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Editorial

The aim of this thematic issue "Recent Advances in Systems, Decision Making, Collaborative Work and Learning" is to continue presenting the research achievement from the area of Systems Approach and Decision Support Systems for assessments of complex problems. The majority of the contributions were presented at the 23rd, Conference on System Research, Informatics and Cybernetics, Baden-Baden, Germany, August 1-5, 2011, in the stream Simulation Based Decision Support, chaired by Miroljub Kljajić. The special issue includes papers dealing with the development of simulation methodology, modeling tools and practice for decision assessment, service systems, control and optimization and ecological dynamics research. The last two decades much stressed on neoliberal education policies as a way to cope with globalization and its impact on nation states. The current trend leads to a paradigm shift that considers a more collectivist trends that includes social and environmental issues in its agenda to a more sustainable living that includes issues of environmental pedagogy and social justice. Current curricula policies emphasize issues of global warming, climate change, protection of species and the ecology as a way to foster a sustainable development, and foci is on social issues such as poverty, health, migration, and cultural diversity, and a need for developing life-long learning skills. To address those issues above firm policies need to be established as a result of continues search for a sustainable future. In that respect, the paper entitled "GEPSUS: Simulation-based decision making system for air pollution accidents", addresses the GIS-based real-time system for emergency response and management of air pollution accidents in an urban area. The GEPSUS project, funded by the NATO programme Science for Peace, presents one attempt in this direction to provide emergency responders with an integrated system for control and management of hazardous gases accidents, especially in urban areas. It integrates automatic data importing with GIS-based hazardous gas dispersion, simulation and decision-making. In this paper, emphasis is placed on accidents caused by industrial and transport facilities, which can be considered as emission point sources. During simulations, the real-time weather conditions are considered such as wind speed and direction as well as atmospheric stability. Decision making is made based on the calculation of threat zones, unsafe area and safe traffic routes. For system validation, Montenegro was selected, specifically several hazardous industrial objects. The same approach can be extended to other hazard sources such as transportation (train derailments, etc), large storage tanks, pipes etc., with small modifications in the dispersion model.

The paper entitled "System dynamics model for policy scenarios of organic farming development" presents the system dynamics model of organic farming development in order to support decision making. It is further improvement of the previous model for the development of organic agriculture in Slovenia in order to identify key variables that determine conversion dynamics and to propose development policy in order to achieve strategic goals as set in the Action plan ANEK. The model seeks answers to strategic questions related to the level of organically utilized area, levels of production and crop selection in a long-term dynamic context. The model will be used for simulation of different policy scenarios for organic farming and their impact on economic and environmental parameters of organic production at an aggregate level. Using the model, several policy scenarios were performed. The main findings and suggestions for further study conclude the article. This is a powerful methodology and computer simulation modelling technique for framing, analyzing, and discussing complex issues and problems.

The paper entitled "The need for simulation in complex industrial systems". This paper discusses the concept of simulation and its application in the resolution of problems in complex industrial systems. Most problems of serious scale, be it an inventory problem, a production and distribution problem, a management of resources or process improvement, all real world problems require a mix of generic, data algorithmic and Ad-hoc solutions making the best of available information. We describe two projects in which analytical solutions were applied or contemplated. The first case study uses linear programming in the optimal allocation of advertising resources by a major internet service provider. The second study, in a series of projects, analyses options for the expansion of the production and distribution network of mining products, as part of a sensitive strategic business review. Using the examples, we make the case for the need of simulation in complex industrial problems where analytical solutions may be attempted but where the size and complexity of the problem forces a Monte Carlo approach.

The paper entitled "Contribution to the collaborative work in virtual organization - a case study" we describes virtual organization as a community of people who interact together socially on a technical platform. These kinds of communities are built on a common interest, a common problem or a common task of its members that is pursued on the basis of implicit and explicit codes of behavior. The six dimensions that are normally used to analyze virtual organizations are the use of technologies, sense of belonging, success factors, level of trust from members, virtual community management, and contents of the virtual community. The virtual organizations defined in the literature are not defined separately for non-profit research virtual organization. Here we present analysis of non-profit research virtual organization, European Working Group on Operational Research for Development (EGW ORD). This paper provides a summary of achievements and challenges faced in building a virtual organization. This kind of analysis plays a vital role in establishing new non-profit virtual organizations to serve the research community in their field of interest. It is also helpful to the group in broadening its presence and involving more researchers, practition-

ers and students in the field of operational research.

The purpose of the study presented in the paper entitled "Comparative analysis of collaborative and simulation based learning in the management environment", Purpose of the study is to compare two different approaches to the collaborative problem solving one with highly control laboratory experiment: Optimisation of business politics using business simulator at different experimental condition which reflect different feedback information structure and Collaborative Learning in the Social Media Environment characterised by non-structured, rule-free and even chaotic feedback information. Comparative analyses of participant's opinion who participate in experiments have been considered in order to find common characteristics relevant for group problem solving. General explanatory causal loop model of learning was found for both experiments with regard to group problem solving and learning. All participants in both cases agree that clear presentation of the problem motivates participants to find the solution. So, in the future, the use of realistic yet sufficiently simple business models is essential, if one wishes to close the gap between business processes understanding and the role of modeling and simulation in problem solving.

In the last paper of the issue, "Application of Fuzzy AHP Approach to Selection of Organizational Structure with Consideration to Contextual Dimensions", the researchers employ a fuzzy multi attribute decision making model (FMADM) to select the most suitable organizational structure based on expert's judgments and by deploying contextual dimensions of the organization. Since the organizational changes especially in the structural levels are along with resistances among involved staffs, the implementation of this model is a supportive tool in addition to help the managers to make a qualified decision and change.

Guest editors hope that our selected topics display the state-of-the-art of the research efforts over the world coping with complex problem solving in a holistic way which is characteristic for modern Systems Research and Cybernetics! Moreover, we are very thankful to our journal Organizacija (Organization - Journal of Management, Information Systems and Human Resources) for having given us the opportunity and honour of hosting this special issue as a scientific project and service to the people on earth. We express our gratitude to the Editors of Organizacija, and hope that our special issue will well-demonstrate Organizacija being a premium journal and of a great scientific and social value!

The Guest Editors:
Miroljub Kljajić and
Gerhard-Wilhelm Weber

In Memoriam – Professor Milton A. Jenkins

It is with great sadness that we learned that Professor Milton A. Jenkins passed away in Annapolis, Maryland on August 16, 2012. A graduate of the Information Systems Program at the University of Minnesota, he spent most of his academic carrier with the University of Baltimore, where he served as Director of the Information Systems Research Center, Department of Management Information Systems.

Milton Jenkins developed numerous international contacts around the world, including in Slovenia. Many successful and beneficial contacts and friendly relations were established during his frequent visits to Slovenia and with Slovenians visiting the US. He is very well known to numerous educators and students, as well as to the IT community and companies in Slovenia.

Professor Jenkins came to Slovenia for the first time in spring 1978 as a visiting scholar of the University of Indiana. The visit was organized in a frame of a long-term US exchange program between the business schools in the US and Yugoslavia. For example, in Slovenia, the Faculty of Economics of the University of Ljubljana was connected with the School of Business of the University of Indiana.

From the early beginning of Professor Jenkins' visits to Slovenia, he engaged in various activities of the Faculty of Organizational Sciences of the University of Maribor. He was named a visiting professor, teaching a graduate course Research in Information Systems for many years; he was offering annual half-day seminars on latest development in information systems (IS) to a business community of the Gorenjska region. Since the third Bled eConference in 1990, he had served on the program committee of the conference and a speaker. Personally, he was very much engaged in the pre-conference two-day Doctoral Consortium organized in Otočec for several years in cooperation with the Ministry of Science of the Republic of Slovenia. The consortium was very special and most probably the first of the kind in the world, bringing together graduate students interested in eCommerce and Inter-Organizational Systems. The consortia were hosted by the Krka Pharmaceuticals company of Novo mesto. Nowadays, numerous IS professor all over the world have in their cabinets a "Krka Fellow" plaque, respectively a "Krka Scholar" plaque those having engaged in the Doctoral Consortia as mentors. The Krka Doctoral Consortia of which Professor Jenkins was the spiritus agens have contributed much to forming the Bled eCommerce community, which was very well echoed in research and action globally.

At the University of Baltimore, Professor Jenkins created and operated the IS Professors Development summer school in the mid-1990s, in cooperation with the Association to Advance Collegiate Schools of Business (AACSB). The summer school was an advanced training program in information systems, a follow-up of a three-week basic summer school conducted by the University of Minnesota in Minneapolis. For several years, already established university professors in various disciplines having interest in IS research spent three weeks in a very intensive program in Baltimore. After returning home with a box of some forty IS books provided by the publishers, many of them began teaching IS courses. Several IS professors in Slovenia have enjoyed a privilege of being invited to the Summer School program on the University of Baltimore campus based on a grant provided by Professor Jenkins.

Professor Jenkins was instrumental in opening opportunities to several IS scholars in Slovenia to teach as visiting professors for one semester at Indiana or Baltimore. With encouragement, assistance in the administrative processes, and by providing his advice and support, Professor Jenkins helped many to start teaching in the US. The hospitality of his family in opening their home to many visitors coming from Slovenia is much appreciated.

In Slovenia, we owe a particular thanks to Professor Jenkins for his contribution to our understanding of a prototype methodology and its application in teaching and research. His seminars on prototyping in Slovenia in the early 1990s and the students' projects in his IS Research class contributed to not only understanding the methodology but also to an acceptance of a new information systems development culture.

His constant message was: "For a user, it is much easier to tell what she/he does not like in an operational prototype than to explain what the application that she/he wants is". His encouragement and assistance were helpful not only in students' projects being implemented in teaching and research in Slovenia but also in numerous e-solutions being practically implemented in Slovenian organizations. They were initiated as a simplified prototypes as a part of the student's project. Due to intensive prototype development and practical implementation in business and government organizations, the eCenter of the Faculty of Organizational Sciences was invited to join the Living Labs community (nowadays the European Network of Living Labs (ENoLL)) in a "first wave" in November 2006.

For his contributions to teaching and research, Professor Jenkins was awarded by the Faculty of Organizational Sciences and named Honorary Senator of the University of Maribor in 2000.

We miss Milt, our good colleague and friend!

Jože Gričar,
Professor Emeritus, University of Maribor

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GEPSUS: Simulation-Based Decision Making System for Air Pollution Accidents

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We describe a GIS-based real-time system for emergency response and management of air pollution accidents in an urban area. The system architecture emphasises the integration of meteorological, chemical and GIS data, dispersion modeling, decision-making and geo-spatial visualization. The threat zones, unsafe areas and safe traffic routes are obtained using an improved Gaussian plume model with a decision-making module and then exported to the Google Earth browser via "kml" file format. Several simulation scenarios were conducted and verified for notable industrial sites in Montenegro using recorded meteorological data. The results demonstrate that emergency response authorities can use the proposed methodology and system as a cost effective and accurate support tool in case of industrial or deliberate air pollution incidents.

Key words: hazardous gas releases, air pollution simulation, emergency management, GIS

1 Introduction

When hazardous gases are released into the atmosphere, whether accidentally or due to a terrorist attack, emergency response authorities require quick and relevant information about the area(s) likely to be affected and anticipated injuries or mortalities. The process is time-critical because of the decision-making loop. This is especially so for urban areas where the population density compounds the potential magnitude of the consequences and complicates evacuation of both the injured and unaffected populace (Pontigia et al., 2010, Abbaspoura and Mansourib, 2005).

Hence there is a pressing need for emergency responders and other civil protection stakeholders to have access to a support system for hazardous gas releases, which will be based on the latest information and communication technologies (ICT). Current air pollutant modeling software applications such as MET, ALOHA, BREEZE, TRACE, SAMS etc. can be applied but provide only a partial solution (Baumann-Stanzer and Stenzel, 2010). They are off-line and predominantly model the pollutant dispersion in 2D or 3D space displaying the concentration profiles (plumes) over digital maps. The plumes are static and do not consider the dynamics of the process, primarily the changes in atmospheric conditions and source strength (De Amicis et al., 2009). In addition, they do not support automatic data importing, incorporation of weather forecasts and, most importantly, decision-making required for a successful response.

A useful system for management and control of accidental/deliberate releases of hazardous gases should at least be real-time with the possibility to integrate several subsystems to enhance response accuracy; a) Geographical Information System (GIS), b) system for measurement and monitoring of chemical parameters, c) system for hydrometeorological monitoring and forecasts, d) system for modeling gas dispersion, e) local sensor networks, and e) system for planning emergency responses forces (De Amicis et al., 2009). For many years such

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subsystem integration was a problem due to technological limitations in ensuring rapid and multifaceted data flow and complex modeling computations in real-time.

The GEPSUS (**G**eographical information processing for **E**nvironmental **P**ollution-related **S**ecurity within **U**rban **S**cale environments) project, funded by the NATO programme Science for Peace, presents one attempt in this direction to provide emergency responders with an integrated system for control and management of hazardous gases accidents, especially in urban areas. It integrates automatic data importing with GIS-based hazardous gas dispersion, simulation and decision-making.

In the present paper, emphasis is placed on accidents caused by industrial and transport facilities, which can be considered as emission point sources. During simulations, the real-time weather conditions are considered such as wind speed and direction as well as atmospheric stability. Decision making is made based on the calculation of threat zones, unsafe area and safe traffic routes. For system validation, Montenegro was selected, specifically several hazardous industrial objects. The same approach can be extended to other hazard sources such as transportation (train derailments, etc), large storage tanks, pipes etc., with small modifications in the dispersion model.

2 System architecture

The structure of the GEPSUS system is shown in Fig. 1. The GEPSUS computing facility is the core of the system, which communicates with inputs and generates the outputs. There are four major automatic inputs from: a) Hydrological and Meteorological Service of Montenegro (HMZCG), b) Centre for Ecotoxicological Research of Montenegro (CETI), c) Real Estate Administration of Montenegro (REA) and, d) GEPSUS Sensor Networks (GSN) installed around critical installations. The HMZCG collects automated current weather data and produces forecasts for a national network of weather stations in Montenegro and through the weather forecast models that are part of the European Community and international weather forecast networks. In addition, HMZCG has its own simulation and modeling capabilities including a High Performance Computing (HPC) Centre for generating forecasts for Montenegro every 3 hours at 1 km resolution. The CETI monitors actual air pollution conditions using a network of automatic telemetric stations measuring the concentration of main gases over Montenegrin cities. The REA provides updated geographical information about geospatial information taken from terrain and cadastral surveys and stored on public servers. GEPSUS communicates with HMZGC, CETI and REA over internet-supported protocol or leased lines. The GSN consists of mobile telemetric stations installed around critical installations. Primarily they measure the wind speed and direction as well as ambient temperature, and transmits data through a GSM network directly to the GEPSUS centre. In future these stations will be equipped with chemical sensors for early warning. HMZCG and CETI provide data on a 10 minute basis, while the GSN has 1 minute averages. GEO data

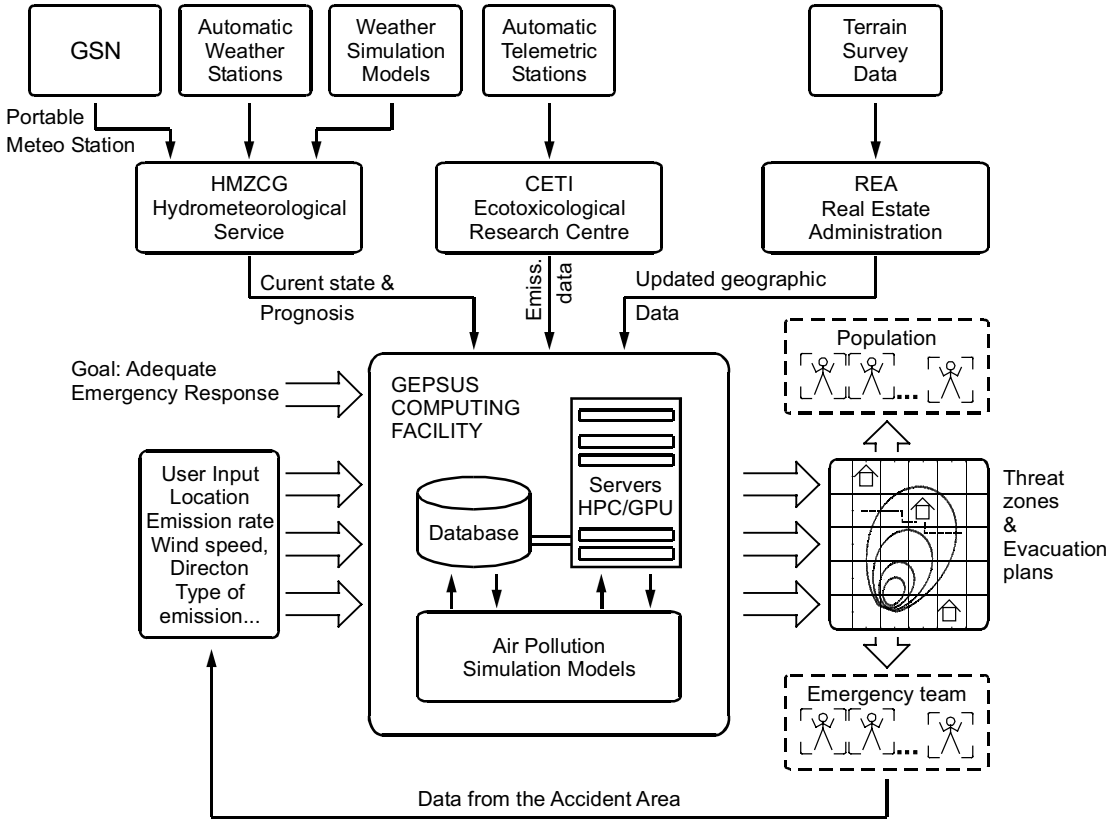

Figure 1: Architecture of the GEPSUS system

are updated on monthly scale or following important changes in geospatial information and hosts data about strategic buildings and areas such as hospitals, schools and public event areas with potentially high attendance (sports stadium, etc.).

The wind conditions (speed and direction) and their forecasts are considered as primary automatic data because the orientation and geometry of a release plume depends predominantly on them. The HMZCG provides wind conditions at a large scale, eg. for a city or region, while spot wind conditions are traced by local stations within the GSN which sends information in predefined formats readable by the GEPSUS application.

In addition to automatic inputs there are several manual inputs, usually entered by an operator or emergency expert. They provide more information about pollutant source(s) and atmospheric conditions as well the definition of the Levels of Concern (LOCs) – threshold levels of concentration in $\mu g/m^3$ or ppm. In future these inputs will also be automated. Source data includes accident location (latitude and longitude), description of the pollutant, type of gas and its characteristics, source type (point, line, area, tank or pipe) and its geometry (dimensions), emission rate, source height above aground, release duration, etc. Ground roughness, cloud cover, stability class, inversions, humidity and other parameters are weather conditions that are set manually. LOCs define the threat zones associated for each gas and they are usually standardized such as for the Emergency Response Planning Guidelines (ERPGs) or Acute Exposure Guideline Levels (AEGLs). As an example, for sulfur dioxide (SO_2) the ERPG-1, ERPG-2 and ERPG-3 levels are 0.3 ppm, 3 ppm and 25 ppm, respectively. Here, other accurate information about an incident can be involved, provided by air pollution experts or rescue crew in the field, who can enter input parameters manually via mobile handheld devices. Fig. 1 does not explicitly show the Emergency room with appropriate servers and equipment where input data are handled and dispersion modeling and decision-making are performed.

3 Modeling and visualization

The dispersion modeling is performed in MATLAB starting from generalized Gaussian plume equation (Chitumalla et al., 2008):

$$C(x,y,z) = \frac{Q}{2\pi u \delta_y \delta_z} e^{-\frac{y^2}{2\delta_y{}^2}} \left(e^{-\frac{(z-H)^2}{2\delta_z{}^2}} + e^{-\frac{(z+H)^2}{2\delta_z{}^2}} \right) + ST \quad (1)$$

$$ST = \sum_{n=1}^{k} e^{-\frac{(z+H-2nz_i)^2}{2\delta_z{}^2}} + e^{-\frac{(z+H+2nz_i)^2}{2\delta_z{}^2}} + e^{-\frac{(z-H-2nz_i)^2}{2\delta_z{}^2}} + e^{-\frac{(z-H+2nz_i)^2}{2\delta_z{}^2}} \quad (2)$$

in which the concentration of pollutant $C(x,y,z)$[g/m^3] in point x[m],y[m],z[m] depends on mass emission rate Q[g/s], wind speed u[m/s], dispersion coefficients σ_y[m], σ_z[m] and effective stack height H[m], which is a sum of actual stack height h^s[m] and plume rise Δh[m], $H=hs+\Delta h$. The ST is a summation term related to the inversion from mixing height z_i, while k is a summation limit for multiple reflection, usually ≤ 4.

The above equation is used to model the plume impacts from point sources, flare releases, and volume releases, and gives satisfactory results under several assumptions/approximations:

- Steady state process.
- Wind blows in x direction which is constant in both, speed and direction.
- Transport with the mean wind is much greater than turbulent transport in the x direction.
- Source emission rate is constant.
- Dispersion coefficients are constant in time and have space dependence towards several approximations, e.g. Pasquill's categories.
- The source emits Chemicals of Concern (COC) at a point in space x = y = 0 and z = H, where H is the effective height of the stack
- The COC are inert, non-decaying and non-reactive
- There is no barrier to plume migration
- Mass is conserved across the plume cross section
- Mass within a plume follows a Gaussian distribution in both the crosswind (y direction) and vertical (z direction).
- It is assumed that exit gas temperature is higher than the ambient temperature and varies in the range of 120-260 C°
- The wind speed at the point of gas release must be from 6-30 m/s.
- The effective stack high H is spatially constant, therefore plume rise has a constant value along the x axis.

Retaining some of the above assumptions, the GEPSUS approach modifies Equation (1) with respect to two main elements:

1) Considering plume rise, Δh is spatially dependant and,
2) Replacing σ_y, σ_z with effective values $\sigma_{y_{eff}}$ and $\sigma_{z_{eff}}$.

3.1 Calculation of plume rise and effective dispersion coefficients

Two categories of smokestack plumes tend to occur: the vertical plume and bent-over plume (Fig 2). They form depending on several parameters such as: stability classes, wind speed,

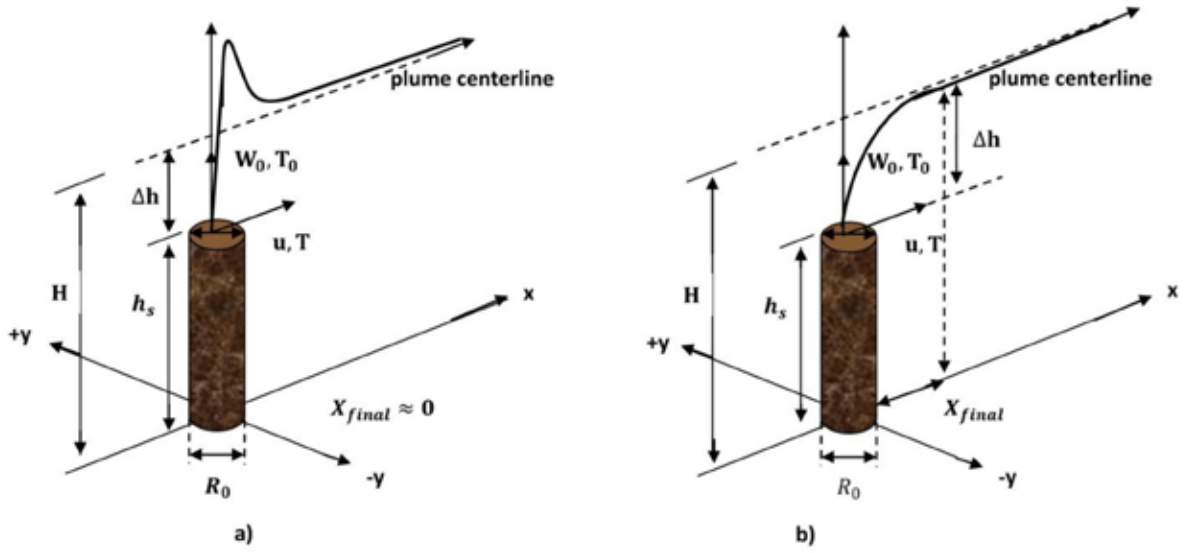

Figure 2: Direct plume (a) and bent-over plume (b).

exit speed of the gas, buoyancy flux parameter, etc. For example, in Pasquill stability classes A to D, when the intensity of wind is significant, the bent-over plume will be dominant, while the vertical form will be present in stable conditions, E or F.

The calculation of plume rise is based on a modified Briggs algorithm (Beychok, 2005) where Δh is calculated for two segments, before X_{final} - the point of maximum plume rise, and after X_{final}. Generally, Δh is a complex function and depends of numerous input parameters.

$$\Delta h = f(x, X_{final}, T, To, u, wo, g, Ro, \frac{\Delta\theta}{\Delta T}, Stability\ Classes) \quad (3)$$

where:

x: downwind distance from plume source [m]

x_{final}: downwind distance from plume source to point of maximum plume [m]

u: wind speed at actual stack height [m/s]

A, B, C, D, E or F: Pasquill stability classes

T_0: pollutant temperature at the source output [K]

T: ambient temperature [K]

W_0: pollutant exit speed at stack exit [m/s]

R_0: diameter of the stack [m]

g: gravitational acceleration [9,81m/s^2]

ΔΘ/ΔT: coefficient in [K/m] which depends on stability classes

The effective values $\sigma_{y_{eff}}$ and $\sigma_{z_{eff}}$ are calculated from dispersion coefficients σ_y and σ_z, taking into consideration the above parameters:

$$\sigma_{y_{eff}},\ \sigma_{z_{eff}} = f(x, X_{final}, T, To, u, wo, g, Ro, \sigma_y\ \sigma_z\ ,\ Terrain\ Type) \quad (4)$$

where σ_y and σ_z are determined from Pasqual-Gifford dispersion coefficients (Briggs, 1965).

