step Three: The final part of scheduling order is shown. Orders which are lagging behind confirmed date will be created first, then the entire remaining order on established schedule.

Detailed description of actual procedure of scheduling process by GA could be found in Breskvar (2002).

Ordering companies are also more and more encountering the need to change already made up work orders – rescheduling. The cause for rescheduling lies in noticing, new orders arrival, urgent orders or machine brake downs. In this cases presents methods do not give us the luxury of simply making a new schedule from scratch. It would take to much time. It is for this reason that a new schedule must be done as quickly as possible from the existing one (Nakano, 1991; Fortemps, 2000).

Beside checking gutted scheduling feasibility visual model is also used for users interactive presentation. With described scheduling method, we wanted to use existing planner knowledge about manufacturing and scheduling processes and supplemented it with a computer, which uses its power of fast computing for sourcing a good solution. Conventional and computer gathered results are also compared. The main advantage of the presented system lies in decomposing the scheduling problem, which presents extending of the article (Kljajic, Breskvar & Bernik, 2002), where the mode of using GA for planning production and visual presentation of production process with discrete event simulation (DES) model.

6 Production scheduling

In building a system for scheduling order the existing way of scheduling work in examined firm was taken into consideration. The system itself imitates the work of planers and at the same time uses its ability of fast result sourcing in large space. Described scheduling system order is divided into two parts:

- grave schedule with criteria and
- final schedule with GA and visual event simulation model.

6. 1 Final scheduling with GA and visual simulation model

After grave schedule is made it is necessary to make a working manufacture schedule. With the help of GA the separate schedule for each logical unit is made. Initial work order is just order of received orders. Scheduling quality is tested on discrete simulation model, which is on data based considered all main system function and limitations. New work schedules are developed from the initial population. By using GA we get from initial population new work schedule to new developed schedule. With GA we search for good schedule, the schedule which is good enough and close to the optimum solution (Nakano, 1991). GA process for necessity scheduling is shown on the Fig. 3.

First generation is composed from random possible work orders. With discrete event simulation system it is as regards to system limitations, each order placed in schedule and for each working schedule in generation is calculated its quality regarding to fitness function. Fitness function represents minimal idle time on working locations.

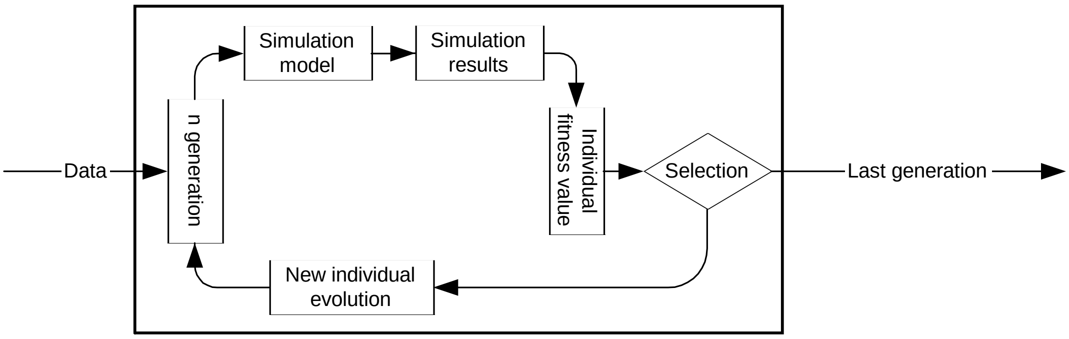


Figure 3: Genetic algorithms and simulation evaluation in the scheduling process (Bernik, 2001)

Selection between work orders is made by calculated fitness function value on individual schedule. New work orders are made with linear crossovers and gene mutation. They are placed into new generation by supplementing work orders with lower fitness function. Cycle of making a new generation is so closed. In described system is the criterion for GA stopping used fitness function. If there is no progress in ten progressive cycles, the stopping criterion is achieved. When GA is must be consider, that there is often a better solution from received (from optimal solution), but bye searching this optimal solution we would consume too much time.

Simulation model is used for fitness function and for work order verification regarding to scheduling order (Fig. 4). On gathered data from firm data base, simulation model was considered individual operation work order, which is necessary for defining setup start time and work time for each work operation.

Schedule is made separately for each logical unit with occupied precedent locations consideration. As a result we get as many work orders as different due dates. Work

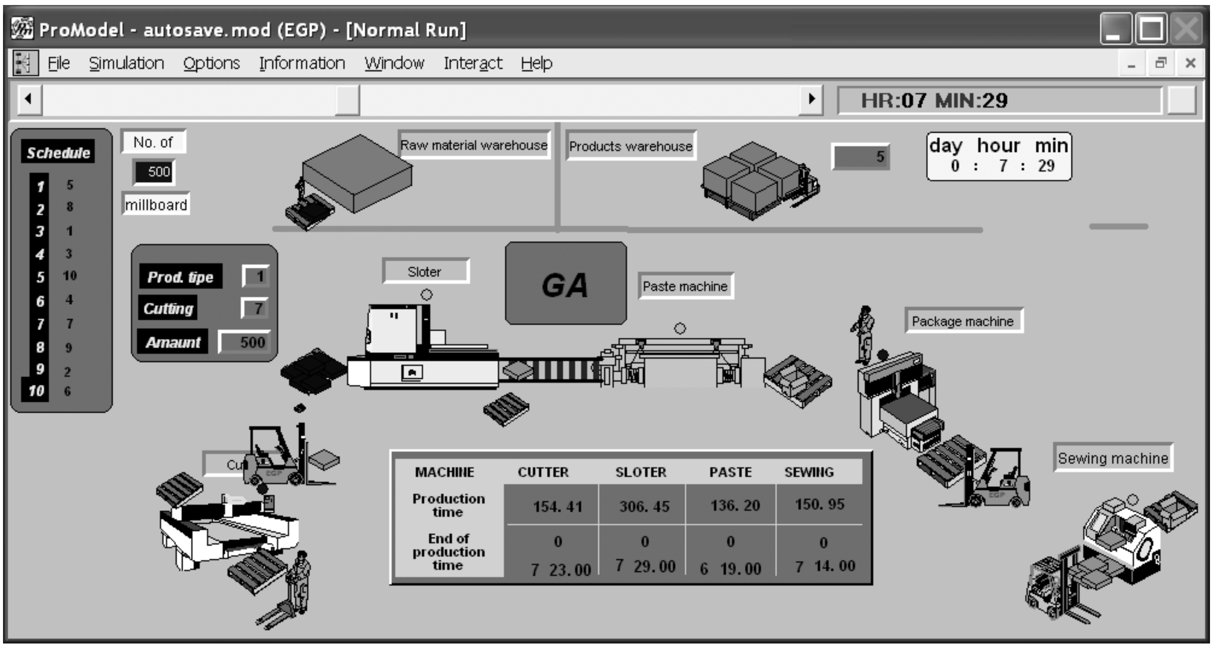


Figure 4: Comparison of the times needed and result quality of the two rescheduling methods

orders are dependent on each other: if one work order in logic unit is changed, all work orders behind them are changed.

7 Comparison between manual and GA scheduling results

The experiment was conducted in the case company with real world data for the duration of four workdays, where a new schedule was made each day. Using order data, we used the GA and DES model to obtain the final GA generation of possible schedules.

A simulation model was used to verify and evaluate the historical schedules. The new schedules with GA were made for the same order data. With conventional method the idle time in manufacture is bigger than with GA and simulation event model method. We can summarize that using GA and simulation yields 5-15% production time-saving (Fig. 5), which translates into higher production utilization 1-6% (Fig. 6) and larger production throughput of the existing production system.

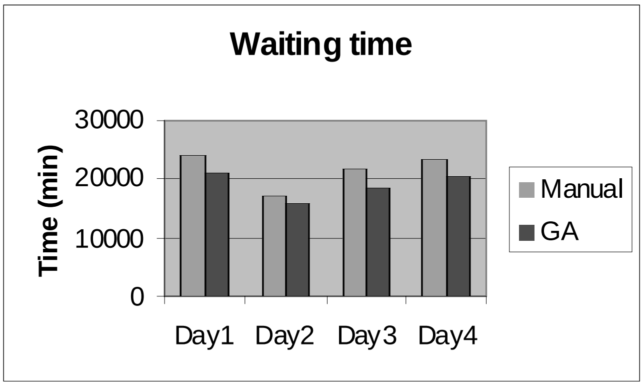


Figure 5: Comparison of conventional schedule with GA and sim. model idle time

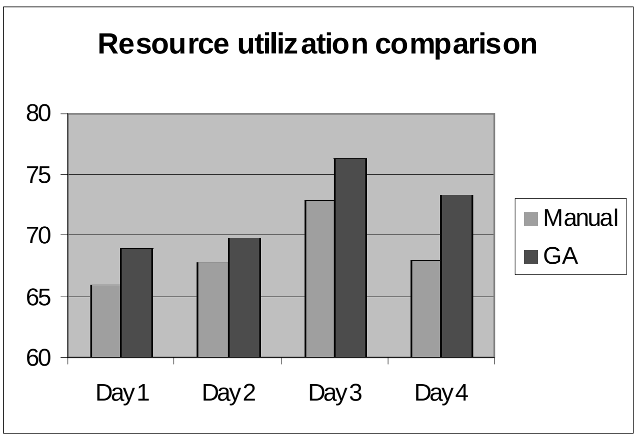


Figure 6: Comparison of conventional schedule with GA and sim. model production utilization

If there were important changes in the production process, the orders were rescheduled with new data.

Changes that warrant rescheduling are:

- order cancellations,
- new orders,
- machine breakdown, and
- unexpected obstruction in the production process.

If an order is cancelled or a new order arrives, the scheduling can be performed from scratch or from the existing schedule (with new orders appended and cancelled orders erased).

The time needed for re-scheduling is much shorter than for scheduling from scratch, as has been confirmed through experiments. A similar problem was the subject of research by Fang et al. (1993), with similar findings.

Figure 7 shows the difference between the two rescheduling methods. At first, the GA took about 25 seconds to prepare schedules for the four days. Before the production start, another three orders arrived and rescheduling was necessary. Starting from scratch with three new orders, approximately another 25 seconds were needed to produce the new schedule. However, when the GA started using the existing schedule, the new orders were simply appended and the new schedule was ready in only seven seconds. Both methods produced the same final schedule.

Final benefits of the presented system are:

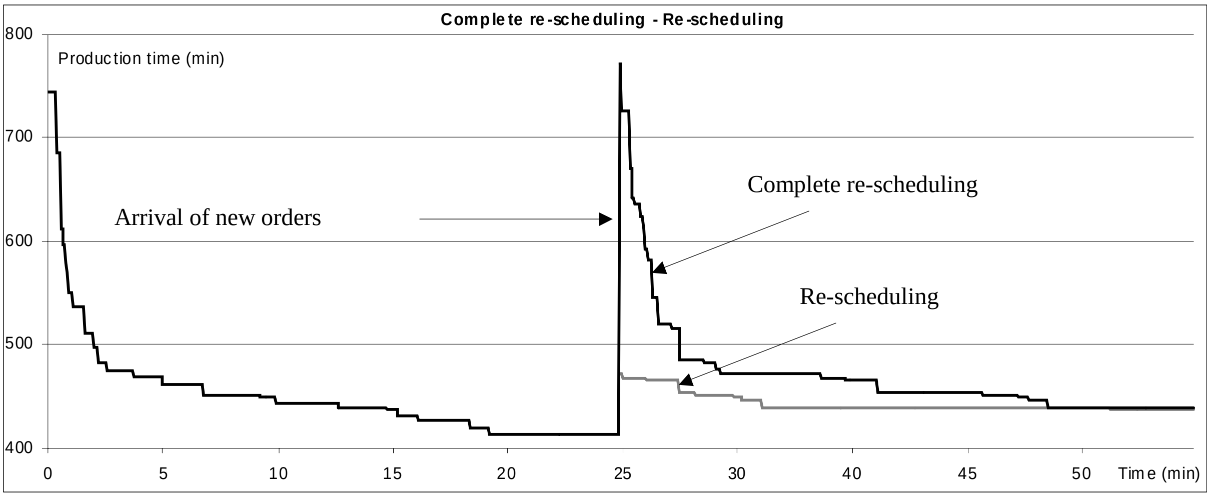
- On line review of production utilization
- Aid in quality schedule development.
- Greater flexibility (from weekly changes to daily changes),
- Reduced impact of human factor on schedule,
- Fast rescheduling in case of order changes, seasonal deviations and machine downtime.
- Easier production tracking.
- Real-time production resource utilization overview,
- Successful usage of work and experience knowledge and
- Using computer for fast computing

Each company has a goal to manufacture more products with lowest costs and to satisfy market need (Dean, Greenwald & Kaelbing, 1994). As it is shown in results, with the use of described procedure production capacities are increased which results in higher production capacity, without additional production input.

8 Conclusion

Simulation has become accessible to a wider range of users with evolution of simulation software packages. Packages allow easier model construction and easier understanding of simulation principles of people who are not experts in simulation. Unexploited simulation possibilities are above all in the production companies. These companies are faced with problems of long term production development and with daily production planning-optimization problems. Simulation model can provide help with these problems as a decision support tool for example as in described case. It has to be admitted that simulation is rarely used in production companies.

To ilustrate methodology a case of production scheduling system using genetic algorithms (GA) and a visual



Picture 7: Comparison of the times needed and result quality of the two rescheduling methods

discrete event simulation (DES) model is described. The main advantage of the presented system is logical problem decomposition. In our case planner is acting as a work order planner and he has the knowledge based on experience. Machine in a computer form is practically using man's knowledge. Knowledge is the main reason for reducing solution searching space, which is good scheduling work order. Computer is using its ability for fast computing and fine tuning man's scheduling work orders. We are talking about two scheduling stages – grave, which is made by man scheduling and computer fine scheduling. With scheduling problem separation in two stages the search space is significaly smaller, which results in excellent solution searching speed. For searching for ultimate solution in reduced but still big space we use GA method. GA method was proven to be very successful in solving numerous NP-hard problems. In our case it was proven that ultimate solution and problem must be appropriately presented to the final users. For this reason the visual simulation event model was used

Increased use of simulation can be expected in production companies in the future. Companies which will decide for a new method of production optimization/management sooner will have significant advantage against their competition.

9 Acknowledgment

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System Dynamics Model of The Canary Islands for Strategic Public Decisions Support

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Model sistemske dinamike Kanarskih otokov za strateške odločitve v javnem sektorju

Prispevek obravnava probleme na področju podpore odločanja ter samih odločitvenih procesov na nivoju odločanja v javnem sektorju. Opisan je razvoj metodološkega pristopa k podpori odločanju v primerih, ko so odločevalci soočeni z nepričakovanimi dogodki. Metodologija obravnava dejstvo, da je strateško odločanje povezano z velkim naborom spremenljivk, kvantitativnih in kvalitativnih ter, da le-te implicirajo interakcije med različnimi subjekti. Metodologija je zasnovana na izgradnji kvantitativnih modelov ter aplikaciji sistemske dinamike pri razvoju simulacijskega modela. Identificirane so bile spremenljivke, ki vplivajo na trajnostni razvoj ter izboljšavo kvalitete življenja na Kanarskih otokih. Relacije med spremenljivkami so podane s kvadratno matriko vplivov M z dimenzijo n=53. Možne vrednosti elementov M so med 0 in 3. Če je a_{ij} =0, sprememba vrednosti spremenljivke V_i ne vpliva na V_j. Če je vrednost a_{ij} med 1 in 3, sprememba spremenljivke »i« povzroči spremembo spremenljivke »j« proporcionalno s predpisano ojačitvijo. Prestavljena metoda je bila uporabljena pri reševanju problema analize vzročno posledičnih sil in razvoju modela sistemske dinamike.

Ključne besede: kvalitativno modeliranje, sistemska dinamika, strateško odločanje v javnem sektorju

1 Introduction

Public decisions, particularly ones related to strategic issues, involve qualitative and quantitative aspects of social systems. Quantitative variables are often crucial for strategic decisions. In addition, qualitative information is provided by a social actor and decision-maker (DM) with an implicit character of uncertainty. The DM has to take decisions in respect to problems that are softly defined in an uncertain and volatile world. In this paper, our efforts are oriented to build a methodological approach that may be useful to improve the public strategic decision-making processes related to sustainable development. This approach needs to allow the integration of quantitative and qualitative information; to treat indetermination of social systems and the uncertainty about the behavior of the variables; and to take into account the implicit knowledge of social actors and decision-makers. The main pillars of our approach are the following: the building of qualitative models that integrate qualitative and quantitative information; the application of Systems Dynamics that is particularly useful in determining the interrelations between the subsystems, to build scenarios and to do strategic simulations; the analysis of the leading forces that help to identify the role of the variables, their leverage potential and, consequently, to highlight key areas of the social system to implement policies. At present, we are working on the identification and interaction of main variables as well as a causal loop diagram (CLD) necessary for building the simulation model for strategic decisions in the Canary Islands. We are also working on structural model validation.

2 The qualitative model of the Canary Islands and the role of variables

The qualitative models and the methodology presented in this paper are useful to help Public Decision-Makers (PDM) in the comprehension of strategic problems and in the preparation and implementation of their decisions. The complexity of the system involved and the uncertainty about key forces and events are at the core of these problems. They involve aspects of different nature;

some of them may be treated in quantified terms and others not. Therefore, to improve the Strategic Decision-Making Process (SDMP), a holistic approach is necessary, which is capable of managing a non-deterministic context at the same time. This is the essential nature of the public decision-makers' problems in respect to the strategy. Being conscious of this nature, the main target of the paper is to develop a model and a methodology to tackle it, in order to improve the SDMP.

As has been stated, an important aspect of the nature of the public decision-makers' problems is that the strategic decisions need a holistic vision, either for the comprehension of the problems, the definition of the strategy or their implementation. However, the public sector tends to think and act in separated compartments, constituted by its different branches. As has been pointed out by Allison (1988), the public sector may be understood as a conglomerate of independent organizations, that have programs established in the functions of their past experiences. When a problem comes about, the organization reacts according to these programs. This deciding process may be useful to face repetitive circumstances that appear in the limits of the decision area of each public organization. However, it is incapable of producing good results at the level of the strategic decisions when the problems are new, involve different areas of the public sector or when it is necessary to cope with long term trends in their general socio-political, economic, ecological and technological environment. In these cases, the qualitative models, combined with the building of scenarios, as the approach developed in this paper proposes, help the decision-makers in their selection of the strategy and the main policies. In fact, not only is the qualitative model treated in this paper, but also the: a) methodological approach to help the DM in respect to their strategic decisions. This is important because it is a system thinking approach, that allows a holistic vision and the transcendence into restrictive areas of each public organization; b) permits the selection of the trends and variables that are relevant and to discard those which are not; c) allows treatment of the uncertain in respect to future trends and other events; d) and, finally, because it makes it possible to concentrate thoughts and decisions on aspects and solutions that are critical in respect to the main problems.

In the Canary Island case, the global vision result of the model was discussed with Government officials as well as with Trade Union Leaders; and the team is presently working on the elaboration of strategies and policies. Thus, the work on the Canary Employment Plan, which is being carried out at present, is particularly important. More details of these processes will be explained in the following paragraphs.

2.1 How the values in the matrices were derived

The Canarian qualitative model is a result of research made for the Islands' government and for the European Trade Union Confederation (ETUC), as part of projects to identify strategies and policies for the Ultra-Peripheral European Regions (Legna & Rivero, 2001; Legna 2002). The bibliography in respect to these models and their utilization to elaborate strategic decisions is extensive. See, for instance, Schlange & Jüttner, (1997). The Canarian Model identifies the principal variables from the perspective of the Sustainable Improvement of the Quality of Life of its population (SIQL) and the implementation of the European Strategy for Employment (ESE): this is the Desired Scenario, the target, of the strategy. It has 53 variables, from which 12 are exogenous. Consequently, it has 41 functions. To build the model, it was necessary to express the Desired Scenario in operational terms. Consequently, a list of indicators of the advances in the direction of the SIQL and the ESE was determined. These indicators constitute the independent variables of Function 1 (column 1 of the matrix that will be explained later on). This function expresses value judgments and is conceptually different from the others in the model. Consequently, in the specific case of this function, the improvement in respect to Vector (column) 1 components means advances in respect to the SIQL and the implementation of the ESE in the Canarian Social System (CSS). For instance, an increase of the real wages and a decrease of the social marginality imply an improvement in respect to the SIQL and the ESE. The model identifies the dealing forces in respect to Vector 1 variables. It gives answers to questions such as: Which are the leading forces of the CSS that shape its future path? Which roles do they play? Which are relevant and which are not for the SDMP?

The qualitative model establishes the relationships between different variables that directly or indirectly affect the Function 1 independent variables. These relationships are represented as: $\mathbf{v_7 = f(v_1; 3v_2; 3v_3; -2v_4; 2v_5; 3v_6)}$. This function means that changes in the variables v_i (i=1...6), will produce changes in the variable "v_7". In some cases these impacts may be quantified and in others it is not possible. In these last ones, it was necessary to work with indicators. In this paper, the functions are expressed in a Matrix "M", where each column represents a function. It reveals the **Direct** cross impacts or **Effects** between the variables. A function as $\mathbf{v_7 = f(v_1; 3v_2; 3v_3; -2v_4; 2v_5; 3v_6)}$ and a vector (column) of M have an identical meaning. If we were to build a matrix M with this function, Column 7 would have the following values in its cases: v_{17}=1; v_{27}=3; v_{37}=3; v_{47}=-2; v_{57}=2; v_{67}=3; and all the other cases equal to "0". A minus sign in a case or in a function means that there is an inverse relationship between the independent and dependent variable: an increase (decrease) of the former implies a decrease (increase) of the last one.

The impacts of the independent variables where estimated with a rank between 0 and 3. A "0" in a case "vij", means that there is no impact from "i" to "j". On the contrary, there is a "3" when the change in an independent variable "i" is capable of producing, **by itself**, a relevant impact on the dependent variable "j". This is the case of x3 in the former function. It is possible that in a function (column of the matrix) there can be more than one independent variable weighted with a 3, as is the case of column V21 (Agricultural Production) of the model. This is because the agricultural production may be substantially affected by the Public Policies (V41) or the endowment of Natural Resources (V36). If there is a "2" in a case, it means that the impact of a change in the independent variable may be important if it is reinforced with changes in other variable(s). For example, the decrease of mortality and birth rates and the increase of immigration, which reinforce each other, affect the Canary Islands' population growth rate (see column V2 of the matrix). For this reason, no column of the matrix has only one 2. The difference between the variables that have a "3" and a "2" in a column (function) is that a change in the former is capable of producing important changes in the depending variable without needing feedback from others: acting independently, it can produce important impacts. On the contrary, the variables that have a "2" need to work together (at least two) to produce significant effects. A variable vi is included in a column with a value equal to "1" when there is a situation similar to the preceding case (weight equal to "2"), but the impact is weaker. It helps to understand these criteria and to evaluate the impacts if we put them in terms of questions, as follow:

- A case vij will have a "3" if the answer to the following questions is "yes": a) the power of "i" over "j" is so essential that these changes are capable of producing a significant impact over "j"; b) Can it produce the effect by itself?
- A "2" will be assigned to a **set of cases** v_{ij} (i=1,2....n) when the answer is affirmative to the following first question and negative to the second one: a change of one variable of the set, interacting with others (any one of the three categories) is capable of producing important changes in the depending variable "j"? Is it capable to produce significant changes in "j" if just it changes?
- Finally, the same questions and answers are applicable to the third category of variables, but taking into account that the impacts are weaker.