Considering the explained modifications, the concentration $C(x,y,z)$ from Equation (1) takes an analytical expression $C'(x,y,z)$, which is considered as a basic equation in GEPSUS calculations for the case of industrial point sources:

$$C'(x,y,z) = \frac{Q}{2\pi u \delta_{y_{eff}} \delta_{z_{eff}}} e^{-\frac{y^2}{2\delta_{y_{eff}}^2}} \left(e^{-\frac{(z-(h_s+\Delta h))^2}{2\delta_{z_{eff}}^2}} + e^{-\frac{(z+(h_s+\Delta h))^2}{2\delta_{z_{eff}}^2}} \right) + \cdots.$$

$$\ldots. + TS(\Delta h, \sigma_{y_{eff}}, \sigma_{z_{eff}}) \quad (5)$$

Usually the summation term *TS* is neglected and concentration is observed at ground level (z=0).

3.2 Visualization and interfacing to GIS

The overall program for calculation of pollutant concentration according to Equations (1) to (5) was developed in MATLAB and has an algorithmic structure, as given in Fig. 3. The function accepts input parameters and produces mid-term output in the form of a 3D concentration matrix $C'(x,y,0)$ and the final output in the form of a set of contour matrices $Coi(x,y)$, i = 1,2..n. In fact $Coi(x,y)$ presents threat zones and is obtained as:

$$Coi(x,y) = \begin{cases} 1 \; for \; C'(x,y,0) = Ti \\ 0 \; elsewhere \end{cases} \quad (6)$$

where *Ti* is LOC for the observed gas in $\frac{\mu g}{m^3}$ or ppm.

In order to be displayed by a GIS, the obtained threat zones need to be transferred into format readable by a Geo Browser. In GEPSUS, Google Earth (Tiwary and Colls, 2009) is used because of its wide availability, good graphical interface and possibility to run even on PDA devices. The "kml" file format is used as an interface between MATLAB and Google Earth (http://www.google.com/earth, Accesed, January 12, 2012). It is an open standard officially named the OpenGIS RKML Encoding Standard (OGC KML) (Google Earth, 2012) and is maintained by the Open Geospatial Consortium, Inc. (OGC). In addition the kml format can be read by a majority of GIS browsers. When kml files are produced from the application, such as MATLAB custom code, the format should be checked for errors with the XML validator against the kml schema. Before generating kml, the contour graphs (given in meters) should be transferred in latitude-longitude coordinates taking into account source position and then rotated wind angle. As a wind reference angle, north (N) is considered (). Coordinate transformation, rotation and kml forming are also implemented in MATLAB according to the algorithmic flow given in Fig. 3 (right-side).

4 Decision making

The determination of air pollution spread in urban areas is not the only content of the GEPSUS system. As was mentioned earlier, the important issue for emergency response authorities is decision-making. Usually, an individual or group must take decisions but, in many cases, techniques can help him to do so faster and with an increased capability of being more accurate (OpenGL, 2012). In this project phase two algorithms for supporting decision-making are considered:

1. Determination of an unsafe area and,
2. Proposing a safe traffic route between two points.

The unsafe area (UA) is associated with an unsafe perimeter and unsafe arc that are related to each threat zone. Three main parameters should be considered (Fig. 4 a): initial perimeter (P), initial angle (IA), perimeter span (PS) and angle span (AS). P is associated with each threat zone and presents the distance between source of emission and farthest point in the observed zone. PS is an extension of P produced by changing input parameters, wind speed, source strength, stability classes etc. AS is predominantly a function of wind direction (WD), while IA is associated with actual WD. As seen in Fig. 4a, the selected threat zone can rotate and translate from $(IA - AS)^O$ to $(IA + AS)^O$ and from *0 to P + PS*. As example is presented in Fig. 4a for IA = 270° and AS = 90°, P about 8 km and PS about 1 km. The emergency response group should evacuate people from unsafe areas without losing precious time. Using current parameters and weather forecasts, it is important to predict PS and AS as precisely as possible and for such purposes special algorithms and expert modules are used (Škraba et al., 2003). As an example, AS is determined from the standard deviation of WD.

As shown the UA overlaps the critical infrastructure such as roads, schools, student hostels and hospitals that are within the plume hazard area, as example 3 critical objects are covered by UA in Fig. 4a. The attributes of critical infrastructure are determined from emergency data base as well as evacuation instructions and plans. The GEPSUS system uses the records of emergency data base.

The second case concerns taking the shortest safe path in urban traffic. Namely, when an accident happens at some location the traffic needs to be redirected through the safe area. Here GEPSUS developed an algorithm for dynamic routing according to the criteria of the shortest path and safest area, based on an acceptable level of pollutant concentration. The

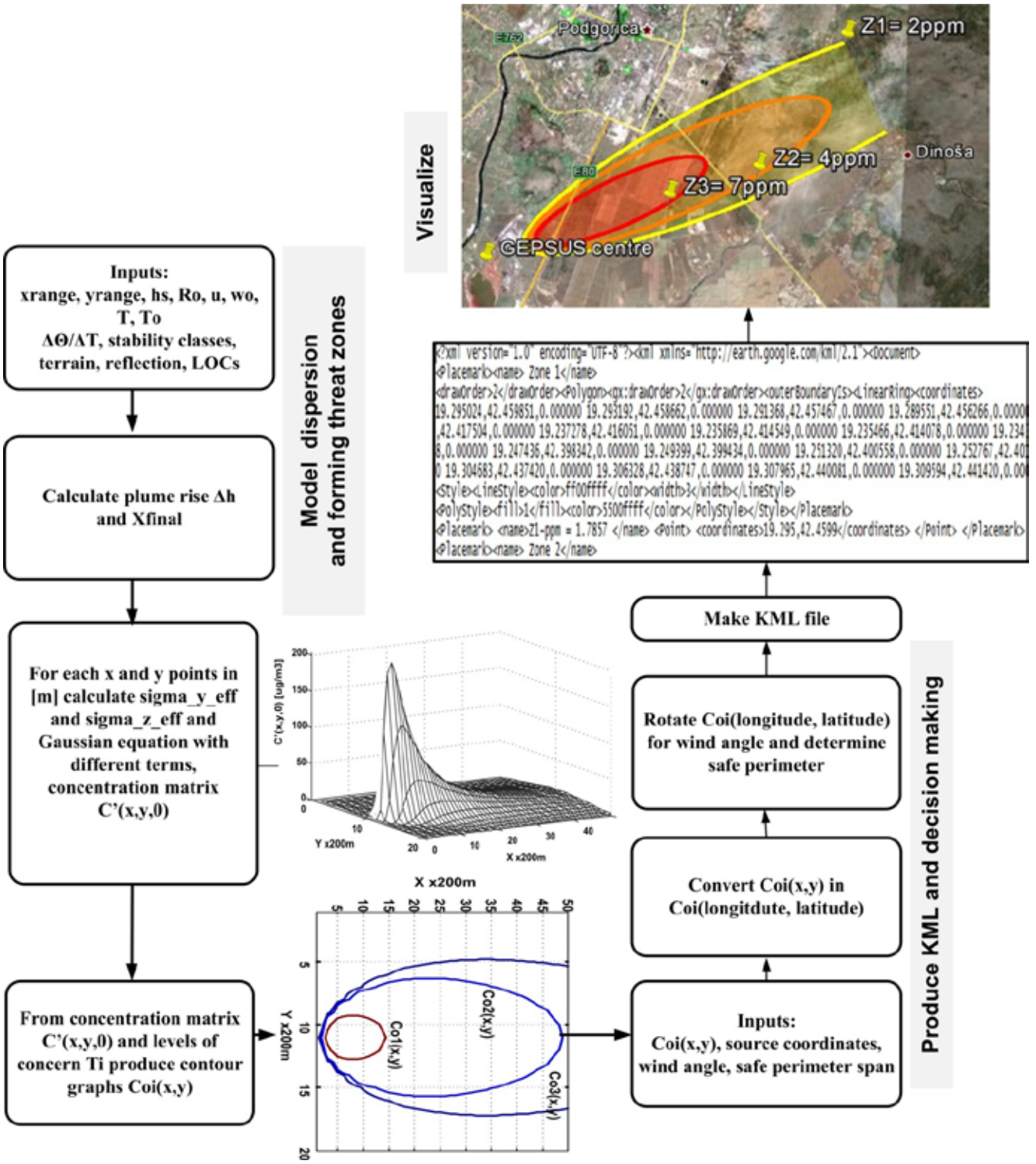

Figure 3: Algorithmic structure of GEPSUS code for modeling and visualization; left side dispersion modeling, right side KML forming with decision-making functions.

algorithm searches for the shortest path between points A and B, Fig. 4b. Concentration thresholds determine the threat zone to be avoided and includes the following steps:

1. Select concentration limit and determine the threat zone
2. Get intersections (nodes) and roads (edges) of the observed area representing possible evacuation routes
3. Remove all nodes and edges inside the polluted area
4. Remove all edges intersecting the polluted area

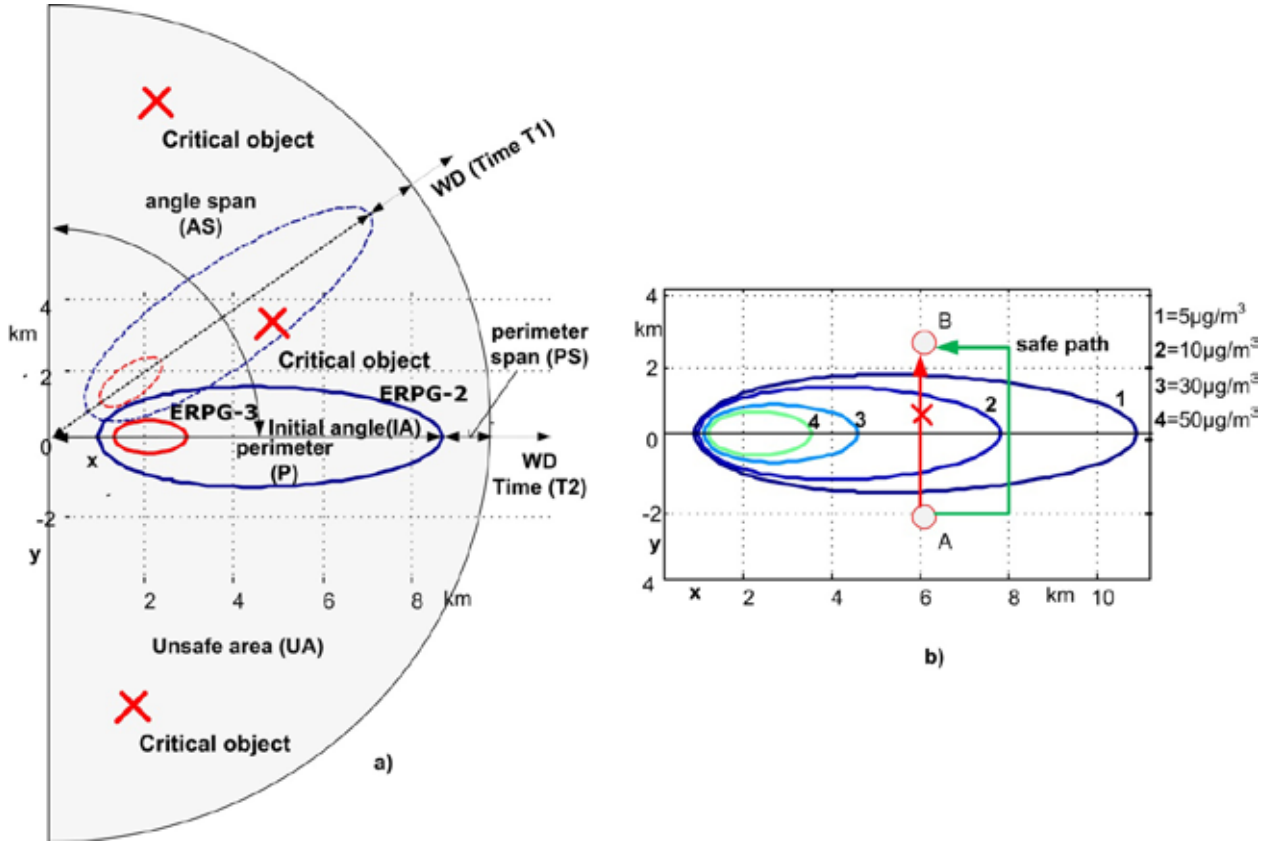

Figure 4: Decision making algorith: a) calculation of unsafe area, b) shortest safe path.

5. Construct a directed graph from remaining nodes and edges where the weight of the edges represents the distance between two nodes
6. Apply the Dijkstra algorithm (Kurashiki et al., 2005; Cormen et al., 2001) to solve the shortest path problem
7. Save shortest route in the kml format

Fig. 4b represents an example of the shortest path (green line) between points A and B. The concentration limit that should be escaped is zone "2" with concentration of 10 μg/m^3 and more.

5 Results and validation

In order to verify the developed dispersion model as well as proposed decision-making techniques, an industrial source in northern Montenegro was used. The Thermo Electric Plant Pljevlja (TEPP) has an output power of 218 MW and is one of the biggest polluters in Montenegro. Due to the lack of filters, harmful gases are released directly into the atmosphere, among others Sulfur Dioxide, SO_2.

As a case study, a day when an accident occurred at TEEP has been selected. Because of specific weather conditions, the plume spread over the city, and the CETI station situated in the city center measured increased concentrations of SO_2 near the alarm value of 110 μg/m^3, the level at or above which the general population could experience life-threatening health effects. At the same time, 09:00, the GEPSUS center, received by automatic link the source parameters from the TEPP Command Room and weather conditions from the HMZCG (Table 1, Scenario 1- SC1). The simulation model was started showing a plume spreading and increased zone of SO_2 over the city area. The simulation of the initial situation is displayed in Fig. 5. The RED zone (Fig. 5d) is associated with 110 μg/m^3, (the Montenegrin alarm threshold), ORANGE 26-50 μg/m^3 (European Union threshold) and YELLOW 25 μg/m^3. The WHITE line border unsafe area was obtained by perimeter and angle spans.

In parallel the span perimeter SP and span angle SA for unsafe areas are defined by emergency experts for the purpose of evacuation (WHITE line around the RED zone) (Fig. 6). Simultaneously, taking into account weather forecasts from the HMZCG, SC2 is considered for the next 3 hours, until 12:00. SC2 shows that wind speed and direction will change as well as temperature (Table 1, SC2). The unsafe area under SC2 shifts to the region around the Thermo Plant, with low population density but measures of protection need to be taken in area SC2. At 12:00 the actual weather conditions are taken, Table 1, SC3, shows the difference in wind speed and direction as obtained by forecasts and actual data. However, with a good delineation of the unsafe area, the actual threat zone (RED in SC3) still overlaps with the unsafe area SC2 (See marker Unsafe Area Z3(SC3&SC2), Fig. 6).

Table 1: Input data for TEPP during an accident, June 12, 2011

Parameter	SC1	SC2	SC3
Gas	SO_2	SO_2	SO_2
Emision rate Q[g/s]	918	918	918
Actual stack height hs [m]	250	250	250
Stack diameter Ro [m]	7.5	7.5	7.5
Ambient temp. T (K)	286.6	298.5	290
Gas temp on exit T(K)	413	413	413
Wind speed at ref point u_r (m/s)	1	3.2	2
Wind direction (deg)	225	18	315
Speed of pollutant on exit (m/s)	6.3	6.3	6.3
Pasquill stability class	B	B	B
Terrain	urban	urban	urban
Reflection	from ground	from ground	from ground
Source location (lat,lon)	43.334269,19.327522	43.334269,19.327522	43.334269,19.327522
Perimeter span PS [m]	1000	1000	1000
Angle span AS [deg]	90	90	90
Critical LOC [µg/m^3]	110	110	110

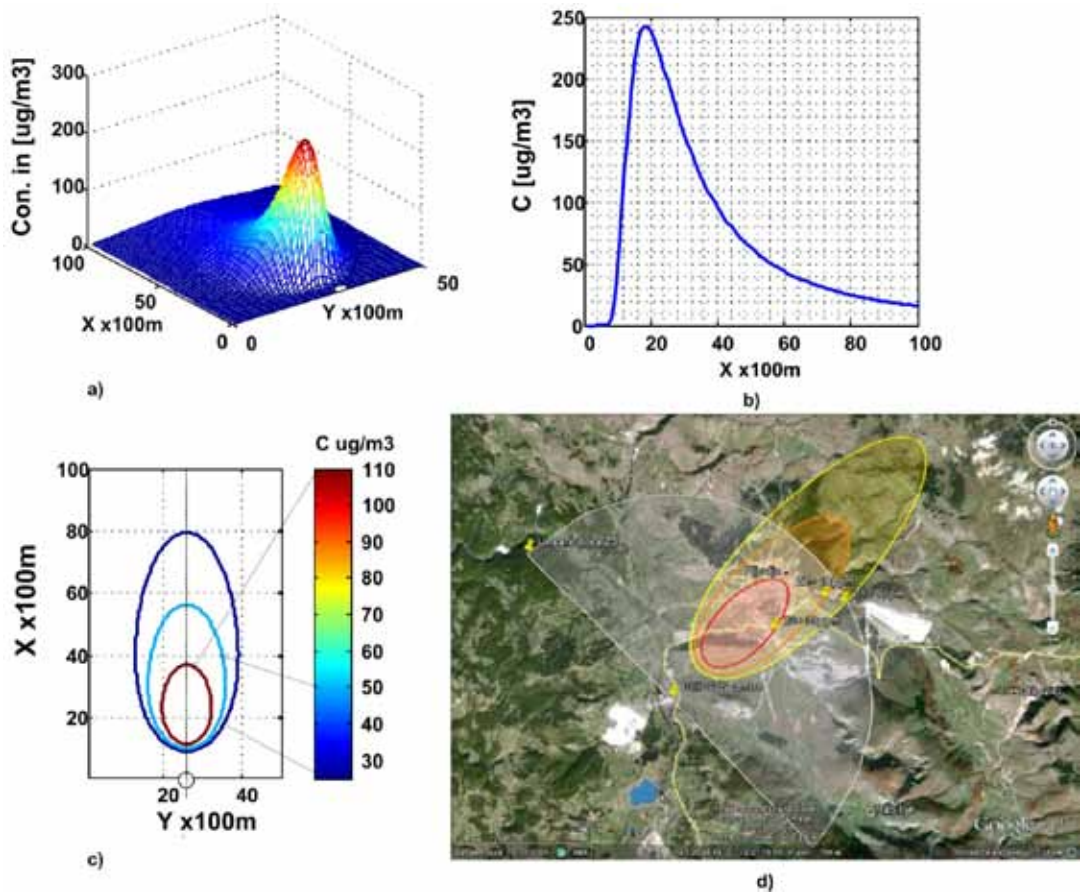

Figure 5: Simulation of scenario SC1: a) 3D concentration plot on ground level, b) downwind profile, c) threat zones for 25 µg/m^3, 50 µg/m^3 and 110 µg/m^3, d) threat zones plot over Google Earth with AS = 90° and PS 1 km. Plume rise (Δh) = 681 m, Xfinal = 1110 m, speed on top of stack u = 1.6 m/s

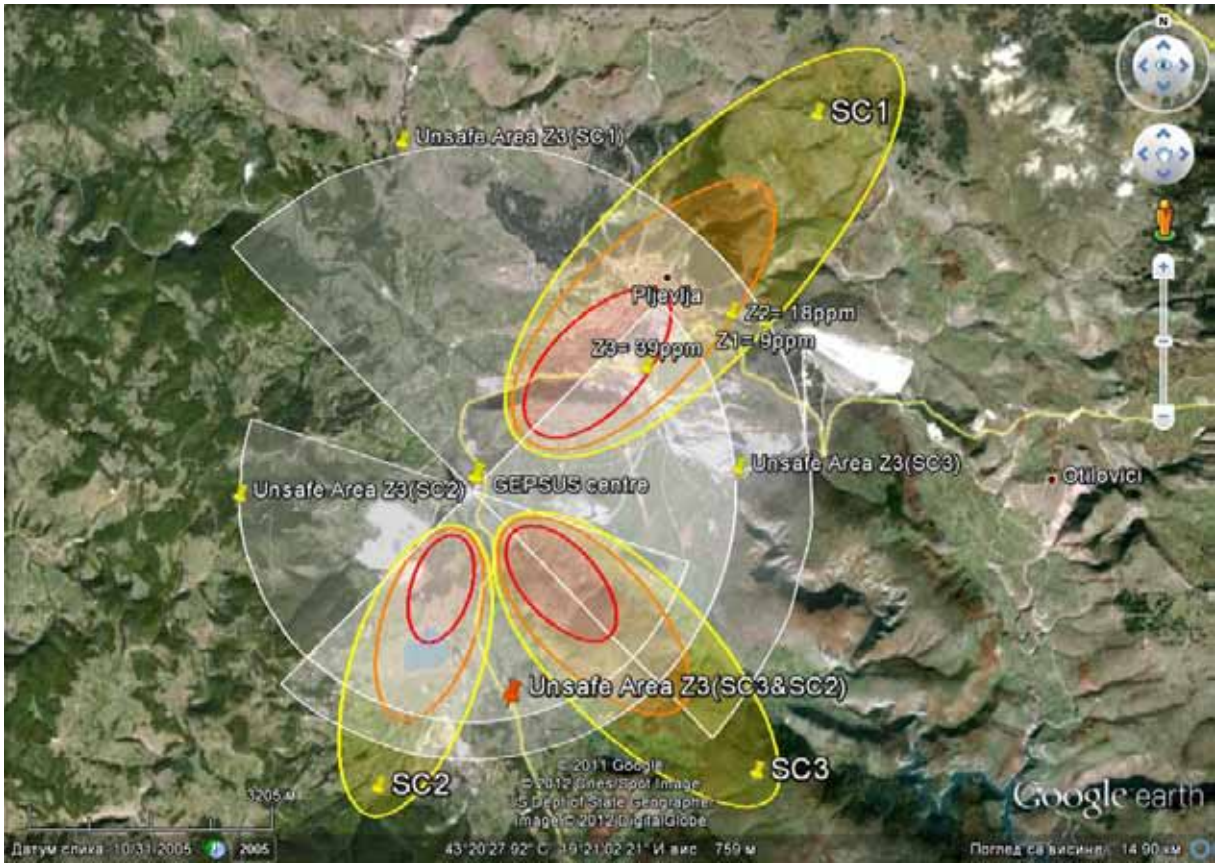

Figure 6: Scenarios SC1, SC2 and SC3 together with unsafe areas

Table 2: Parameters for the release accident at KAP

Parameter	Type/value
Gas	SO2
Emision rate Q [g/s]	200
Actual stack height hs [m]	62
Stack diameter Ro [m]	2.1
Ambient temp. T (K)	301.5
Gas temp on exit T(K)	498
Wind speed at ref point (m/s)	2
Wind direction (deg)	210
Speed of pollutant on exit (m/s)	42.3
Pasquill stability class	B
Terrain	urban
Reflection	from ground
Source location (lat., long.)	42.389000, 19.218797
Critical LOC [μg/m^3]	50

The second simulation example concerns the shortest traffic route for the case of an uncontrolled SO_2 emission from the Aluminum Plant Podgorica (KAP) (Fig. 7), the main polluter in the region of the Montenegrin capital city, Podgorica. The concentration limit was set to the EU standard of 50 μg/m^3 (18 ppm) and because of increased SO_2 emissions (normally less than 50 g/s) and weather conditions, the RED zone spread over the city. Table 2 shows the source parameters and

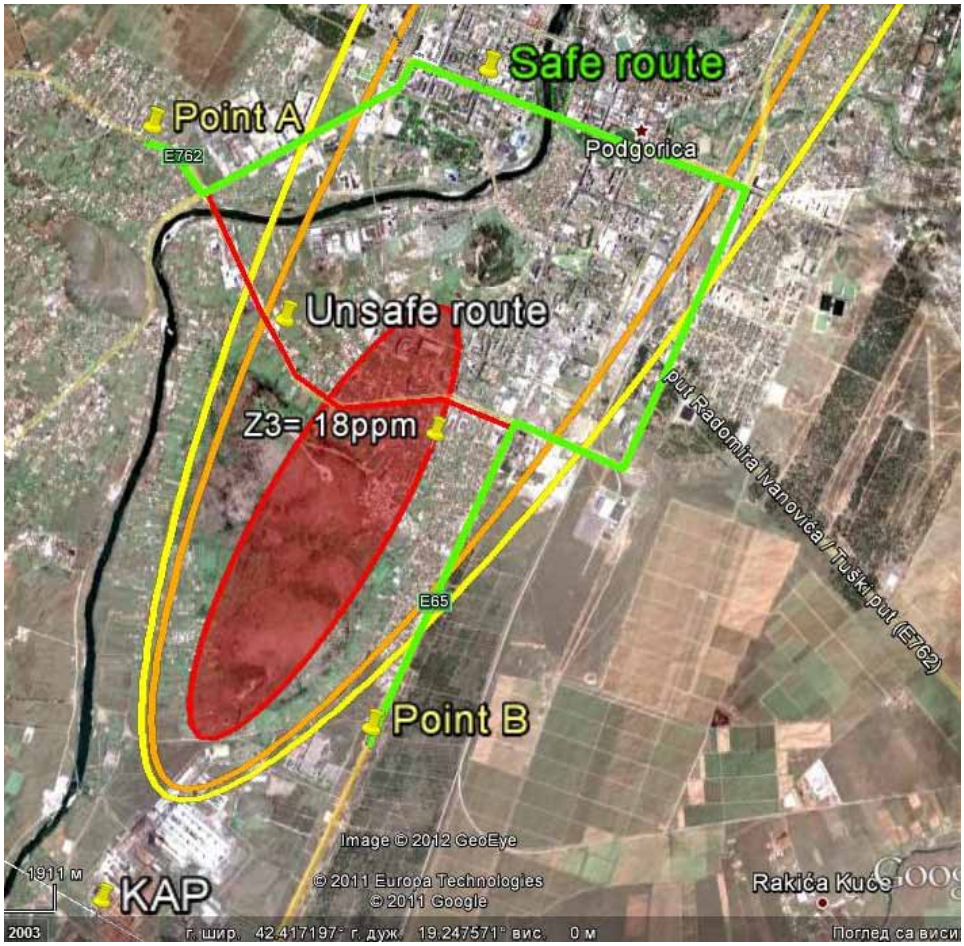

Figure 7: Shortest traffic path in case of an accident at the KAP

weather conditions. In addition to evacuation from the RED zone, the traffic through this zone must be redirected towards the shortest safe route. The driver travels from Point A (road E762) to Point B (road E65). Normally, the shortest way is going through the RED zone (red color path – Unsafe route). The GEPSUS system calculates the Safe route (green path), according to the algorithm given in Section 4, and police patrols redirect traffic on this route.

6 Conclusions

The paper elaborates upon recent developments in the GEPSUS project related to the simulation of hazardous gases releases in urban areas. The structure of the response system from aspects of data importing, modeling and simulation, decision-making, graphical visualization over Google Earth, as well as the results of testing and validation are presented. In case of an accidental or deliberate atmospheric release, the GEPSUS system is able to determine the threat zones, unsafe area and safe traffic routes for purposes of emergency responders. The system is GIS based, web-oriented and its services and outputs can be accessed by standard ICT equipment. Hazardous gas releases is an unpredictable process and thus decision-making has its own uncertainties. However, the GEPSUS tool can support improved decision-making. In future the system will be enhanced with additional features in terms of hazard sources, automated data entry, and a wide range of decision options.

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GEPSUS: Sistem za odločanje pri nesrečah onesnaženja zraka na osnovi simulacije

V članku je opisan sistem za odzivanje na tveganja, ki jih povzroči nenadzorovan izpust nevarnih plinov v ozračje v urbanem okolju. Sistem temelji na GIS tehnologiji in deluje v realnem času. Arhitektura sistema poudarja integracijo meteoroloških, kemijskih in GIS podatkov, modelov disperzije in odločanje ter geo-prostorsko vizualizacijo. Ogrožena področja, nevarna področja in varne prometne poti se določajo na osnovi izpopolnjenega Gausovega modela izpusta z modulom za odločanje. Podatki se nato izvozijo v Google Earth brkljalnik s pomočjo datotek formata »kml«. Izvedenih je bilo več simulacijskih scenarijev, verificirani so bili na pomembnih industrijskih lokacijah v Črni gori, pri čemer so bili uporabljeni registrirani meteorološki podatki. Rezultati kažejo, da bi državni organi, ki so zadolženi za odzivanje na nevarnosti, pri industrijskih ali namernih izpustih nevarnih snovi v ozračje lahko uporabili predlagano metodologijo in sistem, kot ustrezno, cenovno ugodno in natančno orodje.

Ključne besede: izpust nevarnega plina, onesnaženje zraka, simulacija, management nevarnih situacij, GIS

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System Dynamics Model for Policy Scenarios of Organic Farming Development

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This paper presents the system dynamics model of organic farming development in order to support decision making. The model seeks answers to strategic questions related to the level of organically utilized area, levels of production and crop selection in a long-term dynamic context. The model will be used for simulation of different policy scenarios for organic farming and their impact on economic and environmental parameters of organic production at an aggregate level. Using the model, several policy scenarios were performed.

Key words: organic farming; system dynamics; simulation; model

1 Introduction

Organic agriculture system dynamics (SD) methodology (Forrester, 1958) can be used as an alternative to the econometric and mathematical programming approaches (Bockermann et al., 2005; Elshorbagy et al., 2005; Saysel et al., 2002; Škraba et al., 2003) for policy modeling. Recently, there have been many important SD applications in the field of agriculture and environment: Nalil (1992) describes the conceptual development of FOSSIL2, an integrated model of U.S. energy supply and demand, which is used to prepare projections for energy policy analysis in the U.S. Department of Energy's Office of Policy, Planning, and Analysis. Munitič and Trosić, (1997) used system dynamics for the modeling of the ecological subsystem of "Kastela Bay". Guo et al. (2001) presented an environmental system dynamics model named ErhaiSD and developed for supporting an environmental planning task. The ErhaiSD consists of dynamic simulation models that explicitly consider the information feedback that governs interactions within the ecosystem. Such models are capable of synthesizing component-level knowledge into a system behavior simulation at an integrated level. Fischer et al. (2003) utilized the power of three-dimensional visualization to present simulation results from a system dynamics model of global protein consumption. A similar approach has been presented by Weber et al. (1996). Shen et al. (2009) presented a system dynamicsmodel for sustainable land use and urban development in Hong Kong. The model is used to test the outcomes of different development policy scenarios and to make forecasts. It consists of five sub-systems including population, economy, housing, transport and urban/developed land. Yin and Struik (2009) reviewed recent findings on modeling genotypes and environmental interactions at a crop level, moving from system dynamics to system biology. However, the most important works in the field of simulation of development policy scenarios are presented by Shi and Gill (2005), who developed a system dynamics-based simulation model for ecological agriculture development for Jinshan County (China), and by Kljajić et al. (2000, 2002, 2003), who developed an integrated system dynamics model for development in the Canary Islands, where interactions between agriculture, population, industry and ecology were taken into consideration. The preliminary investigations into SD simulation of organic farming development have been conducted by Rozman et al. (2007) and by Škraba et al. (2008). In this model, the overall demand and production has been considered, which is important on the national level and represents certain limitations for expansive development of organic farming.

This paper describes a further improvement of the previous model and presents a system dynamics model for the development of organic agriculture in Slovenia in order to identify key variables that determine conversion dynamics and

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to propose development policy in order to achieve strategic goals as set in the Action plan ANEK. First, we present the main flows and feedback loops within the systems and the development of the system dynamics model. The results section presents scenarios (different policies in organic farming) and their evaluation through application of the developed SD model. The main findings and suggestions for further study conclude the article.

2 Methods

The simulation model should consider the key variables that influence the development of organic farming, such as:

- the number of conventional farms,
- the number of organic farms,
- conversion process,
- subsidies,
- the promotion of organic farming (marketing, market development, education),
- the organization of a general organic farming support environment,
- a system of self-awareness, and
- the delay constants of process change.

A key variable in the model is the number of organic farms. These are the farms that are under the control system of one of the control organizations. The growth in the number of organic farms was initially (in year 1998) almost linear; however, in the years from 2003-2005, the growth moderated to approximately 4%, despite an increase in subsidies of 20-30%.

During the development of the CLD diagram (Figure 1) as the first step toward the development of the SD model, the following key variables were identified:

1. the number of potential candidates (farms) for conversion to organic farming,
2. the number of farms already converted to organic farming, and
3. the flow between (1) and (2): conversion rate (transition).

Loop B1 represents a negative loop, with a goal value of 0 (depleting the number of "Conventional Farms"). The number of "Conventional Farms" divided by the "Total Number of Farms" yields the "Concentration of Conventional Farms", which is initially high, meaning that there should be a high initial preference for "Conversion". "Concentration of Conventional Farms" positively influences the "Communication". This variable represents the general communication between the conventional approach members and the organic approach

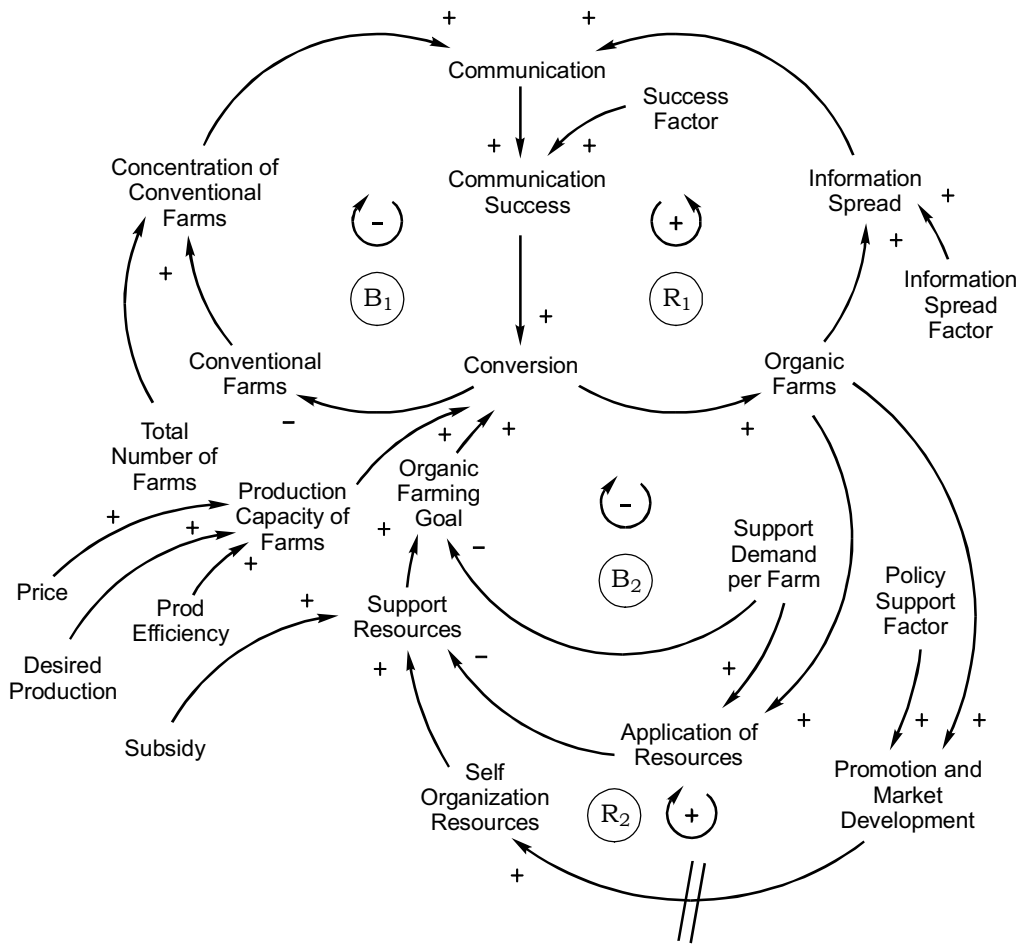

Figure 1: Causal Loop Diagram (CLD) of conversion process to organic farming

members. "Conversion" positively influences the number of "Organic Farms". If the number of "Organic Farms" increases, the "Information Spread" increases above the level that it would otherwise have been. "Information Spread" by "Organic Farms" members is positively influenced by the "Information Spread Factor" which could be, for example, increased by marketing campaigns. "Information Spread" positively influences "Communication". The number of "Conversion" farms is determined by the "Success Factor", which determines the "Communication Success", yielding the number of convinced conventional members that decide to make a "Conversion". Loop R1 is a reinforcing feedback loop compensated for by the initial balancing feedback loop marked with B1. If the number of "Organic Farms" increases, the "Promotion and Market Development", supported by the "Policy Support Factor", increases as well. Higher "Promotion and Market Development" positively influences the "Self Organization Resources", which contribute positively to the "Support Resources" on which the "Conversion" is dependent.

There is a delay mark between the "Promotion and Market Development" and "Self Organization Resources". Longer delays should be expected here since a significant amount of time is needed in order to promote both the organic farming idea and the marketing channels that will support organic farming.

The "Support Resources" are significantly dependent on the government "Subsidy". Furthermore, the higher the "Organic Farming Goal" is set, the more "Support Resources" are available, meaning that a larger number of organic farms can be supported. If the "Organic Farming Goal" increases, the "Conversion" increases above the level that it would otherwise have been.

The interconnections marked with "R2" have the characteristic of reinforcing feedback loop. According to government policy, the growth in the number of "Organic Farms" should be properly supported in order to promote an increase in self-organization of, for example, organic food marketing and pro-

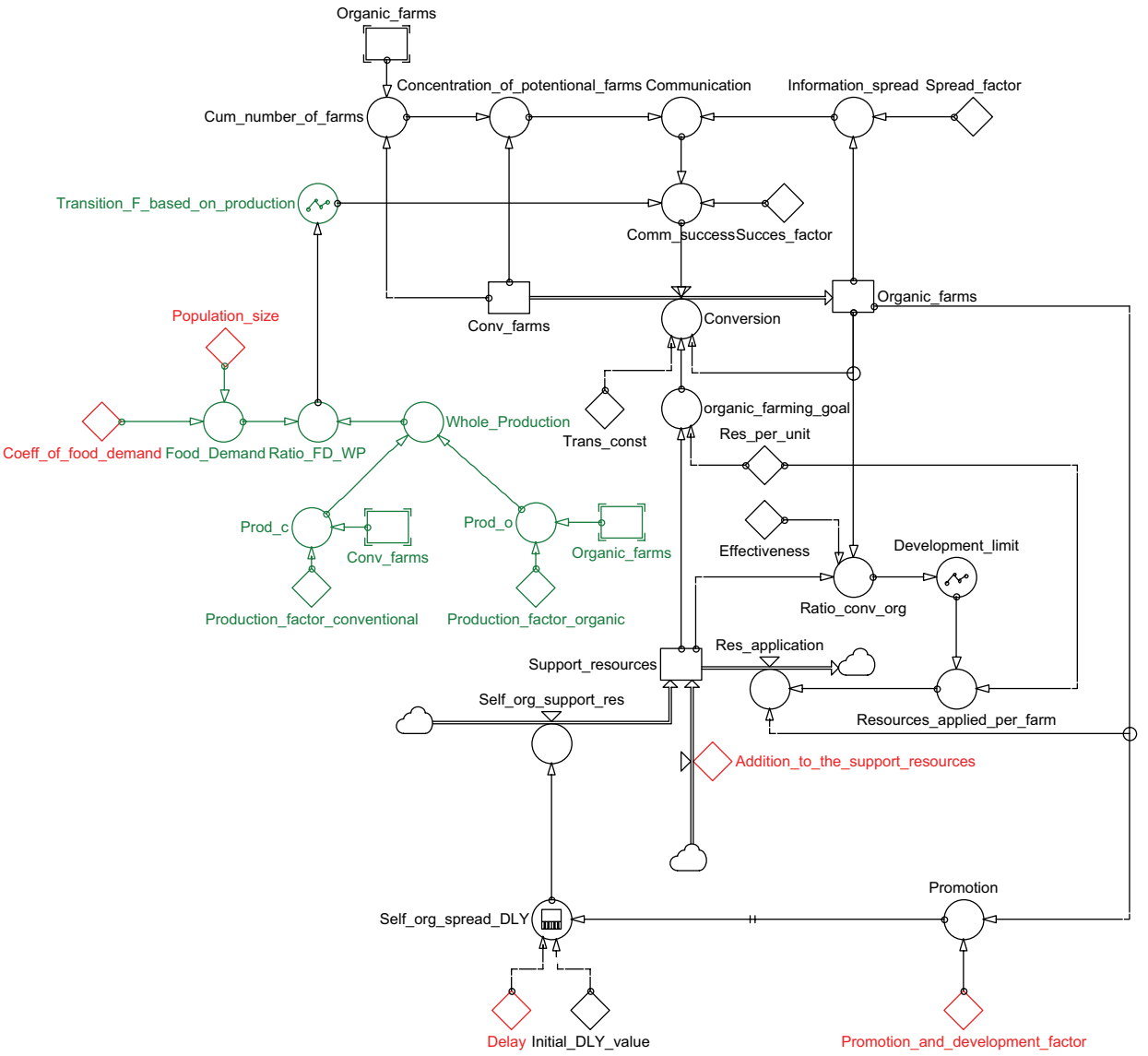

Figure 2: System dynamics model of organic farming development

motion. Thus, the reinforcing feedback loop R2 should serve as a growth generator in the system.

Loop B2 represents a balancing loop. If the number of "Organic Farms" increases, the "Application of Resources" increases above the level that it would otherwise have been. The "Application of Resources" is also dependent on the resources needed per farm, i.e. "Support Demand per Farm". Higher "Application of Resources" can cause the depletion of the "Support Resources". The "Organic Farming Goal" is dependent on the "Support Demand per Farm". If more resources are needed per farm, fewer organic farms can be supported, and therefore lower numbers of "Conversion" should be expected. In considering a real case, the negative loops R1 and R2 are dominant, leaving the system in an undesirable state of equilibrium. This would mean that the number of organic farms is constant and well below that desired. In order to move the system away from the equilibrium, one should consider the policies that would raise the impact of the reinforcing feedback loops B1 and B2, which should move the system state, i.e. the number of "Organic Farms", to the higher equilibrium values. "Price", "Desired Production" and "Production Efficiency" are also important factors which impact the intensity of the transition.

A system dynamics model structure is shown in Figure 2. The model consists of 36 variables and 60 links.

There are two levels to the elements applied in the upper part of the model: The variable "Conventional_farms" represents the number of conventional farms. By the flow "Conversion", the "Conventional_farms" become "Organic_farms".

This structure is commonly known as the market absorption model. "Conversion" is dependent on the "Organic_farming_goal". The goal is set by the "Support_resources" available, modeled as a level element. The desired conversion can be achieved only if there are enough "Support_resources" present in order to make a "Conversion". The "Support_resoures" are not only the financial means. Here, the support of the society is also considered; for example, education should create positive attitudes in relation to organic farming. In this category, the market development, as well as the demand, should also be considered. However, at present, the "Support_resources" are mainly dependent on subsidies from the government. The important variable "Self_organization_resources" is driven by the impact of the policy and the level of societal support, which will intensify with increasing numbers of "Organic_farms". This represents the application of a reinforcing feedback loop

Table 1: Input parameters for each scenario

Scenario	Subsidies	Coefficient of food demand	Delay	Promotion factor	Population
1	2000	1,2	24	0,8	2M
2	3000	1,2	24	0,8	2M
3	4000	1,2	24	0,8	2M
4	4000	1,2	24	2	2M
5	4000	1,2	48	2	2M
6	4000	1,2	48	2	2.3M
7	4000	1,1	48	2	2.3M

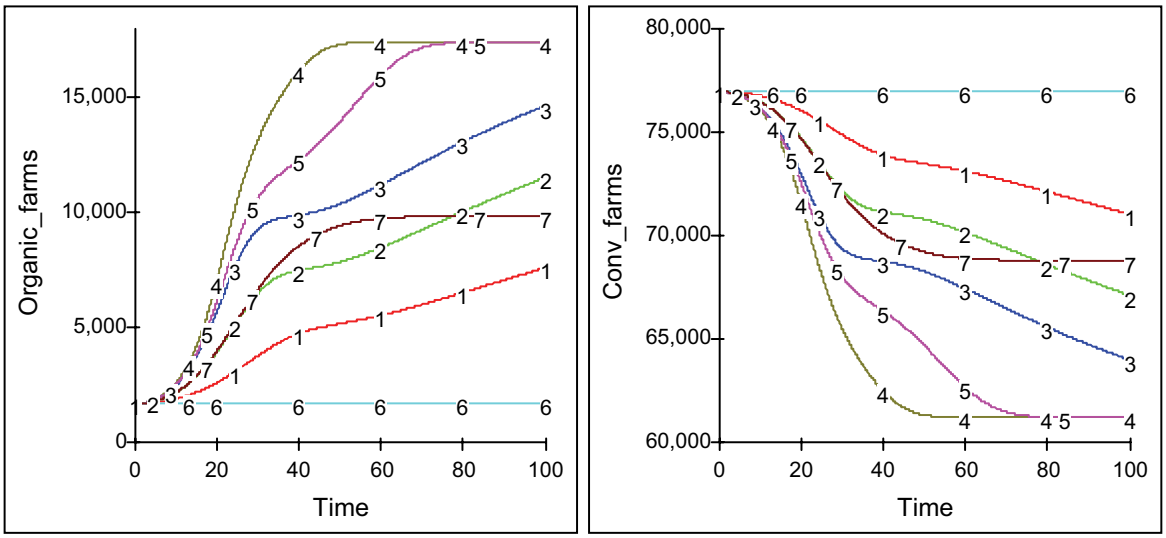

Figure 3: Number of organic farms

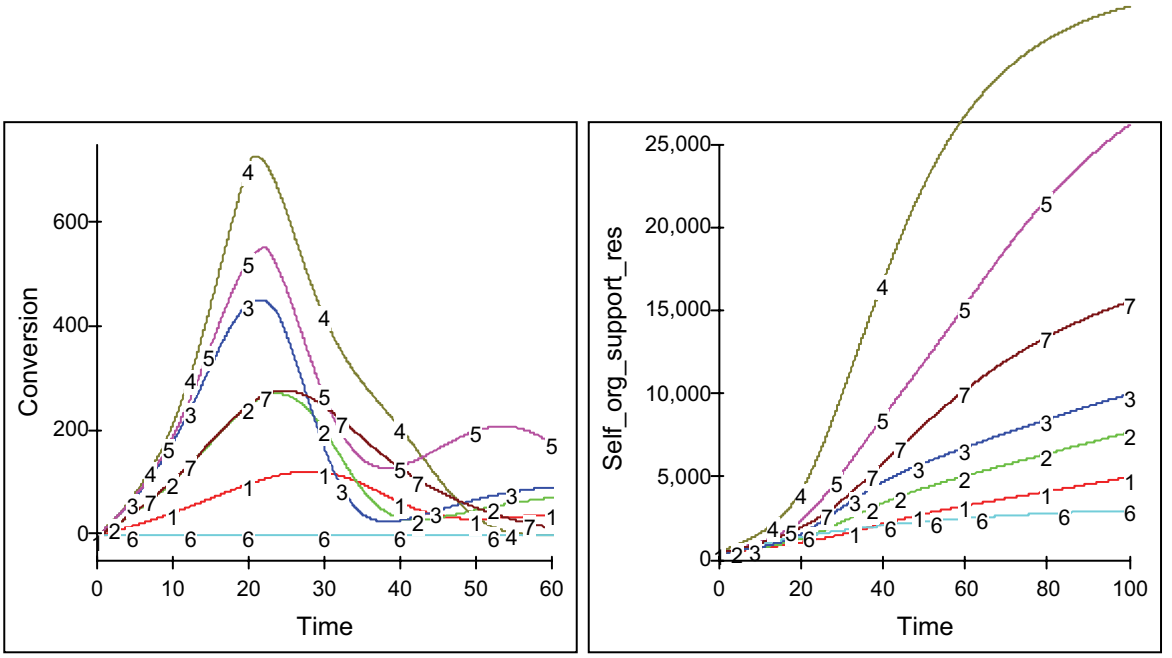

Figure 4: Conversion dynamics

which should be augmented. The "Development_limit" represents the function which considers the variable consumption of the resources. If the resources are scarce, the usage is lower than in the case of abundance. Resources are consumed by the "Organic_farms". The prosperity of the "Organic farms" therefore depends on the "Support_resources", which are not only financial means. Here, the social impact of organic farming represents the supportive environment which should sustain such an activity, which in the world of consumption is counterintuitive. The "Conversion" is also dependent on the total food production and "Food demand".

3 Results and discussion

The model is used in order to simulate different scenarios that enable the assessment of policy scenarios with respect to the development of organic farming. Table 1 shows input parameters for 7 scenarios simulated. The main policy parameter being changed is the "subsidies" category.

Scenarios 1, 2 and 3 (Figures 3 and 4) represent the increase of the subsidies and the impact on the transition rate. Scenario 4 shows the impact of the increased promotion factor, which would yield the higher limit conversion to the organic farming. The impact of the increased delay in providing self-support resources is shown by Scenario 5. Here, one assumes that this delay is increased from two to four years on average. Scenario 6 represents the increase in the population which would lead to the status quo in the number of Organic and Conventional farms. It is supposed that the transition in this case would not occur due to the increased food demand. In this case, the negative conversion could also be considered; however, this is the limitation of the proposed model. Scenario 7 shows the transition to organic farming if the coefficient of food demand decreased, which would be the case if, for example, the imports of food increased.

However, the system dynamics model does not provide numerical forecasts. It is rather a policy tool that examines the behavior of key variables (number of organic farms) over time. Historical data and performance goals provide baselines for determining whether a particular policy generates the behavior of key variables that is better or worse when compared to the baseline or other policies. Furthermore, models provide an explanation for why specific outcomes are achieved. Simulation allows us to compress time so that many different policies can be tested, the outcomes explained, and the causes that generate a specific outcome can be examined by knowledgeable people working in the system before policies are actually implemented.

4 Conclusion

After performing several simulation scenarios, the following findings could be abstracted:

- Conversion to organic farming relies on subsidies which provide the main source of conversion from conventional farming to organic farming.
- Subsidies are not the only driving force in the system; even more important are other activities that promote organic farming.
- Subsidies could not be provided in sufficient amounts in order to complete conversion from conventional to organic farming.
- A feasible strategy to achieve complete conversion should consider reinforcing the feedback loop between resources, number of organic farms and supportive actions which are bounded to the number of organic farms.

- The current output parameter, i.e. number of organic farms, is caught in an unwanted equilibrium value due to the domination of balancing feedback loops in the system.
- The important factor is self-organization of the organic farming environment, which includes market development and general public awareness.

Further strategic actions should consider the dynamic response of the system and the feasibility of the stated system target values. Consideration should be paid to the interaction between the four main feedback loops indicated in the system which determine the system performance and provide the means for proper definition of control strategy. The main advantage of the SD model is its capability to assess policy changes and the response of target variables over time. Such models should be useful tools for policymakers to use in planning strategies for the sustainable development of organic farming. Furthermore, it could be extended to other fields closely related to supplemental activities on organic farms, such as farm tourism.

5 Acknowledgement

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Dinamični model razvoja ekološkega kmetijstva

V prispevku je predstavljen model za simulacije razvoja ekološkega kmetijstva na osnovi metodologije sistemske dinamike. Metodologija sistemske dinamike je celoviti pristop za podporo dinamičnemu reševanju kompleksnih problemov, ki omogoča vpogled v posege s trajnostnimi posledicami. Model pri kreiranju razvojne politike išče odgovore na strateška vprašanja povezana z razvojem ekološkega kmetijstva in trga ekoloških pridelkov. Model se uporablja za simulacije različnih scenarijev razvojnih politik za ekološko kmetijstvo ter njihov vpliv na gospodarske in okoljske parametre ekološke pridelave na agregatni ravni. Z modelom smo analizirali več možnih strategij razvoja ekološkega kmetijstva.

Ključne besede: ekološko kmetovanje; sistemska dinamika, simulacija, model

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The Need for Simulation in Complex Industrial Systems

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We discuss the concept of simulation and its application in the resolution of problems in complex industrial systems. Most problems of serious scale, be it an inventory problem, a production and distribution problem, a management of resources or process improvement, all real world problems require a mix of generic, data algorithmic and Ad-hoc solutions making the best of available information. We describe two projects in which analytical solutions were applied or contemplated. The first case study uses linear programming in the optimal allocation of advertising resources by a major internet service provider. The second study, in a series of projects, analyses options for the expansion of the production and distribution network of mining products, as part of a sensitive strategic business review. Using the examples, we make the case for the need of simulation in complex industrial problems where analytical solutions may be attempted but where the size and complexity of the problem forces a Monte Carlo approach.