2.2 Foundations of the forms of causal relationships

The foundations of the relationships (matrix M) may be explained by means of a description of how the model was built. Throughout their experiences in building these qualitative models, the authors of this paper followed a methodology whose main steps were the following: The first step consisted of an open discussion with the leaders interested in the work in order to establish an initial definition of the problem: for instance, the implementation of the European Strategy for Employment. Keeping in mind the results of the first step (which "did not permit the leaders to sleep"), a brainstorming session was carried out next. Its target was to identify a first list of variables that could be important in respect to the key problem recognized and agreed on during the first step. The members of the team, as well as those in charge of constructing the model, and other specialists and leaders all participated in the brainstorming sessions. At this stage, it was important not to "kill the imagination" by discarding variables that could be crucial. The third step centered on the construction of the functions of the model, that is to say, the matrix M. It was based on the results of research made previously or ad hoc for the model. We will explain these processes with an example. For instance, a conclusion made based on the research conducted by Dirk GODENAU and Sebastián J. ARTEAGA HERRERA, was the following: *"...the aging of the (Canarian) population is due more to the reduction of the fecundity than to the diminution of mortality"* (Godneau & Artaga, 1997). This conclusion may be expressed as a relationship: env = *f* (tnat), where env = aging rate and tnat = birth rate. This would be the function if we were to build a model to reflect past tendencies. Nevertheless, we were interested in the estimation of future impacts. Our vision was dynamic. Therefore, in order to build a function we always had to answer the next question: How will the independent variables impact the depending one? After additional studies, the function adopted was env = *f* (2tnat; 2tmort), where tmort = mortality rate (see column 11 of the matrix). Finally, we have to emphasize that the process is iterative; it is necessary to repeat the step, going back over and over.

Another aspect has to be explained in order to understand the meaning of functions that imply behaviors, for instance, the Canarian entrepreneurs' low propensity to innovate. They have to be understood in probabilistic terms. As has been pointed out by Yager:

"The environment in which people make decisions in many cases consists of a milieu in which the decision-maker has information as to the "usual" value of certain variable and/or the "usual" course of action in a given situation. In addition, these usual rules of thumb involve granular types of knowledge. Examples of these types of decision rules are "John usually takes his car if the weather is nasty" and "We usually invest in companies with good growth potential". These types of rules are characterized by various forms of uncertainty and imprecision." (Yager, 1986).

Table 1 and Table 2 present the variables that were identified, whose relationships are in the matrix M. They were grouped in blocks, as follows:

Table 1: Grouping blocks of identified variables I-V

Blocks	Variables
I	Variable 1. Its column is a vector that expresses the "Desired Scenario", in order to improve the quality of life and to advance in the direction of the EES in a sustainable way.
II	Demographic variables, labor market, employment and rate of employment (V2-V17): V2, Total population residing in the Canary Islands; V3, Birth Rate = (quantity of births by year/total population residing in the Canary Islands)x1000; V4, Mortality Rate=(quantity of people that die by year/total population residing in the Canary Islands)x1000; V5, Immigration Rate=quantity of immigrants that arrive to the Canary Islands in one year/Canarian Population; V6, Female activity rate=(Employed female population + Non-employed female population looking for employment/feminine population between 16 and 65 years old)x100; V7, Male activity rate=(Employed male population + Non-employed male population looking for employment/male population between 16 and 65 years old)x100;V8, the Canary Islands' population rate of activity = [(employed population + population looking for employment)/population who is between 16 and 65 years old)]x100; V9, Active population = Employed population + non-employed population that is looking for work; V10, Population employed; V11, Population aging index = (population residing in the Canary Islands aged 65 years or more/total population residing in the Canary Islands)x100; V12, Labor productivity = Value of the production of the sector/employment in the sector; V13, real wage;V14, Unemployment rate; V15, Internal markets of work; V16, Labor market Primary Segment; V17, Probability to be unemployed.
III	Sectors' production, GDP (Gross Domestic Product) and the effects of the distance of the Canary to central areas (V18-V29): V18, Services Sector Production Value; V19, Construction Sector Production Value; V20, Industry Sector Production Value; V21, Primary Sector Production Value; V22, the Canary Islands’ Gross Domestic Product (GDP) -It is also an indicator of the Size of the Market; V23, the Canary Islands’ medium propensity to import = Total Imports/GDP; V24, Value of the Annual exports of goods and services value; V25, Annual imports of goods and services value; V26, Medium dimension of the Canary Islands' firms; V27, Costs of water; V28, Costs derived of the insularity, the double insularity and the distance; V29 Subsidies to some Canary Islands imports .
IV	R&D, Human Capital and the effects of Values and Culture (V30-V34): V30, Density of the innovation = quantity of innovative companies /quantity of region or sector companies; V31, Canarian Entrepreneurs Propensity to innovate (general values that prevails in Canarian Entrepreneurs in respect to the role of innovation); V32, Human Capital (the set of abilities, dexterities, qualifications, aptitudes and the population's attitudes that favor the economic and social development); V33, R&D Services produced by Canarian Universities and R&D institutions; V34, General values that prevails in Canarian population.
V	Environment (physical and social) and related variables (V35-V39). V35, Urban, rural and marine environment, including that of the beaches. Indicators of its state are the following, among others: the quantity of urban and non-urban residuals that remain without processing in the cities and in the rural areas; the levels of sonic contamination; the contamination either of the air, the sea and the beaches; traffic congestion (measured, for example, by displacement times), and the visual effects of the urbanization pattern and of the extraction of solids that are carried out by the construction sector; V36, Endowment of natural resources; V37, Demographic density=(quantity of population residing in the Canary Islands + V29)/square km. of the Canary Islands territory; V38, Techniques applied in agriculture that produces negative impacts on the environment;V39, Urban violence, drugs, social unrest.

Table 2: Grouping blocks of identified variables VI-VIII

VI	Only one variable, tourism, V40=Total of daily tourists that the Canary Islands receive in a year = tourists that arrive in one year multiplied by the average days that they stay in the Islands. It was treated separately due to the fact that it is a crucial variable.
VII	Political System, only one variable, V41=Public Policies= norms and policy instruments + decision criteria -that produce effects on the population, the companies and the social actors of the Canary Islands. This block needed a special research.
VIII	All the exogenous variables, (V42-V53) -Some of them are external to the Canary System, as the GDP of other countries (V42 and V53); others, as Social Marginality (V51), are internal, but they were treated as exogenous to not extend the model: V42, GDP of countries where immigrants come from; V 43, Percentage of female population aged between 20 and 49 years in respect to the total female population between 16 and 65 years (the women in this stratum have a higher activity rate); V44, Percentage of male population aged between 25 and 54 years in respect to the total male population between 16 and 65 years (the men in this stratum have the higher activity rate); V45, Female; V46, Young active population; V47, European policies (the norms and policy instruments, such as the Structural Fund, the Community Initiatives, etc., that produce effects on the Canary Islands); V48, Supply of Financial Services for the Canary Islands Entrepreneurs' R&D activities; V49, Relative prices of the Canarian tourist services, in respect to the price of the same services in the regions that compete with it; V50, Social Marginality; V51, Revenue distribution between the social groups; V52, Relative rate of inflation of the Canary Islands in respect to the countries that compete with their tourist sector = rate of inflation in the Canary Islands/rate of inflation in the countries that compete with the Canary Islands tourist sector (in the model it is an exogenous variable); V53, GDP of the countries that are market for Canarian exports and of those where tourists come from.

In order to build scenarios and to elaborate strategies it is important to know the role that these variables play in the system. We used two methods to do this: the Analysis of the Driving and Dependent forces that we explain in the next sections and Systems Dynamics.

2.3 The results of the Analysis of the Driving and Dependent forces

Matrix M gives important information about the Canarian Island social and economic system. For instance, if the sum of the values of column "j" is high, it means that the problem "j" has a high level of dependency in the systems: the changes in the other variables affect it strongly. On the contrary, if the sum is low, its dependency is also low. If the sum of a line "i" is high, its changes produce strong impacts in the system. If its sum is low, its effects are not important. But, it only detects the direct effects between the problems. Nevertheless, in social systems the indirect relationships are important: if "A" changes, its change impacts over "B" and "B" affects "C". In addition, variables play different roles in the social game. We will apply the analysis of *"Motricité et Dépendance"* to identify both the indirect effects and the roles. The literature about this analysis is extensive, especially in France. For instance, see Roubelat, (1993).

Multiplication of the matrix permits the detection of indirect effects. For instance, if M is elevated at two, each case aij of the new matrix includes the effects that pass through one variable: $X_i \rightarrow X_u \rightarrow X_i$, X_u being in this case the intermediate variable. If the matrix is elevated at four, it will reveal the effects that pass through 3 intermediate variables, and so on. In the case of our work, we elevated M at two, three and four and afterwards, we built a new matrix MS, which is the sum of M, M^2, M^3 and M^4. Consequently, each case a_{ij} of MS is the sum of the a_{ij} cases of M, M^2, M^3 and M^4 and includes the direct effect of "i" over "j" and the ones that pass through the 1, 2 and 3 intermediaries. With the information provided by M^4 or MS it is possible to detect the role of the variables: a) Active Variables" or "Driving Forces" (AV) that strongly affect other variables but at the same time are not affected (or weakly affected) by them; b) "Passive" or "Reactivates Variables" (RV), that are more affected by the system than they themselves affect the other variables; and c) "Critical Variables" (CV), that have strong feedback effects with the others. Their changes powerfully impact the system and at the same time they are strongly affected by the changes in the other variables. They are strongly interactive and determine the direction the system will take in the future. If a change is produced in a leading variable, it produces feedback loops between the critical variables that may be positives or negatives. If they are negatives the system will return to the previous state. It is the "Equilibrium Poverty" case that development theories have studied. However, if the positive feedback predominates, the system will be pushed out of its present state moving to new ones. Due to these facts, a strategy has to be designed in order to produce changes in the AV and the CV forces that may lead the system to a desirable scenario. If some of these variables are external and there is no capacity to act over them, it is crucial to prevent their possible evolution. We will appreciate these conclusions in the Canary Islands case.

Using the MS matrix of the Canary Islands we built the Graphic of leading and depending forces, which is shown in Figure 1. For each variable, the vertical axle expresses the value of the sum of its line in MS, that is its leverage potential; and the horizontal axle expresses the sum of the column, its dependency. The dependency reveals the level of "steering potential" of a variable. The graphic classifies the variables in four categories: AV, in quadrant I; CV, in quadrant II; RV, in quadrant III; and finally, the variables that are not important due to their low level of leverage and steering potential in quadrant IV. We will concentrate the analysis to the first three quadrants.

The key variables to advance toward the Desired Scenario are in the quadrants I and II. Those in the third quadrant are mainly the results of the structure of the system. The Tourism drives the Services Sector and this one impacts the Construction. These two sectors have multiplying effects over the employment and the GDP; and, consequently, an increased of the final demand is produced that newly stimulates these two sectors: a positive feedback loop is induced by the tourism. In fact, there is a cascade of effects that elevate the demand addressed to all the sectors. The Production of Services is the Economic Base of the Canary Islands. The fluctuations of this base depend on a variable (Tourism) with a very strong leverage potential; and so, all the economic activity and the employment are very sensitive to this variable. It is a society with a high risk. The Economic Base depends on the Environment State, which, in turn, is a result of the Canarian Development Model (quadrant III). This is another crucial feedback loop: the development model impacts over the environment and, if this is destroyed, it will ruin the Economic Base. At present, this base and its effects are producing negative consequences over the environment, via three main processes: a) the pressure over the territory derived from tourism, urbanization and construction persistently reduces scarce agricultural lands and, at the same time, spoils the urban environment; b) an important part of the techniques adopted in the agricultural sector pollute the lands and the water sources; and c) the high rate of growth of construction has ruined some rural environments, by means of the extraction of minerals. Consequently, the Canary Islands are destroying the source of its own economic base and its quality of life: They need to change their development model.

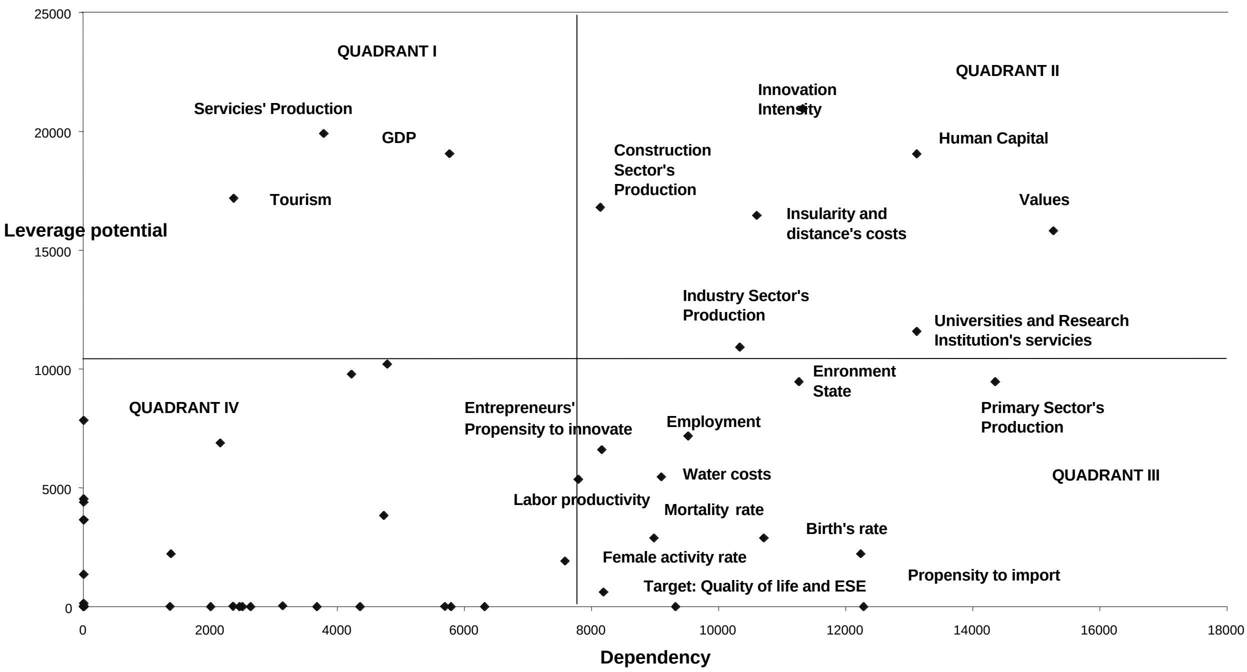

Figure 1: Graphic of leading and depending forces

Other sets of variables also play important roles. The GDP (which is at the same time an indicator of the size of the market) is another center of feedback impacts. Its increase is either a condition to elevate employment and the real salary or to permit the development of activities that need scale economies; and, in turn, is the result of the sector activities, mainly of those of the Base. Its increase reduces the general costs of the system by taking advantage of scale economies. The empirical evidence shows that the increase of the market size reduces the weight of the cost of insularity and the distance over the system.

The state of the variables related to the R&D sub-system (Innovation Intensity, Human Capital, Values and Research Institutions' Services, in quadrant III) is the consequence of the behavior of the system but, at the same time, it determines the path that the Canary Islands will take in the future. The culture and the human capital are a result of the Canary Islands' history and of the policies implemented by the Canarian governments. They have improved steadily during the last decades. However, in spite of this fact, in some sectors of society values predominate that do not impulse the propensity to innovate, especially in small enterprises.

The agricultural (quadrant III) and industrial (low part of quadrant III) sectors have low leverage effects. The first depends strongly on the natural resources (scarce, save the ones related to tourism); and the second is conditioned by the size of the market. They produce positive impacts over employment and revenue, but not as important as those of the services and construction sectors. The entrepreneurs' propensity to innovate (quadrant III) clearly reveals a characteristic of this system: it is highly dependent on the cultural level and the values that predominate in the enterprises; and, at the same time, it has low effects over the competitiveness of the Canarian firms. Due to the fact of this low tendency to innovate, the economic growth has been based on an increase of employment with low productivity and wages. These facts pose a strategic dilemma to the Canary Islands: the development model that has been implanted during the past decades is producing a degradation in the environment; and this degradation is more and more becoming a barrier that will stop the economic growth and the improvement in the quality of life.

With this knowledge of the Canarian Islands system we can build scenarios. To do so, we classify the studied variables in function of the predictability of their behavior during the next five years. We distinguish two sets. The first one consists of the variables in which behavior may be reasonably forecast. The second set includes those that may carry on different paths in the future. In Table 5 we specify the behavior that may be foreseen as variables of set one, and the most important factors that may condition the evolution of set II variables during the next five years.

Table 3: Behavior of the variables in the future

SET I		**SET II**	
Variables	**Behaviour**	**Variables**	**Its behaviour depends on**
V47, European Policies	≈	V40, Total of tourists	EF +V49+V52+V53+V35
V28, Costs the insularity	≈	V18, Services Production	V40+V27+V22+V11
V32, Human Capital	≈ ↑	V19, Construction Prod.	V41+V47+V27+V22+V18
V34, Values	≈ ↑	V22, Market Size	V18+V19+V20+V21
V4, Rate of mortality	≈ ↑	V10, Employment	V18+V19+V20+V21+V12
V33, Production of R&D	≈ ↑	V12, Labour productivity	V18+V19+V20+V21
V20, Industrial Production	≈ ↑	V6, Female rate of activ.	V5+V32+V41+V43
V21, Primary Production	≈ ↑	V36, Available natural res.	V19+V37+V38
	≈ ↓	V35, Environment	V32+V34+V40+V41
		V38, Agric. technologies	V34+V41
		V27, Water costs	V41+V36
		V30, Innovation density	V22+V28+V31+V32+33+ V48

Meanings of the signs and abbreviations: ≈ = more or less the same; ≈ ↑ = more or less the same or slightly increasing; ≈ ↓ = more or less the same or slightly decreasing; EF = External or non controllable Factors, as natural catastrophes or terrorists attacks that increase the fear to travel; PubPol = Canarian Public Policies; V = variable of the qualitative model.

Set I contains characteristics that probably will have or accentuate the Canarian Society during the next five years. Therefore, in the Canarian society the weight of the elderly will probably become more important and at the same time the proportion of youth will be reduced. Combined with characteristics, the cultural general level and the human capital will probably be more important. These features will be present in the different scenarios that depend on the path of the set II variables. Some key scenarios are the following:

- Scenario I, "Auto-destructive Growth with recession". This scenario is Auto-destructive because it supposes the same model of growth of the Economic Base that will lead to the destruction of the environment, so, it will destroy its own basis. The recession is due to the fact that tourism may suffer an important contraction, due especially to external factors (such as the fear of traveling) and internal factors (such as the increase of violence and the contamination of the beaches).
- Scenario II, "Auto-destructive Growth with recession". This is Scenario I but with an increase of tourism. It will accelerate its auto-destruction.
- Scenario III, "Desired Scenario". The main features of this scenario are the following: a) continuation of economic growth and reduction of unemployment; b) but this economic growth is combined with more qua-

lified services provided to tourists, increase in salaries and labor productivity and with a preservation of the environment, in order to ensure the sustainability of the model.

3 The relationship between influence matrix and CLD suitable for SD Modeling

In the previous section the main variables and their interconnection with the Canary Islands, suitable for qualitative analysis of future development, are defined. To move to a quantitative model capable for cause-consequence analysis of decision-maker impact on the long-term behavior influence matrix, they have to be transformed to SD methodology. In this way it is possible for a direct connection between scenario planning (as a consequence of DM) and variable behavior. 53 variables are a rather demanding problem especially in the frame of model validation. In this case it is necessary to specify the initial value of variables, parameters and other functions necessary for model implementation. Therefore, we will develop a procedure of influence matrix transformation to Causal Loop Diagram CLD. The influence diagram is obtained from the influence matrix. The variables in influence matrix *M* represent vertex i.e. the node of the graph and the value represents a gain of a certain branch. Here we suppose that the vertex value represents a directed branch. A different weight in the coefficient matrix represents gain of the certain element in the system. By definition, it is assumed that the vertex or variables belong to a certain entity in the system. Variable relevance in the systems will be estimated with matrix. From this point, the transformation to SD methodology is only the next step. Variables, which represent entities, have cumulative or flow property suitable for system dynamics modeling. To perform the transformation, the influence matrix *M* could be decomposed. In our case we split the influence matrix into several sub-matrixes. In order to facilitate matrix decomposition it is desirable to aggregate variables in natural order. Several similar variables were mapped in one, for example: population, ecology, industry etc. Subjective mapping defined by an aggregation function

$f(v): V \rightarrow X$ give us the following subsets:

$$X_1 = \{V_{48}, V_{30}, V_{33}\}$$
$$X_2 = \{V_{36}, V_{27}, V_{38}, V_{35}\}$$
$$X_3 = \{V_8, V_{11}, V_{10}, V_{12}, V_9, V_4, V_3, V_5, V_{37}, V_{32}, V_2, V_6\}$$
$$X_4 = \{V_{22}, V_{28}, V_{29}, V_{49}, V_{24}, V_{25}, V_{52}\}$$
$$X_5 = \{V_{26}, V_{18}, V_{19}, V_{20}, V_{21}, V_{40}, V_{42}, V_{53}\}$$

As a result of mapping we obtained aggregated connection matrix *C*:

$$C = \begin{array}{c} \\ X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \end{array} \begin{array}{c} \begin{array}{ccccc} X_1 & X_2 & X_3 & X_4 & X_5 \end{array} \\ \begin{bmatrix} 0 & 0 & C_{13} & C_{14} & C_{15} \\ 0 & 0 & 0 & C_{24} & C_{25} \\ C_{31} & C_{32} & 0 & C_{34} & C_{35} \\ C_{41} & C_{42} & C_{43} & 0 & C_{45} \\ C_{51} & C_{52} & C_{53} & C_{54} & 0 \end{bmatrix} \end{array}$$

In matrix *C* the variables describe the following subsystems: X_1 = R&D, X_2= Ecology, X_3 = Population, X_4 = GDP, X_5 = Economy. C_{ij} represent the sub-matrix of the connection between sub-systems X_i and X_j. The elements of the matrix under the main diagonal represent the feedback connections. If sub-systems X_i ; i = ,2,…5 are represented as the nodes of the graph (vertex) and C_{ij} ; i = ,2,…5 ; j = ,2,…5 ; $i \neq j$ represent the branch of the directed graph, we can represent the matrix *C* as the influence diagram or influence graph, see Figure 2.

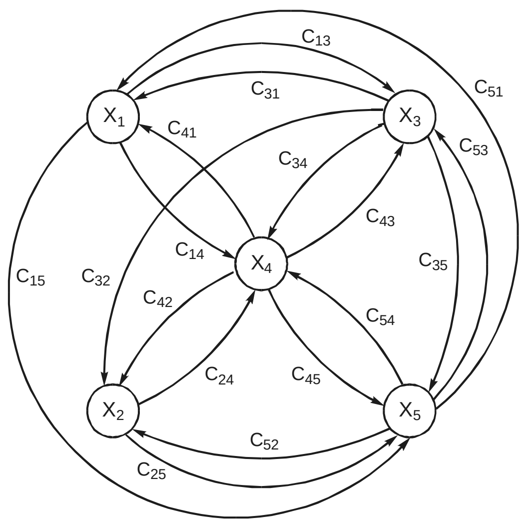

Figure 2: Graph of the aggregated system

Interconnections C_{34} and C_{24} could be neglected because of the small impact on the subsystem which is derived from the original matrix *M*. Although the interconnections exist in the matrix they are not significant on the top level of the influence diagram. This graph is identical to matrix *M* but yet convenient for modeling in SD. The diagram represents a high level of abstraction convenient for further decentralized modeling. At this moment we will analyze the interconnection between main variables relevant for the causal loop diagram CLD as shown in Figure 3. Feedback loops and interactions of particular subsystem are shown in the causal loop diagram. The locations, which are defined with variables, represent the system state element while arrows show the direction of influence between a particular pair of elements. The symbol at the arrowhead in the input and output of a particular element shows the trend of change. For example, if

Gross Domestic Product increases, the Investments in Education and R&D production increases above what it would have been and vice versa, therefore the arrowhead is marked with the "+" symbol. If the Investments in Education and R&D production increases, the Economic volume increases above what it would have been, which is also marked with the "+" symbol. If the Population increases, the Quality of Environment decreases and the cause effect is marked with the "-" symbol. All other causal connections are marked in the same manner. In the simulation process, an expert group in the form of a suggested policy determines key parameters heuristically. The causal loop diagram in Figure 3 represents interactions in the context of regional development and its influence on the regional prosperity and quality of life. The structural analysis of the system is of great significance since mental models of various kinds can be captured using the proposed methodology.

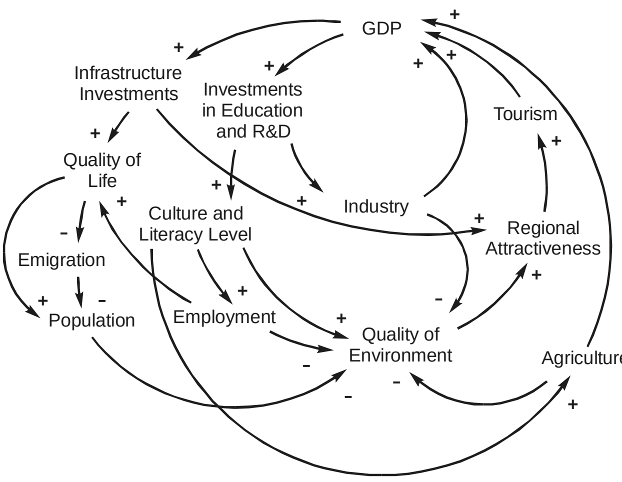

Figure 3: Causal Loop Diagram of The Canary Islands case

After the aggregation of variables i.e. the joining of similarities, the next step is the determination of levels and rates according to system dynamics methodology. Figure 4 represents the population sub-model i.e. X_3 from matrix *C*. Variables are represented by circles and denoted by V_i as defined in matrix *M*, which are interconnected in the form of a directed graph. According to data in matrix *M*, each arrow has its influence marked by a sign +/-. The variables are determined according to System Dynamics methodology as the Levels and the Rates or Auxiliaries marked with *L*, *R* or *A* respectively.

The output from the Population sub-model X_3 is connected to the input of the Ecology subsystem X_2, Finance sub-model X_4 and Economy X_5. In the input, the subsystems of X_1: R&D, X_2: Ecology, X_4: GDP and X_5: Economy influence the Population sub-model.

Figure 5 represents the Finance sub-model, which incorporates the main financial factors for the studied case. The Finance sub-model has an influence on all the other sub-models, which indicates the importance of this sector.

With the proposed methodology the system can be entirely determined by the System Dynamics models,

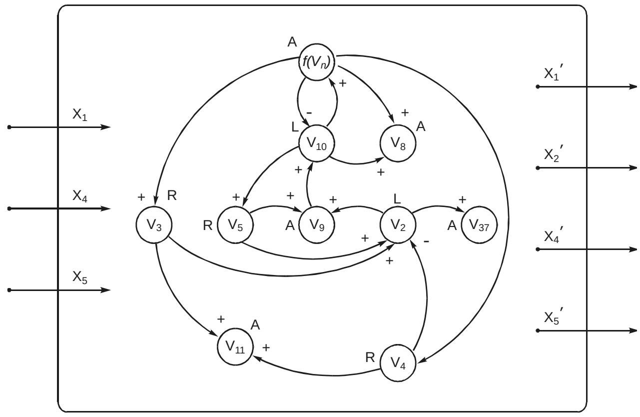

Figure 4: Population sub-model X3 influence diagram

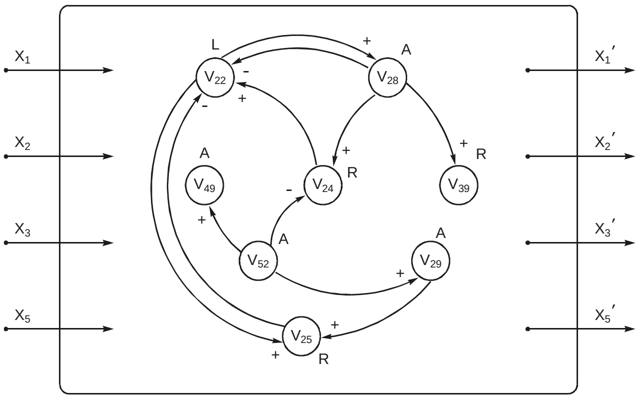

Figure 5: Finance sub-model influence diagram

which form the general simulation model for the regional development of the considered case. Such decomposition allows for a multilevel approach in modeling, which facilitates the process of model validation. System Dynamics simulation models provide a basis for designing more effective industrial and economic systems in terms of material, energy and other aspects such as ecology (Forrester, 1973). The combination of System Dynamics, expert systems and interactive experimentation based on business scenarios aids in the process of creating a regional policy.

A preliminary sub-model was developed for population dynamics, which incorporated 150 parameters. The model enables changes for different population variables, which are relevant for decision makers. Users have the opportunity to actively participate in the decision process by defining relevant criteria and their importance, in spite of the large number of different simulation scenarios. The decision process is clear and creative. The user-friendly interface of the developed simulator in the early stages of the development cycle allows the user to perform the tests easily. Later developments in the field consider group model building (Vennix, 1996) and the application of System Dynamics models (Kljajic et al., 2000b; 2000a). The preliminary model is built using the simulation tool Powersim (www.powersim.com), which provides results for the real application of the organizational strategy. The completed simulation model should enable the testing of different simulation scenarios and alternatives i.e. policies considering certain effects of actions on the environment and population. Simulation also enables the inner view of system behavior for the selected scenario. The System makes it possible to analyze different situations, which is the basis for achieving the consistent formulation of a policy. The building of the model is still in progress.

4 Conclusion and discussion

This contribution describes the concept of using dynamic model building for decision assessment of sustainable development in the Canary Islands. Model development is based on the influence matrix and SD methodology. Nowadays, a strategic and public decision-making model for political planning in the global market is ultimate. Rapid development of information technology and the Internet significantly contribute to the globalization of markets and idea sharing. A typical branch of economy that is influenced by such changes is tourism. Tourism subsystems are strongly inter-connected enabling them on one hand to smoothly obtain the world market while on the other hand to create turbulence in the world market with the demand for flexibility and quick reactions from the entire service industry. Tourism organizations, which are of significant importance in our case, belong to inter-organizational systems with global and local properties. Problems are softly defined and phenomena uncertain. Policy makers, who have the task of providing sustainable development, are requested to make fast and integral decisions and are responsible for the satisfaction of citizens. Thus, there is an urgent need for a methodology approach for the presented problem (Kljajić 2000b; Kljajić & Lazanski, 2001). There are many different methodologies and methods, which try to master soft-structured problems. Here we meet the methods and tools of System Dynamics and system thinking, which became common tools of management in the 90s. These tools were first brought into force in the learning and training area in the form of different computer games and later as tools for decision-making and systems re-engineering. Decisions, which include wide financial, technical, logistic and environmental resources, demand the decisions' simulation before they go into action in a form of policy realization (Kljajić, et al., 2000a). With all organizational systems, human skills and creativity play an important role in efficient problem solving. Therefore, teamwork has to be included in the decision process for achieving the satisfactory solution. Implementation of a group decision support system enables participants the testing of different simulation scenarios and the sharing of common views regarding a problem. Following this, the indirect effect of testing policies is understood in an environment, which is less risky prior to the actual implementation of regional policy (Legna, 2000). On the outline one can find the polarity of the loop and estimate the qualitative trend of system behavior. The business system simulator will be the base for the assessment of strategy development. The simulator will be connected to a Group Support System (GSS) as well as the database so that an expert group can analyze each scenario. In this way the dynamics of a business system can be better understood. Simulation results are evaluated with the help of group decision support systems and with expert systems. The model and its sub-models are in the phase of structural validation and relevant parameter values determination.

5 Acknowledgement

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Development of Simulation Model of the Canary Islands for Strategic Decision Making

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Razvoj simulacijskega modela Kanarskih otokov za strateško odločanje

Prispevek obravnava razvoj modela sistemske dinamike za podporo odločanju na strateškem nivoju pri razvoju Kanarskih otokov. Kvantitativno modeliranje zajema relevantne spremenljivke, ki vplivajo na trajnostni razvoj in kvaliteto življenja na Kanarskih otokih. Relacije med ključnimi spremenljivkami so bile formalno opredeljene s pomočjo matrike vpliva. Opredeljen je bil vzročno posledični diagram, ki določa povezavo med elementi matrike. Analizirani so bili pod-modeli populacije, turističnega trga, kmetijstva, okolja ter BDP. Programsko orodje Powersim je bilo uporabljeno pri simulaciji modela. Analiziranih ter opisanih je več simulacijskih scenarijev z odzivi. Trenutno je model v fazi validacije. Začetni rezultati obetajo pozitivne validacijski izid.

Ključne besede: sistemska dinamika, simulacija, model, sistem za podporo odločanju, trajnostni razvoj, turizem

1 Introduction

In our previous work (Kljajić et al, 2002) we have described the model of the Canary Islands for development and decision support. Initially, the model consisted of 52 variables defined by the influence matrix **M** representing the size of 52x52 (Legna & Riveros, 2001). Each value of the interaction was scored between zero and five according to its impact on regional development. On the basis of the graph theory, the matrix was reduced and decomposed to sub-models (Kljajić et al, 2002). In this paper the integral simulation model of the Canary Islands for public decision support will be described. Several scenarios of future developments will be studied which consider strategic public decisions. The developed model should be viewed as decision support on the strategic level. The systematic solution, which incorporates the developed model, tends to diminish the uncertainty that affects the decision processes in the region. Such an approach is not new; Forrester's World model č Forrester (1971); Meadows et al. (1991); Mesarovic & Pastel (1984), but is seldom applied in regional planning. The starting point of our work was a thorough examination of the problem stated through the means of the influence matrix, which is described in our previous work (Legna % Ceballos, 2001; Kljajić et al.; 2002, Kljajić et al, 2000). The influence matrix was the source of information in the model building process. It contained the most important variables and the information regarding interactions between them as noted by the decision makers. The applied methodology of decomposition enabled us to divide the model to sub-models in order to assure the transparency of model validation. Simulation scenarios were prepared to study the possible strategic development of the region. The key variables that strongly influence the economic system development are considered as: Population, education level of the population, agriculture and industry production, tourism market, infrastructure and the environment. Scenarios that describe possible future development of the region are analyzed in order to achieve proper policy change, which should result in the improvement of the economic system. At present preliminary results for three basic scenarios were obtained in order to model validation. It must be stressed that the main effort in model building and evaluation were performed through e-mail communications therefore some achievements will be revised and improved.

2 The model of the Canary Islands

Figure 1 shows the CLD with the main variables for the Canary Islands case. There are five main feedback loops marked in the diagram, three reinforcing and two balancing. The positive loop, which interconnects GDP, Development Policy and the Tourism Market, represents the development cycle of the economy, which tends to grow. The second positive feedback loop from GDP, Development Policy, Agriculture and Industry Production also has positive characteristics, which lead to enhanced industrial and agriculture production. There is also the positive feedback loop, which includes the Tourism Market, Employment Opportunities and Quality of Life, Immigration, Population, Human resources, Agriculture and Industry. This reinforcing loop represents development, which incorporates population, employment opportunities and immigration. The model is balanced by the negative feedback loop, which considers the Tourism Market, Preservation of Natural Resources and Regional Attractiveness. Although the system tends to increase the Tourism Market on the Islands, the process is moderated by the environmental attractiveness, which is diminished by the overcrowding of the region. Similar negative effects are represented by the loop, which interconnects Agriculture Production and Preservation of Natural Resources. An important negative feedback loop is also present between the GDP, Population and the Preservation of Natural Resources. Therefore the CLD model highlights the main variables, which determine the development of the Canary Islands region. On one side, there are three positive loops, which represent the technological development in the field of Tourism and Agriculture and on the other side, two negative loops that consider environmental preservation. The proper balance between the loops should result in sustainable development of the region. More detailed examination of the variables was presented in our previous work (Kljajić et al., 2002).

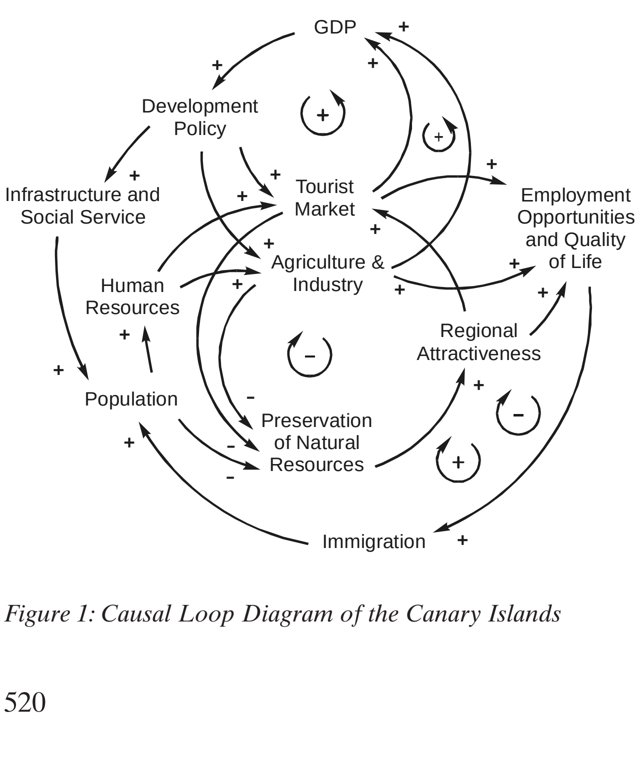

Figure 1: Causal Loop Diagram of the Canary Islands

Tourism as the main economic entity determines the activity of the production sector and increases employment. However the development of tourism increases the negative environmental impacts such as infrastructure building and increased agricultural production. Natural resources are the main factor in the development model of the Canary Islands. These resources are under certain stress and should be preserved in order to formulate a sustainable development policy. The negative impact is identified by two processes:

- increased tourism and infrastructure building diminish the quality of agricultural and urban land
- agricultural technology and industry have a great negative impact on the environment and water resources

Consequently, the system considered reduces its own economic resources and the quality of life. Therefore, the developmental model of the region should be changed.

This model takes into consideration the following main sub models, which are described as: Population, Tourism, Agriculture, Environment and GDP. The complete model consists of 171 variables and parameters, realized in the Powersim™.

2.1 Population sub-model

Figure 3 represents the population sub-model where the population is divided into three categories: the population under the age of 16 (minors), the active population between 16 and 65 and the elderly, over 65. The total number of residents on the Islands is approximately 1.8 million. The main variables that characterize the dynamics of the population are the birth rate coefficient, mortality coefficient and immigration. The Canary Islands acreage is 7447 km^2. The demographic density is 240 people/ km^2. The demographic density of Spain, for example, is 80 people/ km^2. If we include the "dynamic" population of about 10 million tourists that visit the Canary Islands every year we can see, that the area demographic density is relatively high. Besides the high demographic density it should be mentioned, that the population is relatively young in comparison to other regions of Spain. The population is rapidly increasing due to the high birth ratio. In Spain, 44 % of the population is younger than 30, while on the Canary Islands, this ratio is 51%. The mortality is lower than the Spanish average therefore the parameters for population growth is certainly met.

2.2 Tourism sub-model

Tourism is the main economic activity of the region. Figure 5 represents the Tourism sub-model, which incorporates the number of tourists that are residing in the Canary Islands. The tourist population is influenced by their arrivals and departures. The income from tourism is determined by the number of tourists, the service price and the GDP of the tourists' country of origin. The number of tourists that arrive to the Canary Islands in one year is de-

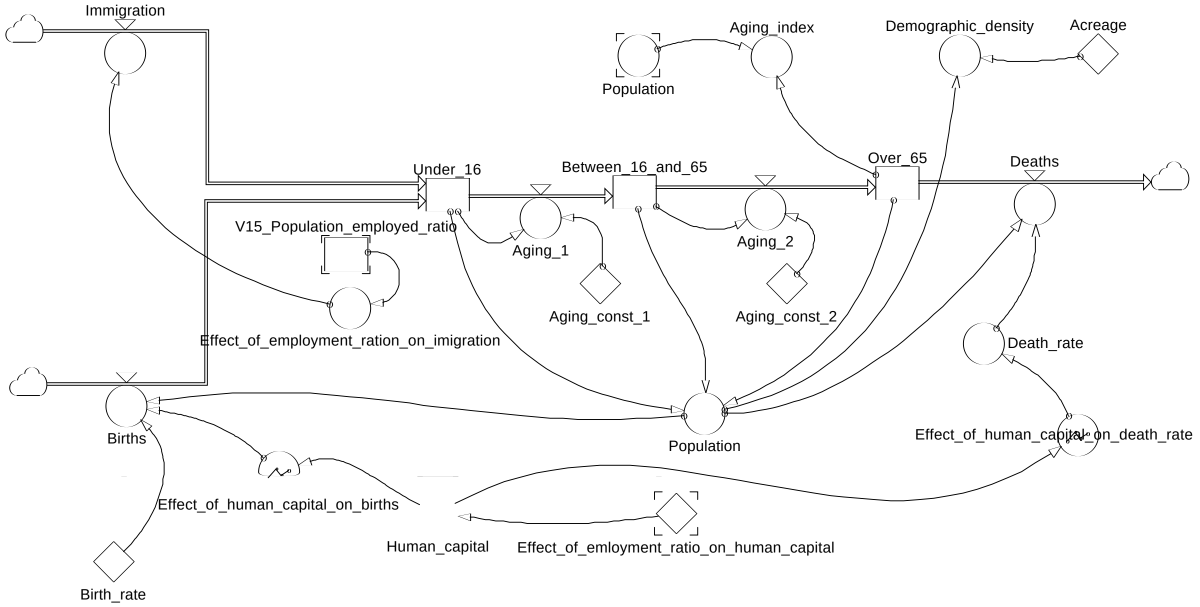

Figure 2: Population sub-model

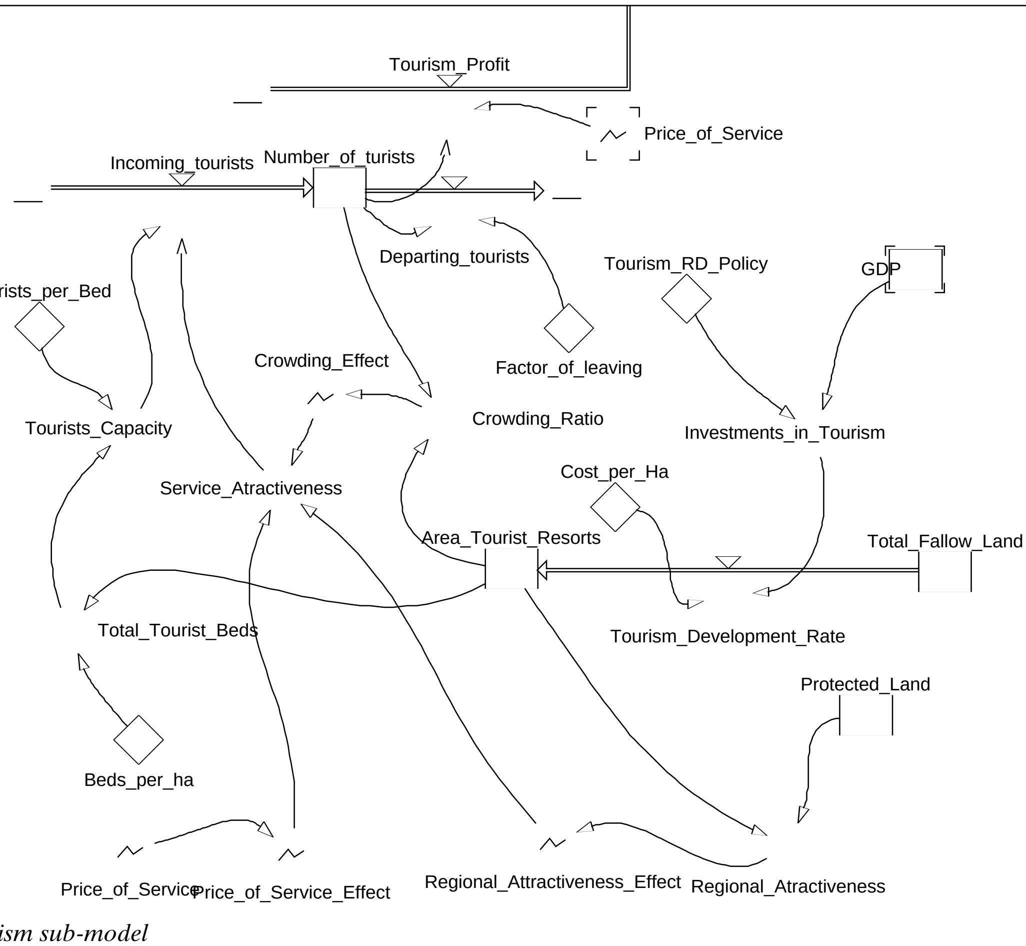

Figure 3: Tourism sub-model

pendant on the tourist capacities and the attractiveness of the service. The capacity to house the tourists determines the number of arrivals. There are approximately 350,000 beds available. Service attractiveness depends on the service price, environmental attractiveness and demographic density of tourist resorts. The GDP is mainly dependant on the number of tourists that arrive to the islands each year. Increased income causes additional investments in the tourism infrastructure. This negatively affects the environmental attractiveness, which negatively influences the number of tourists. There is also the negative effect of crowding by the increasing number of residing tourists.

The important factor is the ratio of the GDP that is relative to the R&D in the field of tourism. It is anticipated, that the price of service would remain the same with reduced costs and environmental pollution. This should increase the funding of further research, which is indicated as the positive feedback loop. The improved preservation of the environment results in the increase of environmental attractiveness and consequently in growing interest from potential tourists.

Regional Attractiveness depends on the acreage of Tourist Resorts and Protected Land. This is transformed by the arbitrary function to the Regional Attractiveness Effect, which determines the Service attractiveness. The Regional Attractiveness Effect is normalized and the output value of the function is transformed to the interval Š0, 1Ć. This is one of the possibilities to formulate the Attractiveness factor in the model. In our case there should be equilibrium between the Protected Land by which the tourists are mostly attracted and the Tourist Resorts, which have to be provided in order to accommodate the tourists.

2.3 Agriculture sub model

Agriculture is the traditional economic branch in the Canary Islands. The crops are produced for domestic as well as for the export market. The land is fertile but the region is exposed to aridness. The main crops are bananas, tomatoes, sugar cane and tobacco. Fishing is also an important activity. Agriculture in general offers a small contribution to the GDP however the impact of agriculture on the environment and natural resources is rather significant. Agricultural production is dependant on the price of crops. Production is relative to the high cost of watering the fields. The cost for the water is dependant on the demand. The model also considers the application of the techniques used in agriculture. The greater proportion of the GDP intended for R&D should positively impact land exploitation, which influences the income and GDP. Here we can indicate the positive feedback loop, which leads to better agricultural land exploitation.