Keywords: simulation, linear programming, multi-echelon inventory, production process.

1 Introduction

Physical sciences attempt to put into equations the world surrounding us. Even when those equations are known, it is hard to predict the outcome of events subject to a combination of rules. When designing an airplane, engineers test a model in wind tunnels. The turbulence and the aerodynamic forces are too complex to allow an analytical prediction. Simulating in a wind tunnel is the alternative. The act of reenacting a behavior many times in a simulation allows estimation and inference. When looking into complex industrial systems, the difficulty is due to the fact that many components interact and some have stochastic components. Often simulation is the only resort to predicting the behavior of the system. Time is taken to be discrete, in small intervals, to allow the modeling of the system in what is called discrete-event simulation. In discrete-event simulation, the operation of a system is represented as a chronological sequence of events. A large body of literature exists on carrying out discrete-event simulation in systems that lead themselves to the approach. In essence, there are three parts; (1) the construction of a conceptual framework or model that describes the system, (2) the simulation, that is perform experiments using computer implementation of the model and (3) the analysis and drawing of conclusions from the computer model output. A number of books have been written, a classic being Ross (2006). There is a large number of open source and commercial software. Many researchers and entire firms specialize in simulation. We describe two projects in which analytical solutions were applied or contemplated. The first case study uses linear programming in the optimal allocation of advertising resources by a major internet service provider. The second study, in a series of projects, analyses options for the expansion of the production and distribution network of mining products, as part of a sensitive strategic business review. Using the examples, we make the case for the need of simulation in complex industrial problems where analytical solutions may be attempted but where the size and complexity of the problems force a Monte Carlo approach.

1.1 Dynamic allocation of web advertising resources

America Online (AOL) was the largest internet services provider in the late 1990's. It was a leading company in times of the Dot-com bubble. The internet boom created a steady commercial use of the internet and AOL was selling a lot of advertising on its web pages. Clients contracted for advertising

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time and their respective contract sizes were constantly changing. The ensuing dynamic process of bookings and reservations created a serious planning problem. The problem was further complicated by the clients' choices. Each client chose a designated advertising area, a class of web pages in which to advertise. The policy of AOL for accepting all orders, in a highly dynamic reservation process, created difficult situations and bottlenecks. To bring improvement, Theoretica Inc. was contracted for the development of solutions (Aboura et al., 2001). Linear programming models were developed capturing the decision rules favored for allocating and re-allocating the advertising resources. Linear programming is a powerful tool used successfully in many complex problems. It proved useful again in this situation. However, when the size of the problem grows in such planning problems, the computing becomes difficult and brings about the consideration of simulation.

1.2 Facilities planning for production and distribution

Three studies were conducted for an Australian chemical company that produces, stores and sells ammonium nitrate to mining companies in Australia and overseas (Aboura et al., 1994; Aboura et al., 1995a; Aboura et al., 1995b). The chemical company is one of the world's leading suppliers of commercial products to the mining industry. The ammonium nitrate is a white inorganic salt with a melting point of 169.6 Celsius. It is an oxidizer which can make fuel substances burn more intensely than with air only. Air contains 21% Oxygen while ammonium nitrate contains 60%. Many forms of ammonium nitrate can be used to make a blasting agent. The company's product is in the form of small porous spherical prills. The porous prill form is preferred for several reasons. It has good chemical properties, good physical properties and is easy to handle, distribute and store. The company also produces a gel form of the product for an easier use by the mining clients. For the products distribution to the mining industry, the company set up on-site plants near the mines. The on-site plants receive the ammonium nitrate products from regional distribution centers by trucks. The regional centers receive the ammonium nitrate prill and the ammonium nitrate liquor from the manufacturing plant by rail and road. There is also an onsite delivery system where the products are delivered directly to the customers from the plant.

The goals of the research projects were to; (1) compare different configurations to the existing production/distribution system, (2) simulate the operations of the plant and (3) develop an inventory/distribution model for the production facility. In the first problem, alternative configurations of a

Table 1: Definitions and terminology

AdSpace	Advertising entity where a client's ad can be placed. It is an entity to which an order's demand or part of that demand can be assigned. Differently phrased, an AdSpace allocates advertising resources to a customer's order.
Group	A set of AdSpaces. Such sets are formed to organize the AdSpaces under a common marketing theme. An AdSpace can be placed in one, two or more groups.
Client	A client is a customer that contracts for advertising. A client may have one or more contracts over a specified period of time.
Contract	An agreement that specifies a customer's order to place an ad in one or several groups of choice.
Order	A contract creates an order for placing an ad for a certain amount of advertising resources.
Group(s) of Choice	A group or groups preferred by a client's contract. The group(s) of choice is part of the order along with the magnitude of that order.
AdSpace Id	A number that identifies an AdSpace.
Group Id	A number to identify a group.
Group Intersection	The intersection of two groups is the set of AdSpaces that belong to both groups.
Adjacent Groups	Two groups are said to be adjacent if they intersect.
Impressions	One unit of advertising resource is an impression unit.
AdSpace Availability	The number of impressions available for allocation from an AdSpace.
AdSpace Capacity	The maximum availability of an AdSpace is the capacity of the AdSpace.

multi-echelon production and distribution system were evaluated. The relevant differences in the configurations considered were the setup, inventory and transportation costs and the availability of product (costs vs stockouts). The mining customers do not plan their demand. The company has to deliver upon demand, the next day the command is made. The on-site-plants located near the customers had limited storage capacity and needed some time to replenish from the regional center. Even more time was needed to deliver from the plant to the regional centers. To store the liquid form at the on-site plants required special and expensive storage tanks. All of this made for a production/distribution system that had a Just-in-Time operating mode. In addition, the demand was expected to increase substantially over the next years and the company was looking at expanding its distribution network in the most efficient way.

2 Research Methodology for Dynamic Group Reservation

In this section we present the research methodology applied in the analytical study phase of the Dynamic Group Reservation project (Aboura et al., 2001). The analytical study phase consisted of determining solution approaches and methodology for the optimal allocation of web advertising resources for America Online (Section 1.1).

2.1 Definitions and terminology

The service provided to customers is the placing of the customers' ads in web advertising spaces. The advertising spaces are referred to as Ad Spaces, or AdSpaces for ease of terminology. The AdSpaces are limited in number and their number varies over time due to the creation and elimination of some of these AdSpaces. The AdSpaces are entities with advertising resources measured in number of impressions. At a point in time, an AdSpace may be used to a certain percentage of its capacity. The remaining resources make up that AdSpace's availability. In Table 1, we introduce some definitions and terminology.

An AdSpace allocates resources to an order by providing a number of impressions to satisfy the order's demand or part of it. When an AdSpace allocates resources towards the demand of an order, we define that part of the demand that has been satisfied by the AdSpace as having been assigned to that AdSpace. The two operations, allocation and assignment are the same. The former applies to the resources going out of the AdSpace while the later refers to the ad (in a number of impressions demanded) going into the AdSpace. The groups are labeled G_1, G_2, G_3 … . They may also be referred to as A, B, C … . AdSpaces are labeled MN_1, MN_2, MN_3 …, or simply 1,2,3 …, as understood from the context of the situation being described. The orders from different contracts are referred to as O_1, O_2, O_3 … The AdSpaces capacities are labeled c_1, c_2, c_3 … . AdSpace utilization is the percentage of impressions already allocated, that is (capacity – availability) x 100 / capacity. The AdSpaces utilizations are labeled u_1, u_2, u_3 … .

2.2 The Basic Allocation/Assignment Problem

We first considered the problem of how to re-allocate resources so that a set of arriving demands can be satisfied. This problem is called the *Basic Allocation/Assignment Problem*. The solution to the basic problem provides the solution to the more general problem of optimally allocating advertising resources over large periods of time. In the basic problem, the new order is labeled an *arriving order* with an *arriving demand*. The problem is how to allocate resources to this new demand from its *group(s) of choice* when some of the resources of the AdSpaces of those group have already been allocated. A customer order's demand may be divided so that its parts can be assigned to different AdSpaces.

Suppose that an arriving order O is of magnitude d_0. Suppose that the corresponding contract states the group A as its *group of choice*. That is, the corresponding customer prefers that the ad appears in group A for a number d_0 of impressions. In this basic case, the contract targets only one group. In general, the contract may specify additional groups of choice. If there is enough availability in group A, that is the sum of unused advertising resources in the AdSpaces of group A are greater than or equal to d_0, then the order O is satisfied. d_0 is divided among some or all the AdSpaces in group A. The availabilities of the AdSpaces providing resources to satisfy the demand are reduced by the amount they provide. If one AdSpace in A can accommodate the whole of d_0 then there is no need to divide d_0. This situation is ideal as the problem is solved easily. Most often it is not the case. The interest is on solving the problem when the arriving order does not find enough availability in that group. To be able to assign the demand d_0 in A when the total availability in A is less than d_0, previously assigned demands in AdSpaces of A (or parts of previously assigned demands) are reassigned to other AdSpaces in groups other than A. Preferably, this reassignment is done in adjacent groups of A so that demands moved are not 'too far' from their *group of choice*. That is, by reconsidering previously made assignments, enough resources in group A are freed to accommodate the arriving demand d_0. This re-allocation is done so that the new order is satisfied while all previous demands also remain satisfied. The problem is to find the best way to do a reallocation and create a minimal displacement of previously assigned demands from their current AdSpaces. We present two solutions. We first discuss an Ad-hoc solution favored by the planning department. We then present the optimal linear programming solution.

2.3 Groups-AdSpaces structure

The AdSpaces are numerous and their large number creates the complexity of the problem. For the sake of the analytical study, we considered the number of AdSpaces to be constant over time. The solutions can be extended to the case where new AdSpaces are created and some existing ones eliminated. Groups are sets of AdSpaces. An AdSpace can belong to many groups. This creates a topology that is important to the resolution of the problem. Upon analysis, the Groups-AdSpaces structure revealed a clustered form. Some sets of groups form

clusters, as symbolically shown in Figure 1 where a Venn diagram set represents a group. The result allowed us to focus attention to a cluster of groups therefore reducing the size of the problem. This was done through some mathematical modelling techniques such as dummy variables to artificially divide the set of groups into clusters. For the reminder of the work, we assume that our world is a cluster. We define a cluster of groups as being a set of groups that can be connected to each other through a series of intersections.

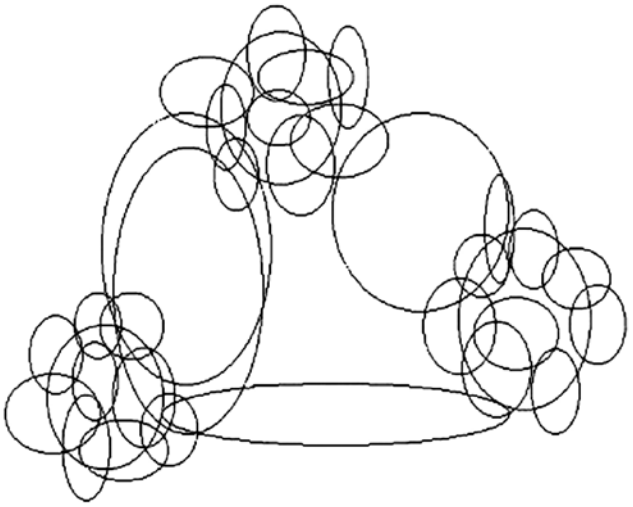

Figure 1: Cluster structure of groups

We then introduced the notion of a distance between groups. This measure is essential to the construction of a solution. Let A be a group. We first define the distance of A to itself as being zero. We use the notation Dist(A,A) = 0. Let B be another group. A and B are not the same group but they do intersect. We define the distance of B to A, and by symmetry the distance of A to B, as being Dist(A,B) = Dist(B,A) = 1, if $A \cap B \neq \emptyset$. Let C be another group. Assume that C does not intersect with A but C does intersect with B. We define the distance of C to A to be 2; Dist(A,C) = 2, if $A \cap C = \emptyset$, $A \cap B \neq \emptyset$ and $B \cap C \neq \emptyset$. The group distance is defined as the minimum number of groups needed to link the two groups. In Figure 2, we illustrate the case where two groups are linked through a series of intersecting groups. However, it is the minimum number of groups in one series that provides the value of the distance from one group to the other.

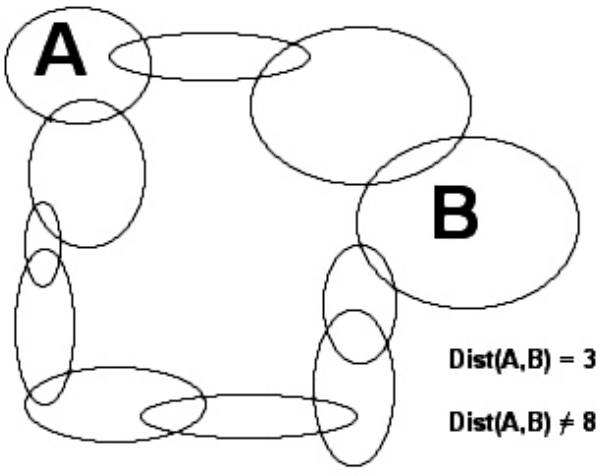

Figure 2: Two groups linked through two series of intersecting groups

The solution to the problem is the specification of assignment made to AdSpaces. In order to construct a solution algorithm, we must define the distance between two AdSpaces. Let two AdSpaces be MN_i and MN_j. We define the distance of these two AdSpaces to be zero if they are the same AdSpace; $Da(MN_i,MN_j) = 0$, if i = j. If the AdSpaces belong to the same group, then similarly $Da(MN_i,MN_j) = 0$. Otherwise, let $Da(MN_i,MN_j)$ = minimum Dist(A,B), the minimum taken over all the groups A and B such that $MN_i \in A$ and $MN_j \in B$. The distance of two AdSpaces that do not belong to the same group is the minimum distance between the groups to which these AdSpaces belong. Figure 3 shows an example.

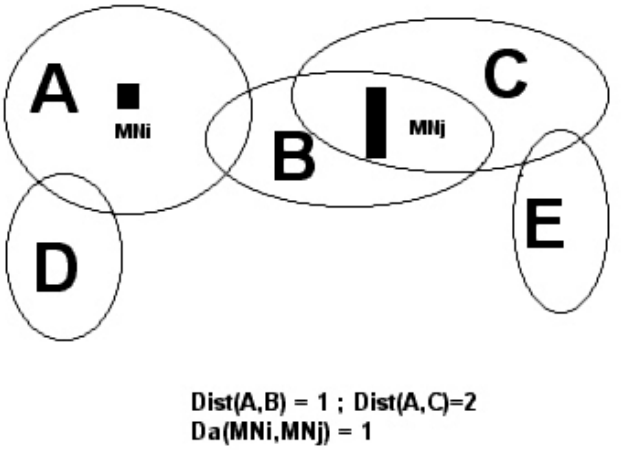

Figure 3: Distance between AdSpaces

2.4 Ad-hoc Solution: The Top-Down Approach

Consider an arriving order O that carries a demand d_0 for its *group of choice* A. Suppose that group A intersects with groups B, C and D. Suppose that groups B and C intersect with group E and group D intersects with group F. Furthermore, in this example, groups A, E and F do not intersect. F does not intersect with either B or C nor does E intersect with D. Figure 4 shows a representation of these groups.

If the availability of group A, that is the sum of the availabilities of its AdSpaces, is greater than or equal to d_0, then the order is satisfied. If d_0 is greater than the availability of group A, let $e = d_0 - \text{Availability(A)}$. e is the part of the arriving order that could not be assigned to group A. To satisfy the order, we must free resources in A. Based on the premise that we allow moving orders (or parts of) already assigned to neighboring AdSpaces and groups, we reassign some of the content of the AdSpaces of A into AdSpaces of groups B, C and D. If it is possible to do so for at least e impressions, we have solved the problem, at least until the next order. However, the availabilities of groups B, C and D may not add up to e. In which case we must move some of the content of the AdSpaces of

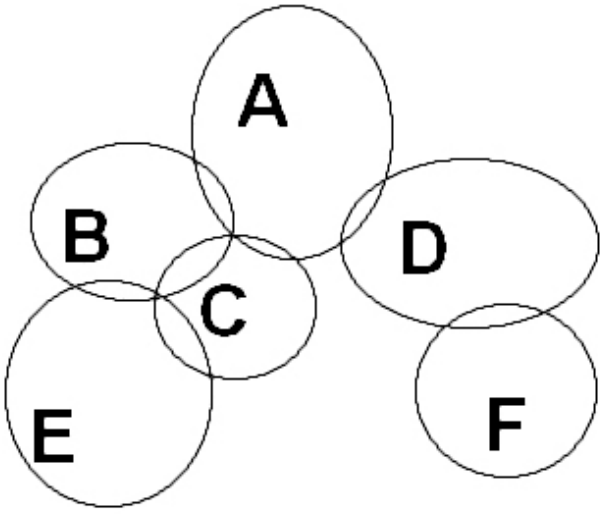

Figure 4: Groups A, B, C, D, E and F

B and C into AdSpaces that belong to group E. If still necessary, we also do the same to AdSpaces in D and move some of their content into group F. In this manner, we free enough resources in B, C and D, which in turn free enough for the remaining unsatisfied amount e in A. We prefer that all assignments are made as close as possible to their *groups of choice*. In assigning a quantity from an order, or reassigning a number of impressions from an AdSpace, we choose an AdSpace that is either in the *group of choice* or the same group for an already assigned quantity. The next preferred AdSpace would be in an adjacent group, then in a group that is adjacent to an adjacent group and so on. We can see that a hierarchical notion would organize the cluster. We use the notion of distance. With the measure of distance between groups of a cluster, we can formally describe the *Top-Down approach*. Dist(A,B) = Dist(A,C) = Dist(A,D) = 1, Dist(B,E) = Dist(C,E) = Dist(D,F) = 1 and Dist(A,E) = Dist(A,F) = 2. Dist(B,C) = 1, Dist(D,E) = Dist(B,F) = Dist(C,F) = 3 and Dist(E,F) = 4. We organize these 6 groups into a hierarchical structure according to their distances to group A, as shown in Figure 5.

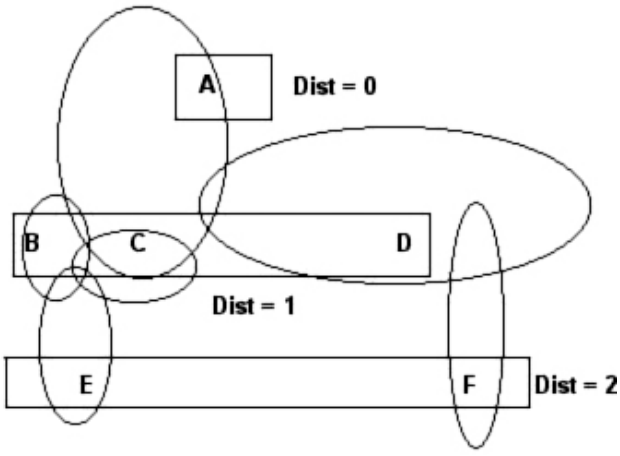

Figure 5: Hierarchical Structure

To proceed with order O, we go from one hierarchical level to the next lower one to free resources so that they can be allocated to the higher hierarchical level. This is the Top-Down Approach. In applying the Top-Down Approach, we add up the distances traveled by quantities of impressions from one group to another. The algorithm reassigns quantities but keeps track of the total distance traveled. The goal is to determine the minimal total sum of distances traveled to satisfy the arriving demand. Suppose that a unit of impression is moved to the lower level, incurring a cost of 1 since the traveled distance is 1. But to do so we need to move another unit of impression from that lower level to its next lower level to make space for the first unit. The total cost becomes 2. In the Top-Down Approach, the solution prohibits that first unit from jumping down two levels unless it has to. However, if we use the algorithm basing ourselves only on the notion of distance, we may be overlooking the case where a unit jumps two levels down when it can be avoided. To make sure the algorithm performs according to the solution concept, we introduced a function to weight the distances. Let W(.) be a real function that applies to a distance between two groups. W(.) is such that W(Dist(A,B)) < Dist(A,B) for all distinct groups A and B except the most distant ones, W(0)=0 and W(Dmax)=Dmax, where Dmax is the maximum distance found in the cluster. It is a function that rescales the distances. For example, a simple function W(.) would be $W(x) = x^2/Dmax$. If we now instruct the algorithm to keep track of not the distances, but of the weighted distances W(Dist(.,.)), then we will assure that the jump cited above does not occur. The proof of this is simple and will be omitted here. By introducing the notion of weighted distances among groups, we force the algorithm to perform precisely as desired by the Top-Down Approach. The same weight function needs to apply to distances between AdSpaces.

2.5 Linear Programming Solution

The Top-Down Approach provides a sensible answer to the Basic Allocation/Assignment Problem. However, as we will show in this section, one can do better in terms of minimizing the total displacement. We revisit the example used in the previous section. We add to the 6 groups considered a seventh group G. We make group G the second *group of choice*. Figure 6 shows how G relates to the other 6 groups.

We assume that d_0 = 15; A is full and has capacity 10. The availabilities of groups B, C, D, and E are zero. The availability of F is 10. G has a capacity of 20 but is being utilized at 50%. Availability of G is 10. Let us assume further that no other group is relevant to this example. Solution one may start by considering first how to allocate as much as possible from group A to the new order, then if remaining, it would then turn to group G. In this case, the cost incurred is 10(.2) + 10 (.2) + 0 = 4, since W(1) = 1/5 = .2, as we assume that Dmax = 5 in this example. We are using the weighting function described above. Since 10 units are first moved from D to F, then 10 units are moved from A to D to make room for 10 units of the new demand, and since the cost of putting the remaining 5 units in G is zero, then the total cost is 4. However, if the

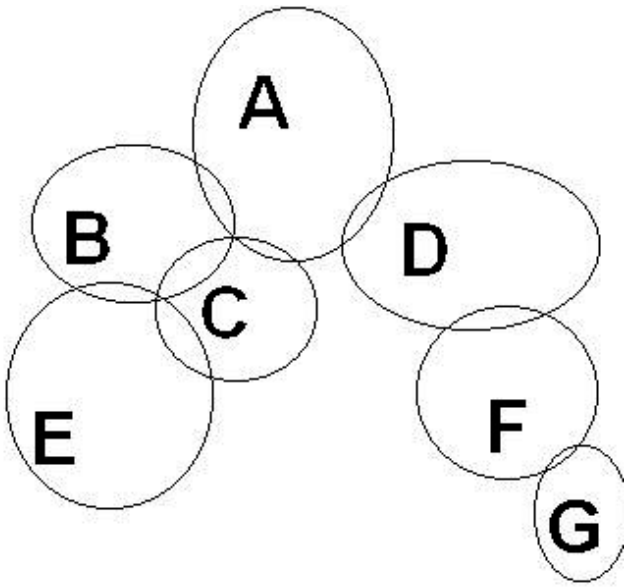

Figure 6: Example with a seventh group G

Top-Down Approach algorithm was to start with G, then the cost would be 0 + 5(.2) = 1, since 10 units are assigned immediately to G, then 5 units previously assigned to G are moved into F therefore freeing another 5 units in G. The difference in displacement is important. One may then rank the *groups of choice* in order to start the solution algorithm with the most available group. Perhaps, but then consider the same example with F having an availability of 15 and G is full. In this case, the Top-Down Approach would have to fill up F as it is the only remaining availability of the sub-system we are considering. If the Top-Down Approach starts by considering group A as the first target, the incurred cost is 10(.2) + 10(.2) + 5(.2) = 5, whereas starting with G leads to a 15(.2) = 3 cost. One may now think of developing other criteria for ranking the *groups of choice* as sequential targets for assigning the new demand. One can probably devise such a method. However, as the number of *groups of choice* increase, one is forced to start looking for a global approach to the problem. To do so, we revert to a mathematical formulation of the problem that would extend the idea of the first solution and considers all the interdependencies of the groups, their capacities, their availabilities and their AdSpaces at the same time. The mathematical model is a linear programming problem.

The solution, in concept, is to empty all the AdSpaces relevant to the problem, add the new demand d_0 to the problem and refill the AdSpaces so as to minimize the total displacement. Consider a set of groups that are relevant to the problem and let their AdSpaces be MN_1, MN_2, MN_3, … , MN_n. Next, we setup a fictitious AdSpace, call it MN_0, that has capacity 0. Let c_0, c_1, c_2, c_3, …, c_n be the capacities of the respective AdSpaces, including the dummy AdSpace. Let d_0, d_1, d_2, d_3, …, d_n be demands constructed as follows; d_0 is itself, that is the new demand we want to assign to some *groups of choice*. d_j, j = 1, 2, 3, …, n, is the content of AdSpace MN_j before we just emptied it. In other words, d_j is what was assigned to AdSpace MN_j before we started looking at the new demand. Let $v_{i,j}$, i = 1, 2, 3, …, n, j = 1, 2, 3, …, n, be the decision variables of the mathematical model. Let $w_{i,j}$, i = 1, 2, 3, …, n, j = 1, 2, 3, …, n, be the weighted distances of AdSpaces MN_i and MN_j. That is $w_{i,j} = W(Da(MN_i, MN_j))$, i = 1, 2, 3, …, n, j = 1, 2, 3, …, n. Let $w_{0,j} = w_{j,0}$, j = 1, 2, 3, …, n be such that $w_{0,j} = 0$ if N_j is an AdSpace that belongs to one of the *groups of choice*, and $w_{0,j}$ = minimum W(Dist(GC,G)), the minimum taken over all *groups of choice* and all groups to which AdSpace MN_j belongs. $w_{0,j}$ is the minimum weighted distance from any group of choice to AdSpace MN_j, that is to groups to which AdSpace MN_j belongs. We now define v_{ij} to be that part of the demand d_j that will be assigned to AdSpace MN_i. We have emptied the AdSpaces from their contents to construct n fictitious new demands, in addition to the new demand d_0. We now want all these demands to compete going back into the AdSpaces. v_{ij} represent that part of demand d_j that will be going into AdSpace MN_i. The mathematical formulation is:

$$\min \sum_{i=0}^{n} \sum_{j=0}^{n} w_{ij} v_{ij}$$

Subject to

$$\sum_{j=0}^{n} v_{i,j} \le c_i \qquad \text{For all i, i = 0, …, n,}$$

$$\sum_{i=0}^{n} v_{i,j} = d_j \qquad \text{For all j, j = 0, …, n,}$$

$$v_{i,j} \ge 0.$$

The AdSpaces have capacities that cannot be exceeded. We introduce this part of the problem in the form of constraints on the decision variables. We do not want to assign more than the existing demands and the new one, in this problem. We therefore add another set of constraints on the decisions variables. All the decision variables must be non-negative. This is a formulation known as the Transportation Problem, a special case of linear programming. The mathematical problem seeks the minimization of the objective function. The final value of the objective function will give a magnitude of how much the quantities in the AdSpaces got reshuffled. If the value of the objective function is 0 (zero), it means that nothing was moved from its original location (the d_j s returned to the groups from which they came, and d_0 found space in *groups of choice*), or that the only reassignments occurred within the same groups. If the final value of the objective function (that is the value returned after the run of the algorithm) is moderate, then the quantity displaced is moderate. The objective function is a score function that tells us how much displacement needs to occur so that we can insert the new order.