The following tendency of development can be estimated for agricultural production:

i. The stagnation of agricultural production combined with the continuous use of techniques degrades the environment and cause low productivity. A significant number of non-competitive productions require subsidization.

ii. The increase in agricultural production market value due to the augmentation of productivity and the appropriate selection of products to be produced by this sector (eliminating low productivity branches). This increase is combined with the reduction of the damaging effects of some agricultural products on the environment and water consumption.

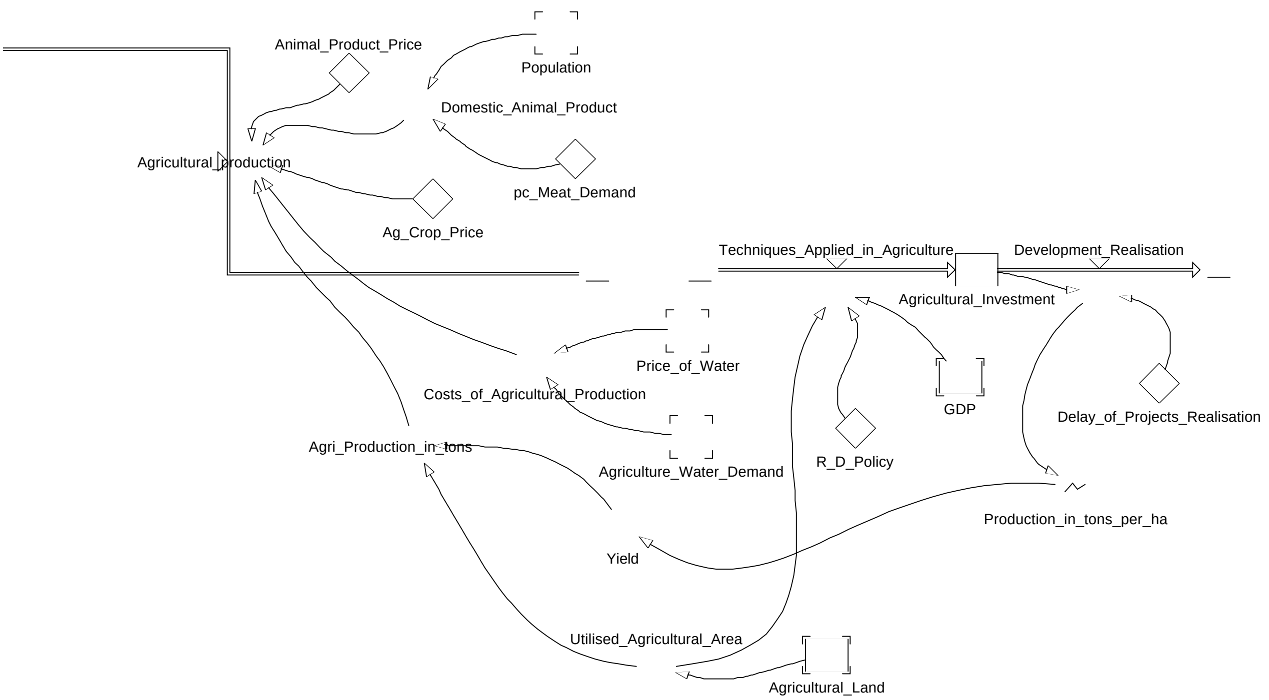

Figure 4: Agriculture sub model

2.4 Ecology sub model

Figure 8 shows the environment sub-model, which incorporates the following levels: Tourist Resorts, Fallow Land, Agricultural Land, Urban Land and Protected Land. Fallow land is estimated at 338,000 ha and decreases yearly. 12, 000 ha are exploited as tourist resorts. The proportion of land that is devoted to tourism increases each year. This is mainly influenced by the GDP, which determines the investments in tourism infrastructure building. In future years, ¾ of the total investments in Spain will be designated for the Canary Islands. The agricultural land is estimated to be 100,000 ha, however only ½ of the land has been efficiently exploited. Agricultural land is diminishing on account of the population growth. The size of the agricultural land is dependant on the GDP that is dedicated to the development of the rural area and the costs that are related to those improvements. 40% of the total acreage has the status of protected territory. The laws of natural areas, which were set in 1992, govern the protection. A large portion of the land which was initially intended for tourism infrastructure is now under protection (Cipriano, 2000). The size of urban land is 100,000 ha. Due to the increasing population, the size of urban land is increasing. This portion is also dependant on the GDP, which influences the development of the urban infrastructure. The variable Environmental Attractiveness has a significant impact on service attractiveness and the number of tourists. The factor is dependant on the size of the natural environment, agricultural land, urban land and tourist resorts. Due to the shrinking natural environment this factor is slowly decreasing. From a strategic point of view, the conclusions are quite interesting:

i. The increase of revenue and the services generated by the tourist sector are crucial, because they are important factors in determining the rates of increase in employment, the GDP and the revenue of the Canarian population.
ii. This increase in tourism and the related activities will have a "ceiling" in the future, due to the degradation of the environment and the crowding effect.
iii. Consequently, in order to achieve sustainable economic development and development in the quality of life of the Canarian society, protecting environmental quality and reducing the Crowding effect of tourists that arrive to the Islands are necessary.
iv. In particular, the protection and improvement of the environment require urban and agricultural land planning (including the control of land degradation and using appropriate agricultural techniques).

2.5 GDP sub model

There are several measurements that are applied to determine economic activity. One of the most common is Gross Domestic Product (GDP) which measures the value of all produced goods and services in a certain economic system for the given period; usually for the period of one year. GDP is represented as the level in Figure 10, which is dependant on Industrial Production, Construction Sector Production, Tourism Income, and Agricultural Production. The GDP is also dependant on Government Expenditures, Investments and Trade, which are determined as the difference between exports and imports. In our case, the trade balance is negative i.e. imports are greater than exports. The main trading partners are France, Germany and Italy. The economic growth of the Canary Islands (3.5%) is higher than the Spanish average and has consistently increased over the last 15 years. GDP per capita is 14,000.00 USD and above 75% of the European average. Economic growth is shadowed by the population growth due to immigration (Consejeria de Economia 2003). The economic growth of the region is greater than other regions of the European Community, which can be observed in Table 1 where the main macro-economic parameters for the year 1999 are shown.

The services and construction sectors are the main cause of economic growth, which can be seen in Table 2.

The tourism sector is the most important economic activity on the Canary Islands as the income from tourism represents 80% of the GDP. Due to the importance of tourism income this sector is studied in detail and mode-

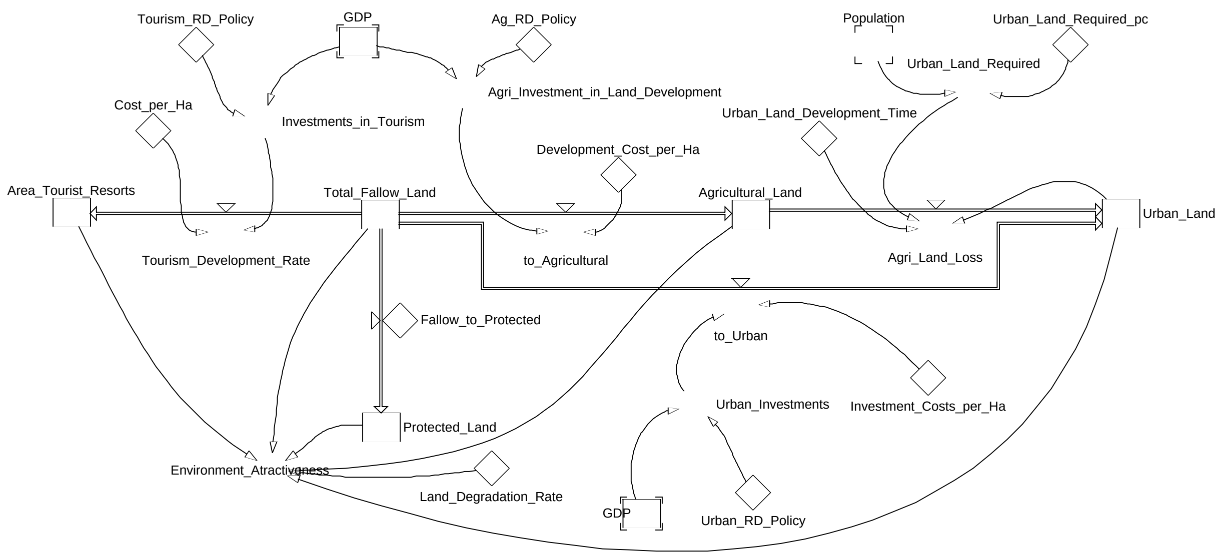

Figure 5: Environment sub model

Table 1: Main Macro-Economic Parameters for 1999

% ->	GDP	Import	Price index	Unemployment
EC	2.30	3.00	1.30	9.20
Canary	4.58	7.10	2.40	14.53
Spain	4.24	8.50	2.90	15.85

Table 2: Sector growth for the Canary Islands for 1999

	% real growth
Primary sector	-5.10
Industry	3.60
Construction sector	13.20
Services sector	4.30

led as described in section 2.2. The Construction sector has been significantly developed in the past few years mainly on account of infrastructure investments. Income from the production sector represents 8% of the GDP. Similarly, the industrial sector also represents 8% of the GDP, however it is decreasing. Canary Islands industry consists of enterprise branches that manage the two important strategic resources on the islands: water and energy. Production for the domestic market is very important. The development of the industry has certain constraints such as the limitation of natural resources, remoteness of the region, and high transportation costs between the islands. There is also a problem with human resources, which are needed for the innovative development of the sector. Agricultural production is estimated at 4% of the GDP.

3 Test simulation – initial model validation

There is no general theory of model validation or the model building of a complex open system. Based on the problem being studied, we can usually deduce: the definition of the task, the criteria, the model in relation to the system's variables and its environments etc. However, the essence of each complex simulation model can be found in its validation. There are several heuristic approaches in model validation derived from model philosophy of model building: structural, functional, replicate, predictive etc. Data such as the initial condition of variables, parameter values, and functional dependence among variables are usually very difficult conditions that have to be met

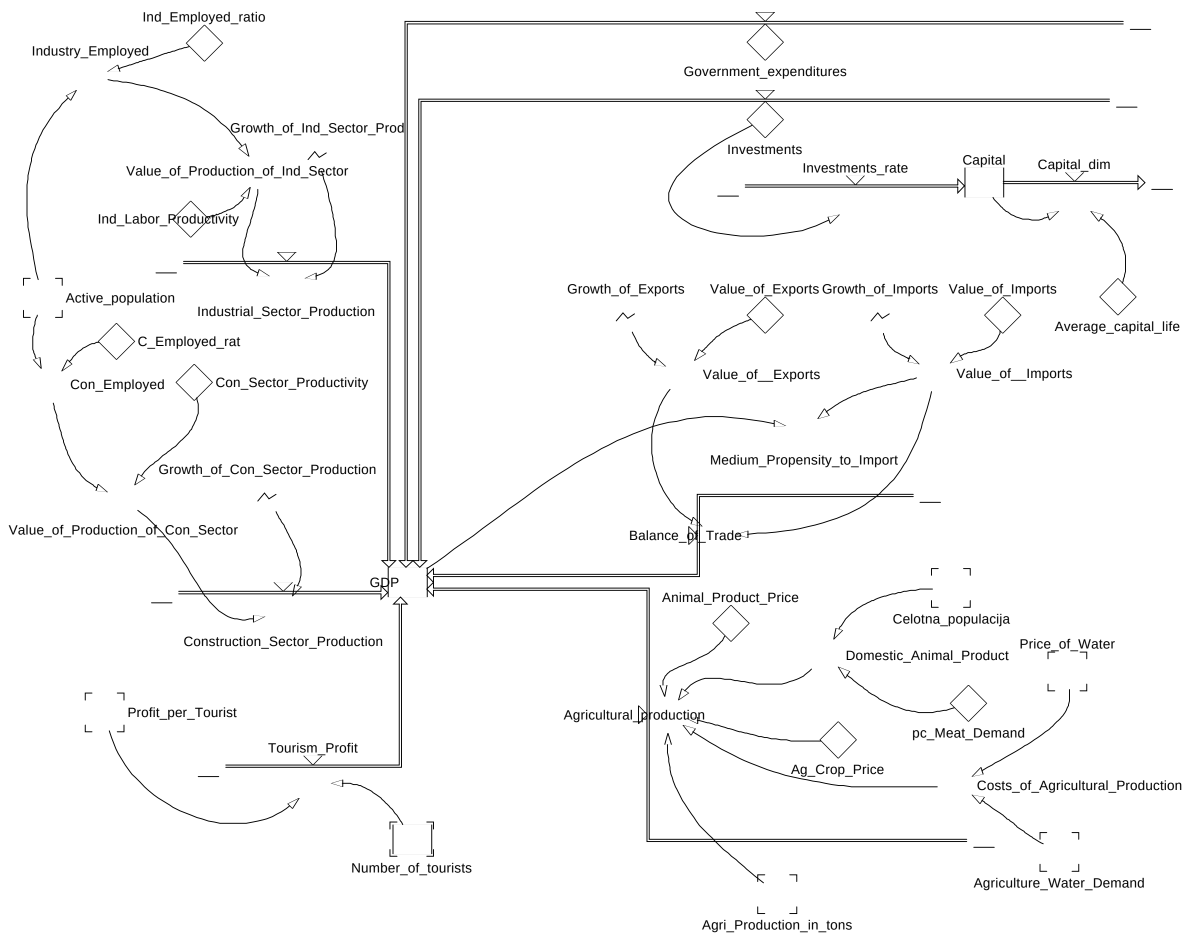

Figure 6: Sub-model of GDP – economic view

for good simulation. Usually each phase of model validation is interactive and interdependent (Forrester, 1973). In our case, structural and logical validation was described in our previous work in Palermo (Kljajić et al., 2002). For further validation and confidence in the implemented model in Powersim™ we tested its behavior in relation to the behavior we expected in the near future on the basis of the what-if philosophy. Therefore, we developed two simple scenarios regarding possible population trends. In the first part of this section we will describe some basic scenarios which represent the starting point of the proper policy design which would lead us to a goal: better quality of life and sustainable development of the region. Sustainable development fulfills the needs of the present, which do not threaten the ability of future generations to fulfill their needs. Sustainable development should be based on:

- social development which incorporates the needs of each individual
- effective environment preservation
- reasonable exploitation of the natural resources
- preserving high and stable economic growth.

The following two scenarios considering population dynamics were tested:

1. The growth of the population remains consistent for the following 25 years. This is likely to occur if there are no other external forces to influence the birth coefficient. The expected exponential growth should result in the higher number of inhabitants causing overcrowding and negative impact to the environment.
2. The growth of the population is controlled and moderately reduced in order to achieve the stable population numbers. This should contribute to the preservation of the Islands from population overcrowding, which negatively impacts the environment and further development, which is interconnected through the tourism market.

Figure 7 represents these two possible scenarios of population growth. The curve labeled 1 represents the scenario where the birth coefficient remains the same for the next 25 years. As we can see, this causes exponential growth. With the increasing number of inhabitants, sustainable development is much harder to provide. The quality of life under this scenario will also decrease. In our second scenario, labeled 2, the birth rate is considered to be moderately decreasing over the next 25 years. By decreasing the birth rate coefficient the rate of births and deaths should be equal at the end of the 25 year period. This is the condition where the population is stabilizing. Growth in the second scenario is more moderate.

Therefore, the following trajectories depict the possible population:

i). Population permanently (and population density) increases, with a low birth rate and a high immigration rate. In this case, the main cause of population augmentation is immigration. In turn, this immigration may be classified in two categories: a) older people who are on retreat and come to the Canary Islands to profit from its climate and environment (generally Europeans); or b) people classified in the working age (between 16 and 65). This trajectory refers to situations where the aging of the population pyramid is very strong.

ii). The zero or negative increase of the total population, due to the combination of a low birth rate with low immigration.

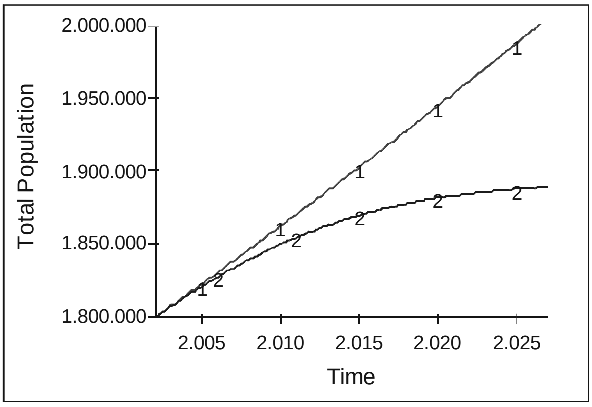

Figure 7: Total Population 1 ~ Constant Birth Coefficient, 2 ~ Decreasing Birth Coefficient

Population pyramid dynamics can be observed in Figure 14. The diagram on the left shows the result when the birth coefficient is constant and the diagram on the right represents the dynamics where the coefficient is decreasing. This is another key theme, from the perspective of strategic decision making for the Canarian future. According to the projections of the first scenario, the population in the “working age” (16-65 years old) will be stable during the following 20-25 years; the population of older people will increase. At the same time, the population of youth will decrease. An important conclusion is made: the increase of the total population is not due to the increase in the working age population. On the contrary, the factor of its augment is the growth of the older population. If this is so, the offer of quality labor is not substantially affected by the increase in population. This conclusion is stronger in other scenarios. In any case, if these projections are correct, the increase of the GDP will need, as a necessary condition, an augment in labor productivity. This need will be accentuated more in the case of the second scenario. The change of the population pyramid structure, toward an older one, affects the demand of public and private services. The quality and the quantity of public services such as education, health and urban services need to be adapted to the new structure of population. That is to say, the public sector ought to design and implement strategic plans in these sectors, taking into account the new conditions. The same points apply to some private sectors such as tourism, personal services (paramedical, cultural services, house keeping, and so on). Interestingly, at the same time, these new conditions present a possibility, an opportunity, and an open “window” for the development of different and more qualified jobs in the work market.

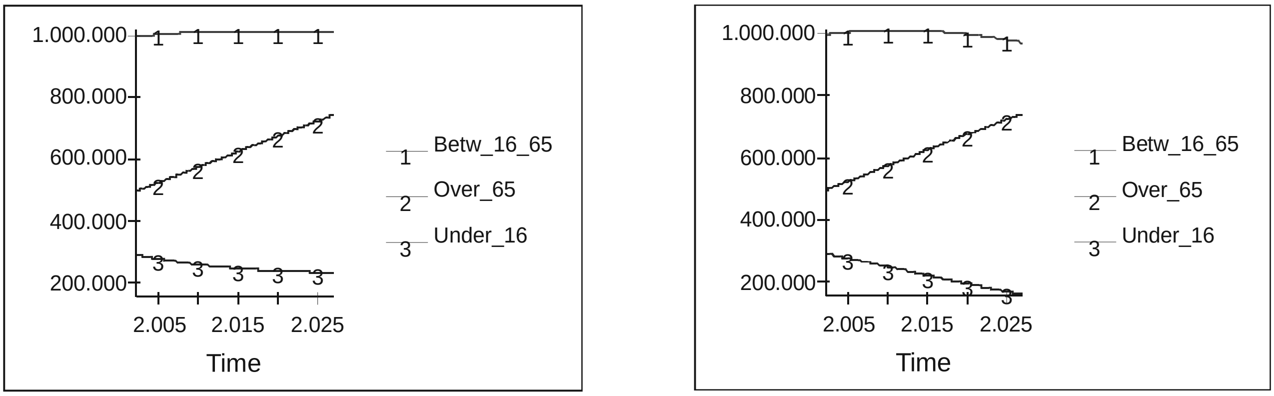

Figure 8: Population pyramid dynamics; left ~ Constant Birth Coefficient, right ~ Decreasing Birth Coefficient

By changing the birth ratio the demographic density has also changed which is represented in Figure 9. In the year 2025 the demographic density of the Canary Islands would be 398.25 per square km.

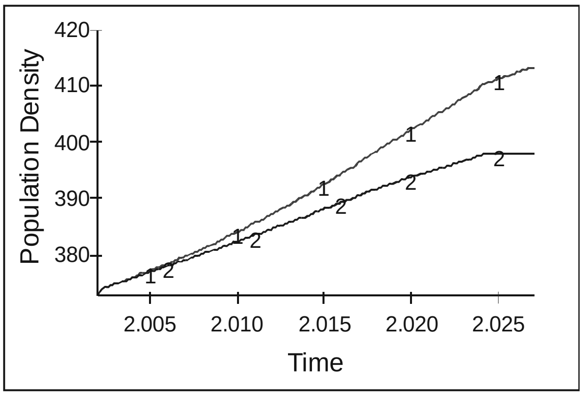

Figure 9: Population density; 1 ~ Constant Birth Coefficient, 2 ~ Decreasing Birth Coefficient

Changing the birth ratio coefficient in the model is something completely different from changing the coefficient in the real case. One of the more applicable solutions would be to limit immigration, which would also raise the population.

Figure 10 represents the effect of a decreased birth coefficient on the cost of water. The demand in scenario 2, where the population is sustained, would result in a lower cost of water due to lower demand. It is reasonable to suppose that water demand will increase in the future, due to augmentation of the population and economic activities. Thus, the strategic variables for the Canarian sustainable development are the following: “waste water reuse”, efficient use of “ground water”, “desalination” and reduction of water waste.

In the seventies there was a growth in infrastructure development of tourism objects . Today, the construction of the tourist infrastructure is still the leading force of the growth in tourism with its negative impact on the environment. To achieve sustainable development the balance between different economic, environmental and social goals have to be met. The alternative for mass tourism should not be eko-tourism or rural tourism. We have to consider that 11 million tourists visit the Islands each year. Eko-tourism in such numbers would mean an additional threat to the environment. Such tourism would need a new infrastructure, which would negatively impact the preserved environment. One of the possible scenarios would be the moderation of investments in the tourist infrastructure. In the original scenario the 0.001 % of the GDP was invested in infrastructure construction. If this investment would be moderated or stopped, the response of the number of tourists would be as seen in Figure 20. If the construction of infrastructure will stop, then the number of tourists would fall under 11 million (curve 1). That is 10% less than in the basic scenario, where the number of tourists rises well above 12 million.

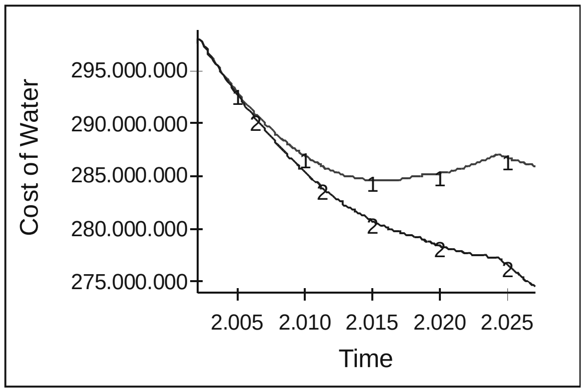

Figure 10: Cost of Water; 1 ~ Constant Birth Coefficient, 2 ~ Decreasing Birth Coefficient

The following trajectories regarding tourism could be identified:

i. A decline in total tourism near 2020-25 due to the degradation of the environment, the crowding effect, the augmentation of the price of water and the reduction of regional attractiveness. These declines will lead to the reduction of activity in the services, construction and industrial sectors and the GDP rate and consequently, an augmentation of the unemployment rate.
ii. A constant increase in massive tourism combined with the degradation of the environment, the crowding effect, augmentation of the price of water and the reduction of regional attractiveness.

iii. The maintenance of total tourism combined with: an improvement in the environment and quality of life; and a type of tourism more interested in qualified services that produce multiplying effects on other sectors such as education, health, environment, etc. In this case, population density problems are lower than in the precedent case.

iv. A slow reduction of total tourism (particularly mass tourism) combined with: an improvement in the environment and the quality of life; and a type of tourism more interested in qualified services that produce multiplying effects on other sectors such as education, health, environment, etc. In this case, population density problems are lower than in the precedent case.

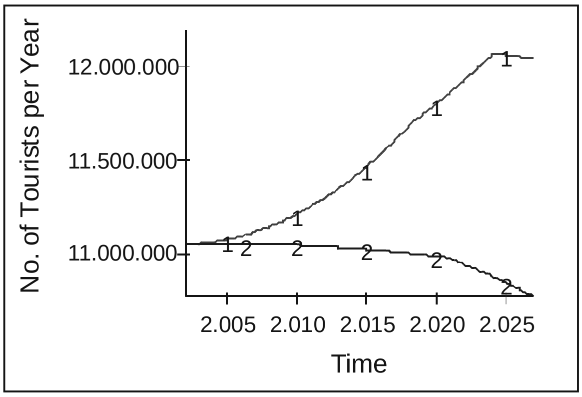

Figure 11: Number of Tourists per Year; 1 ~ investments continue, 2 ~ moderated investments

Figure 12 shows the demographic density in the case where investments in infrastructure are moderated (curve 3). We can observe that on account of the lower number of tourists residing in the region, the demographic density has fallen which contributes to the higher quality of the environment.

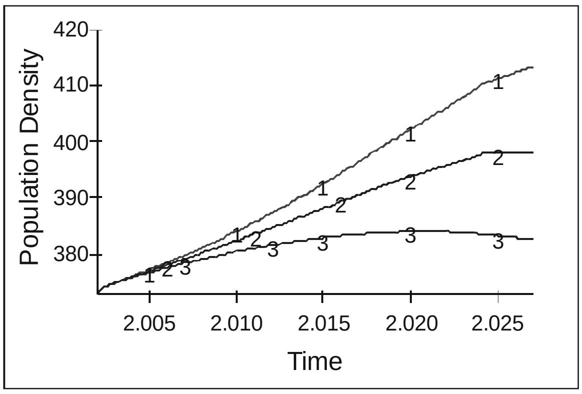

Figure 12: Demographic density; 1 ~ constant birth coefficient, basic scenario, 2 ~ decreasing birth coefficient and 3 ~ moderation of investments

Figure 13 shows the effect of the moderation of investments on Environment Attractiveness. As already mentioned, the attractiveness is higher if the building of new capacities is moderated (curve 2).

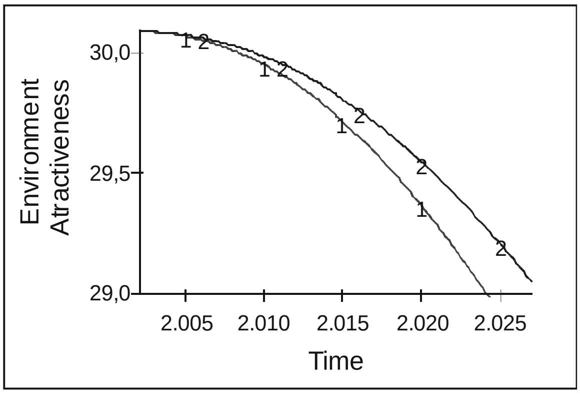

Figure 13: Environment Attractiveness 1 ~ continuation of investments, 2 ~ moderation of investments

According to our projections, various scenarios are possible in the future. From the perspective of the strategic and policy elaboration it is useful to outline the main characteristics of the more probable ones. We should follow the following methodological approach to build them: a) first of all, we identify the probable trajectory of some key variables, taking projections into account; b) secondly, combine them (for instance, one population trend, one of the tourist sectors, another of the industrial sectors, etc.). Each combination (scenario) ought to be internally coherent, in the sense that it is not admitted as a scenario that includes, for instance, two contradictory trends, as the increase of tourists interested in the environment and an economic model that destroy it. Each scenario has its internal logic. In the following section we will name each scenario according to this logic.

4 Future scenario preparation

In the preceding sections we have examined several possibilities of further development of the Canaries. According to the study of the dynamics of the key variables, several scenarios are formulated and should be tested in our future work.

By mixing the different trajectories of the five precedent categories it is possible to build 96 scenarios. But it does not make sense to construct all the mathematically possible combinations because some are not consistent with regard to the Canarian social system. A more practical way is to choose some logics and to build the scenarios according to them. With this approach we built the following scenarios.

Scenario 1. A non-innovative society, with a population and political leaders who are not really concerned with the environment and sustainable development. The importance of the immigration of elders and the constant increase of the total population. This scenario mixes trends of permanent population increase, the decline of tourism due to environmental degradation, stagnation of the agricultural sector and persistence of non-innovative SMEs. It is not sustainable in the long term, because the crisis in tourism (and other activities boosted by it) and the degradation of the environment will reduce the immigration of elders. This contraction will reinforce the economic crisis and the increase in unemployment. The economic crisis will most likely be accompanied by social unrest and political troubles.

Scenario 2. A non-innovative society, with a population and political leaders who are not really concerned with the environment and sustainable development. Importance of immigration of the population in the working age. A permanent increase of the total population. This scenario is the same as the precedent, except that in the projection the aging of he population is lower. In this scenario the crisis will be more evident and stronger in the work market. In the medium and long term the degradation of the environment, the unemployment and social unrest will feed back between them.

Scenario 3. An innovative society, with where the population and political leaders arer really concerned with the environment and sustainable development. There is a great weight of elders in the population pyramid. There is a permanent increase in the total population. This scenario mixes trends of permanent population increase, the slow reduction of total tourism, the increase in agricultural production due to the increased productivity and augmentation of innovative SMEs. It is sustainable in medium terms, because there will not be a crisis in tourism (and other activities will be boosted by it) and the environment will not be destroyed. There will be opportunities to increase the quality of employment due to innovative activities and the demand of elders. Nevertheless, this scenario is not sustainable in the long term, because the increase of the population can't go on indefinitely. This scenario will be transformed into another one, as number 5 or 6.

Scenario 4. An innovative society, with a population and political leaders who are really concerned with the environment and sustainable development. The weight of the population is in the working age, due to immigration. There is a permanent increase in the total population. This scenario differs from the precedent only because the tendency of permanent population growth is replaced by a lower population-ageing factor. The sustainability in medium terms depends on the equilibrium in the work market and on the profiles of the immigrants. As the precedent, it is not sustainable in the long term because the increase in the population can't go on indefinitely. However, this scenario will be transformed into another one such as number 5 and 6.

Scenario 5. A non-innovative society, with a population and political leaders who are not really concerned with the environment and sustainable development. Immigration of elders is important. There is a decrease or constancy of the total population. This scenario differs from number 1 only because the population development is held so that there is a zero increase in population. It is one of the worst scenarios for the long term, because the reduction of immigration will be due to the crisis in tourism (and other activities will be boosted by it), the degradation of the environment and social unrest. A similar and undesirable scenario may be built on the basis of scenario number 2. It is important to observe that these two scenarios are not improbable because some political leaders have emphasized the importance of economic development in the short and medium term, without considering its impact on the environment.

Scenario 6. An innovative society, with a population and political leaders who really are concerned with the environment and sustainable development. The weight of the population is in the working age, due to immigration, but the rate of immigration is lower than in scenario 4. There is a decrease or constancy of the total population. This scenario differs from number 4 in the fact that the total population does not increase indefinitely, because the immigration rate is lower. With this scenario the sustainability of the improvement of the quality of life (that includes an increase in revenues, a low unemployment rate, high wages and an enjoyable environment) is possible. It is not the only scenario that may be built to assure the sustainable development of the quality of life. Another one may be constructed on the basis of scenario 3.

5 Conclusion and discussion

The development of the model from the influence matrix was a demanding task. The model itself represents a valuable tool for considering the strategic decisions of regional development. Several presented scenarios are the starting point for further investigation of possible strategic acts. The result of our study is the determination of 96 possible scenarios, which have to be examined in future work.

The scenarios throw light over future possible ways of societal development. None are pre-determined. The concrete way society will adopt changes depends on external factors and, more importantly, on the behavior of its population and leaders. In order to lead the social Canarian system towards a certain path it is necessary, first of all, to design and chose the path (let's say, for instance, one of the possible future scenarios), and to plan and implement the appropriate strategy and policies. An example of them is presented in Legna (2002). Future testing and improvements of models and scenarios are conditio sine qua non for development of a simulation system for decision assessment of public decision.

6 Acknowledgement

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Short biographies of the three autors are published on page 518.

An Intelligent Decision Support System (IDSS) for Public Decisions Using System Dynamics and Case Based Reasoning (CBR)

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Inteligentni sistem za podporo odločanju v javnem sektorju na osnovi sistemske dinamike in študije primerov

Prispevek predstavlja snovanje in razvoj IDSS, ki omogoča odločevalcem identifikacijo ključnih dejavnikov, ki vplivajo na prihodnji razvoj družbenega sistema kot pomoč pri izboljšavi oblikovanja razvojne politike. Implementacija sistema je trenutno v teku tako, da prispevek obravnava dosedanje dosežke na tem področju. Metodološki pristop je kombinacija umetne inteligence s kvalitativnimi modeli ter simulacijo po principu sistemske dinamike. Pomemben faktor pri izbiri strategij in razvoj politike na področju kompleksnih družbenih sistemov je vpliv nabora spremenljivk, ki niso kvantificirane. Zaradi tega je bil zgrajen model, ki omogoča obravnavo tovrstnih spremenljivk. Predlagana je metodologija, ki je sestavljena iz treh faz. V prvi fazi je zgrajen model za simulacijo dinamike sistema ter oblikovanja scenarijev. Pri tem služi model ot analitično orodje. Omenjena faza omogoča določitev ključnih spremenljivk ter dejstev. Rezultati, ki so pridobljeni s pomočjo simulacije, so arhivirani v podatkovni bazi ter uporabljeni kot vhod v proces logične obravnave. Tako predstavljajo rezultati izhodiščno točko za drugo fazo. V tej fazi uporabljamo tehniko CBR (Case Based Reasoning), kjer je določen primer definiran z naborom norm oz. skupnih atributov, primerov in indeksov (atributi za diskriminacijo primerov), problema, rešitve ter razlage. Različne vrednosti omenjenih atributov predstavljajo nov primer. Zadnja faza ima za rezultat različne rešitve, ki omogočajo odločevalcu razlago o dejstvih, ki govorijo v prid ter proti posamezni alternativi. V primeru, da nobena od predlaganih alternativ ni sprejemljiva s strani uporabnikov IDSS, lahko le-ti vključijo nove rešitve, ki so po njihovem mnenju sprejemljive. Pomembno dejstvo je, da IDSS omogoča konsistentno vodenje ter spodbuja konsenz pri odločevalcih.

Ključne besede: sistem za podporo odločanju, situacijsko orientirani logični proces, odločitev, javni sektor, strateško odločanje

1 Introduction

At present, we are working on the design of an IDSS to help the strategic decision in the public sector and semi-public organizations in the Canary Islands, in order to establish a new development model. The model consolidated up to the present has serious problems to assure a sustainable and equitable development of the quality of life of the regional population. In previous works we have treated these problems (Legna 2000; 2001; 2002; Kljajic et al. 2002; 2003a; 2003b), and in this paper we are centered in the design of an intelligent tool to support Strategic Public Decisions (SPD) and the achievement of consensus between the main social actors. This paper resumes our line of researches and works with public or semi-public organizations (as Canary Islands Government, Spain European Trade Unions Confederation and Canarian Trade Unions).

The IDSS allows the representation of a large number of variables of the Canary Islands model, their interdependences and the heuristic knowledge of the processes. Also, it is useful to analyze the behavior of the social system through multiple possible scenarios, recording assumptions, decisions and results of the actions. In this way, the decision makers can see the impacts of their decisions and the IDSS can give suggestions about the best alternatives to follow.

In a DSS there are inference mechanisms (rules and ways to understand the problem) and an expert knowledge base of different solutions for the problem. Thus, it can advise decision makers about risks and advantages in particular decision situations. When it happens, the DSS is intelligent (Bhargava et al.,1999). In some situations there is more than one alternative solution for each problem, and the specialist has pre-solved similar cases, in case that it is necessary to solve new ones. Then, we can store and structure these cases in a CBR.

Pre-solved cases can be exceptions to rules in comparison with new cases. For this reason, pre-solved cases are showed as a selection of cases. In pseudo-code, the structure of a rule set (tupla) is performed as follows:

- CASE (pre-condition- data set that define the case [scenario, problem])
- A1: (alternative solution 1, explanation 1),
- A2: (alternative solution 2, explanation 2),
- ….
- An: (alternative solution n, explanation n).

Consequently, when there is not any case defined in the same circumstances like other stored case, the answer will be based in an application of a similar case. It is obtained through an inference process, called "adaptation".

In our application, we propose a methodology divided into three phases:

a) Problem definition through modeling and simulation.
b) Case base definition and representation of the reasoning process.
c) Integration of the Simulation and IA techniques to create an IDSS.

In the following sections we present the advances achieved in each phase up to the present.

2 Problem definition trough modeling and simulation

The Canarian Model was built and various scenarios were constructed using system dynamics. For the description of the model and an explanation of how it was built , see Kljajic et al. (2002). The scenarios are the following:

"Scenario 1: Non-innovative society, with population and political leaders not really concerned with the environment and the sustainable development; the importance of immigration of pensioners people; constant increase of the total population.

This scenario mixes trends of permanent population increase, decline of tourism due to the environment degradation, stagnation of the agriculture sector and persistence of non-innovative Small and Medium Enterprises (SMEs). The first scenario is not sustainable in the long term, because the crisis in tourism (and other activities boosted by it) and the degradation of the environment will reduce the immigration of pensioners. This contraction will reinforce the economic crisis and the increase of the unemployment. The economic crisis will probably be accompanied by social unrest and political troubles.

Scenario 2: Non-innovative society, with population and political leaders not really concerned with the environment and sustainable development; importance of immigration of population in working age; permanent increase of the total population.

This scenario is the same as the former, except that the projection of the aging population is lower. In this scenario the crisis will be more evident and stronger in the work market. In the medium and long term the degradation of the environment and unemployment and social unrest will feed back between them.

Scenario 3: Innovative society, with population and political leaders concerned with the environment and sustainable development; weight of pensioners in the population pyramid; permanent increase of the total population.

This scenario mixes trends of permanent population increase, slow reduction of total tourism, increase in agricultural production due to the increased productivity and augmentation of innovative SMEs. This is sustainable in the medium term, because there will not be a crisis in tourism (and the other activities boosted by it) and the environment will not be destroyed. There will be opportunities to increase the quality of employment, due to the innovative activities and the demand of elders. Nevertheless, this scenario is not sustainable in the long term, because the increase of the population can't go on indefinitely. This scenario will be transformed into another one: Number 5 or 6.

Scenario 4: Innovative society, with population and political leaders concerned with the environment and sustainable development; high weight of population at working age, due to immigration; permanent increase of the total population.

This scenario differs from the former only because the tendency of permanent population growth is replaced by a lower population ageing factor. The sustainability in the medium term depends on the equilibrium in the work market and on the profiles of the immigrants. Like the former, it is not sustainable in the long term, because the increase of the population can't go on indefinitely. So, this scenario will be transformed into another one: Number 5 or 6.

Scenario 5: Non-innovative society, with population and political leaders not concerned with the environment and sustainable development; importance of immigration of pensioners; decrease or constancy of the total population.

This scenario differs from number 1 only because the population development is stable. This is one of the worst scenarios for the long term, because the reduction in immigration will be due to the crisis in tourism (and the other activities boosted by it), the degradation of the environment and social unrest. A similar and undesirable scenario may be built on the basis of scenario 2. It is important to observe that these two scenarios are not improbable because some political leaders have emphasized the importance of economic development in the short and medium term, without considering its impact on the environment.

Scenario 6: Innovative society, with population and political leaders concerned with the environment and sustainable development; weight of population at working age, due to immigration, but rate of immigration lower than in scenario 4; decrease or constancy of the total population.

This scenario differs from number 4 in the fact that the total population does not increase indefinitely, because the immigration rate is lower. With this scenario the sustainability of improving the quality of life (that includes the increase of revenues, low unemployment rate, high wages and an enjoyable environment) is possible. It is not the only that may be built to assure the sustainable development of the quality of life. Another one may be constructed on the basis of number 3 (Kljajic et al., 2002).

The scenarios throw light on possible ways of future society development. None are pre-determined. The exact path that society will adopt will depend on external factors and, more importantly, will also depend on the behavior of its population and its leaders. To guide the Canarian social system along a certain path it will be necessary, first of all, to design and chose it (let us say, for instance, one of the possible future scenarios), and to plan and implement the appropriate strategy and policies. An example of them is presented in Kljajic et al. (2002).

At present we are working in the phases two and three. They are described in the following paragraphs.

3 Case base definition and representation of the reasoning process

Decision support systems (DSS) are interactive computer-based information systems that are designed to help human decision makers. These systems allows the processing of data and models in order to identify, structure, and solve semi-structured or unstructured problems and to make choices among different alternatives (Zolghadri et al , 2002).

In this category of applications, experts must evaluate and make decisions with the data showed by analysis tools. One way to create a useful tool is to represent the reasoning process in a form of rules and build an expert knowledge based system. But knowledge based systems have several problems related with the process of extraction and representation of expert knowledge. Therefore, generally these systems are slow and usually can not access to huge amount of information. That is why we propose a case based reasoning method, that allows the resolution of new problems through the adaptation of past solutions used to solve similar problems (Riesbeck & Schank, 1989).

One advantage of this type of techniques is that it doesn't require an explicit knowledge of the domain. The extraction process is reduced to collect historic cases and to identify relevant attributes to describe the cases. We plan to start with a small amount of cases, then eliminate cases that are not useful, and add new ones. In addition, we can give explanations, use techniques of database to administrate a large amount of information, and the best advantage, the system can learn, acquiring new knowledge as cases. All these features makes the system easy to maintain and reuse.

In our application we define each case as a set formed by [(scenario, problem), (solution, explanation)]. Initially, we define cases for proposed scenarios, but the system is not limited to these ones, because it can learn and add to the database news scenarios and new solutions suggested by the user.

The simulation module gives facts that define an actual case. This case will be processed by the Inference Engine module. The CBR Cycle of work is the following (figure 1) (Aamodt & Plaza, 1994):

1. Similar case retrieval (a new problem is matched with similar cases stored in case data base);
2. Re-use proposed solutions in cases to try to solve the problem;
3. Revise proposed solution (in case it is necessary);
4. Retain the new solution as part of a new case.

The cycle is completed with user intervention.

The information stored for each case is related to:

1. The conditions that defines the scenario;
2. The problem, that emerges from the particular conditions of the scenario;
3. A description of the solution found for the problem and the decisions made;
4. A result describing the state of the system after the application of actions suggested.

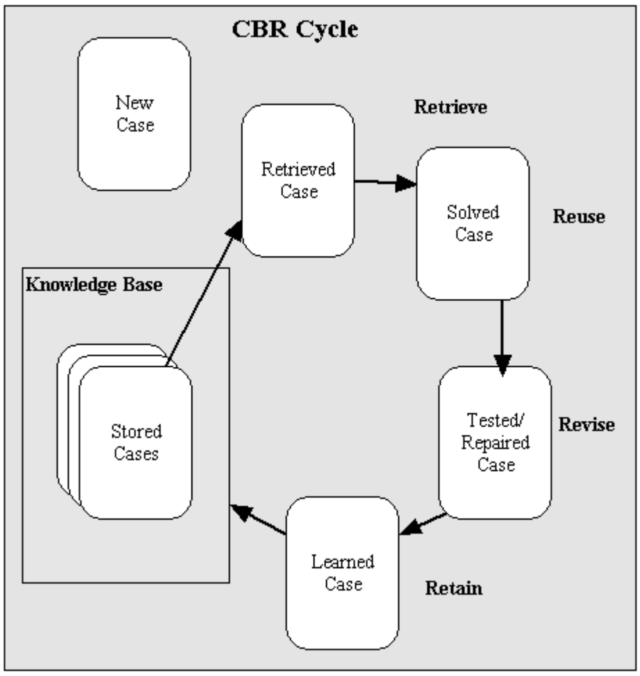

Figure 1: CBR life cycle

If one scenario has more than one problem, it is a new case for the case data base. In other words, (scenario1, problem1) <> (scenario1, problem2) <>…<> (scenario1, problem n).

To define a case and establish differences with others, we consider information regarding to: (i) functionality and (ii) easy acquisition of information represented in the case.

Concerning to cases recovery, we assign indexes for each case, and select an indexation method based on similarity. This method generates a set of indexes for abstract cases created with cases that share common attributes. Attributes not shared are used as indexes in original cases.

In relation with a case memory model, we use one called category-exemplar (Bareiss, 1989). In this model, cases are called exemplars and are organized in a semantic net of categories, semantic relations, cases and indexes. Each case is associated with a category. Case attributes have different weights; these weights indicate if they match up or not with a category.

There are three indexes that indicate:

- Attributes (descriptors of cases -scenario, problem- of cases or categories);
- Categories with their associated cases;
- Categories with neighbor cases which are differenced with a small number of attributes.

An exemplar is stored according to the level of similarity to a prototype category. A new case with small differences to another one is not stored.

The problem of finding the best case involves heuristic methods to limit/guide the search. Heuristics must allow making partial matches. We use a method based on templates, like SQL queries, where all cases that satisfy certain parameters are retrieved. Then we apply an inductive technique, that let us determine which attributes differences better the cases and to generate a decision tree, to organize the case in memory.

4 Integration of the Simulation and IA techniques to create a IDSS

Our system is based on a new approach including both simulation and intelligent analysis techniques.

Initially, dynamics of the system are modeled and the results of the simulations are stored in a database. This is the first step in the reasoning process. Then, the inference engine module identifies the case, selecting the case by similarity using templates and inductive techniques and predictions are performed. Finally, the solutions are showed to user with explanations of the consequences of the application of different possible solutions. If the results and the explanations do not satisfy the user, it is possible to introduce new ones. Thus, the system can be validated and can learn new solutions from the user.