3 Research Results

3.1 Resources allocation problem

In the linear programming formulation of the optimal allocation of web advertising resources, if the number of decision variables n + 1 is large, the solution becomes difficult to track in real time. The properties of the transportation problem allow determining how big n needs to be. A necessary and suf-

ficient condition for the existence of a solution is that the total capacity of all the AdSpaces considered must be greater than or equal to all the total quantity we want to assign to them. When a new order d_0 arrives, we need only to go down the groups such that we have enough AdSpaces considered, i.e. n is large enough so that the above condition is satisfied. By doing so we restrict the size of the problem. However, n may still be very large and may cause computational problems. A set of programs to implement the solutions was developed comprising three main routines, supporting interface and a utility for the analysis of data sets. The solution was applied on sets of data and observed to perform adequately. However, overnight the Dot-com bubble burst. The study was eventually abandoned. The demand for advertising decreased so rapidly the bottlenecks disappeared. While the solution remained a viable approach, we could foresee difficulties in applying it to the whole system, in view of the size and complexity involved.

3.2 The production/distribution problem

Part of the facilities planning problem for production and distribution of Section 1.2 is a simple version of a multi-echelon, multi-indenture inventory problem. A lot of research has been conducted in the development of analytical solutions for multi-echelon, multi-indenture inventory problems. The solutions make simplifying Poisson assumptions to utilize Palm's theorem (Cox and Miller, 1977) in Queuing theory. The solutions are steady-state measures of effectiveness. The METRIC family models of the US Air Force or ACIM of the US Navy are solutions based on the Poisson assumption (Sherbrooke, 2004). In some cases, solutions must be tailored. A mix of generic, algorithmic and Ad-hoc solutions were applied to the IBM distribution network. OPTIMIZER was developed in 1983-84 by IBM researchers and academic team (Cohen et al., 1990). It presented a system for flexible and optimal control of service levels and spare parts inventory that addresses IBM's inherent complexity and very large scale problem. OPTIMIZER greatly improved IBM's Service Business, resulted in reduced inventory investment and operating cost and improved service levels and proved to be highly flexible. However, it took many years to develop and required the willingness of IBM to drastically change its inventory management policy.

In the case of the production/distribution problem of Section 1.2 for comparing different configurations, an analytical solution was considered. However it would have landed short as the system was too complex to accept simplifying assumptions. For reasons of commercial competitiveness, the company was in need of a solution as the market was expanding and the competition was swift between the different providers. Simulation became the most sensible approach. It took into account all relevant details and delivered a quick comparison between all considered expansion configurations, along with good estimates for forecast values. Company managers have also an easier attitude towards a simulation model once validation is conducted. The simulation was conducted with an animated solution. A simulation of three system configurations was conducted after a proper statistical analysis and modeling of all stochastic components. The statistical analysis looked at customer demand, daily production, frequency of train departures and other characteristics. A statistical model was developed for each on-site plant that allowed build-in annual increase. For the simulation, runs of several replications for a period of two years were made. Most statistics didn't require a larger number of replications for variance reduction. A confidential conclusion was reached (Aboura et al., 1994) that preceded a major expansion of the company in the mining sector. Satisfaction was expressed by the company and led to two other projects whereby a simulation of the operations of the plant was conducted in detail along with the simulation of its inventory and distribution system in Australia and overseas (Aboura et al., 1995a, Aboura et al., 1995b).

4 Discussion

Linear programming is well suited to allocation problems. In the Basic Allocation/Assignment Problem, we assign orders to AdSpaces or equivalently allocate resources from the AdSpace to a contract. These types of problems have been well studied and the transportation problem solution applies well. The general transportation problem is concerned with distributing any commodity from any group of supply centers, called sources, to any group of receiving centers, called destinations, in such a way as to minimize the total distribution cost. Any linear programming problem that fits this special formulation is of the transportation problem type, regardless of its physical context. Linear programming proved valuable for modeling many and diverse types of problems. Scientific research on the topic dates to the 1950's when the Simplex Method was developed by Dantzig (Rardin, 1998). Linear programs in thousands of variables and constraints are nowadays viewed as small. However, in a booking environment like that of the web advertising company, time is of the essence and the computational speed becomes an important issue. The Simplex Method has a number of iterations that seems linear in the size of the problem. Klee and Minty (1972) however found examples where the number of iterations performed by certain variants of the method was exponential. In general, linear programming problems can be solved in time polynomial. But these results proved theoretical. Consequently, other methods, known as interior-point methods were developed in the 1980's, based on the idea of a logarithmic barrier path studied by Fiacco and McCormick (1990).

On the other hand, computer simulation has become an indispensable tool for understanding the dynamics of complex industrial systems. Many successful businesses intensively use simulation for operational and strategic planning. Potential problems can be avoided by testing the operative and strategic business plans. Simulation, supported with animation, which demonstrates the operations of the modelled system, helps participants recognize the specifics of the presented system (Kljajic et al., 2006). Kljajic et al. (2000) describe the methodology and procedure of implementation of simulation methods in solving the decision-making problem in a medium-sized company in order to improve the operation planning and re-engineering process. Multiple criteria decision methods of the simulation scenario evaluation for decision support in the

manufacturing system are described. The system described is based on the system dynamics methodology (Forrester, 1961) combined with discrete event simulation, connected with a group support system (GSS) and an expert system. In a factory which produces concrete goods, problems of production management occur, as well as prolonged delivery time due to increasing demand. The production performance described in the article was planned and simulated on the basis of present and expected future demand. The evaluation criteria and business goals were gained by GSS methods in connection with the method of the Analytical Hierarchy Process (Saaty, 1990). It is often the case that simulation is combined with analytical approaches. Kljajic et al. (2001) describe an integrated simulation system for decision support making in enterprise. The business aspect of the simulation system was described by the Forrester's system dynamics, while the production aspect has been modelled using the discrete event simulation block diagram technique and Petri Nets. Kljajic et al. (2002) describe an approach to using simulation and visualization of discrete event oriented simulation models for multi-criteria scheduling optimization with genetic algorithms. The methodology provided the planner with a quick and efficient scheduling method for the production plan. The scheduling system is composed of a business information system; a database, a discrete event simulation model and a scheduling algorithm. By comparing various scheduling methods, it was established that the system utilizing genetic algorithms and simulation yielded from 5% to 15% better scheduling within a shorter time compared to manual scheduling. Genetic algorithms were also used in combination with simulation in Kofjač et al. (2008) in a real-case production optimization. Simulation is a powerful tool for modeling system dynamics. It can be applied to a variety of complex industrial systems. Finally, there are situations that cannot be modelled analyticaly. For example, in a plant where two overhead cranes operate simultaneously on the same rails, the daily output cannot be modeled unless the movement of the cranes is modeled. However, such traffic relies heavily on the coordination between the crane drivers, a set of rules and the large production traffic bellow the cranes (Welgama et al., 1996).

5 Conclusion

While an analytical method such as linear programming provides a solution at times, as in the bottleneck problem of the AOL booking system, the solution may be hard to implement. On the other hand, simulation proved to be an effective tool in the planning problem for the production and distribution of mining products. We make the point that, in complex industrial systems, simulation provides a better approach in designing and testing a solution. The fast paced and constantly changing reservation system prohibits a static mathematical formulation. Modern simulation software can handle the problem as long as good statistical input is provided. An analytical solution like linear programming can easily blow up in size and prohibit a realistic solution. Furthermore simulation provides a way to test the system for different forecasts, an issue of importance in most problems. A Monte Carlo approach is an effective approach to resolve serious issues in complicated setups. At times, there are complexities that simply cannot be modelled analyticaly but have a great impact on final assessments. If care is taken in modelling the problem, simulation offers a better solution and often allows to consider changes as the solution develops. As shown using the two examples, some situations are best modeled using simulation.

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Potreba po simulaciji kompleksnih industrijskih sistemov

V članku razpravljamo o konceptu simulacije in njeni uporabi pri obravnavi kompleksnih industrijskih procesov. Večina zapletenih industrijskih problemov, kot so vodenje zalog, proizvodnja in distribucija, upravljanje virov ali izboljšave procesa, zahtevajo kombinacijo različnih metod kot na primer linearno programiranje, ad-hoc algoritmi ali simulacija za reševanje problemov na podlagi razpoložljivih informacij. V članku smo opisali dva projekta kjer smo ubrali analitično pot in kritično razmišljali o njej. V prvem primeru smo uporabili linearno programiranje za optimalno alokacijo marketinških virov za glavnega internetnega ponudnika storitev. Drugi primer sestoji od vrste projektov, kjer analiziramo možnost razširitve proizvodnje in mreže dostave rudarskih izdelkov kot del občutljive strategije poslovne politike podjetja. Na podlagi primerov smo utemeljili potrebo po Monte Carlo simulaciji v kompleksnih industrijskih problemih kot bolj učinkovitega pristopa od analitičnega.

Ključne besede: Simulacija, linearno programiranje, proizvodnja, več-nivojska skladišča

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Contribution to the Collaborative Work in Virtual Organization - a Case Study

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A virtual organization is a community of people who interact together socially on a technical platform. These kinds of communities are built on a common interest, a common problem or a common task of its members that is pursued on the basis of implicit and explicit codes of behavior. The six dimensions that are normally used to analyze virtual organizations are the use of technologies, sense of belonging, success factors, level of trust from members, virtual community management, and contents of the virtual community. The virtual organizations defined in the literature are not defined separately for non-profit research virtual organization. Here we present analysis of non-profit research virtual organization, European Working Group on Operational Research for Development (EGW ORD). This paper provides a summary of achievements and challenges faced in building a virtual organization. This kind of analysis plays a vital role in establishing new non-profit virtual organizations to serve the research community in their field of interest. It is also helpful to the group in broadening its presence and involving more researchers, practitioners and students in the field of operational research.

Keywords: Virtual organization, Virtual community, Operational Research, Societies, EURO.

1 Introduction

Virtual organizations are defined as a community of people who interact together socially on a technical platform. The community is mainly built on a common interest / common problem / common task that are pursued on the basis of implicit and explicit codes of behavior. In 1993, Howard Rheingold coined this word in his book on virtual community and virtual organization. The technical platform which is the basis for virtual organization / community enables and supports the members of the community through interactions and helps to build trust and common areas of interest among the members (Leimeister et al., 2006). It also helps the members to collaborate, maintain and sustain member relationships in distributed work environment through various modern communications media that are geographically dispersed (Luna-Reyes et al., 2008, Zurada 2009). In recent years, there are several virtual organizations started over the internet. One such successful and popular virtual organization is Facebook, LinkedIn, Twitter, and so on. In order to establish a virtual organization, there is need for a community of people with a common interest having the ability of using cyber infrastructure. Virtual organization and virtual communities are interchangeably used in the literature and in this paper.

In the last decade, there are several researchers who study the internet phenomenon on virtual communities in order to understand virtual organizations and communities (for example: Leimeister et al., 2006). At the starting phase of each virtual community, the organizers or initiators need to get an idea on the value added to the people involved in the virtual community. This will be one of the stepping stones for the success of virtual community / organizations. Rodgers and Chen (2005) study the impact of virtual organizations initiated by women suffering from breast cancer in terms of psychosocial benefits such as experience sharing, societal support for patients, discussion blogs, and so on.

Yuan et al., (2000) explores the concept of virtuality as a nature of organizations and proposes a framework containing six critical dimensions, which may be used as a basis to characterize, study and compare virtual organizations. These critical dimensions are purpose, connectivity, technology, boundary, business process and people. This paper contributes

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to the conceptual discussion of virtual organizations and provides some important insights useful in the design of virtual organizations and the transformation of traditional organizations into virtual organizations. There are several research studies that are concerned with the six dimensions that are used to analyze a virtual community / virtual organization. These are the use of technologies (Wamalwa 2007, Kljajić Borštnar, 2012), sense of belonging (Blanchard and Markus, 2002), success factors (Leimeister, et al., 2006), level of trust among members (Abdul-Rahman and Hailes 2000, Leimeister and Krcmar 2005), virtual community management (Jansson et al., 2007), and contents of the virtual community (not well studied).

Moreover, most of the implementations of virtual organization in the literature are not focused non-profit research organization. This is one of the first studies that presents a case study that indicates the achievements and challenges faced in establishing nonprofit research virtual organizations. The case study presented in this is the experiences and achievements of the European Working Group on Operational Research for Development (EWG ORD) as a virtual organization in terms of the six dimensions mentioned above. Furthermore, the challenges met by EWG ORD are discussed. This study may enlighten researchers who wish to establish new virtual organizations in their field of research interest.

2 Virtual organizations / Virtual communities

Zurada (2009) presents some common characteristics of virtual community and virtual organization as shown below. Virtual community and virtual organization are

- Distributed across space, with participants spanning localities and institutions,
- Distributed across time, allowing synchronous as well asynchronous interactions,
- Dynamic structures and processes, at every stage of the organizational lifecycle,
- Computationally enabled, via collaboration support systems including e-mail, teleconferencing, telepresence, awareness, social computing, and group information management tools, and
- Computationally enhanced, with simulations, databases, instrumentation, analytic tools and services which facilitate interaction with humans that are integral to the functioning of the organization.

Figure 1 illustrates a paradigm of six dimensions that are required for analysis of a virtual organization. The six dimensions includes use of technologies, sense of belonging, success factors, level of trust from members, virtual community management, and contents of the virtual community.

Most of the studies that are presented in the literature are not very well studied in the context of nonprofit virtual organizations is content. So, the following section tries to illustrate all the dimensions used to analyze the nonprofit research virtual organization. The success in this type of organization mainly depends on the factors such as contents of the organization which is not well studied in the literature. Therefore, we attempt to summarize it with a case study.

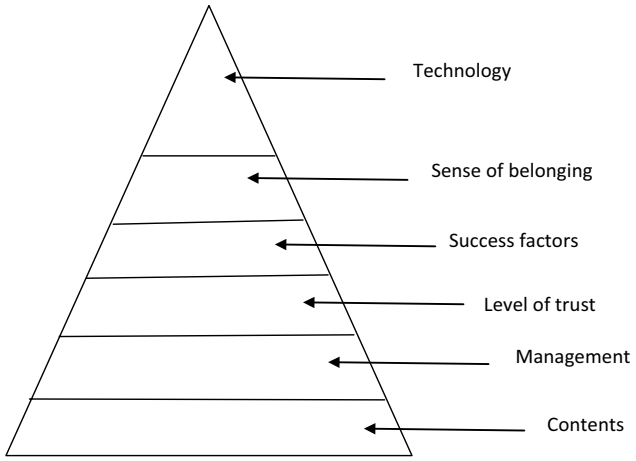

Figure 1: Six dimensions required for analysis of a virtual organization.

3 Case Study: EWG ORD: European working group on operational research for development

Brief history:
EURO, the Association of European Operational Research Societies, is a "non profit" association domiciled in Switzerland. Its affairs are regulated by a Council consisting of representatives of all its members and an Executive Committee which constitutes its board of directors. Its aim is to promote Operational Research throughout Europe. EWG ORD, a working group of EURO, is a creative idea that has evolved during informal conversations between fellow researchers and doctoral students at the EURO Summer Institute (ESIXXII, 2004). One of the main motivations behind starting this group is leverage the research and educational opportunities for research students, researchers, and practitioners from developing countries. One of the other driving forces in founding this working group is to lead the way to systematically analyze the data from projects developed in developing countries, to exchange ideas between researchers working on various projects meant for developing the status of various countries below poverty line. However, this working group is not limited to individuals from developing countries. The first and foremost thing which everybody in founding members of the working group agreed up on is to maintain regular and organized communication among members. This regular communication will help to configure research ideas and highlight topics of interest that need immediate attention.

In the following months, members of the founding team started interacting with potential members for the working group through emails and presentations with the aim of submitting a proposal to EURO. These efforts lead to the formation of the working group, EWG ORD.

Aim of the EWG ORD:

The aim and objectives of the working group are listed below (http://web.ing.puc.cl/~fcrespo/eurofdv/):

- to disseminate state-of-the-art knowledge and to support research in operational research for development,
- to assist in gathering the operational research for development communities in Europe organized under the umbrella of EURO,
- to support preparation, refereeing and editing of publications,
- to establish regular information channels and regular meetings,
- to involve industrial organizations and users of optimization in the activities listed above,
- to achieve vivid exchange between scientific experience and enthusiasm of the youth,
- to promote education, qualification and democratic participation in decision making at all levels,
- to promote collaborative learning,
- to encourage building up a common and developing Europe, and
- to establish peace and friendship in Europe and in the world.

Members of EWG ORD:

EWG ORD has 155 registered members from 37 different countries and a presence in five different continents. Figure 2 illustrates the composition of the members indicating the success of the working group in reaching the researchers across the globe.

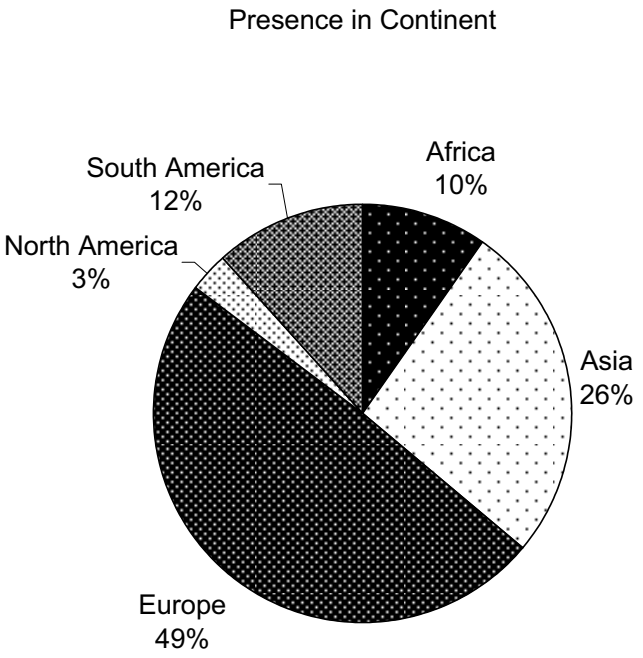

Figure 2: Member distribution across different continents.

The group's member composition also confirms the motivation of researchers both from the developed and the developing nations in the concept of Operational Research applications.

3 EWG ORD: A virtual organization

In this section, a list the achievements and challenges in terms of the six dimensions of virtual organizations that help the EWG ORD increase its influence and broaden developments.

3.1 Use of technology

After the proposal of the EWG ORD group, the first important step for using technology (Wamalwa 2007) was to build a website that would enable the cohesion and the permanent diffusion of the group's activities (EWG ORD 2010). The format of this website is similar to other established working groups from EURO (EURO 2010). The goal of such similarity is to help users (who are familiar with other working groups) in easy navigation. In fact, most the group members have memberships in other working groups established in EURO. After building the website, emails were sent to potential members from other EURO working groups, to INFORMS members, and other OR societies from developed and developing nations. The main focus of the website is to use open source technologies such as PHP, HTML in order to offset the cost burden. The technology aspects that are not fully integrated are instant messaging facility, Internet relay chat (IRC), bulletin boards, blogs, wikis, collaborative software, social network search engines, social book marking, peer-to-peer, virtual presence (Wamalwa 2007), Skype and messengers (from Gmail or Microsoft Messenger).

Administrative concerns are the cause of these missing tools. The web page is hosted by a university server that is subjected to the university information technology policies. These policies restrict the use of some open source software available over the internet such as IRC messenger and internet blogging, which are used in community sites.

The next step in the technology dimension is to identify the common interests and needs of the members in the working group. One of the main challenges in this step is to gauge the technical expertise of the members in using these technologies. The other challenge is implementing the technologies that allow users to find the researchers with common interests. In fact, this is the main goal of social networks. So, adding interactive technologies to the web site can indeed open up new joint projects.

3.2 Sense of belonging

The concept of the sense of belonging to a community is a feeling of the individual's personal connections to a social group that leads to important outcomes in face-to-face organizations and human communities. In work organizations, sense of belonging to a community increases job satisfaction and organizational citizenship behavior, i.e. loyalty, civic virtue, altruism, and courtesy to the organization (Blanchard and Markus, 2002). In the case of EWG ORD, sense of belonging is one of the core objectives which will enable the organization to move forward and build a strong community. Blanchard and Markus (2002) present the four dimensions of sense of belonging to communities that are listed below:

1. Feelings of membership:
   This dimension can be defined as the feelings of belonging to, and identifying with, the community.
2. Feelings of influence:
   This is defined as the feelings of having influence on, and being influenced by, the community.
3. Integration and fulfillment of needs:
   This is presented as the feelings of being supported by others in the community while also supporting them.
4. Shared emotional connection:
   This sense of belonging to the community is defined as the feelings of relationships, shared history, and a "spirit" of community.

These aspects are very difficult to see and measure, as EWG ORD does not have formal information on this dimension. However, sense of belonging can be gauged by the involvement of the member in the working group activities such as attending workshops, conferences, meetings organized by the EWG ORD. In the future, EWG ORD is planning to collect data that may be in the form of naturalistic inquiry (Blanchard and Markus, 2002). This data can be used for understanding community belongingness to EWG ORD group.

One of the primary indicators of the sense of belonging among group members is the number of presentations that are made by the members and the research community in the workshops/conference streams that are organized by EWG ORD. Figure 3 illustrates the annual number of presentations made from the year 2006 onwards.

The other important indicator is sharing important and exciting data in the conferences / workshop organized by EWG ORD. Some interesting exchanges of ideas made during meetings are listed below.

Rosario and Rosario (2010) present two private initiatives in Philippines towards development in education. These initiatives are made on two fronts: a national OR organization working on projects for the government to promote good governance and private foundation efforts at uplifting public school education. Their work also illustrates OR as a tool that can help policy-makers realize the goal of an improved education for the poor.

Cochran (2010) discusses his experiences with Statistics Without Borders (SWB), Operations Research Practice for Africa (OPRA), and INFORMS Transactions on Education (ITE). His talk mainly focuses on SWB's efforts in collecting post earthquake data in Haiti, OPRA's efforts in using OR to address urban transportation and water resource management issues in Africa, and ITE's efforts in building and maintaining a collection of freely accessible of OR cases (with teaching notes) for classroom use by college instructors.

Weber et al., (2010) present as system dynamic approach to study the effects of infrastructure facilities on the quality of primary education. The model is built using the Cross Impact Analysis (CIA) method of relating entities and attributes relevant to the primary education system in any given community. The resulting model enables to predict the effects of infrastructural facilities on the access of primary education by the community so that policy makers take more effective actions in campaigns.

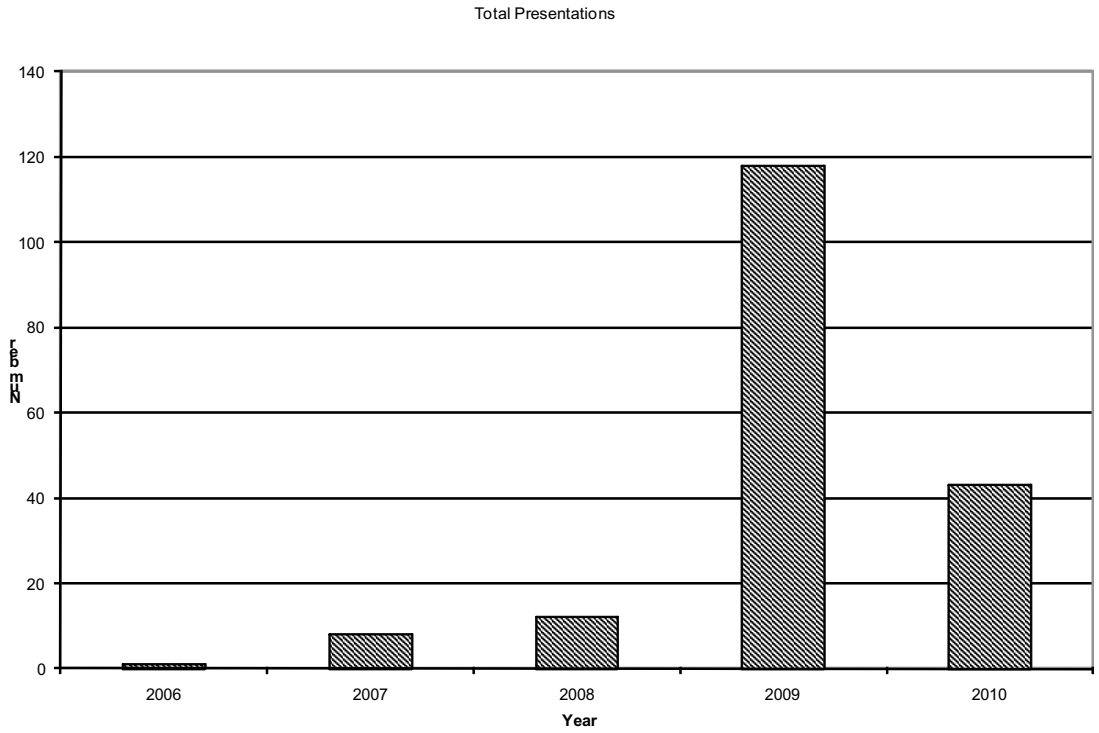

Figure 3: Distribution of total number of presentations made over the years in EWG ORD streams.