For carry out the execution of our IDSS we have designed 4 main modules:

- Problem Definition, Modelling and Simulation Module;

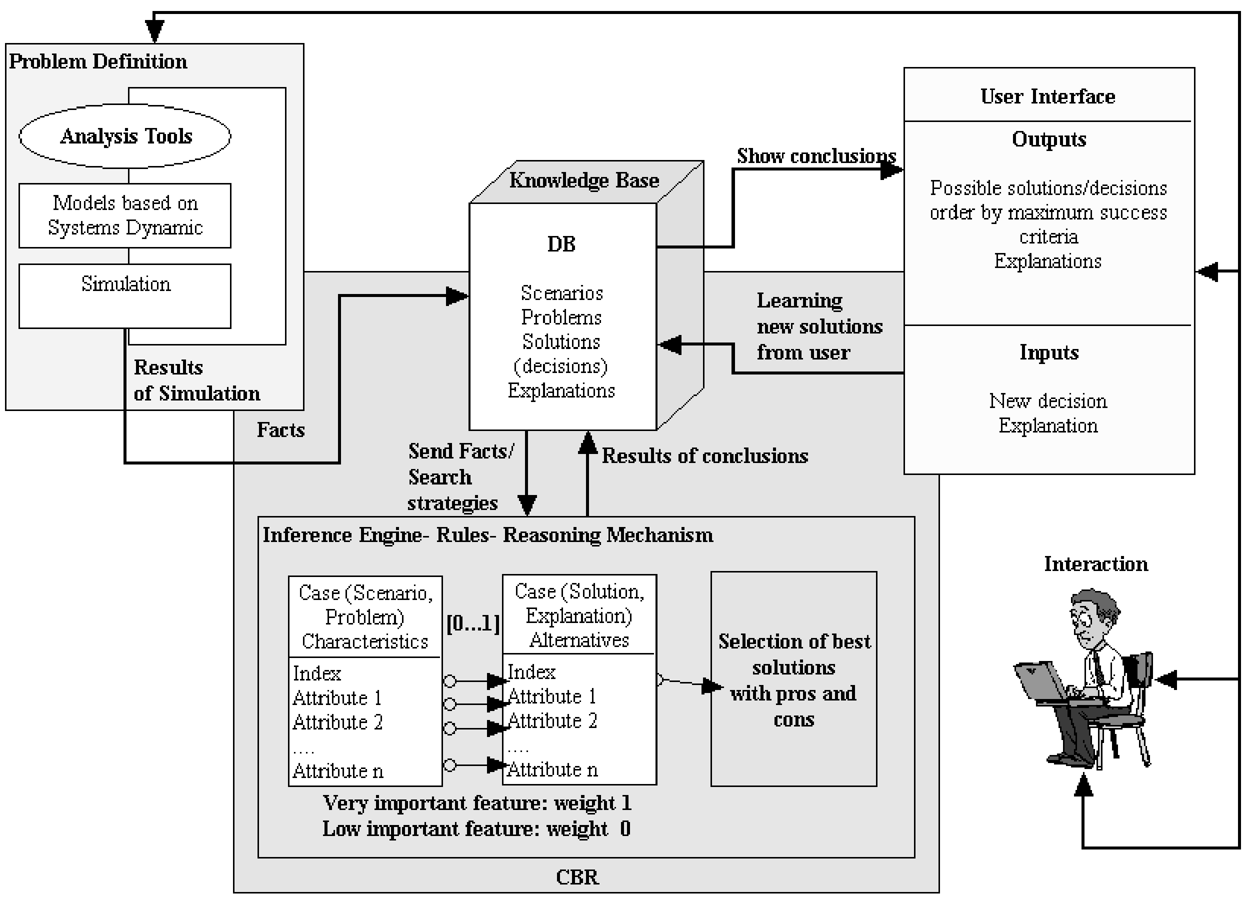

Figure 2. Architecture of IDSS-Canary Islands

- Knowledge Base Module, a DB with information of cases.
- Inference Engine Module, formed by representations of heuristic methods and case selection. It carries out the reasoning process.
- User Interface, that produces the best choices and the solutions for each case. It develops the learning and validation process trough feedback with the system.

Inter-relations among modules can be observed in Figure 2.

Simulation module gives facts that define the actual case. This case will be processed by de Inference Engine module. Initially, we start defining cases for proposed scenarios, but the system can learn on new scenarios and new solutions, adding to the database news scenarios created by modelling and simulation tools and new solutions suggested by the user.

In order to give a solution to the user for a specific problem in one scenario the following sequence of actions is carried out (figure 3).

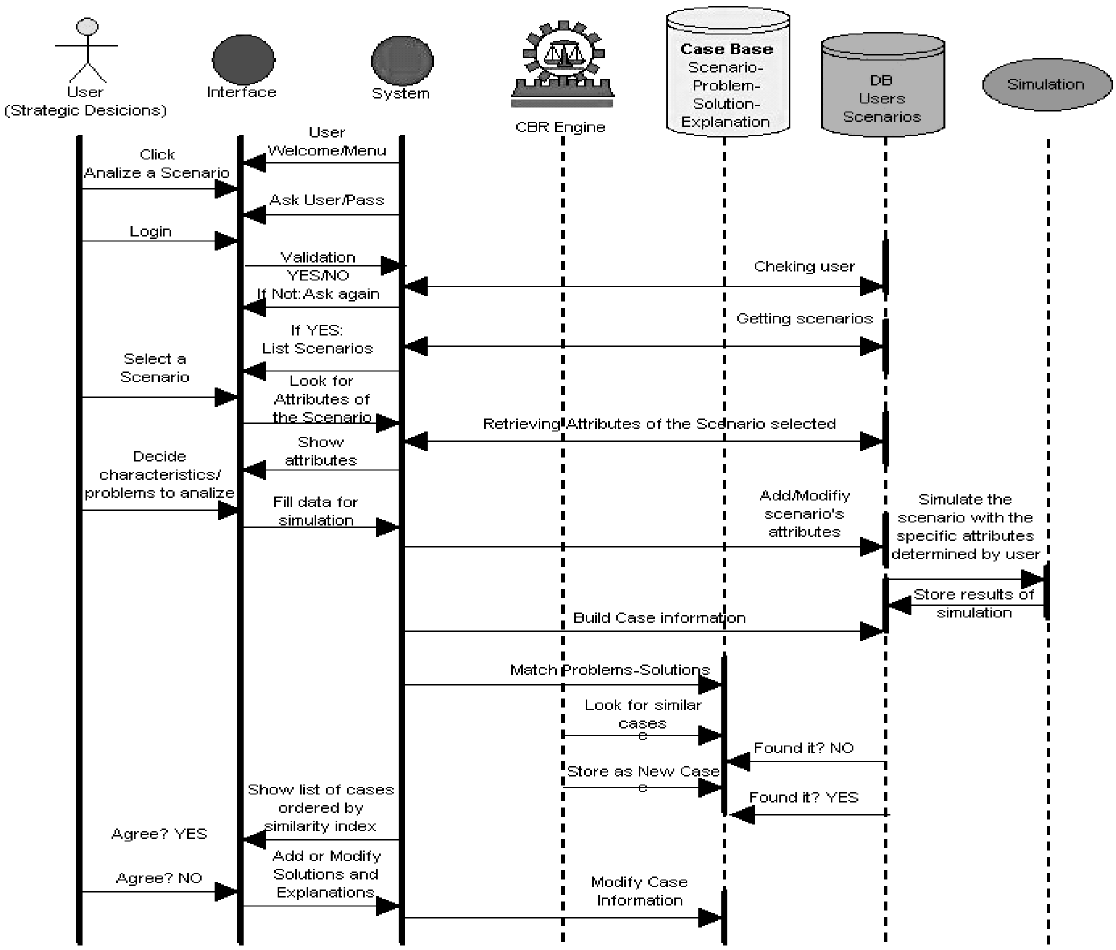

Figure 3. Sequence Diagram. Giving solutions for a scenario/problem.

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Carlos A. Legna Verna - rec biogaphy on page 518.

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Simulation with Cellular Automata - Diffusion of Electronic Commerce in Small Organizations

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Simulacija s celičnimi avtomati – širjenje elektronskega poslovanja v malih organizacijah

Članek opisuje simulacijo elektronskega poslovanja v malih organizacijah s pomočjo celičnih avtomatov. Model in metoda sta verificirana na zgodovinskih podatkih. Namen raziskave je bil preučevanje dolgoročnih vplivov na elektronsko poslovanje, ki so posledica karakteristik organizacij. Definiranih je pet stopenj zrelosti v elektronskem poslovanju. Raziskava je potrdila, da je najpomembnejši dejavnik na širjenje elektronskega poslovanja „podpora vodstva". Na dinamiko uvajanja in uporabe elektronskega poslovanja v organizacijah, ki niso inovatorji, pomembno vpliva proces verbalizacije. Največji napredek v stopnji zrelosti elektronskega poslovanja v malih organizacijah je bil dosežen pri dominantnejšem vplivu notranjih dejavnikov pred zunanjimi. Razvita metoda je pokazala nov pristop k uporabi celičnih avtomatov za preučevanje organizacijskih sistemov.

Ključne besede: mala organizacija, celični avtomat, elektronsko poslovanje, širjenje inovacije

1 Introduction

The Internet is the subject of great research and commercial interest, because it potentially enables global interconnectivity. It has evolved from a non-commercial research tool into interactive broadcast medium with unparalleled performance and interactivity. This interest has led to large investments to expand its capacity and capabilities. The result has been tremendous growth in electronic commerce. Electronic data interchange between business partners was a major driving power which set up the concept of inter-organisational systems and awareness of global connectivity – electronic business. Electronic commerce is an important part of electronic business in terms of revenues. Therefore, it has become increasingly important for enterprises to understand various issues affecting electronic commerce, such as uptake and development of electronic commerce among enterprises nationally and internationally.

There is no commonly agreed definition of electronic commerce. Wikipedia (2005) for example states: "Electronic commerce, e-commerce or ecommerce consists primarily of the distributing, buying, selling, marketing, and servicing of products or services over electronic systems such as the Internet and other computer networks. The information technology industry might see it as an electronic business application aimed at commercial transactions. It can involve electronic funds transfer, supply chain management, e-marketing, online marketing, online transaction processing, electronic data interchange, automated inventory management systems, and automated data-collection systems. It typically uses electronic communications technology such as the Internet, extranets, e-mail, Ebooks, databases, and mobile phones". The definitions seem to vary with time so we use the term electronic commerce in the following way: conducting business on-line.

In many studies it is shown that the uptake of electronic commerce is too slow and varies significantly in small businesses (e.g. Zupan, 2003; Podlogar & Pucihar, 2004). This is not encouraging, since over the last decade small enterprises have been recognized worldwide as making significant contributions to technological progress and increased competitiveness, creating new jobs and contributing to the economic revival of undeveloped regions within countries. Therefore electronic commerce in small enterprises is becoming vitally important and deserves serious attention. Thus we need to know more about the electronic commerce and the process of its diffusion among small enterprises. We believe that this phenomenon demands a rational examination.

The probability of unsuccessful introduction of information systems (IT) in a business has been reduced with many years of history of IT projects and efforts put into development of iterative and incremental methodologies and practices. But the introduction of electronic commerce into small businesses is not the same as previous generations of IT, and it needs a new approach to systems analysis. Due to the complexity of the problem and decisions which demand groups of experts many researchers propose powerful simulation approach and tools (e.g. Kljajić, 2004; Škraba & Kljajić-Borštnar, 2004).

Small Enterprise in Slovenia

Small enterprises researchers often define small enterprises differently. The criteria may vary according to different factors: the nature of business, industry, country etc. Most authors use the total number of employees as a criterion for research analysis. In this study, the decision criterion is adopted from the Chamber of Commerce and Industry of Slovenia. Enterprises in Slovenia are classified according to the number of employees, annual income and average annual assets during the past business year. The number of employees in small enterprises must not exceed 50, annual income not more than 1 million dollars and average annual assets 0.5 million dollars (UL, 1993). We have termed medium and large-sized organizations under one common name: larger organizations.

Electronic commerce maturity

Various levels of electronic commerce maturity can be expressed as a discrete range. The range begins with cluster of enterprises with no computers at all and ends with a cluster of enterprises with real time interaction with customers. To distinguish different forms of electronic commerce, the classification of electronic commerce maturity within small businesses would be very helpful. Unfortunately there is no commonly accepted categorisation of these levels. Therefore, we propose the following levels of electronic commerce maturity:

- Level 1: Getting connected
  The company acquires Internet access and starts exploring the Web with the objective of better understanding the new media. The rising awareness of the business owners towards the potential of the Internet and electronic commerce is recognised.
- Level 2: Establishing a presence
  This involves the use of electronic mail, and using the Web for gathering information, looking at competitors' sites, and similar purposes. The company decides to develop a presence on the Internet, and develops a simple informational company homepage.
- Level 3: Primitive interaction with customers
  The organisation realizes that customers can reach the company via the Internet. They are gaining experience with purchasing, selling and banking on the Internet. The organisation prepares first business plans for electronic commerce.
- Level 4: Transforming the homepage into a service
  The homepage is developed into a full service site where customers can give structured information to the company in order to get assistance in their shopping efforts. Customers can also place orders for the company's products/services online.
- Level 5: Enabling real-time interaction with customers
  The fully electronic commerce mature business will have information and communication technology, including their Internet use and web sites, properly integrated with their business processes and information flows. The Website strives to create personalized relations to every customer, by using database technology, in conjunction with technologies for dynamic Web page generation, to create an informed and personal treatment of each individual customer.

Electronic commerce diffusion

Descriptions and explanations of information technology (IT) diffusion have received growing attention among researchers since early 1990s. Often the diffusion was considered as innovation where the adopting population was relatively homogeneous and boundaries were known. But the usefulness and applicability of diffusion of innovation theory might be questionable in explaining a complex and networked-based technology such as electronic commerce. Inter-organisational systems are different from intra-organisational systems in many respects. Inter-organisational systems diminish organisational boundaries, support inter-organisational cooperation, depend on resources that are not under control of one organisation and they necessitate a mature information infrastructure in place both internally and externally. There are some researchers that seek to understand the broader context of diffusion by dissecting the process on inter-organisational basis. Factors that have been found to influence diffusion rates include adopter characteristics, the social network they belong to, the communication process, the characteristics of the promoters and attributes of innovation (Lyytinen & Damsgaard, 2001).

2 Methodology

Research objectives

The purpose of this study is to study dynamics of electronic commerce diffusion in small organisations with a cellular automata simulation model. This objective can be translated into the following research questions:

- Can simulation models from other fields of applications describe the dynamics of electronic commerce diffusion?
- If the previous answer is positive, which simulation models are the most appropriate as a base of dynamics model of organisational systems?
- How accurate are results of simulated electronic commerce diffusion?

Research phases

The methodology is based on cellular automata approach, diffusion theory, small organization characteristics and studies on factors affecting electronic commerce introduction and usage in small organizations. The study was conducted in following research phases:

- study of relevant literature;
- survey and interviews preparation;
- data gathering (survey and interviews) and analyses (descriptive statistics, correlations, parametric and non-parametric ANOVA, factor analysis);
- analyses of data from RIS study (RIS, 2001);
- development of the simulation model that captures the features of opinion dynamic models and additionally biases in the verbalization process. We defined the maturity level of individual organization (positioned in the grid, identified by indexes i,j) in discrete time (t+1) with equation 1:

$$s_{ij}(t+1)=\hat{a}f_{ij}s_{ij}(t)+f_{i+1,j}\,s_{i+1,j}(t)+f_{i-1,j}\,s_{i-1,j}(t)+f_{i,j+1}\,s_{i,j+1}(t)+f_{i,j-1}\,s_{ij-1}(t)+f_{i+1,j+1}\,s_{i+1,j+1}(t)+$$
$$+f_{i-1,j+1}\,s_{i-1,j+1}(t)+f_{i+1,j-1}\,s_{i,j+1}(t)+f_{i-1,j-1}\,s_{ij-1}(t)+\sum_{k=1}^{N}C_{ijk}(t)$$

(Equation 1)

where:
f_{ij} - strength of influence,
- one's own strength to keep a temporary state,
C_{ijk} - function of influence of N business partners of organization ij;

- development of the user-friendly simulation system (MS Access as database and GUI, , Mathematica as processing and visualization tool);
- analysis of proposed model, applying the concept of different scenarios of electronic commerce diffusion.

Input data

The proposed cognitive and social model depends on availability of data:

- Questionnaires and interviews in small organisations,
- Data of the RIS study 2001 (usage of Internet in Slovenia).

Questionnaires and interviews in small organisations

A list of organizations for interviews and the survey was collected from official data available on the portal (Register, 2003). Our sample included small enterprises that meet the following criteria: 1) small enterprise as defined in legislation, 2) the small enterprise has a registered e-mail address (firmname@domainname, something-@firmdomainname), 3) the small enterprise e-mail address may not include the prefixes and postfixes such as some@hotmail.com, some@yahoo.com, personalname-@siol.net, personalname@guest.arnes.si.

The purpose of interviews was to classify organizational factors according to their impact on electronic commerce introduction and usage. Major factors that influence electronic commerce adoption and usage expectations of small enterprises were identified through review of the literature on IT and electronic commerce adoption and usage in small businesses (e.g. Chen & Williams, 1998; Chwelos et al., 2001; Zupan & Leskovar, 2003). In general, the factors are aggregated into internal and external factors. In this research we focused on organizational characteristics and interactions with business environment as major factors that influence electronic commerce adoption and usage:

- Business Activity,
- Intensity of Doing Business with Larger Business Partners,
- Number of Employees, Financial Resources,
- IT Resources,
- Human Resources,
- Strategic Planning,
- Managerial Enthusiasm,
- Employees Relation to the Electronic Commerce,
- Legal Issues, Culture, Competitors,
- Business Partners
- Influence of Local Organisations and
- Global Influence.

The purpose of the survey was to obtain a picture of electronic commerce maturity and electronic commerce readiness in the years 1997 and 2002. The survey focused only on small businesses that had already shown their interest in electronic commerce by using company-based e-mail communication. Therefore, it was assumed that they had some experience with electronic commerce. These limitations were needed because only electronic commerce literate organizations were able to answer questions on electronic commerce adoption and usage. These limitations leave a sample of 1,553 enterprises, all of which were organizations in Slovenia that meet our criterion. We randomly choose 1,003 organizations and send them a survey. The questionnaire was sent to the head of the organizations from the sample. The survey lasted 21 days, from November 12 until December 3, 2002. The response rate was 29% or 292 questionnaires.

Data of the RIS study 2001 (usage of Internet in Slovenia)

While our research focused just on small businesses that had already shown their interest in electronic commerce, we also decided to obtain the state of electronic commerce maturity from the study Research on Internet in Slovenia (RIS, 2001). This study also included organisations that did not conduct business electronically. This gave us a more realistic overview of electronic commerce maturity among small organisations.

We do not describe the entire process of these interactions between modelling and data collection here because it is not the focus of this paper. This is why the data is described first and then the model and results. However, we would like to stress that the process of modelling and data building has been iterative.

3 Model

Cellular automata based models have used for approximately fifty years and are often presented as simple grid of cells, where the individual cells change states according to a set of rules. They are useful for research because simple basic structures very often induce complex dynamics with surprising macro effects (e.g. Wolfram, 1986). By building appropriate rules into cellular automata many kinds of complex behaviour can be simulated, ranging from physical phenomena to social phenomena.

An analysis of the electronic commerce literature and diffusion theory suggests a multi-layered approach in studying electronic commerce diffusion. Because of fundamental similarities in the characteristics of cellular automata, social science and organisational science, it is feasible to built a cellular automata model to simulate organisational systems based on findings in social sciences (e.g. Urbig, 2003). Therefore, we introduce the classic opinion dynamic and verbalisation process to model electronic commerce diffusion with cellular automata.

This research rebuilds models of continuous opinion dynamics, which can be found in Urbig (2003). The proposed model of opinion dynamics focus on the communication between organisations as the source for changes of opinions (Figure 1). The impact of others' opinions depends on factors such as the source of the opinion (business partners, organisations in neighbourhood, competitors) and the differences between an organisation's own and the perceived opinion. Major forces of electronic commerce diffusion within a business society are: business activity, intensity of doing business with one organisation, managerial enthusiasm and support and business partner's electronic commerce maturity. The model identifies four processes that are the foundation of a basic communication model: verbalisation, transmission, interpretation and adoption. Opinions are verbalised attitudes. In in our model, attitude towards electronic commerce is denoted by ep_i. An attitude verbalisation process gives the relation between attitudes that are internal states and opinions (o_i) that are expressions able to be communicated via a communication channel. The opinion is transmitted through a communication channel and controlled by the environment. The message received (pm_i) by organisation x_j is interpreted as a perceived message. According to an organisation's (x_j) characteristics (expressed by vector n_j) and its own attitudes (n_j) and perceived message ($\hat{o}_{ij}$) organisation x_j decides on the impact the other organisation (x_i) has on its own attitude on electronic commerce (ep_j).

The simulation model is written in the Mathematica 4.0 program language. Electronic commerce diffusion is

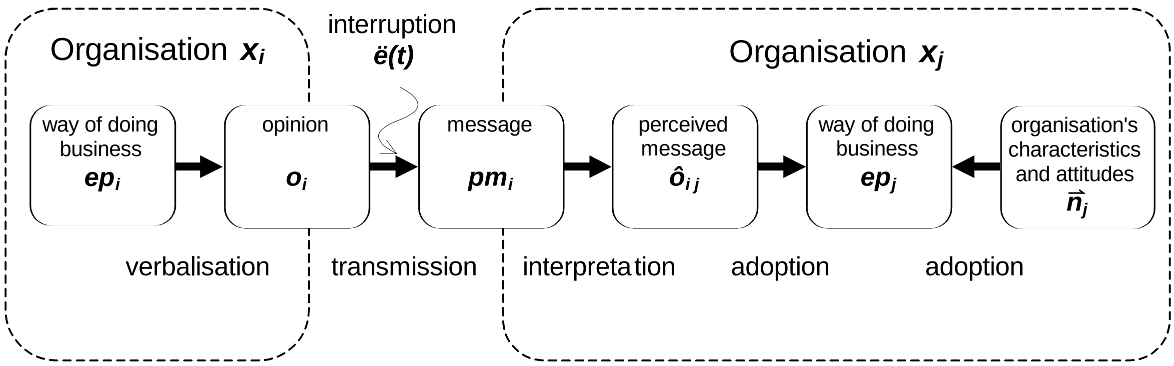

Figure 1: Simulation model

simulated with cellular automata where time, space and states of the system are all discrete and have following properties: 1) space is represented by a regular two-dimensional lattice, 2) cells in cellular automata represent organisations, 3) the geodesic net of Slovenia is transformed into a two-dimensional lattice, 4) the coordinate system D48 of Republic of Slovenia is used to position organisations over the lattice, 5) coordinates of organisations are known from organisation's address, 6) initial states of organisations are gained by survey and 7) each organisation in the lattice is in a given state at given instant of time, 8) the system evolves synchronously in each time step and 9) states of electronic commerce in organisations are updated according to the set of rules.

Our model uses a square 150 by 150 lattice with wraparound boundary conditions. There is a population density p of organisations occupying lattice sites. Empty cells stay empty. The system evolves over a given number of time steps t.

4 Results

Experiments on empirical data and different scenarios of electronic commerce diffusion showed that 32 time steps are needed to transit from initial state in 1997 to initial state in 2002 (Figure 2 and 3 – marked with black triangle). Time interval of changes is approximately two months and it was used as mean transition time. It is interesting that only internal factors cause comparable results of two simulations. There is a little deviation from simulated state (after 32 steps in 1997) and initial state in 2002, which we can assign to other factors of electronic commerce that were not disclosed in this research.

Results could be explained with the characteristics of small organizations that were surveyed. All organizations from the sample have already showed interest in electronic commerce. Because they were among the first that began electronic commerce they did not have a lot of backer-organisations. This organizations could be can be na-

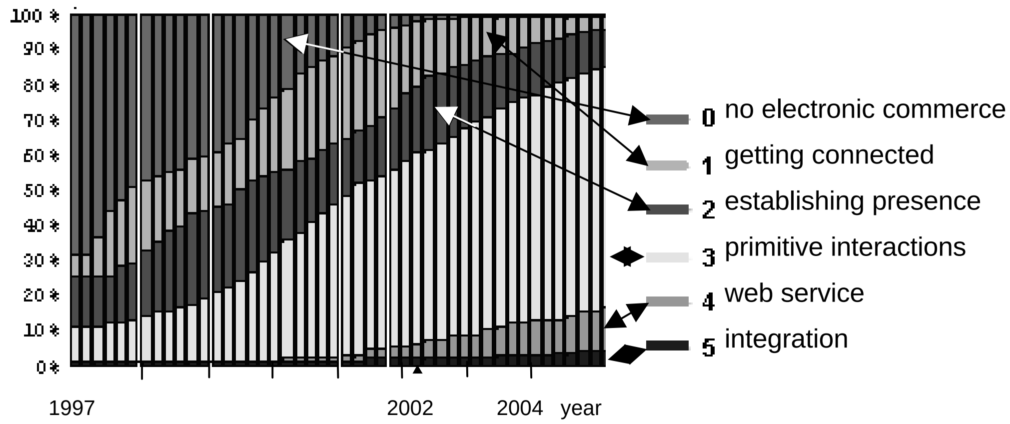

Figure 2: Dynamics of electronic commerce maturity (initial data for year 1997), internal factors.