There are several other works presented in these meetings, such as OR applications in urban occupation patterns analysis (Rave, 2010), design of strategic international business centers for suppliers (Bashiri and Mohtajeb, 2010), and so on.

These and similar discussions help to disseminate the state-of-the-art knowledge within and outside the community and to support research in this field while motivating researchers in using OR to solve real problems in other fields of research.

3.3 Success Factor

Leimeister et al., (2006) identify 32 factors of success and rank them on the basis of importance to an organization and also validate these factors in the context of a real virtual organization. However, EWG ORD is not a profit making organization, so it adapts the success factors listed in Leimeister et al., (2002). In the following analysis, we use the adapted ranking scheme without differentiating the group population by sex, because EWG ORD is not a service based organization that offers services based on gender. Some of the adapted success factors are listed below:

- Sensitive handling of member data:
  We only use the data to send emails that are informative about the community activities. EWG ORD does not use the data for commercial use.
- Stability and Fast reaction time of the website:
  Changes on the web site are incorporated within 24 to 48 hours, because EWG ORD needs to manage different time zones. The principal decisions and updates are made by members distributed in Asia, USA, Europe, and Latin America.
- Assistance for new members by experienced members and establishing codes of behavior:
  EWG ORD members consist of a group of professionals who join in the group to exchange ideas and assist each other with their expertise in problem solving. Exchange of ideas and creation of platform to solve the problems through dialogue are the foundation stones for the EWG ORD. The basic communication used in exchange of ideas and interactions between the members is through emails. Also, web admin plays a vital role in these exchange and interactions through posting in the website. EWG ORD has an implicit code of behavior for text or emails contemplated in the organizers consent which is channeled through the web admin.
- Offering up-to-date content and offering high-quality content:
  EWG ORD offers links to national and international congress, workshop and events, and information shared in the workshops / conferences through reports. An ongoing proposal in the working group is to make a repository with the talks of past presentations at EWG ORD events, and also to publish emails of authors or researchers who wish to share their study in order to educate new generation researchers and students.
- Encouraging interaction between members, evolution of the community according to the ideas of its members, building trust among the members, arranging regular events and supporting the community by regular real-world meetings:
  EWG ORD is actively involved in organizing / co-organizing workshops or streams on operational research for development in EURO 2006, EURO 2007, EURO 2008, IFORS 2008 and EURO 2009. For 2010, EWG ORD organized a workshop on operational research for development in EURO 2010 and ALIO INFORMS 2010, and involved in several national and international workshops and satellite events. This allows managing board members to interact with members of the community and also update the members. Also, this involvement attracts / motivates new members to join the group and it gives an invisible attachment to EWG ORD.
- Intuitive user guidance/usability:
  This factor is explained in detail under the design of the web site factor.
- Reaching a high number of members within a short period of time, personalized page design of the community-site according to the preferences of its members:
  EWG ORD does not provide a preference based web site.
- Integration of the members into the administration of the community and appreciation of contributions of the members by the operators:
  These factors are the most difficult to implement, because paradoxically the response in terms of work is better from people from developed countries or with people who maintain relations with people from developed countries. The reason might be that developing countries are not so advanced in OR applications.
- About "Offering privileges or bonus programs to members" and "Establishing and supporting sub-groups within the community", members of EWG ORD look for funds to contribute to the organization of workshops and to give small scholarships to members from developing countries.
  The factors "Sustaining neutrality when presenting and selecting offers", "Constant extension of offerings", "Price efficiency of offered products and services", "existence of an offline customer club as a starting advantage", "Increase of market transparency for community members", "Special treatment of loyal members", "Personalized product and service offers for community members" do not apply to EWG ORD, because the principal and primary priority is in academic and research order, not a commercial one. However, if EWG ORD were to get funds from enterprises in developing countries some of these factors could be discussed.

These factors offer a variety of aspects to consider empowering EWG ORD as a reference to look for information in Operational Research in developing countries and to build a bridge between researchers in developed and developing countries.

3.4 Level of Trust

In this dimension, EWG ORD gained adequate level of trust in terms of reputation (see Abdul-Rahman and Hailes 2000

for reputation of web sites), because of the academic identities of its fellow researchers and members in the Managing and Advisory Boards. Globally recognized academicians generate trust for new and old members. However, there are some weak points; one such weak point is that EWG ORD doesn't have a platform to connect members of common research areas to interact with each other after a particular meeting or conference. The current implemented method is through emails that are shared across attendees of a particular conference / workshop.

Leimeister and Krcmar (2005) suggest two major factors, perceived competence and perceived goodwill that influence the development of trust. In the case of the first factor, EWG ORD does not have detailed information, but as stated above, reputation is a first step for it. For EWG ORD, the perceived competence published in special editions or portals does not apply, because EWG ORD does not receive funds and nor does it transfer funds from its members. Perceived goodwill can be experienced as the discovery of a cooperating partner's good intentions and can further lead to the development of interpersonal trust (Leimeister and Krcmar 2005). Regarding the set of trust-supporting components for the virtual community (Leimeister and Krcmar 2005), EWG ORD offers an adequate access rights concept and reasonable role models, but it is not evaluated yet, because users do not include their academic data, and for the moment, EWG ORD does not use trust seals.

The number of presentations illustrated in Figure 3 might be accepted an indicator for the level of trust in the community through their support to the workshops / conferences organized. From 2006 to 2009 there is sharp increase in the number of contributions. The main reason in decline in the number of contributions in 2010 is the limited number of workshops organized.

3.5 Virtual community management

Leimeister and Krcmar (2005) describe that community management is usually associated with the activities of community development and the community. Strong and diligent management may play an active role in establishing trust between members and the community at the early/later stages of initiation of a virtual community.

The objective of virtual community management is without forcing power, through creating trust and considering risks while acting on incomplete information (Jansson, et al., 2007). EWG ORD is managed democratically by managing board members. These voluntary board members devote their time in organizing, educating, helping members of the community. The risks are related to the fact that EWG ORD does not have inscription of members, and it cannot change the members of managing boards permanently. Incomplete information is a constant factor affecting the capacity of bringing people together people in the workshop.

Figure 4 illustrates community management through organizing streams in several international and national conferences. It also indicates the success EWG ORD achieved in a short span of time and its impact on the community. There

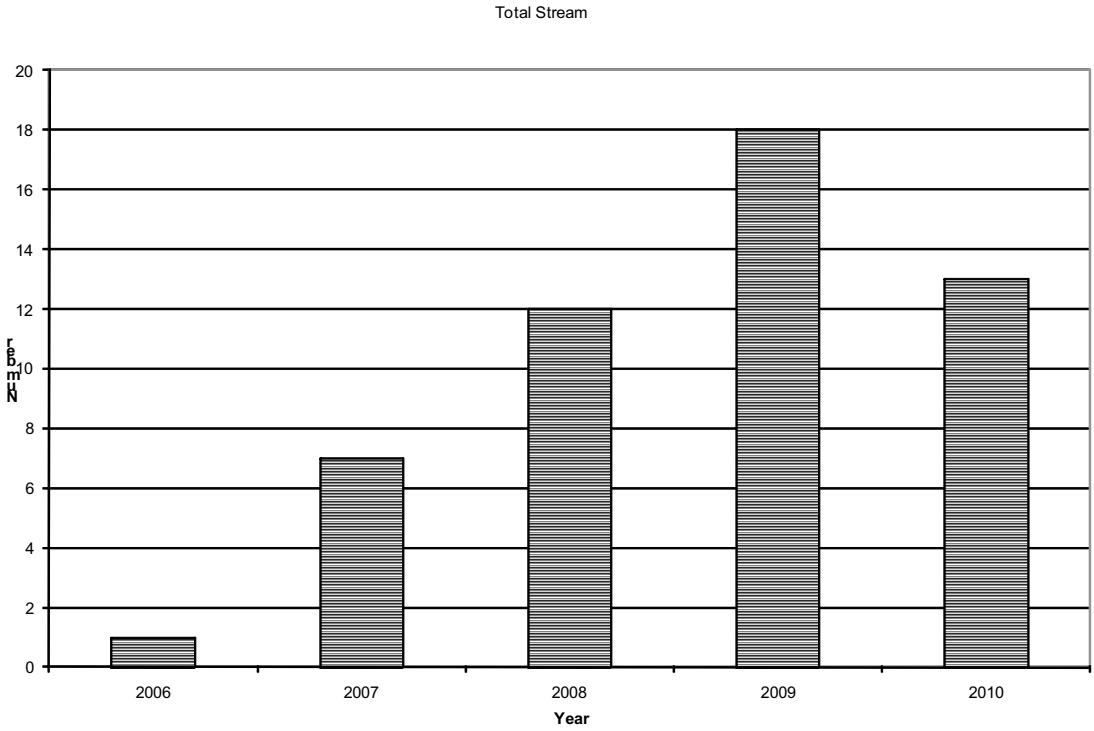

Figure 4: Distribution of total number of streams organized over the years

is a steady increase in the number of streams organized every year except for the year 2010.

3.6 Contents of the virtual community

This dimension is not very well studied in the literature in the context of nonprofit virtual organizations. In the context of EWG ORD, the contents are mainly based on the goals and objectives of the working group. The main objective of this working group is to create a knowledge repository of real-time problems/case studies and applications of operational research that are solved in developing countries. EWG ORD also creates a platform to point out and exchange the problems that need to be addressed and solved in developing nations. As this virtual community does not receive any kind of membership fees from members and from EURO, its contents are more unbiased.

In summary, EURO ORD website is very specific form of social networking website. In case EURO ORD, website offers a platform for people to communicate and exchange ideas through emails, workshops, conferences and meetings. Here the website is facilitator which helps this networking possible. The specific topics discussed in this forum are application, methods to solve real-time problems in developing countries. These exchanges of ideas, so on excel the human capabilities in solving problem in more effective way. One of the main goals of any social networking website is to exchange views, ideas, and communicate about recent happening. EURO ORD serves all these goals without any doubt.

4 Conclusions

Nowadays, virtual organizations are a very popular and efficient tool to form a community of people with similar interests or ideas. In this paper, we present such a successful implementation of a non-profit research virtual organization, EWG ORD, which has evolved from common research interests. Here, we attempt to identify and analyze the six dimensions of virtual organizations in the context of the EWG ORD. The main strengths of this organization are its members and its managing board members and advisory board. EWG ORD successfully understands the needs of the community and creates a good level of trust. The level of trust, sense of belonging, and its management are illustrated by the participation of members the working group's conference streams.

A similar analysis can be conducted for understanding working groups not only under EURO but also under other international bodies. Such analysis also helps to generate ideas for building new working groups in the future.

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Prispevek k skupnemu delu v virtualni organizaciji – študija primera

Virtualna organizacija je skupnost ljudi, ki vzajemno delujejo v svojem socialnem in tehničnem okolju. Te vrste skupnosti izhajajo iz nekega skupnega interesa, skupnega problema ali skupne naloge svojih članov, za katerega si prizadevajo, upoštevajoč implicitna ali eksplicitna pravila ravnanja in obnašanja. Običajno se pri analizi virtualnih organizacij uporablja šest dimenzij: uporaba tehnologij, občutek pripadnosti, dejavniki uspeha, nivo zaupanja s strani članov, management virtualne skupnosti in vsebina virtualne skupnosti. V literaturi ne najdemo definicije virtualne organizacije posebej za neprofitne raziskovalne virtualne organizacije. V prispevku predstavljamo analizo neprofitne raziskovalne organizacije, Evropske delovne skupine za operacijsko raziskovanje za razvoj (EGWG ORD). V članku je prikazan povzetek dosežkov in izzivov pri izgradnji takšne virtualne organizacije. Takšna analiza je ključnega pomena pri vzpostavljanju novih neprofitnih organizaciji, ki služijo skupnosti raziskovalcev na področju njihovega raziskovalnega interesa. Prav tako ji je lahko v pomoč pri razširjanju svoje prisotnosti in vključevanju nadaljnjih raziskovalcev, praktikov in študentov na področju operacijskega raziskovanja.

Ključne besede: virtualna organizacija, virtualna skupnost, operacijske raziskave, združanja, EURO

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Comparative Analysis of Collaborative and Simulation Based Learning in the Management Environment

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Purpose of the study is to compare two different approaches to the collaborative problem solving one in a highly controlled laboratory experiment: Optimisation of business politics using business simulator at different experimental condition which reflect different feedback information structure and one in a collaborative environment of the social media, characterised by non-structured, rule-free and even chaotic feedback information. Comparative analyses of participant's opinion who participate in experiments have been considered in order to find common characteristics relevant for group/collaborative problem solving. Based on these findings a general explanatory causal loop model of collaborative learning during problem solving was built.

Keywords: Group decision support, Information structure, collaborative learning, simulation model, social net

1 Introduction

Decision making is the most important process in human existence, being on an individual or societal level. More general, decision processes are immanent in all leaving beings at different level and in different context. The decision process can be regarded as complex problem solving: because it is a complex cognitive process comprised of systematic processing of knowledge and rationalisation, which should minimize the possibility of making a mistake (Wang, 1997). It is being described as a learning process that should provide sufficient knowledge for efficient problem solving and adaptation. Further on, such process can be efficiently supported by information systems, which basic role must be to provide the right information when needed. Nevertheless, information alone is not sufficient for successful decision making. The decision-making process often takes place in a social context. Decisions generated in organizational systems are not dependent on the individual decision of a subject, but rather on a group of individuals participating in decision making. The group as a whole understands the problem better (Hale, 1997), which should lead to synergistic effects. On the other hand, groups can be difficult to manage. There are problems of trust, conflicts, … which can hinder the benefits of the group decision-making. Group support systems (GSS) are designed to manage these problems and enhance the positive effects of group work. Nevertheless, the positive effects of GSS are not unanimous in literature (Fjermestad, 2004). The problem lies in complexity of the process itself, with people as creative actors: there are problems with the level of facilitation, quantity, content, and frequency information feedback (Hsiao & Richardson, 1999; Khalifa, Davison and Kwok., 2002; Rouwette, Größler and Vennix, 2004). The importance of process facilitation was shown by Kljajić Borštnar et al. (2011) and Limayem, Khalifa and Ma (2002). Furthermore, the study of Limayem et al. (2002) reported no difference between live and computer facilitation. Kim (2010) argued that the role of a leader is turned into a facilitator and that "… facilitation encourages uncooperative members to improve their participation in order to increase group cohesiveness." (Kim, 2010, p. 1569); therefore, the role of a facilitator is similar to the role of a teacher.

Managerial problems are usually complex and dynamic and are being described and vizualized in many ways in order to improve understanding and missperception of feedback. The simulation model described in this study is used as an explanatory tool for a better understanding of the decision process and/or for learning processes in enterprises and in schools. Many successful businesses intensively use simulation as a tool for operational and strategic planning as well as enterprise resource planning (ERP) (Schniederjans & Kim, 2003; Muscatello, Small and Chen, 2003). Findings in literature (Forrester, 1969; Homer, 1996) emphasize that in a variety of industries real problems can be solved with computer simulation for different purposes and conditions. At the

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same time, potential problems can be avoided and operative and strategic business plans may also be tested. From previous research on simulation-based problem solving (Škraba, Kljajić and Leskovar, 2003; Škraba, Kljajić and Kljajić Borštnar, 2007; Kljajić Borštnar et al., 2011), we have come to some understanding about the nature of groups working together in a computer-supported virtual environment. Specifically, in the process of complex managerial problem solving supported by a simulation model and a GSS, the role of facilitator in a group process was shown, and the group belonging effect was empirically proven (Kljajić Borštnar et al., 2011). Further, the structure of feedback information was shown to have a great impact on the performance of the group. When the individual feedback information of a simulation model efficiently supported individual learning (Škraba et al., 2003), the contribution of group information feedback was not as straightforward (Škraba et al., 2007). When group information feedback was provided in a controlled and facilitated process, it contributed to greater unity and better performance of the group members; in contrast, when it was freely accessible to the group members and the process was not facilitated, it caused the group to perform poorly and perceive the experiment poorly.

Recent developments in computer virtual communities and social media suggest that collaborative problem solving can be as or even more efficient than highly controlled computer virtual environments (Tapscott and Williams, 2006; Barabasi, 2002; Potter, McClure and Sellers, 2010). To be able to use collaborative problem solving while learning in educational, organizational and inter-organizational environments, we have to understand the environment and the learning processes. Our interest is focused on how people solve complex problems, and not the optimization of it, but the understanding of how it actually happens (Kljajić Borštnar, 2012).

The collaboration in a social media environment is not limited to a classroom, a set time and a small number of participants. Collaboration is considered to be any process of working with others with common objective. Similar to the description of a group learning process that may or may not result in a measurable learning outcome, but still displays the underlying group learning process (Lizeo, 2005), the collaboration process does not necessarily end up in creating values within specified spaces (Dillenbourg, 1999). This means that all collaboration tools available for supporting and promoting participative behaviour are not sufficient for the group to learn. In search of the concept of collaborative learning in the social media environment, Garrison, Anderson and Archer (2000), Freire (2000) and Wells (1999) argue that a critical discourse is of great importance within collaborative learning environments. Rosen (2007), in his book on the culture of collaboration, proposes ten cultural elements that support value creation: trust, sharing, goals, innovation, environment, collaborative chaos, constructive confrontation, communication, community, and value.

Purpose of the study is to compare two different approaches to collective problem solving. One in a highly controlled laboratory experiment, supported by a simulation model (Škraba et al., 2003; Kljajić Borštnar et al., 2011) and second, a task oriented collaborative problem solving in a social media environment (Kljajić Borštnar, 2012).

2 Methodology

Comparative analysis of participant's opinion from two different experiments has been considered in order to find general explanatory model of learning. Following experiments, denoted as Case 1 and 2 were described in (Škraba et al., 2003; Kljajić Borštnar et al., 2011) and (Kljajić Borštnar, 2012) respectively:

Case 1: **Optimisation of business strategy using business simulator,**

Case 2: **Collaborative Learning in a Social Media Environment**.

2.1 Experiments description

2.1.1 Business simulator – a tool to improve learning process - Case 1

In order to improve the method of teaching the »Modelling and simulation« course, and to explicate that simulation methods in management science are not only a tool for solving already known academic problems, but to support real-life problems, we built a business simulator. Students had to take active part in an experiment, solving the proposed business problem and report their results at the predefined times. They were motivated to regularly attend lectures and hands-on training, therefore similar level of participants' knowledge could be presumed. Furthermore, special care should be put on organizing the experiment, since the problem, task, environment and the business simulator have to reasonably reflect the real business situation and its utility.

Detailed description of the simulation model, developed by the system dynamics (SD) method, can be found in Škraba et. al (2003). The model consists of production, workforce and marketing segments. It was stated that product price positively influences income. However, as prices increase, demand decreases below the level it would otherwise have been. Therefore, the proper pricing that customers would accept can be determined. If marketing costs increase, demand increases above what it would have been as a result of marketing campaigns. The production system must provide the proper inventory level to cover the demand, which is achieved with the proper determination of the desired inventory value. Surplus inventory creates unwanted costs due to warehousing; therefore, these costs have to be considered. The number of workers employed is dependent on the production volume and workforce productivity, which is stimulated through salaries. Proper stimulation should provide reasonable productivity.

The participants in the experiment had the task of promoting a product on the market, whose life cycle is one year. The participants changed the parameter values via a user interface that incorporated sliders and input fields for adjusting the values. The goal of the participants was to maximize the criteria function, which was explicitly stated in order to achieve a proper level of experimental control with regard to the results obtained. The simulator enabled simultaneous observation of the system response for all variables stated by the criteria function during the experiment.

In total, 147 subjects, senior university students randomly scheduled into three groups, participated in the experiment. The experiment was conducted under three experimental conditions:

a_0) Determination of strategy on the basis of a subjective judgment of the task

Under this condition, a subject had to make an individual judgment about the best possible strategy on the basis of the presentation of the model by the Causal Loop Diagram (CLD) and the stated Criteria Function. The participants had 30 minutes to determine the appropriate values of decision parameters and record their decisions on paper.

a_1) Individual decision-making supported by the simulation model

Under this condition, each subject was supported by the simulation model, which provided feedback information about the anticipated business outcome. There was no limitation on the number of simulation runs a particular participant executed on the simulation model within the experimental time. After each predetermined time interval (8 + 8 + 8 + 6 minutes), participants had to forward their selected business strategy to the network server and continue the search for the optimal business strategy. Participants had to make a final decision about the best business strategy and forward the selected decision parameter to the server after 30 minutes.

a_2) Decision-making supported by both the simulation model and group feedback information

The simulation model was connected to the GSS, which enabled the introduction of group feedback information into the decision process. Each individual subject was supported by the simulation model, which provided feedback information on the anticipated business outcome, and restricted interaction between subjects was enabled by GSS. Participants were able to examine the chosen business strategies (decision parameter values) of other participants in the decision group after the strategies were submitted to the network server. The participants could look into the "group's achievements" after the 8^{th}, 16^{th} and 24^{th} minutes. There were no limitations on how many times they could seek group feedback. Group feedback information was presented in the form of a table, which contained input parameter values selected by each participant anonymously, and the average values of the parameters with the standard deviation.

The hypothesis that model application and group feedback information positively influence the convergence of the decision process and contribute to higher criteria function values was confirmed at the p = .01 level. The results revealed that the final criteria function values were higher when group feedback information was introduced (a_2) compared to the decision process that was based only on individual experience with a simulation model (a_1), and the lowest criteria function values were achieved on the basis of subjective judgment (a_0). However, we expected that the results gathered after the first eight minutes would not differ for the groups working with simulator (a_1 and a_2) where the same conditions were in force in the first eight minutes: individual use of simulator. Because groups were randomized and homogenous, we expected no difference in participants' use of simulator. However, the frequency of simulator use in first eight minutes was significantly higher in Group a_2 than Group a_1. We repeated the experiment with conditions a_1 and a_2 (Škraba et. al, 2007) and the results were similar. In order to explain this phenomenon the pseudo Solomon Four-Group Experimental was designed (Kljajić Borštnar et al., 2011) wich permits testing of the interaction between pretest (in our case pretest can be interpreted as decision point at the 8th minute of experiment) and treatment (group information feedback). In this experiment we formed four groups: two were using only simulator, one with and the other without the faciliatotr. Two groups were using simulator accompanied with the group information feedback, one with and the other without the faciliatotr, therefore two new experimental conditions were added:

a_3) Continuous individual determination of strategy supported by a simulation model.

This condition assumed individual assessment of the decision maker, supported by simulator without facilitation, when determining the parameter values $\{r_1, r_2, r_3, r_4\}$ by maximization of the criteria function. At the end of the experiment, the subjects submitted their best-achieved parameter values to the network server.

a_4) Continuous individual determination of strategy supported by a simulation model plus GIF.

This condition assumed that subjects individually explored the simulation model and its behavior (Individual Information Feedback), but had additional information about the work of the group at their disposal at all times (GIF). Every simulation run (decision parameters r_i) was recorded in the database. The last performed simulation run of each subject along with the current average value of decision parameters (r_i) were fed back as GIF. The subjects could access GIF in the form of a table by clicking the *Group Information Feedback* button on the user interface at any time. The participants' decisions were collected only once, at the end of the experiment, therefore the decision maker had 30 minutes time to experiment on the business simulator with the possibility of looking into the work of the group (GIF). At the end of the experiment, the subjects submitted their best-achieved parameter values to the network server.

Hypothesys that there is positive correlation between the frequency of simulation runs and the value of criteria function was accepted. This implies that the simulation model supports the individual learning on the trial and error basis. The hypothesis that an insight into group information feedback is influenced by the presence of facilitation was proven. More specifically, the information seeking behavior tends to be lower when facilitation is omitted. Furthermore, the interaction between treatment (GIF) and facilitation was shown to have an impact on the frequency of simulation runs.

All participants had to fill in the questionaire about their experience at the end of experiment.

2.1.2 Collaborative Learning in the Social Media Environment - Case 2

The second case described the preliminary research of collaborative problem solving in a social media environment (Kljajić Borštnar, 2012). It is based on the assumption that collaborative learning can be efficiently supported in a rule-free and social media unstructured environment, and that it has a positive impact on the self-organizing of the group and thus contributes to problem solving and learning. Students had three weeks' time to complete the assigned study tasks using the Flowr social media (www.theflowr.com). Research was performed by observing them in the natural setting of the class conduction for the duration of three weeks. With observation methods and questionnaires, we aimed to answer the following research question: Does collaborative problem solving without formal structure and facilitation in the social media environment stimulate the self-management of the group?

The research took place in the 'natural environment' of a Computer Systems and Communication class. The class was comprised of 45 school hours of lectures (3 weeks), followed by 30 hours of practical training in the computer classroom (two weeks) plus individual students' work. Twenty-four undergraduate students of the class, aged between 20 and 23 years from the Faculty of Organizational Sciences, University of Maribor, participated in the study. At the beginning of the last week of lectures, students were presented a study task (a research topic) that they had to research and present at the end of the two weeks of practical training, thereby giving them three weeks of time (one week of lectures plus two weeks of practical training). Their work on the topic was not limited to the classroom; they were free to cooperate at the time of their own choosing. They were asked to form three groups with a maximum of 10 members per group was allowed. For the purpose of keeping the 'natural environment' intact, they were not told they were participating in a study. The role of the teacher (part of the research team) was to observe their work without interfering or facilitating it. The students were able to use the computer classrooms, but were also allowed to work from home or any facility and at time of their choice. Their task was to create a presentation of the research on topic selected by an individual group. Groups were given four topics from the class curriculum to choose from: 1) cloud computing, 2) collective problem solving, 3) information security, and 4) virtualization. The three groups selected the first three research topics.

Students received simple written and oral guidance for their assignment, explaining that they had to create groups that would research the selected topics, using the social collaboration service Flowr (www.theflowr.com). The instructions included instructions on how to use the Flowr service, and a description of the problem and the task. The task was part of the class curriculum; the topics are changed yearly according to the state of the art in the ICT field. The only new factor for the students was the use of a previously non-familiar social service.

After three weeks of collaborative work, students presented their work and reported their opinions through an anonymous questionnaire. The questionnaire was devoted mostly on the collaborative work. Statements formed key variables (constructs) researched in the study: general experiment quality, motivation, self-management of the group, trust, conflicts, absence of formal facilitation and structure, group satisfaction, and user experience. Two basic constructs, self-management of the group and the absence of structure and facilitation, and their association to motivation, trust and conflicts within the group was analyzed (Kljajić Borštnar, 2012).

We have provided evidence that less facilitation and structure is associated with grater ability to self manage (r_S = - .483, p = .017). Further, the increase in motivation is associated with an increase in the ability of the group members to effectively self-organize (r_S = .555, p = .006), and that a higher sense of trust is positively associated with an increase in the ability of the group members to effectively self-organize (r_S = .455, p = .026). Finally, the results revealed that there is no correlation between trust and formal structure and facilitation (r_S = .177, p = .408). Findings suggest that perceived trust is not related to the amount of formal structure and facilitation.

3 Results and Discussion

The two experiments described above have several things in common. In both cases the participants were graduate students who were enrolled in the regular classes. Their tasks were to solve the stated problem. They were motivated to participate as their participation was rewarded within the final exam grade. However, there were differences which should be clearly stated:

- In case 1 the problem and the task were highly controllable in contrast to case 2 where the problem and task wouldn't give much control over the experiment (the result in Case 1 can be measured and analyzed quantitatively), the results in Case 2 cannot be objectively measured)
- The environment in Case 1 was controllable (limited time and place) in contrast to Case 2 where students had more time and no limits to their whereabouts.
- The main difference was still in facilitation of the problem solving process in Case 1 and no facilitation of Case 2.

In both cases our assumptions were based on the individual and collective learning during the problem solving process. According to Sterman (1994) learning can be described as a feedback process. Edmondson (1999) proposes that it can be observed as a feedback seeking behaviour on an individual level, but on a group or collective level it is very difficult to identify. The collective learning can be present without the measurable results and the results cannot always be attributed to the collective problem solving.

In Case 2 we were predominantly interested how trust and motivation affect the collaborative problem solving. Although sets of hypotheses that were answered in Case 1 and Case 2 provide answers in different contexts, the union of them gives an important view on organisation of collaborative problem solving process and therefore learning.

Case 1 (paragraph 2.1.1) in its nature represent learning supported by a simulation model with precisely defined and measurable decision task. Such an experiment has a

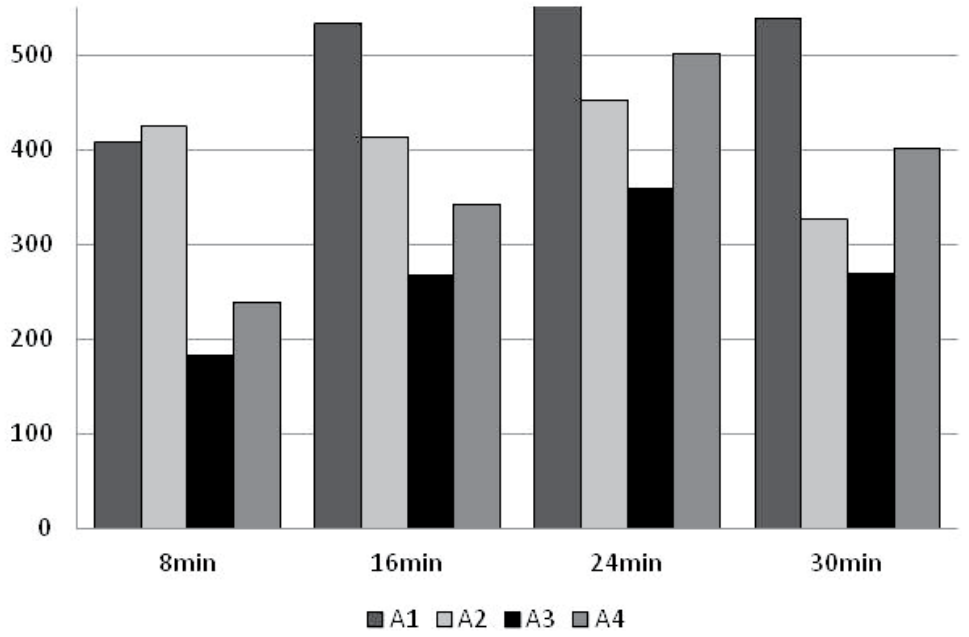

Figure 1: Individual feedback seeking behaviour – the use of simulation model

fixed decision-making structure. During the experiment we observed different types of feedback structure (interrupted goal oriented and continuous feedback information) and roles of the facilitator. Illustration of the impact of structure of group feedback information (goal oriented vs continuous) and the role of facilitator on the individual seeking behaviour is shown in Figure 1. We can observe from Figure 1 that the feedback seeking behaviour varies with time and with experimental condition. Two facilitated groups (a_1 and a_2) showed higher interest in exploring the simulator compared to non-facilitated groups (a_3 and a_4). Nevertheless, the trend in feedback seeking behaviour in time is consistant in groups receiving group information feedback (a_2 and a_4) and in groups receiving individual information feedback only (a_1 and a_3).

In Figure 2 the group feedback seeking behaviour for the two groups, where group information was introduced (a_2 and a_4) is presented. From Figure 2 it is evident that the facilitated group, a_2 (M = 5) was significantly more active in seeking group information feedback compared to the non-facilitated group, a_4 (M = 2). From Figure 2 we can observe that the facilitated group (a_2) showed much more feedback seeking behaviour compared to group a_4 where facilitation was omitted and the group information feedback was accessible at all time whereas in group a_2 it was accessible only after 8^{th}, 16^{th}, and 24^{th} minute. Furthermore, from both figures (1 and 2) it can be observed that the presence of facilitator motivated the feedback seeking behaviour in both individual and group feedback condition. Also, it can be observed from both figures that participants sought the individual feedback more often than group feedback.

Besides the feedback seeking behaviour, we have tested the level of knowledge gained at the course "Modelling and simulation" of the participants, who participated in the simulation experiments and students, who didn't participate in the experiments by comparing grades received at the final examination (Kljajić Borštnar, 2010). Final exam grades (grades ranging from 1 to 5 – fail, 6 - 10 - pass) at the first attempt differ significantly in two groups: students who took part in the experiment (M = 7.08, SD = 1.78, N = 118), students attending regular classes without experiment (M = 3.38, SD = 1.96, N = 91). Experiment classes showed evidence that students were highly motivated to attend classes, which are not obligatory by default as opposed to the non-experiment classes, where students' attendance was rather low. It must be emphasized that the final grade of the course is derived from the student's individual project (40%) and a written exam (60%). The written exam consists of six standard question prepared in advance and selected by chance for all students, regardless of whether they had attend lectures or not. Therefore, the analysis of the results could be considered an unbiased one.

The participant's opinions about their involvement in the experiment were solicited with questionnaires. Participants filled in the questionnaires via a web application. Questions were posed in a form of a statement, and agreement to the statement was measured on a 7- point Likert type scale, where 1 represents very weak agreement, 4 a neutral opinion, and 7 perfect agreement with the statement.

Majority of the participants agreed on the general quality of the experiment (99%). Of all the participants, 84% agreed that the use of simulator contributed to understanding of the problem. Agreement to the statement that they were motivated for problem solving among all the participants was 63%. Further, students agreed that participating in the experiment had significant benefit to understanding the subject matter

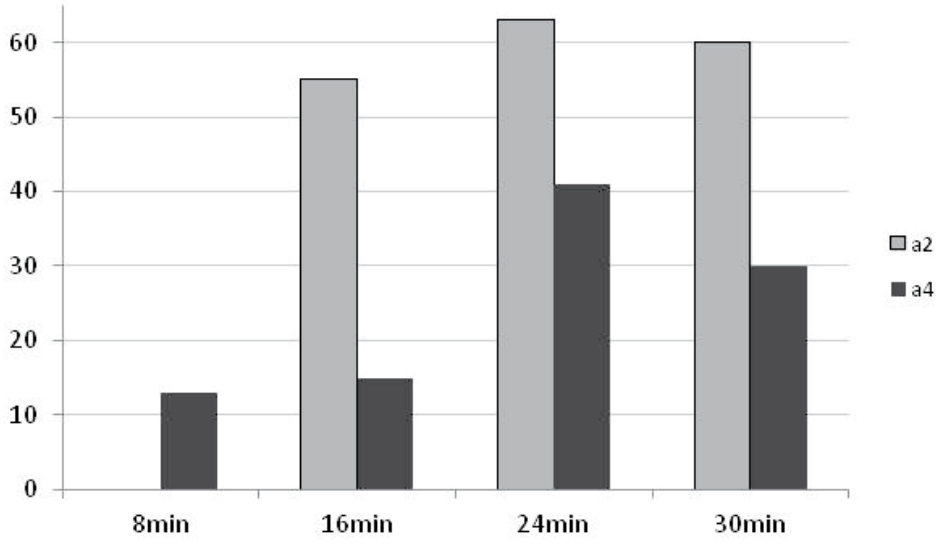

Figure 2: Group feedback-seeking behavior (insight into GIF per minute per subject) of groups a_2 and a_4 adapted from (Kljajić Borštnar et al., 2011)

(88% agreed), and they identified simulator as an important aid to decision-making (92% agreed). These are cross-group averages and represent the overall agreement to the statements.

We performed an ANOVA test to explore the differences in opinions among the four groups (a_1, a_2, a_3, and a_4). The ANOVA test showed high agreement in opinion between groups as well. The groups' opinions differ significantly only in two questions: 4) simplicity of use of the simulator ($F = 3.067$, $p = .031$), and 5) contribution of simulator to understanding of the problem ($F = 3.274$, $p = .024$), which can both be explained by different experimental conditions requiring slightly different user interface and thus different levels of man-computer communication.

In Case 2 (described in paragraph 2.1.2) students reported results on research topics freely, without facilitation, using social collaboration system Flowr. Common in both cases is the use of group collaboration technology and group problem solving with one difference: in the first case the task and technology were structured and controlled by an facilitator (part of research team) and in second case the task and technology were not structured nor controlled. The participants' opinion regarding the collaborative problem solving in the social media environment was solicited by the questionnaire (Kljajić Borštnar, 2012).

The majority of respondents agreed that the general quality of the experiment was good. They agreed (reported four or more points on the 5-point scale) that they were motivated for the work (60.87%). More than 80% agreed that group had sufficiently self organized, i.e. members assigned roles, leadership and workload easily. Agreement on trust among members was assessed as good by more than 80% of respondents, while 66.67% of the respondents stated there were no conflicts in the group. Only 4.17% reported strong agreement and 16.67% reported agreement to the statement that there were conflicts within the group. This corresponds to the reports of conflicts within one group during the experiment, which led to the one group member transition to another group. A mere 8.33% strongly agreed and 37.5% agreed that facilitation and structure would contribute to better group work; 45.83% were neutral on this and only 8.34% disagreed on this. The vast majority of the respondents (more than 88%) reported that they were satisfied with the work of the group. Further 45.83% of respondents reported neutral opinions about the user experience, half of them agreed to having had good user experience, while none reported negative user experiences.

Since the two cases questionaires consist of the same questions and the population is of the same background (senior students at the Faculty of Organizational Sciences, University of Maribor), we can perform a meta-analysis on this data. In Table 1 we present the corresponding questions along with the average value of agreement and standard deviation.

From Table 1 we can read the average and standard deviation values of responses on seven common questions from Cases 1 and 2. The responses from Case 1 were recoded from 7 to 5-point Likert type scale.

An independent-samples t-test was conducted to compare the effect of simulation experiment and social media experiment conditions. There was a significant difference in the scores for simulation experiment ($M = 4.5$, $SD = 0.701$) and social media experiment ($M = 4.0$, $SD = 0.834$) conditions regarding the perceived general experiment quality; $t(140) = 3.082$, $p = .002$.

On the question of problem presentation, the participants of the simulation experiment reported significantly higher scores compared to the participants of the social media experiment. T-test indicated that the mean score for the social media condition ($M = 3.29$, $SD = 1.042$) was significantly different than the simulation experiment condition ($M = 4.43$, $SD = 0.852$); $t(139) = 4.495$, $p = .000$.

Table 1: t-test for questionaire of the Case 1 and Case 2 participants opinion

Statement	Case 1	Case 2	t	df	p
General experiment quality	4.50	4.00	3.082	140	.002
	(0.701)	*(0.834)*			
Problem presentation	4.43	3.29	5.748	140	.000
	(.852)	*(1.042)*			
Problem understanding	4.38	3.92	2.063	140	.041
	(.986)	*(1.100)*			
Ease of use of the IT tool	4.76	2.71	13.536	140	.000
	(0.595)	*(0.999)*			
Time for problem solving	4.06	4.42	- 1.228	140	.221
	(1.373)	*(0.830)*			
Motivation for problem solving	3.72	3.54	0.634	140	.527
	(1.280)	*(1.141)*			
Contribution of experiment	4.53	3.74	4.495	139	.000
	(0.725)	*(0.964)*			

Note: Average
(Standard deviation)
Opinion was measured on 5 point Likert type scale
N = 118

Further, based on the t-test we have found significant differences between the two conditions on the question of ease of use of the ICT tool in question (simulator in Case 1 and social media tool Flowr in Case 2); t (140) = 13.536, p = .002. As we can observe from Table 1, the Case 1 participants reported high agreement to the statement that the simulator was easy to use, where Case 2 participants disagreed to this statement. Similar, opinion on the overall contribution of the experiment to the class conduction, differ between the Case 1 and Case 2 participants. An independent-samples t-test was conducted to compare the effect of simulation experiment and social media experiment conditions. There was a significant difference in the scores for simulation experiment (M = 4.53, SD = 0.725) and social media experiment (M = 3.74, SD = 0.964) conditions regarding the perceived general experiment quality; t (140) = 3.082, p = .002.

The findings that simulation experiment participants perceived grater general experiment quality, better problem presentation and understanding than the participants of the social media experiment, can be explained by the facts that the first had an uniform video presentation of the problem, task and the tool and their role was highly determined, whereas the roles and organization of work of the Case 2 participants was left to their own freedom and creativity. Feedback seeking behaviour, as one of the measurable criteria of learning behaviour, was shown to have been impacted by the level of freedom. In Figure 1 we have observed the feedback seeking behaviour of the simulation experiment participants. Particularly at condition a_4 they showed less involvement in the problem solving when left to their own freedom to seek (or not) feedback information (individual and group). The participants at the social media experiment (Case 2) also showed some evidence of discomfort with the experiment. They perceived general experiment quality, problem presentation and understanding, the ease of use of the tool and assessment of overall contribution of the experiment to the class conduction is significantly lower than their colleagues in the highly regulated experiment. However, participants' opinions about the time for problem solving and motivation did not differ. This may suggest that given enough time to solve the problem and a common interest (task) in the social media environment, the groups were able to self-organize and understand the stated problem regardless the fact that they perceived problem presentation and understanding insufficient. However, it is interesting that the opinion about perceived motivation to solve the problem of participants at both experiments was regarded as neutral and it did not differ between the groups.

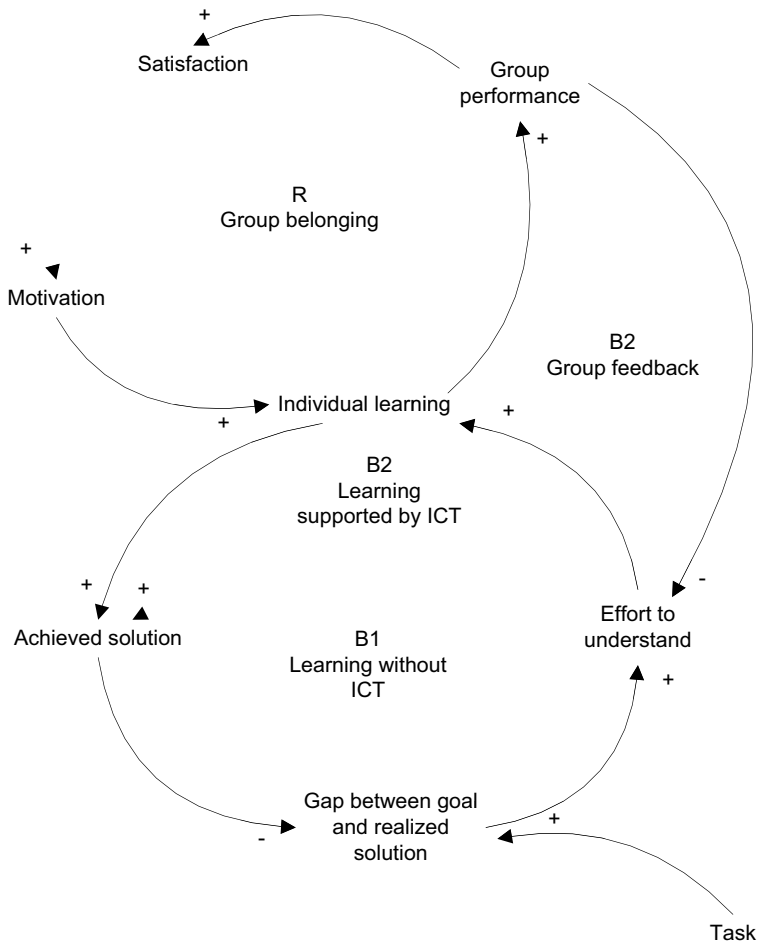

Figure 3: Causal loop diagram of group problem solving and learning adapted from (Kljajić Borštnar et al., 2011)

Common background of both experiments with regard to group problem solving and learning is presented in Figure 3 which represents generalisation of the model described in (Kljajić Borštnar et al., 2011).

On Figure 3 loop B1 represents heuristic problem solving without the aid of any tools except paper and pen. Loop B2 represents additional information in the problem solving provided by using ICT (simulation model/social media environment). The sum of both loops, B1 and B2, provides feedback information to participants in the process of problem solving and learning. B3 represents additional information provided by the group and its performance, and facilitates individual to understand the problem better. This we call the collaborative learning and group information feedback. In this loop different structure of information feedback is possible in Case 1 as well as in Case 2. Finally, loop R represents reinforcing loop which positively impacts motivation and satisfaction of an individual. However, gain of this reinforcing loop is proved to be strongly dependent on the structure of group information feedback (), quality of user interface. Furthermore, we showed that the time for problem solving is affected by the structure of information feedback (group a4 from Case 1 and Case 2) and level of freedom in the process of problem solving. Given enough time, the group would self-organize and creatively participate in problem solving (Case 2). On the contrary, when time is restricted, the group would show less feedback seeking behaviour, be less satisfied with the group performance and consequently be less motivated to participate in problem solving.

4 Conclusions

This paper analyzes experience in teaching of "Modeling and simulation" course using business simulation model as an experimental tool (Case 1), and collaborative problem solving phenomenon in a social media environment (Case 2) for senior students of the Faculty of Organizational Sciences, University of Maribor.

Case 1 in its nature represent learning based by means of simulation model with precisely defined (measurable) decision task. However, we observed different type of feedback structure to the participants and rolls of the facilitator. Such experiment has fixed structure in decision making. It was found that model application and group feedback information positively influence the convergence of the decision process

and contribute to higher criteria function. More precisely, the results of the decision process gathered when group feedback information was introduced were better than in cases where the decision was based only on individual experience with a simulation model and the worst results were achieved on the basis of subjective judgment. However, group feedback and the facilitator are extremely important during complex problem solving. The results show that management students taking the course of Modeling and Simulation thought that application of the simulation model do contribute to a greater understanding of the problem, faster solution finding and greater confidence in participants.

In case 2 we analysed on trust and motivation in course of self managed of the group during problem solving. It was assumed that collaborative learning can be efficiently supported in a rule-free and social media unstructured environment, and that it has a positive impact on the self-organizing of the group and thus contributes to problem solving and learning. With observation methods and questionnaires, we aim to answer the following research question: Does collaborative problem solving without formal structure and facilitation in the social media environment stimulate the self-management of the group?

We developed generalised CLD model on Figure 1 that cover common background of both experiments with regard to group problem solving and learning. All participants in both cases agree that clear presentation of the problem motivates participants to find the solution. So, in the future, the use of realistic yet sufficiently simple business models is essential, if one wishes to close the gap between business processes understanding and the role of modeling and simulation in problem solving.

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Primerjalna analiza sodelovalnega učenja in učenja, podprtega s simulacijskimi modeli v sistemih upravljanja

Namen raziskave je primerjati različna pristopa k skupinskemu reševanju problemov, enega v strogo nadzorovanem laboratorijskem posksu (optimizacija poslovne strategije z uporabo poslovnega simulatorja pri različnih poskusnih pogojih) ter durgega v sodelovalnem okolju družabnih omrežij, za katerega sta značilna odsotnost pravil ter nestrukturirana povratna informacija. Primerjalna analiza mnenj udeležencev, ki so sodelovali v obeh poskusih, je bila opravljena z namenom identifikacije splošnih značilnosti, ki vplivajo na sodelovalno reševanje problemov. Na podlagi izsledkov primerjalne analize smo razvili splošen vzročno posledični model, ki pojasnjuje sodelovalno učenje v procesu reševanja problema.

Ključne besede: podpora skupinskega odločanja, struktura informacije, sodelovalno učenje, simulacijski model, družabna omrežja

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Application of Fuzzy AHP Approach to Selection of Organizational Structure with Consideration to Contextual Dimensions

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The literature of organizational structure design is relatively rich along with conceptual and complex patterns. This complexity arising from the number of elements and numerous relations in addition to the nature of variables. Thereby, the lack of operational decision-making models is felt to propose adequate structural designs in practice. In this article, the researchers employ a fuzzy multi attribute decision making model (FMADM) to select the most suitable organizational structure based on expert's judgments and by deploying contextual dimensions of the organization. Since the organizational changes especially in the structural levels are along with resistances among involved staffs, the implementation of this model is a supportive tool in addition to help the managers to make a qualified decision and change.

Keywords: Organizational Structure Designing, Business Process Reengineering, Development Management, Integration, Fuzzy AHP

1 Introduction

Change occurrence in a phenomenon is an admitted principle, in particular, a planned and opportune change is essential for an organization. Change and development with utilization of recognized approaches such as business process re-engineering, total quality management, and organizational downsizing are based on a primary assumption; organizations should observe their business with a process-oriented perception to concentrate again on their main responsibility and fulfillment of costumers' needs (Grover et al., 1995). Business process is composed those basic activities that are not restricted to duty boundaries in an organization. Meanwhile, one of the managerial significant decisions in organizations occurs in a frame of new organizational structure in order to integrate process of organizational departments and units. To make a right decision, managers and decision makers need to be informed about the process aspects of the contextual and structural dimensions of the organization (Sethi and Nicholson , 2001).

Although the literature of organizational structure design is relatively rich, it lacks operational and decision making models to propose adequate structural designs (Bafandeh, 2009; Chou and Cheng, 2006; Adler, 2011). Since organizational design theories are mainly conceptual patterns, the complexity of subjects provide problems in order to actual implementation in the organizations. This complexity is because of the number of elements and subsequently their relations in addition to the nature of used variables. For instance, most of the variables used for definition and explanation of the organizational subjects are linguistic variables. The linguistic variables are not precise and explicit in contrast to quantitative ones (Cernancky et al., 2007).

This research in the frame of a fuzzy multi-attribute decision-making model (FMADM), and by deploying contextual dimensions of the organizations discusses about the selection of the suitable organizational structure in the commercial departments of a sample organization. The fuzzy approach is employed in this research in light of the complicated, vague, and uncertain nature of the organizational structure, and contextual dimensions. To make a final decision, the judgments of the staffs and professionals in the different levels of the organization are used. Since the organizational changes especially in the structural levels are along with some resistances among involved different staffs, the implementation of group

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decision-making models and participating beneficiary staffs would be a supportive tool in this kind of strategic decision-making.

2 Literature Review

Today organizations change with the development of internal and external environments. Even efficient organizations need to improve and develop their structures. The structure design is the process of selecting an organizational structure that can be applicable for a certain strategy and environment (Daft, 2009).

Structural development in organizations has been under effect of duty-oriented vision for a long time. According to this vision, organizations are considered as a hierarchy of authority and control in which activities are aggregated and sorted in duty-organizational sections (Robbins, 2006). Therefore, groups of experts are established in the organization that emphasize on their limited functional tasks.

In recent years, various concepts and tools have been introduced for organizational developments that are mostly focus on business processes as a concept to design an organization. Re-engineering of business processes is a frequent example in which the organizational losses are recognized and resolved by emphasizing on the main organizational processes, i.e. those create added value for internal and external costumers (Damjanovic, 2010).

There is an incompatibility between expectations and goals of re-engineering, and what is happening in reality (Al-Mashari and Zairi, 1999). Studies indicate that the outputs of re-engineering programs still consider to the organizations as a structure instead of a set of processes affected by the organizational variables. Thereby, in most cases, re-engineering is considered wrongly as a tool for minimizing the organization size. Therefore, it seems before any development in the organizational structure, the important and effective variables on organizational structure design must be recognized. These variables named contextual dimensions of the organization: Strategy, Environmental uncertainty, Technology, Size of the organization, and Culture (Daft, 2009). They are dynamic and complex in order to application in organizational structure design.

2.1 Contextual Dimensions of the Organization

Contextual dimensions address the entire of organization and its conditions, as well as determination of structural dimensions of the organization. They are composed of strategy, environmental uncertainty, technology, size of organization and organizational culture (Daft, 2009). The elements of structure should be selected regarding to their internal compatibility and the situation of the organization, i.e. size and background, environment of activity and etc. (Mintzberg, 2007). In this article, these dimensions are employed as principal criteria required for designing and selection of organizational structure. The structure that has the most conformity with the contextual dimensions of the organization is in priority for selection and implementation. Table 1 marks some point of each dimensions briefly.

2.2 Incorporation and Integration of Organizational Processes

Studies show that incorporation and integration of work processes are two of the keys success factors to achieve synergy in organization (Ketchen and Hult, 2007). Meanwhile, incorporation and integration are two of the manager's interests as they believe that incorporation and integration can speed growth, efficiency and performance improvement, and cost reduction. Re-engineering of processes is one of the most common process approaches that ascertain the integration idea and unification of managers. According to the assumptions of re-engineering, the internal operations are designed and structured in the format of processes. The processes are a set of internal operations that totally fulfill a unique goal and create a unique added value for the organization (Hall and Johnson, 2009).