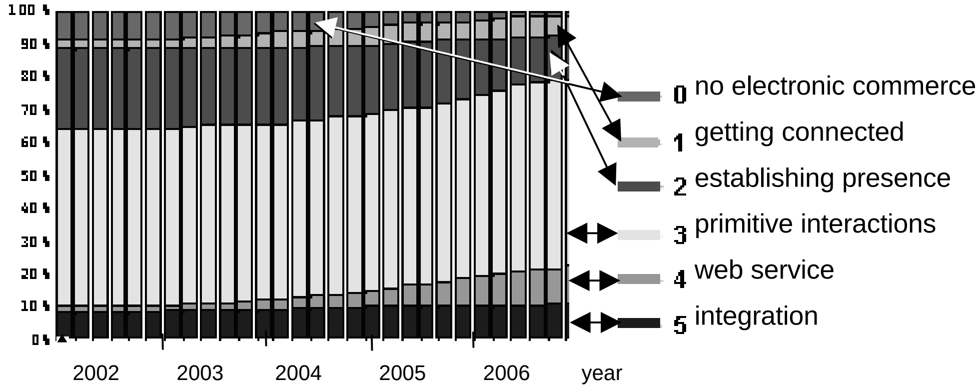

Figure 3: Dynamics of electronic commerce maturity (initial data for year 2002), internal factors.

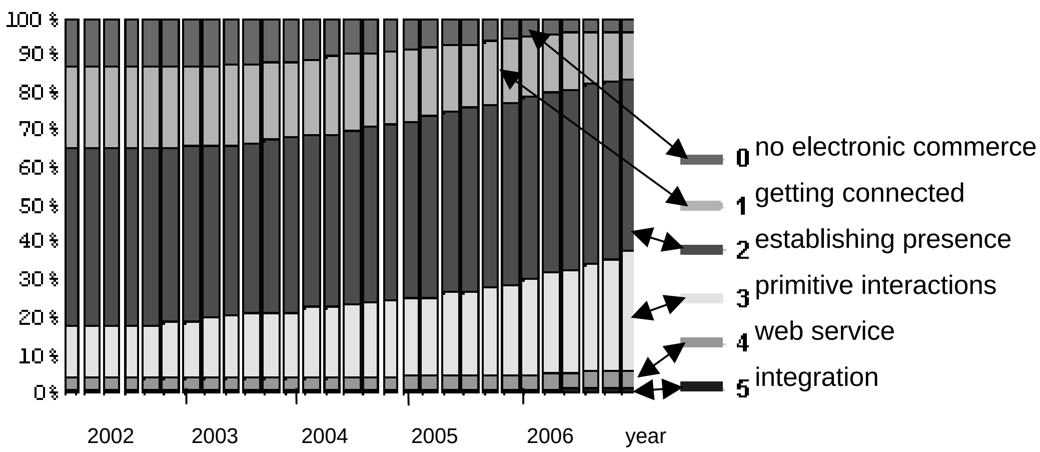

Figure 4: Dynamics of electronic commerce maturity (initial data from RIS 2001), internal factors

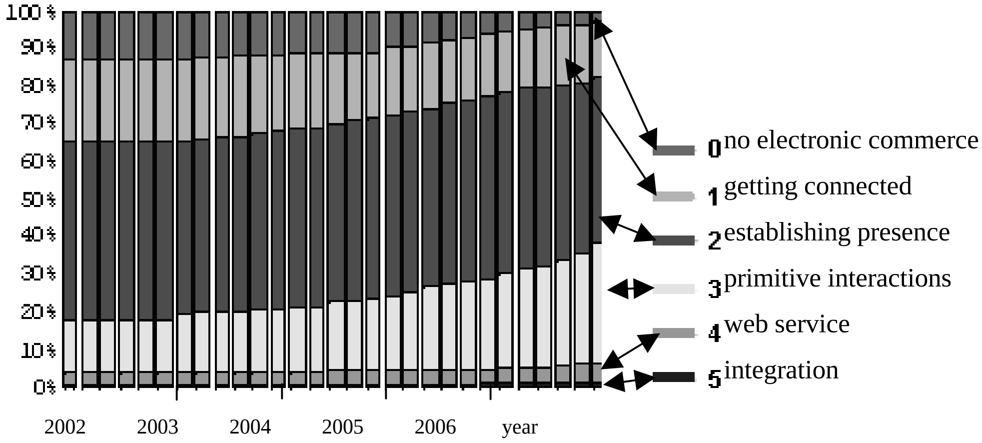

Figure 5: Dynamics of electronic commerce maturity (initial data by RIS 2001), internal and external factors are in ratio 3:1.

med as innovators. They were pushed by their inner instincts and vision to start electronic commerce.

The same experiments as described above were performed on statistical data gathered from RIS (2001). Figure 4 shows results with the scenario that was most appropriate with empirical data. It shows that most of organisations will achieve the second and third levels of electronic commerce maturity while other levels are forecast as changing change more slowly. The fourth and fifth maturity levels in particular rise very slowly. The probability of transitions to fourth and fifth maturity levels decrease with rise of mean maturity.

Figure 5 shows results of simulation where internal factors are predominant over external factors (ratio 3:1). Such a relation between internal and external factors causes greater changes in electronic commerce maturity than any other scenario of electronic commerce diffusion.

This result is not surprising as most organisations except innovators are influenced by their environment. These organisations are affected by business partners. The result is most probable and confirmed in real life.

Forecasts of electronic commerce maturity levels simulated by the most probable scenario parameters for year 2006 are given in table 1.

Table 1: Electronic commerce maturity: 2001 empirical data and 2006 simulated.

	2001 (in %)	2006 (in %)
Level 0: no electronic commerce	10	2
Level 1: getting connected	3	5
Level 2: establishing presence	25	15
Level 3: primitive interactions	56	60
Level 4: web services	2	8
Level 5: integration	4	10

5 Conclusion

While we were developing the cellular automata model of diffusion of electronic commerce among small organizations we were continuously focusing on the feasibility and usability of this approach in organizational sciences. Simulation models from other fields of applications loosely describe the dynamics of electronic commerce diffusion. A re-engineered model of continuous opinion dynamics was developed. The final results confirm the potential benefits and encourage further research in organisational systems. The accuracy of the proposed model in anticipating the progress has yet to be determined. Several possibilities for research activity arise: modelling of maturity downgrading caused by natural disasters or changed global economy, uncertainty modelling and fuzzy model embedding along with real-time data collecting system over the Internet.

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An Alternative Criteria Research Methodology for Selecting a New Product

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Metodologija za analizo kriterijev alternativ ob izbiri novega proizvoda

Prispevek obravnava metodologijo uporabljeno pri raziskavi kompleksnih problemov pri poslovnem odločanju: določitev relativne pomembnosti kriterijev ob izboru novega proizvoda. Metodologija podpira generiranje predlogov za definicijo relativne pomembnosti kriterijev in podkriterijev za izbiro novega proizvoda glede na trenutno situacijo v podjetju (ki izbira nov proizvod) in stanje. Z uporabo predlagane metodologije lahko določimo vpliv relativne pomembnosti kriterijev za izbor novega proizvoda na stopnjo uspešnosti podjetja. Zaradi omenjenega ima celotna procedura dinamičen značaj in je lahko uporabljena v različnih situacijah ter ob različnih časih opazovanja. Oblikovani predlogi predstavljajo vhodne podatke ter podporo sledečemu večkriterijskemu rangiranju alternativ za nove proizvode.
Metodologija je potrjena v praksi vendar pričujoči prispevek ne podaja podrobnosti v zvezi s tem, saj je cilj prispevka predstavitev raziskovalne procedure na področju določitve kriterijev pri izboru novega proizvoda kakor tudi opredelitev pomembnosti le-te. Poleg tega je uporabljena procedura pomembna zaradi svoje univerzalnosti saj jo lahko uporabimo pri opredelitvi kriterijev v drugih odločitvenih situacijah z ali brez dodatnih sprememb.

Ključne besede: metodologija, raziskave, kriteriji za izbiro novega proizvoda

1 Introduction

One of the most significant problems in business decision-making is the selection of a new product, which usually has to be performed on the basis of a larger number of criteria. That is why various multi-criteria analysis methods are frequently applied (AHP, PROMETHEE, and others). Selecting a new product is not only important for the survival and future of every company, but it also presents an extremely complex task because of the range of this problem area and a large number of influential values which are of a prevailingly stochastic character. Complexity and subjectivity are particularly prominent in the procedure of assigning relative values to criteria when selecting a new product.

Existing research of the criteria for selecting a new product (indices of the future success of a product) mainly deal with singling out several such indices and determining the intensity of their influence. Then potentially new products are compared with these indices, and the product with the best assessments is adopted. This is the basic idea in much important research which has been carried out in this way, for example (Cooper & Kleinschmidt, 1987; Henard & Szymanski, 2001; Montoya-Weiss & Calantone, 1987; Parry & Song, 1994).

However, it is very difficult, almost impossible, to make a universal model (a model which could be suitable for a large number of companies) for defining the relative importance of criteria when selecting a new product. In the research carried out in (Nikolić, 2004), the initial hypothesis was that every company is a multi-dimensional system, with its specificities and characteristics which have direct influence on assigning certain levels of importance to individual criteria. As a consequence of this, there is the question of variability of the importance of individual criteria that depend on numerous characteristic features of the company, and above all, the company's degree of success. Furthermore, if one takes into account the fact that a company is a dynamic system in which there are constant numerous changes, as well as changes in its setting, then there is the question of variability of importance of some criteria in time, for one and the same company.

Furthermore, it must not be overlooked that the existing research, for example (Cooper & Kleinschmidt, 1987; Henard & Szymanski, 2001; Montoya-Weiss & Calantone, 1987), mainly refers to countries with developed economies. Hence, it follows that the results of this research especially favour the indices related to the originality and attractiveness of a product, user's needs and the like, whereas indices related to the very capacities of the company, above all financial, are largely ignored. As a consequence of this, similar research in the countries in transition must take into account more seriously the financial capacities of both the company and the market.

Because of all this, a special research methodology has been developed to research the relative importance of the criteria for selecting a new product, taking into account the above-mentioned difficulties. This methodology is essentially based on expert methods and fuzzy sets theory.

2 Alternative research methodology of criteria for selecting a new product

The main difference between this methodology and some existing research, for example, (Cooper & Kleinschmidt, 1987; Henard & Szymanski, 2001; Montoya-Weiss & Calantone, 1987; Parry & Song, 1994), is that the methodology proposed here highlights the importance of defining precisely at the start the criteria for selecting a new product, and that they are fixed. Therefore, the objective of the research is not to determine which criteria are important and to what level they are important, but to research the importance of predetermined criteria depending on the characteristics of a company and its setting. What has contributed to such formulation is the concept that the criteria are generally the same and that they can be defined on the grounds of existing knowledge, and that a more significant problem is that these criteria do not have the same importance for all companies and in all conditions. So, the stress is laid on establishing the dependence of importance of criteria for selecting a new product on the company's degree of success and the conditions in its setting. What characterizes the proposed methodology is that the research can be repeated and realized for different groups of criteria when it is necessary, or in the case of a different approach. The ultimate objective is to determine the recommendations on the basis of which every company could define the importance (relative weights) of the criteria according to its own characteristics at a given point of time.

The proposed research methodology of the criteria for selecting a new product foresees an eight-step procedure. Detailed descriptions of each step follow.

Step One: Selection of criteria and sub-criteria for selecting a new product

In this step, the criteria for selecting a new product are defined . These criteria are researched in the further procedure. The methodology that is presented here also foresees defining the sub-criteria for each criterion (one can also work without any sub-criteria).

Step Two: Selection of parameters which influence the selected criteria and sub-criteria

In step two the parameters which have influence on the selected criteria and sub-criteria for selecting a new product are identified . These parameters are in reality the characteristics of companies influencing the importance of a particular criterion. Certain parameters can simultaneously influence a larger number of the selected criteria. The parameters have the greatest importance in the last step, step eight, as well as when applying the results of the research, which will also be discussed in a further presentation.

Table 1 was formed with the aim of illustrating mutual dependence between the criteria for selecting a new product and the parameters which describe these criteria.

Table 1: Mutual dependence of the criteria for selecting a new product and the parameters that describe these criteria

	Criteria				
	C_1	C_2	C_3	...	C_p
Parameters which describe the selected criteria	X_{11}	X_{21}	X_{31}	...	X_{p1}
	X_{12}	X_{22}	X_{32}	...	X_{p2}
	X_{13}	X_{23}	X_{33}	...	X_{p3}
	...	...	...	...	...
	X_{1n}	X_{2n}	X_{3n}	...	X_{pn}

Labels in Table 1 have the following meanings:

C_i – criterion for selecting a new product, where: i = 1, 2, 3, ..., p – the number of the observed criterion

X_{ij} – j-th parameter which describes the i-th criterion, where j = 1, 2, 3, ..., n – the number of the observed parameter. It should be pointed out that the parameter numbers which describe particular criteria (represented by 'n') do not have to be in any way equal for all the criteria. The number of these parameters depends on the criterion itself.

Step Three: Polling of experts in the field of product development (Survey 1)

Each criterion is described with a certain number of influential parameters. However, the importance of these parameters (within each criterion) does not have to be the same and it is usually not the same: some parameters have a greater influence, and some less. For this reason, it is necessary to determine relative weights of the selected parameters within the framework of each criterion separately. These weights are used in step eight when determining the similarity value of the companies which belong to the same classes, as when applying the models.

Relative weights of the selected parameters which influence the criteria and the sub-criteria for selecting a new product are determined on the basis of the opinion given by the experts in the field of product development. The necessary opinions are collected through the survey (Survey 1). The polled are asked to evaluate each parameter with an assessment in the intervals between 0 and 10. This assessment should represent the quantitatively expressed strength of influence of a particular parameter on the importance of the observed criterion for selecting a new product.

In view of the fact that some parameters can have influence on more criteria, such parameters ought to be assessed more than once. In other words, the same parameter can have a different influence on the importance of different criteria.

The research related to determining the relative weights of the parameters for each criterion should be entrusted to experts from scientific institutions and to experts from the companies who deal with the problems of company development, and especially product development. Those polled should be organization engineers, managers, mechanical engineers, economists, technichians, etc .

Step Four: Determining relative weights of the selected parameters for each criterion

In this step, processing of the data provided in the previous step is carried out. All the parameter assessments (given by the experts) are translated into fuzzy assessments, or the interval [0, 1], through the function $y = x / 10$, where: $x \in [0, 10]$. Fuzzy assessments of each parameter for a particular criterion are observed. A set is formed from these fuzzy assessments, and processing is performed with this set by determining the average value of the set. The obtained average values represent the final fuzzy assessments of all the parameters for each criterion.

The final fuzzy assessment of the parameters within one criterion represent the input data for determining the relative weights of the parameters for that criterion. In the process, one of numerous procedures can be applied; like, for example (Leskinen, 2000; Noghin, 1997; Podinovski, 2002) and others. An original approach is applied in (Nikolić, 2004), which is also presented in (Nikolić & Sajfert 2004). In this way relative weights of parameters within each criterion are obtained separately. These are values w_{ij} – relative weight of the j-th parameter for the i-th criterion (item 2.1.). They are applied in step eight, and also when applying the research results (item 3.).

Step Five: Polling company managers (Survey 2)

This is the step in which polling of company managers in certain companies is carried out (Survey 2). The basic characteristics of polling in this case are:

1. *Company Type.* In order to focus on the problem, it is necessary to select the subject of the research in the form of the type of company which will be researched. In (Nikolić, 2004), a research which applied the proposed methodology was carried out for the companies in the food processing industry. The rationale is that food industry is the most vital part of the economy of Serbia and Montenegro, in addition to being the part of economy with the greatest potential.
2. *The Polled*. The polled must be at high-level leading positions in companies so that they can have insight in the company's business results, its development strategy, and the like. It is assumed that they are university-educated, and are by vocation economists, managers, mechanical engineers, technologists and similar. In a further text, those polled who answer questions in Survey 2 will be called 'managers'.
3. *Number of Managers*. For the scope of getting reliable and relevant data, it is foreseen that it is necessary to poll N = 150 - 200 managers.
4. *Research Domain in Geographical Terms.* Research must also include the plan of the area in which the research would be carried out.

The research requires asking two groups of questions:

1. Questions that can provide the data about all the identified parameters (characteristics) of the company describing the selected criteria. Those polled will be required to quantitatively assess the required parameters in the assessment range between 0 and 10. It is very important that those polled assess the parameters according to the current state of the company.
2. Questions which provide the data on all the selected criteria and sub-criteria. Those polled will be asked to quantitatively assess the importance of the criteria and sub-criteria with one single assessment in the range between 0 and 10. It is also very important that the subjects assess the criteria and sub-criteria according to the current state in that company and its setting.

The primary objective of this survey is to establish the mutual dependence between parameters and criteria. That is why stress is laid on the subjective opinion of an individual (manager), and the company is in the background serving as the framework in which an individual forms his/her opinion.

Step Six: Ranking of companies into classes according to the relative importance of the criteria

Ranking of companies into classes is carried out at the level of a single criterion, i.e., for each criterion separately. It is essential that the ranking be carried out according to the size of the relative importance of the observed criterion in relation to other criteria.

The managers, according to their opinion, quantitatively assess the importance of the criteria with one assessment ranging from 0 to 10 (step five). These assessments are translated into the interval [0, 1] by means of the function $y = x / 10$, where $x \in [0, 10]$ (columns $FA(C_i)$ in Table 2). Determining the criterion's relative importance for a manager is carried out according to the fuzzy assessment ($FA(C_i)$). In order to do this, one of the following procedures can be applied (Leskinen, 2000; Noghin, 1997; Podinovski, 2002) and others (original approach is applied in (Nikolić, 2004), which is also presented in (Nikolić & Sajfert 2004)). This is repeated for every polled manager separately (columns w_{Ci} in Table 2).

Then, companies (managers' opinions) are ranked according to the size of the relative importance of the observed criterion, starting from the highest to the lowest. The total number of companies is divided by the desired number of classes and the number of companies in one class is obtained. For example, if 150 managers were surveyed in companies, and we want to rank them into three classes, then the number of companies in each class is 50. The first 50 companies make up the first class, the second 50 companies the second, and the third 50 companies make up the third class for the observed criterion. This procedure is carried out for each criterion separately. The companies are thus divided into three classes according to each criterion separately:

Class I – Companies whose managers assigned a high fuzzy assessment to the observed criterion in relation to the other criteria, as a result of which the relative importance of the observed criterion is great (for these managers, the observed criterion has a great importance in relation to the other ones),

Class II – Companies whose managers assigned an average fuzzy assessment to the observed criterion in relation to other criteria, as a result of which the relative importance of the observed criterion is average (for these managers, the observed criterion has an average importance in relation to the other ones),

Class III – Companies whose managers assigned a low fuzzy assessment to the observed criterion in relation to other criteria, as a result of which the relative importance of the observed criterion is low (for these managers, the observed criterion has an average importance in relation to the other ones).

The classification is carried out according to the relative weights of the criteria, and not according to the fuzzy assessments of the criteria because the managers can use different parts of the 0–10 scale. Therefore, what is important is the position of the observed criterion in relation to other criteria, and not only its initial fuzzy assessment.

In a general case, the procedure of ranking the managers into classes is shown in Table 2. The columns with values w_{Ci} are ranked according to the size for each criterion separately.

Table 2: Ranking of managers into classes for all the criteria

Managers	Criterion assessment according to the managers' opinion with calculation of the criteria relative weights for each manager individually									
	$FA(C_1)$	w_{C1}	$FA(C_2)$	w_{C2}	$FA(C_3)$	w_{C3}	…	…	$FA(C_p)$	w_{Cp}
M_1										
M_2										
M_3										
…										
M_N										

Labels in Table 2 have the following meaning:
M_k – the k-th polled manager, where k = 1, 2, 3, ..., N – ordinal number of the observed manager,
$FA(C_i)$ – fuzzy assessments of the i-th criterion for each manager from k = 1, 2, 3, ..., N,
w_{Ci} – the relative weight of the C_i criterion for each manager from k = 1, 2, 3, ..., N.

It is proposed here that the number of classes be S = 3. When determining the number of classes it was certain that the number of classes ought to be an odd one in order to have the category *"average"* and several qualitative values on both sides of the average. Seven classes would be far too many, so that the main dilemma was whether the number of classes ought to be three or five. Considering the fact that the planned number of polled managers was N = 150–200 , the number of classes S = 3 is more appropriate, since there would be 50 to 60 companies within one class, which represent a sufficient number for drawing certain conclusions. It would require considerably more managers to form five classes.

Since managers form their opinions on the basis of the characteristics and potentials of their respective companies, the next conclusion is that the companies in one class must have significant mutual similarities. For groups of similar companies within one criterion, it is possible to carry out objective statistical processing of the data obtained.

Step Seven: Statistical processing of the data within each class for each criterion separately

Statistical processing of the data provided by polling company managers (Survey 2) is carried out in this step. All the assessments obtained by Survey 2 are translated into fuzzy assessments, that is, the interval [0, 1]. Processing is carried out within each class for each criterion separately. Data processing is carried out in two segments:

1. Determining the criteria fuzzy assessments

Values from one w_{ci} column (Table 2) are ranked according to their size and are divided into the desired number of classes (it is proposed that S = 3 classes), as with dividing into classes (step six). For each class the average of values, w_{ci}, in that class (values $w_{Ci,av,cl}$) is found . The ranking is carried out for each criterion separately, and the average of respective values, w_{ci}, is found for each class within each criterion. It is obvious that in the first class there will always be the highest average, and in the third the lowest. Then follows the fuzzification of these average relative weights for every class of every single criterion. The fuzzification is carried out by applying the function shown on Figure 1.

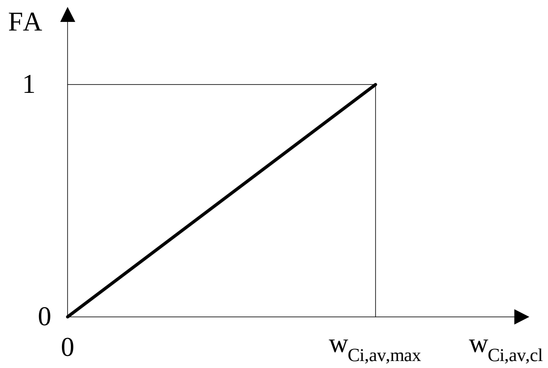

Figure 1: Fuzzification of average relative weights of the criteria for each class

On the graph abscissa on Figure 1 the average criteria relative weights for each class are plotted . The value in relation to which fuzzification is carried out is labelled as $w_{Ci,av,max}$, and it indicates the criterion's maximum average relative weight, for all the criteria average relative weights in all the classes (values $w_{Ci,av,cl}$). Fuzzification is carried out for every average of every class. For example: if there are 12 criteria in a model, and within each criterion the companies are divided into 3 classes, then it is necessary to carry out fuzzification of 36 values. These fuzzy assessments represent the fuzzy assessments of each class of a single criterion, and they are used in the application of the model (described in item 3).

2. Determining the sub-criteria relative weights for each criterion separately

Managers follow their opinion when they quantitatively evaluate the importance of the sub-criteria with one of the assessments from the 0–10 range (step five). These assessments are translated into the [0, 1] interval by means of the function y = x / 10, where: $x \in [0, 10]$. The sub-criteria relative weights are determined for each criterion separately, that is, for each class of companies within each criterion separately. In Table 3, an example of the s-th class of the C_i criterion is given. The assessments given by the managers from the s-th class to the sub-criteria of the i-th criterion (columns M_{sik} in Table 3) are entered first. After that, the average value of the fuzzy assessment for each sub-criterion (the column with averages in Table 3) is determined. The sub-criteria relative weights are calculated on the basis of fuzzy assessments of these sub-criteria for each class of that criterion separately. To do that, one of the procedures can be applied, for example: (Leskinen, 2000; Noghin, 1997; Podinovski, 2002) and others. An original approach is applied in (Nikolić, 2004), which is also presented in (Nikolić & Sajfert 2004).

Table 3: Determining relative weights of the C_i criterion sub-criteria for the s-th class

		Managers whose assessments belong to the sth class for the C_i criterion					Average	Relative weight
		M_{si1}	M_{si2}	M_{si3}	…	M_{siH}		
C_i criterion sub-criteria (s-th class)	SC_{i1}				…			
	SC_{i2}				…			
	SC_{i3}				…			
	SC_{i4}				…			
	…				…			
	SC_{iq}				…			

Labels in Table 3 have the following meaning:

M_{sik} – the k-th polled manager from the s-th class for the i-th criterion, where k = 1, 2, ..., H – the number of the polled company from the s-th class for the i-th criterion, H = N / S – the number of managers in one class,

SC_{ir} – the r-th sub-criterion of the i-th criterion, where: r = 1, 2, 3, ..., q – the number of the observed i-th criterion's sub-criterion.

Step Eight: Determining of the company-representative for each class

Step eight is necessary because of the possibility of application of the calculated recommendations in a concrete case.

All the parameter assessments obtained in the fifth step are translated into fuzzy assessments, in other words, into the [0, 1] interval, with the function y = x / 10, where: $x \in [0, 10]$. If the assessments obtained for the parameters which affect a single criterion in one company are observed, then these assessments actually represent a fuzzy set of characteristics of the company observed which have influence on a certain criterion and its sub-criteria for that company (C_{ksi} columns on Table 4). Observed at the level of one single criterion for all the companies, there are N fuzzy sets, where N is the the number of analyzed companies.

Note: What is meant as 'company' here is the opinion expressed by the manager which was formed on the basis of the situation in his/her company. That is why the term *company* is used in further text, which is more convenient than the term *manager* for this presentation.

The essence of this step is to determine for each class those companies which are 'most similar' to the companies of its class (within a given criterion). These companies are representatives of their class. The class representatives have parameter values which all other companies of that class aim at. It is adopted that for each class there are three representatives. In this way, greater stability of the results is expected than in the case of each class having one representative. On the other hand, by further increasing the number of the class representatives, a decrease in the representativeness of these representatives can occur.

Table 4: Tabular presentation of fuzzy sets for the companies of the s-th class according to the i-th criterion

Class CL_{si}		Companies of the CL_{si} class				
		C_{1si}	C_{2si}	C_{3si}	...	C_{Hsi}
Parameters which describe the i-th criterion	X_{1i}	μ_{1s1i}	μ_{2s1i}	μ_{3s1i}	...	μ_{Hs1i}
	X_{2i}	μ_{1s2i}	μ_{2s2i}	μ_{3s2i}	...	μ_{Hs2i}
	X_{3i}	μ_{1s3i}	μ_{2s3i}	μ_{3s3i}	...	μ_{Hs3i}
	...	...	...	...	...	...
	X_{ni}	μ_{1sni}	μ_{2sni}	μ_{3sni}	...	μ_{Hsni}

Labels in Table 4 have the following meaning:

X_{ji} – the parameter which describes the i-th criterion, where j = 1, 2, 3, ..., n – the number of the observed parameter,

C_{ksi} – the k_{th} surveyed company from the s-th class for the i-th criterion, where k = 1, 2, ..., H – the number of the company surveyed from the s-th class for the i-th criterion,

μ_{ksji} – degree of membership (fuzzy assessment) of the k-th company from the s-th class, for the j-th parameter, according to the i-th criterion.

Table 5: Determining the similarity measure of each fuzzy set with each other, between the companies belonging to one class

CL_{si} Class		CL_{si} Class Companies					$\sum_{j=1, j\neq k}^{H} m_{kji}$	m_{srk}
		C_{1si}	C_{2si}	C_{3si}	...	C_{Hsi}		
Companies in the PI_{si} subinterval	C_{1si}	-	m_{12i}	m_{13i}	...	m_{1Hi}	$\sum_{j=1, j\neq k}^{H} m_{1ji}$	m_{sr1}
	C_{2si}	m_{21i}	-	m_{23i}	...	m_{2Hi}	$\sum_{j=1, j\neq k}^{H} m_{2ji}$	m_{sr2}
	C_{3si}	m_{31i}	m_{32i}	-	...	m_{3Hi}	$\sum_{j=1, j\neq k}^{H} m_{3ji}$	m_{sr3}
	...	...	...	...	-	...		...
	C_{Hsi}	m_{N1i}	m_{N2i}	m_{N3i}	...	-	$\sum_{j=1, j\neq k}^{H} m_{Hji}$	m_{srH}

Labels in Table 5 have the following meaning:

C_{ksi} – the k-th polled company from the s-th class for the i-th criterion, where k = 1, 2, ..., H – the number of the company surveyed from the s-th class for the i-th criterion,

m_{kji} – the similarity measure of the k-th company to the j-th company, according to the i-th criterion. The similarity measure takes its value from the [0, 1] interval. In the process, equality $m_{kji} = m_{jki}$ still applies.

$\sum_{j=1, j\neq k}^{H} m_{kji}$ - sum total of the measures of similarity of the k-th company in relation to the other companies from the s-th class,

m_{srk} – average similarity measure of the k-th company in relation to the other companies from the s-th class. It is calculated in the following way:

$$m_{srk} = \frac{\sum_{j=1, j\neq k}^{H} m_{kji}}{H-1} \quad (1)$$

The method of processing in step eight can be represented with Tables 4 and 5. For each class of companies (the companies in which the observed criterion is equally important), there is H of fuzzy sets, where H – the number of companies (managers) in one class. This is shown in Table 4.

After forming Table 4, the similarity measures of each fuzzy set to each other within the companies of one class are determined, and the results are entered in Table 5. The companies are compared with themselves. The expression (3) is used to determine the degree of similarity.

The class representatives are three companies which have the highest average similarity measures in relation to the other companies from the same class, which is manifest from the last column in Table 4. The procedure is repeated for all the classes within one criterion, and the same is then repeated for all other criteria.

2.1 Fuzzy measure selection and defining

The right selection of the fuzzy measure that will be applied in the research represents a special problem. When defining the corresponding fuzzy measure, the references which treat the area of multi-criteria decision-making and fuzzy sets (Pedrycz & Gomide, 1998; Royo & Verdegay, 2000; Triantaphyllou, 2000) were particularly useful. On the basis of this, and based on the needs and specificities of the given research, a fuzzy measure was defined which rests on Hamming's distance:

$$m_{abi} = 1 - \frac{\sum_{j=1}^{n} \left| X_{jai} - X_{jbi} \right|}{n_i} \qquad (2)$$

where:

m_{abi} – the similarity measure of the a-th company to the b-th company according to the i-th criterion,

X_{jai} – fuzzy assessment of the j-th parameter for the a-th company according to the i-th criterion,

X_{jbi} – fuzzy assessment of the j-th parameter for the b-th company according to the i-th criterion,

n_i – the parameter number of pairs, that is, the number of parameters which describe the i-th criterion.

The subtrahend in expression (2) represents, in fact, the average difference (distance) between the a-th and the b-th company according to the i-th criterion.

In order to determine more objectively the similarity measure, expansion of the previous expression is introduced, which takes into account the relative weights of individual parameters within the same criterion.

$$m_{abi} = 1 - \frac{\sum_{j=1}^{n} \left| X_{jai} - X_{jbi} \right| \cdot W_{ij}}{n_i} \qquad (3)$$

where:

W_{ij} – proportional (expanded) relative weight of the j-th parameter for the i-th criterion.

$$W_{ij} = w_{ij} \cdot n_i \qquad (4)$$

where:

w_{ij} – the relative weight of the j-th parameter for the i-th criterion. These weights for all the parameters within all the criteria are obtained in the step four, on the basis of Survey 1 (step three).

In the expression (3), W_{ij} values must be used, because in this case there is no unreal increase in the similarity measure. If the w_{ij} values were used, there would be unreal decrease in the average difference, and with it the unreal increase in the degree of the similarity measure.

2.2 Presentation of the final research results

The final results of the research can be presented in table form (Table 6). A table showing elements contained in Table 6 is formed is created for each criterion.

Table 6: Presentation of the final research results in a general case (for the C^i criterion)

CL_{si} Class	Parameter values of all the representatives of the C_i class criterion (determined in step eight)				C_i criterion fuzzy assessments for each class (determined in step seven)	Relative weights of all the C_i criterion sub-criteria for each class (determined in step seven)			
	X_{i1}	X_{i2}	...	X_{in}		SC_{i1}	SC_{i2}	...	SC_{iq}
I									
II									
III									

3 Application of th research results

What is understood under ‘application of the research results’ of the criteria and sub-criteria is the procedure of determining the fuzzy assessments of all the criteria and relative weights of their sub-criteria for a concrete company (the company which is selecting a new product) in the current conditions. The procedure is the following:

1. The managers from a concrete company assess their own company according to all the required x_{ij} parameters (like the managers in the first part of Survey 2 - step five did). The assessments are awarded for the current state in the company and its setting. These are the n_{ji} values, which are entered in the last row of Table 7.
2. Fuzzy sets are formed from the given assessments for each criterion separately (elements of these fuzzy sets are parameter values for a corresponding criterion). Then, the fuzzy set for one single criterion is compared with the fuzzy sets of representatives of all the classes within that criterion through the selected fuzzy measure, expression (3). The similarity measures are added up for every three representatives of each class (the Sm_{si} values in the last column in Table 7). The class within this criterion with which the concrete company has the highest collective similarity measure is finally adopted. This procedure is shown in Table 7.

Table 7: Determining the highest collective similarity measure of a concrete company (CC) with the representatives of all the C^i criterion classes

Class CL_{si}	Parameter values of all the C_i criterion class representatives with				Similarity measures of a CC and representatives of all the C_i criterion class representatives	Collective simil. measures of the i-th criterion’s s-th class
	X_{i1}	X_{i2}	...	X_{in}		
	W_{i1}	W_{i2}	...	W_{in}		
I	μ_{1I1i}	μ_{1I2i}	...	μ_{1Ini}	$m_{1,I,i}$	$\Sigma m_{I,i}$
	μ_{2I1i}	μ_{2I2i}	...	μ_{2Ini}	$m_{2,I,i}$	
	μ_{3I1i}	μ_{3I2i}	...	μ_{3Ini}	$m_{3,I,i}$	
II	μ_{1II1i}	μ_{1II2i}	...	μ_{1IIni}	$m_{1,II,i}$	$\Sigma m_{II,i}$
	μ_{2II1i}	μ_{2II2i}	...	μ_{2IIni}	$m_{2,II,i}$	
	μ_{3II1i}	μ_{3II2i}	...	μ_{3IIni}	$m_{3,II,i}$	
III	μ_{1III1i}	μ_{1III2i}	...	μ_{1IIIni}	$m_{1,III,i}$	$\Sigma m_{III,i}$
	μ_{2III1i}	μ_{2III2i}	...	μ_{2IIIni}	$m_{2,III,i}$	
	μ_{3III1i}	μ_{3III2i}	...	μ_{3IIIni}	$m_{3,III,i}$	
CC – Concrete Company	ν_{1i}	ν_{2i}	...	ν_{ni}		

The labels in Table 7 have the following meaning:

X_{ij} – the j-th parameter which describes the i-th criterion, where: j = 1, 2, 3, ..., n – the number of the observed parameter,

W_{ij} – Extended relative weight of the j-th parameter for the i-th criterion, where: : j = 1, 2, 3, ..., n – the number of the observed parameter,

μ_{ksji} – fuzzy assessment of the k-th representative in the s-th C_i criterion class for the j-th parameter,

ν_{ji} –fuzzy assessment of the k-th representative in the s-th C_i criterion class for the j-th parameter,

m_{ksi} – the similarity measure of a concrete company to the k-th representative of the s-th C_i criterion class.

3. In the last column in Table 7 is required maximum value $S\mu_{si}$ – collective similarity measure of the i-th criterion s-th class. In this way, it is determined which class of companies the concrete company is most similar to according to the observed criterion. A concrete company adopts the recommendations on fuzzy assessment of the observed criterion and relative weights of their sub-criteria (which is obtained by data processing in the Seventh step) for the class of companies it is most similar to. To do this, the structured data from Table 6 are used. The same procedure is repeated for all the criteria. In this way, a concrete company determines the values of fuzzy assessments of all the criteria and the relative weights of their sub-criteria.

The only thing left is to determine the relative weights of the basic criteria. The values of fuzzy assessments of all the criteria serve as the starting point for determining the criteria relative weights. To do this, we can use some of the procedures such as: (Leskinen, 2000; Noghin, 1997; Podinovski, 2002) and others; original approach is applied in (Nikolić, 2004), which is also presented in (Nikolić & Sajfert 2004). With the data on the relative weights of all the criteria and sub-criteria, the procedure of multi-criteria selection of a new product is entered by applying one of the multi-criteria analysis methods.

If it is assumed that there are 12 criteria for selecting a new product which are researched, and that within each criterion there are 3 classes of companies, (like in Nikolić, 2004), then a concrete company can get recommendations for one of $3^{12} = 531441$ possibilities of defining the relative weights of the basic criteria.

4 Examples

4.1 Example of criteria, sub-criteria, and parameters

Example of criteria (Nikolić, 2004):

C_1 - Company Business Policy,

C_2 - Management of spatial capacities,

C_3 - Possession of technological knowledge (know-how),

C_4 - Management of production capacities (machinery, tools, equipment),

C_5 - Supply of Raw Materials,

C_6 - Personnel Potentials,

C_7 - Product Potentials (originality, attractiveness, value for the user and the like),

C_8 - Market Size,

C_9 - Market Needs,

C_{10} - Market Growth and Prospects,

C_{11} - Strength of Competition,

C_{12} - Time period of return of invested funds.

Example of sub-criteria of criterion C_9 - Market Needs (Nikolić, 2004):

SC_{91} - Evaluation of the demand for the new product on the local market,

SC_{92} - Evaluation of the demand for the new product on the national market,

SC_{93} - Evaluation of the demand for the new product on the international market.

Example of some parameters of criterion C_9 - Market Needs (Nikolić, 2004):

X_{91} - Timeliness and reliability of information from the market,

X_{92} - Continuity in information inflow from the market,

X_{93} - Degree of change in consumers' needs,

X_{94} - Degree of acquaintance and awareness of consumers' needs,

X_{95} - Consumers' satisfaction with company's existing products, etc.

4.2 An example of application of the research results

A shortened example of application of the results obtained by the research is shown in Table 8. The example refers to a single criterion (criterion C_i is viewed here). In Table 8 are shown:

- parameter values for all the three representatives of each C_i criterion class (determined in Step 8),
- values of extended relative weights of all the criterion C_i parameters (expression 4),
- C_i criterion fuzzy assessments (FA) for all classes (determined in Step 7, segment 1),
- relative weights of the C_i criterion sub-criteria for each class (determined in Step 7, segment 2), and
- parameter values for a CC (Concrete Company) (to be assigned by the decision-maker in the company which is selecting a new product).

By applying the procedure from item 3 of the paper, one can determine which class is a CC most similar to according to the observed criterion C_i. In this way, recommendations are obtained on fuzzy assessments of the C_i criterion, and the relative weights of the C_i criterion sub-criteria. In the example given in Table 8, it can be seen that the CC is most similar to the criterion C_i I class. The same procedure is repeated for all the criteria in the model. The criteria relative weights are obtained on the basis of the recommended fuzzy assessments for each criterion. Some of the quoted procedures can be used in the process.

5 Conclusion

Criteria for selecting a new product do not have equal importance (relative weights) for all companies and all settings. There is a mutual dependence between the importance of the criteria for selecting a new product and the company's degree of success and the situation in its setting. That is the reason why an original methodology of research of the criteria for selecting a new product was developed. It enabled obtaining recommendations on the importance of criteria and sub-criteria for selecting a new product, but depending on the current characteristics of a company and its setting.

The most significant characteristic and advantage of the proposed methodology is that with a change of certain conditions inside the company and its setting, there are corresponding changes of exiting the model (recommendations for each criterion) For all this, the whole procedure has a dynamic character and the possibility of application in different situations and at different moments of observation. The company which is selecting a new product obtains the recommendations according to its current state and situation in its setting. The recommendations are obtained in the form of fuzzy assessments of the importance of the criteria and their sub-criteria relative weights. The obtained recommendations represent important input data and support for multi-criteria ranking of the alternatives for new products.

The proposed methodology also has its practical value. In (Nikolić, 2004) research of the criteria in food industry was carried out. The research was carried out on the territory of Serbia and Montenegro, more precisely on the territory of Vojvodina and in the Belgrade metropolitan area. The obtained results have significance primarily

Table 8: An example of application of the research results of criterion C_i

Class CL_{si}	Value of parameters of all representatives of classes of criterion C_i			Measures of similarity with CC	FA of criterion C_i for every class	Rel. weights of all crit. C_i sub-criteria for every class		
	X_{i1}	X_{i2}	X_{i3}					
	$w_{i1} = 0.4$ $W_{i1} = 1.2$	$w_{i2} = 0.35$ $W_{i2} = 1.05$	$w_{i3} = 0.25$ $W_{i3} = 0.75$			SC_{i1}	SC_{i2}	SC_{i3}
I	0.6	0.7	0.8	0.86	0.9824	0.3142	0.3716	0.3142
	0.7	0.5	0.6	0.9				
	0.5	0.6	0.7	0.88				
	$\Sigma m_{I,i}$			2.64				
II	0.6	0.4	0.6	0.825	0.7083	0.3405	0.3743	0.2852
	0.5	0.6	0.5	0.83				
	0.5	0.5	0.7	0.845				
	$\Sigma m_{II,i}$			2.5				
III	0.4	0.5	0.6	0.78	0.5022	0.3388	0.3885	0.2727
	0.4	0.5	0.4	0.73				
	0.5	0.4	0.4	0.735				
	$\Sigma m_{III,i}$			2.245				
CC	0.8	0.6	0.7					

for the food industry in Serbia and Montenegro, but could also be significant for other countries in transition. With certain alterations, above all at the criteria, sub-criteria and parameter defining stage, the proposed methodology can be applied to research the criteria for selecting a new product in other economies and economic conditions as well. The concrete results of the research are not presented here because of the size of the paper, and above all because of the desire to point to the very procedure of work, its significance, and its universality.

The results obtained by applying the proposed methodology are primarily significant for medium-sized and large companies, although their application in small companies should not be ruled out. In this way, all categories of new products can be ranked: completely new products, products that are new for the company observed, innovated existing products, etc. The results of the research are already applied in the concrete situations of selecting a new product. The products that have been selected in this way achieve very good results on the market and positively influence the company's business. These claims have been confirmed in 12, up to now, situations analyzed.

Additional importance of the methodology presented in this paper is in that its basic principles, with adequate modification, can be used for researching other problems and phenomena in industrial engineering, management, but also in other areas.

Regarding drawbacks of the given methodology, the most prominent is the fact that it is essential to define the criteria and sub-criteria for selecting a new product, as well as the influential parameters. This subjectivity is real, but the stress is laid on the validity of the procedure itself, which can be repeated and realized for different sets of criteria and parameters if necessary. The observed drawback can be significantly reduced, or completely overcome if one uses those criteria which have been identified as the key ones in one of the known research projects. In this respect, the research method of the criteria for selecting a new product proposed here could be accepted as a continuation and addition to similar research.

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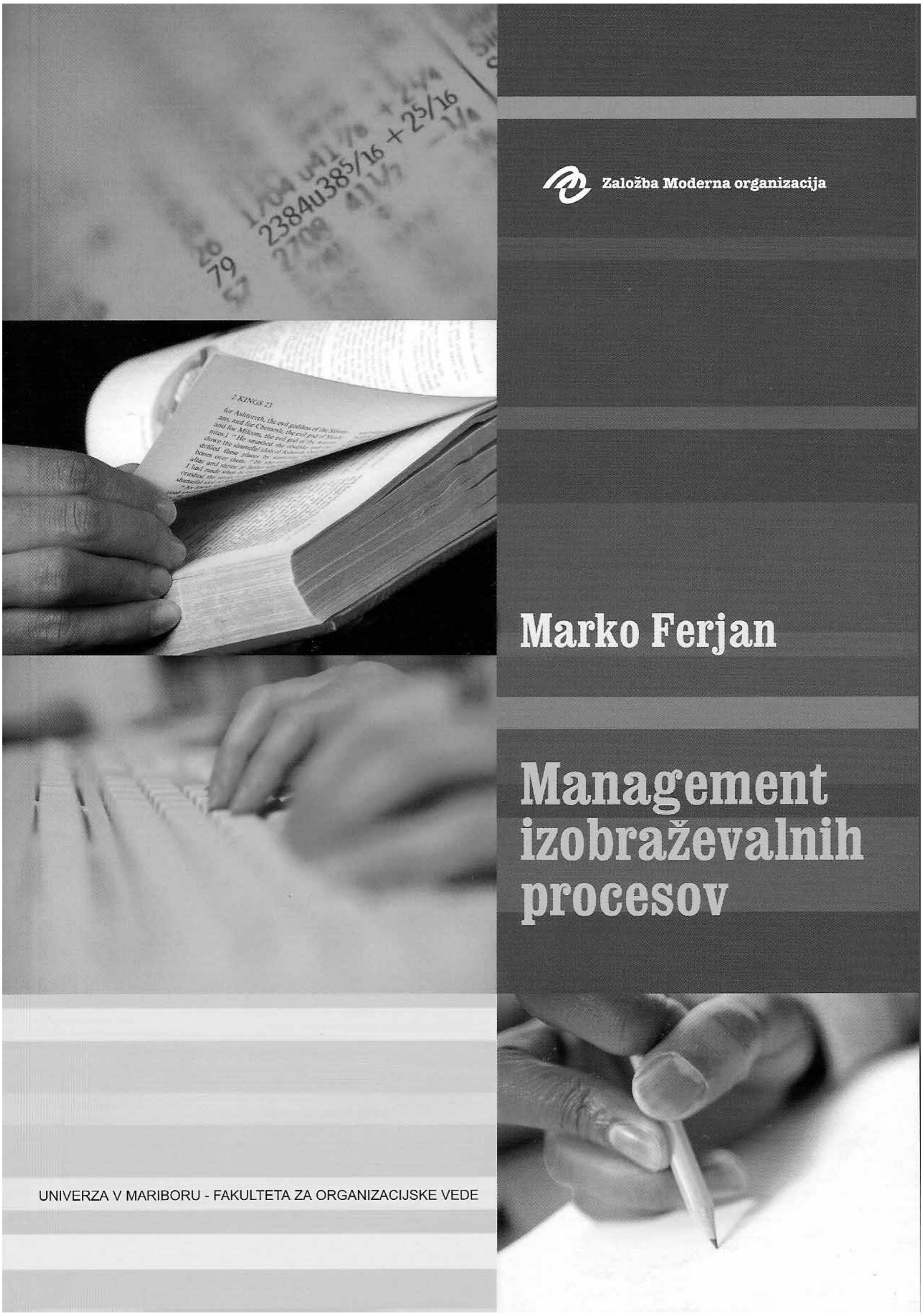

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