One of the most crucial processes in manufacturing and service organizations is commercial sector. This area in a manufacturing organization consists of the processes such as purchasing, sale, marketing, ordering, warehousing, financial affairs and etc. In most of the organizations considering to their size, these processes are recognized in the form of independent offices or related departments. Due to mutual dependence and dynamic nature of the commercial departments, exposure of interactions and conflicts are permanently expected. For instance, conflicts exist between sales and marketing units about pricing and advertising, sales and finance units about the commitments of buyers, purchasing and programming of orders and etc. (Bennett and Savani, 2004). In this article, the authors have focused on the selection of the suitable organizational structure.

3 Case Study Overview

The commercial departments of an after sale services organization in automobile industry in Iran was selected as a case study of the research (CS). In after sales services organizations, commercial sectors are like units engaging in the line of fire. Since the main factor for costumer's satisfaction in an automobile manufacturer is the quality of after sale services (i.e., supplying spare parts), the strategic role of the commercial departments insight of some costumer's satisfaction indicators such as service level and etc. are important. Second, these organizations have service natures that are generally costly for manufacturers. Therefore, commercial activities of the after sales services organizations are very important for shareholders and automobile manufacturer from profitability aspect. Commercial activities in these organizations consist of supplying and distribution of spare parts to their dealers and customers.

CS is the biggest private organization in the field of after sale services in Iran and owns 180 authorized dealers in automobile sale and after sale services network operating with more than 300 direct employed staff and 1500 employees working in distribution sectors. The organization covers required services and spare parts for more than 10 different automobiles in cooperation with domestic and international

Table 1. Description of contextual dimensions

No.	Dimensions	Brief Description
1	**Strategy**	* Since managers design organizational structure to achieve the goals, the structure should principally follow the strategy, and change when it varies (Daft, 2009). * The relation between strategy and structure were first studied by Alfred Chandler (Hatch and Cunliffe, 2006).
2	**Environmental Uncertainty**	* Since organizations encounter environments with different levels of uncertainty, the management in an organization endeavors to reduce the environmental uncertainty by changing the structure. * The environmental uncertainty is particularly caused by unpredictability of different groups such as suppliers, competitors and costumers. Those organizations that are running in unconfident environments must have a flexible structure to respond the uncertainty, compare to those work in confident environments (Hatch and Cunliffe, 2006). * The organizational structure of the companies with highly confident environments is focused with formal rules and regulations. In contrast, an uncertain environment demands further organizational flexibility and internal independence.
3	**Technology**	* The first study about technology and its relation with the structure, which is still reliable, is attributed to Ms. Woodward. She classified companies in regard with one of the three types of technology, unit production, mass production and process production (Robbins, 2006). * Perrow focused on knowledge-based technology instead of concentration on production technology (Robbins, 2006). In his model, Perrow offers four service technology types based on two respective dimensions of task variability and problem decomposability. These technologies consist of repetitive (invariable), engineering, artistic and industrial, and non-repetitive ones.
4	**Size**	* The number of employees is an adequate index to realize the size of organization (Robbins, 2006). * Size of organization effects on the structural dimensions of that organization by an inclining rate. On the other words, the structural dimensions of small organizations are highly sensitive, compare to the larger ones, to the growth in staff members (Daft, 2009).
5	**Culture**	* Organizational culture is one of the key factors to achieve organizational strategies and goals, and change management in addition to improving the organizational efficiency. * Organizational culture and organizational structure are in mutual association so that the organizational structure is affected by organizational culture, but is effective in strength and consolidation of its respective organizational culture (Daft, 2009). * Those structures that benefit from higher flexibility and power of compatibility are powerfully able to consolidate and stabilize their organizational culture. In an organization with a characteristics of high level culture such as; authority bestowing, the spirit of innovation and creativity, risk-taking, harmony and tolerance of ambiguity, it is not possible to design a structure that merely insists on running the organizational relations through the limited channel of hierarchy, or power accumulation instead of distribution, and restrictive bureaucratic regulations (Hatch and Cunliffe, 2006).

spare parts supply companies from various countries including Japan, China, India, Germany and etc. The company could reach the net sale of 27.60 million $ with 45% of the market share in 2010.

With respect to development of the market which is resulted by automobiles manufacturing and automobiles import done by the mother company, the financial indicators in commercial sector depicts a decrease in the market share of spare parts in CS. Therefore, while the average ratio of market volume growth to the sale growth has been 1.53 in three recent years, the average percentages of budget and profit attainment were 85% and 73% in 2010. In light of this strategic gap, the CS commenced the re-engineering project of their processes with especial focus on the commercial departments. The result of re-engineering realized a gap in the commercial structure of the organization that was a subset of task structure. Figure 1 shows the organizational chart of the CS(commercial sections) at the beginning of re-engineering project.

After comparing the common and prevalent organizational structures in similar companies such as TOYOTA, FORD, VOLVO, MAZDA, and the gap analysis, four new organizational structures (scenarios) were introduced in the re-engineering project in order to implement in CS.

3.1 Task type: Reform Current Structure and Tasks Integration (S1)

In the structure based on task, the activities are sorted in light of the nature of job functions. For example, sale staffs are

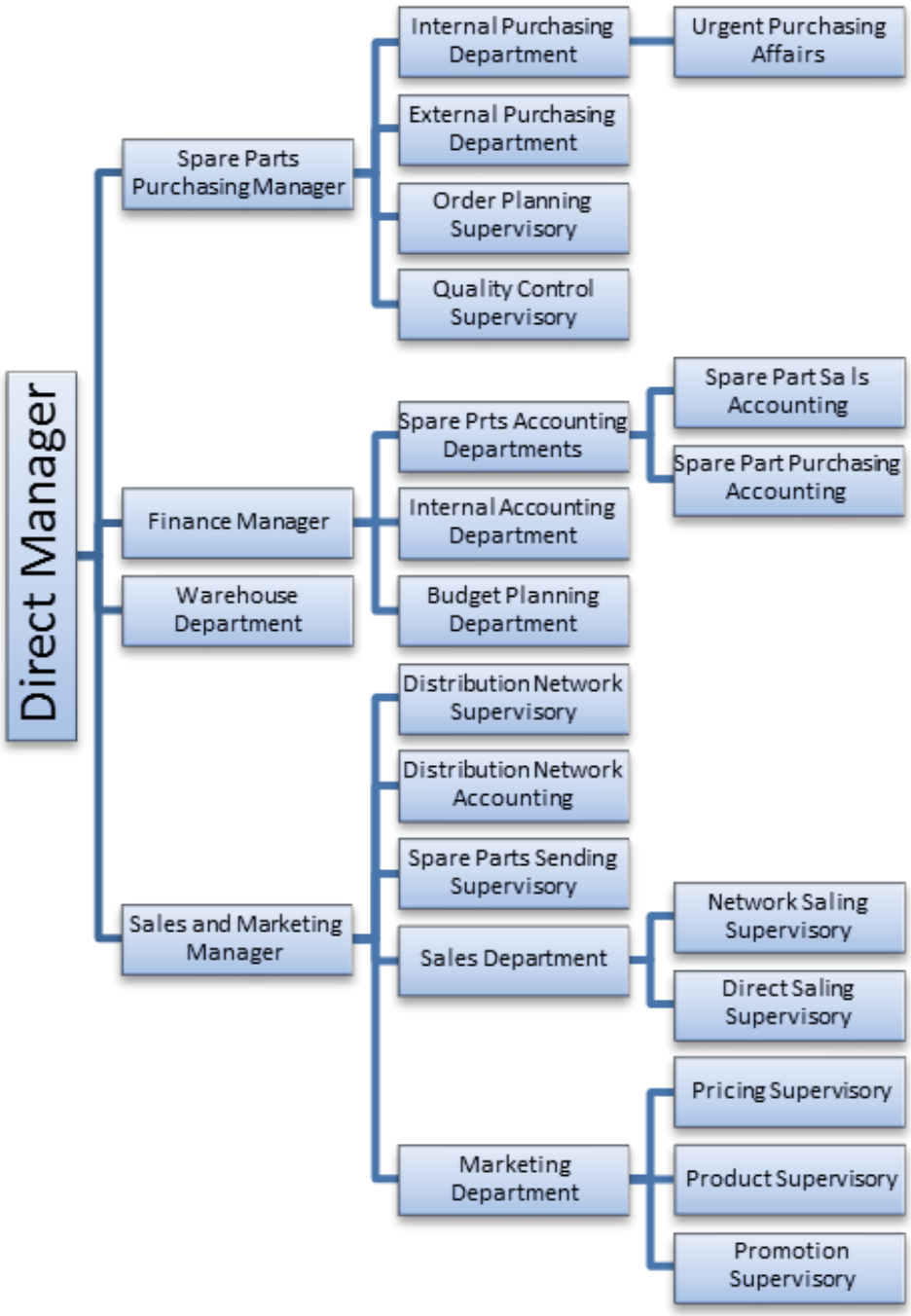

Figure 1: CS's organizational chart- commercial section-(Source; Human Resource Department)

settled in the sale unit and head of the unit is responsible for all the activities (Dessler, 2007). The previous structure of CS was designed based on this frame. After re-engineering of commercial processes, changes are suggested as following:

1. Integration of "spare part purchasing management" with "sales and marketing management" in a new frame named "spare parts supply chain deputy" and eliminating former managements,
2. Integration of "spare parts sending supervisory" at "sales and marketing management" with "spare parts quality control supervisory" at "purchasing department",
3. Integration of "orders planning supervisory" with "product supervisory" of the "marketing department",
4. Submission and integration of "distribution network supervisory" at "sale and marketing management" with "after sale services management", beyond the commercial departments,

5. Establishment of "finance affairs supervisory" under direct supervision of "supply chain deputy" and "integration of "dealers accounting supervisory" in it,

A new structure decreases about 14% of the staffs. In addition, one manager and three supervisor positions will be removed.

3.2 Product Type: Reform Organizational Structure Regarding Product Diversity (S2)

In the structures based on the product, different parts of commercial sector in the organization are organized in respect of the product type, service type, and a set of products, work type, basic plans or programs or benefit points (DuBrin, 2006).

In this scenario, two substantial changes are offered for CS. First, the entire tasks affairs of each automobile (i.e., automobile A) including marketing, sale, and ordering integrate in new units with supervisors under direct supervision of marketing manager. For instance, a new department related to automobile A is introduced, and the whole tasks of spare parts ordering, marketing, and sale to distribution network is transferred to the new department (three new departments for CS). The second change is to integrate the "distribution network supervisory" and "promotion supervisory" in a unit under title of "distribution network development supervisory."

The number of staff in new structure decreases about 9%.

3.3 Based on Region: Reform Organizational Structure Based on Geographical Distribution (S3)

One of the categories of organizational structure is based on the customer dissipation. The most prevalent structure of this classification is based on geographical region (DuBrin, 2006). In this structure, the organizations can be compatible with the requirements of each region. However, the salient point that may be challenging is coordination between the regional units.

Based on this frame, the entire affairs associated with marketing, sale, ordering, and finance of 180 distribution networks are integrated in the form of three regional departments: "north and west", "central", and "east and south" for CS.

In this scenario, the number of staff in commercial departments will increase about 2%.

3.4 Matrix Structure (S4)

Having two structures of task and product oriented simultaneously is one of the exclusive characteristics of Matrix structure (Dessler, 2007). This structure is suitable for the environments with uncertainty and complicated technology (Daft, 2009).

Three significant changes should be happened for CS to frame this structure:

1. Integration of "sales and marketing" and "purchasing managements" in the form of a new department named "commercial management,"
2. The units of marketing, ordering, and spare parts purchasing (internal and external) are integrated in the form of four supervisors,
3. Sale department operates independently,

This scenario increases the number of staff about 9%.

4 Research Methodology

The research method of this work is an applied research insight of purpose, and a descriptive-analytical and mathematical research from data gathering viewpoint (Sarmad, 2009). The innovation aspects of this research are as following:

- Comprehensive Assessment: The utilized approach suggests the evaluation and selection of the best suitable organizational structure with respect to judgment of engaged staffs of the organization, and contextual dimensions.
- Fuzziness: The world is changing constantly and this trend may not provide the certainty of past events. In this regard, the inclination for implementation of fuzzy logic in the literature of management and operations research has been increased. The fuzzy logic is used in this article due to the high-efficiency of it.
- Flexibility: The used analytical approach has a high flexibility for evaluation of organizational structures. For instance, the managers as main decision makers can change the weights of criteria without any injury to the logic of approach.

4.1 The implementation of Fuzzy AHP for Selection of Suitable Organizational Structure

Since the decision criteria in this research are qualitative, prioritization of suitable organizational structure is considered as a complex model of multi-criteria decision-making (MCDM) (Patton, 2002). This means ordinary MCDM models are inefficient to adjust with the real conditions caused by conversion of qualitative variables into quantitative ones. Therefore, a suitable multi-attribute fuzzy model of decision-making was employed for data analysis. In this approach, to reduce the undesirable impacts in conversion of qualitative variables, linguistic variables and triangular fuzzy numbers were utilized (Momeni, 2007). To formulate the model and due to the complexity of criteria, the Fuzzy AHP and Extent Analysis Method were used. The Analytic Hierarchy Process (AHP) is one of the best and valid methods in multi-criteria decision-making (MCDM) (Ishizaka and Labib, 2011). The group pairwise comparisons also were implemented to weight the criteria that have advantages like more consistent ability for respondents and both qualitative and quantitative information can be compared by using informed judgments to derive weights and priorities (Hwang and Yoon, 1981; Aslani et al., 2012a; Aslani et al., 2012 b).

4.1.1 Fuzzy AHP and Extent Analysis Method (EA)

The extend analysis method (EA) was presented in 1996 by Chang(Chang, 1996). Triangular Fuzzy Numbers (TFN) is used in this model. A TFN is characterized by the three folds (l, m, u) (Figure 2). Fuzzy algebraic operations can be calculated for triangular fuzzy numbers by using extension principle as following (Azar, 2008):

(L1, M1, U1)+ (L2, M2, U2) = (L1+L2, M1+M2, U1+U2)
(L1, M1, U1)- (L2, M2, U2) = (L1-L2, M1-M2, U1- U2)
(L1, M1, U1)* (L2, M2, U2) = (L1L2, M1M2, U1U2)

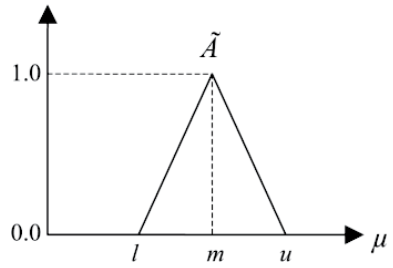

Figure 2: Triangular Fuzzy Number

For each row of pairwise comparisons matrix, the value that is a TFN is defined as follow (Chang, 1996);

$$Sk = \sum_{j=1}^{n} Mkj \times [\sum_{i=1}^{m}\sum_{j=1}^{n} Mij]^{-1}$$

K is line number, and i and j show alternatives (suggested organization structures) and criteria (contextual dimensions).

The degree of possibility of M1 > = M 2 is defined as (Chang, 1996):

V (M1>=M2) =1 m1>=m2
V (M>=M2) = hgt (M1 ∩ M2) Other

Based on a mathematic principle:

$$hgt(M1 \cap M2) = \frac{u1 - L2}{(u1 - L2) + (m2 - m1)}$$

The degree possibility of a TFN to be greater than other can be defined by;

V (M1>=M2 … Mk) =V (M1>=M2) and … and V (M1>=Mk)

The weights of criteria in pairwise comparisons are calculated according to follow;

W' (xi) = min $\{V(si \geq sj)\}$ k= 1, 2, n

Then the weight vector of criteria is given by;

W'= [W'(x1), W'(x2), …, W'(xn)] ^{t}

Where W' is a nonfuzzy number.

4.2 Data collection and analysis

Figure 3 shows the hierarchy decision-making model of the research. In the next step, a questionnaire consists of pairwise comparisons of five criteria and four alternatives with respect to the criteria were designed. In order to correct the transfer of contextual dimensions concepts to responders, three

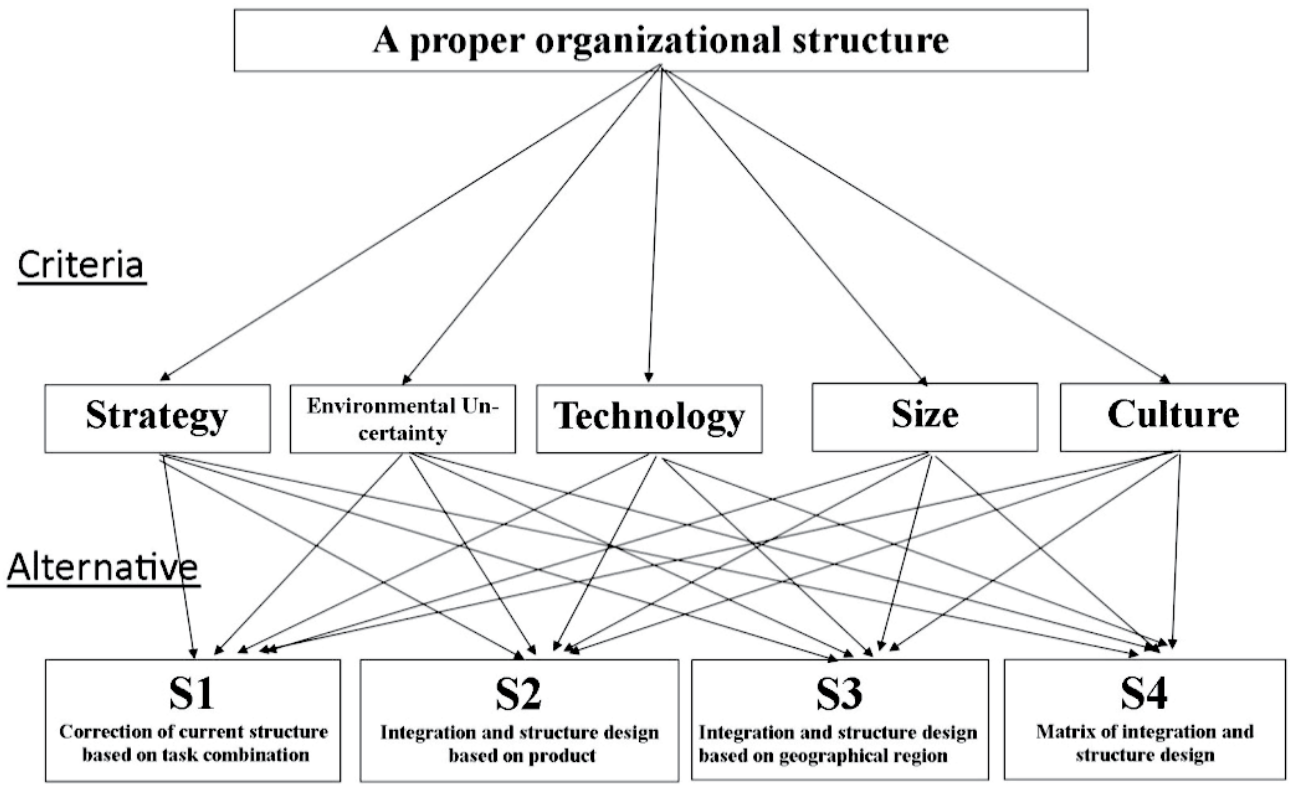

Figure 3: Decision making model

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgement slightly favour one over another
5	Strong importance	Experience and judgement strongly favour one over another
7	Very strong importance	An activity is strongly favoured and its dominance is demonstrated in practice
9	Absolute importance	The importance of one over another affirmed on the highest possible order
2, 4, 6,8	Intermediate values	Used to represent compromise between the priorities listed above

Figure 4: Pairwise comparison scales (Saaty and Peniwati, 2007)

lines interpretations related to criteria and organization were expressed in pairwise comparison of each criteria. Also the phrasing of the questions was formulated carefully in order to reflect the scales intensity of relative importance (Figure 4) (9 to 1/9 Saaty Scales) (Saaty and Peniwati, 2007). The equal numbers in which used in the questionnaire were based on TFN.

The validity of the questionnaire was confirmed by using the standard table of AHP method (Saaty and Peniwati, 2007; Aslani et al., 2012a). The questionnaires were distributed among 43 staffs in all levels of relevant units of CS. Because this research had been supported by high level managers, the return rate of responses was 100%. 33% of respondents were postgraduate, 52% graduate and 15% undergraduate or high school leaving degree with more than 10 years' work experience in the organization. The total experience average of respondents is 6 years. For assessing the reliability of the questionnaire, the consistency rate of each table was calculated (Saaty and Peniwati, 2007). For example, the consistency rate for pairwise comparison of criteria was 0.034. Since this number is less than 0.1, the consistency rate is acceptable (Saaty and Peniwati, 2007). So, the entries of pairwise comparison matrix were calculated. In this regard, the completed tables of questionnaires were analyzed. The results of these analyzes are the weights of criteria (Wi) and alternatives (Xij) (figure 5 and table 2).

The weights of contextual dimensions, illustrated in figure 5, can be interpreted in two levels: service organizations level; and the case study level. It shows that the size of organization is the most important criteria for structure designing in the service organizations. As we discussed before, the size reflects the number of people in the organization and consider to the

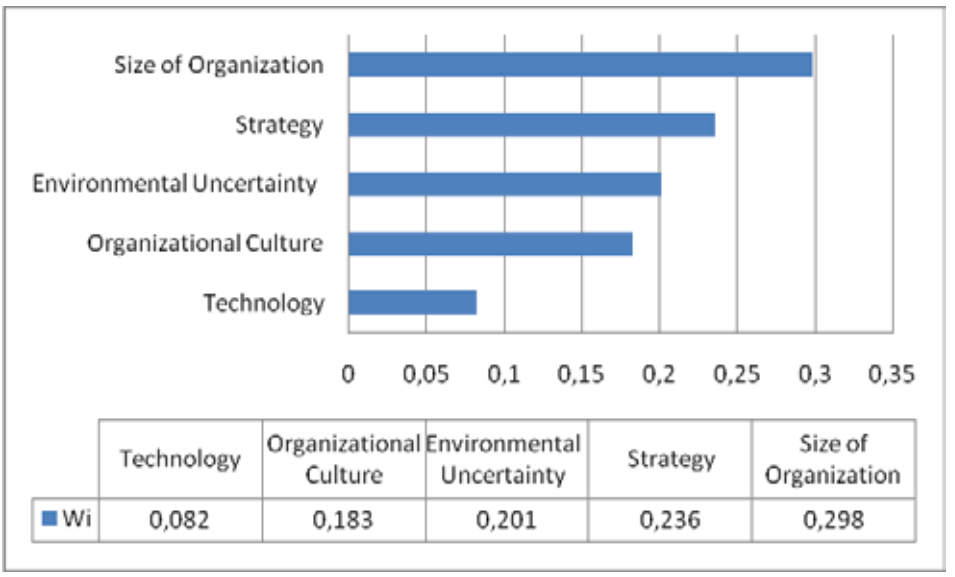

Figure 5: The weights of Criteria

Table 2: The weight of each alternative related with each criteria

	Strategy	Environmental Uncertainty	Technology	Size of Organization	Organizational Culture
S1	0.312	0.281	0.279	0.236	0.271
S2	0.348	0.311	0.332	0.402	0.261
S3	0.228	0.193	0.118	0.091	0.237
S4	0.112	0.215	0.271	0.271	0.231

Table 3: Final ranking

Rank	Recommended Alternative
1	S2; Integration and structure design based on product
2	S1; Correction of current structure based on task combination
3	S4; Matrix of integration and structure design
4	S3; Integration and structure design based on geographical region

organization as a social system. The next priority is strategy which indicates the purpose and competitive techniques of the organization. The low weight of technology in compare with other dimensions also means that this indicator has the least priority in this kind of organizations.

Discussion and results

Table 3 shows the final results of the organizational structures ranking. Therefore, from the expert's viewpoint, the product type of organizational structure is the most proposed structure for CS.

Therefore, the product organizational structure is a good selection for commercial parts of the companies with retail dealers in various cities. This selection also declines 9% of the commercial staff in the CS company.

5 Conclusion

Change in proper time is an axiomatic principle in all phenomena especially for organizations. Changing in organizational structure and determining an appropriate structure are the salient factors of successful organizations. Although the theories of structure design are rich, they have a detail-oriented thinking that make the determination of suitable structures with difficulty.

In this article, the researchers attempted to offer a model that could illustrate the effect of the contextual variables and dimensions on the selection of organizational structure in practice. A multi-attribute model of decision-making based on the fuzzy AHP was employed to prioritize and select a suitable organizational structure. The main accomplishments of the research are categorized in two groups. First, the priority of contextual dimensions in service organizations(figure 5) that shows the role of size and strategy in the structure designing of service organizations. Second, the selection of the most proper organizational structure based on a quantitative approach in which the direct effect of contextual dimensions is observable (table2). Other advantages of this approach are to participation of beneficiary staff in the process of decision-making, and to work as a supportive tool for managers to speed their changes programs.

As future studies, the application of this approach can be investigated in other kinds of organizations such as manufacturing, and other service organizations in different industries. Finally as a limitation of the mathematical approach, we should note that the EA method sometimes give the weight of zero in the process of calculations. Therefore, we also advise to prospective researchers to consider to other AHP Fuzzy methods such as Buckley's fuzzy AHP in their analysis and decion-making.

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Uporaba zabrisanega AHP pristopa za določanje organizacijske strukture z upoštevanjem kontekstualnih dimenzij

Obstaja Razmeroma veliko literature obravnava načrtovanje organizacijskih struktur, tudi konceptualnih in kompleksnih vzorcev. Razlog za kompleksnost je – poleg same narave spremenljivk – veliko število elementov in povezav med njimi. Zato najdemo malo operativnih modelov za podporo odločanju, ki bi pomagali pri praktičnem načrtovanju ustreznih struktur. V tem članku je predstavljena uporaba zabrisanega (ang. fuzzy) multi-atributnega modela za podporo pri izbiranju najustreznejše organizacijske strukture, izhajajoč iz ekspertnih ocen in upoštevajoč kontekstualne dimenzije organizacije. Ker pri organizacijskih spremembah – še posebej pri tistih na nivoju strukture – pogosto prihaja do odporov zaposlenih, ta model predstavlja orodje za podporo odločanju, ki pomaga managerjem, da sprejemajo boljše odločitve.

Ključne besede: Organizacijska struktura, načrtovanje, prenova poslovnih procesov, integracija, management, AHP metoda


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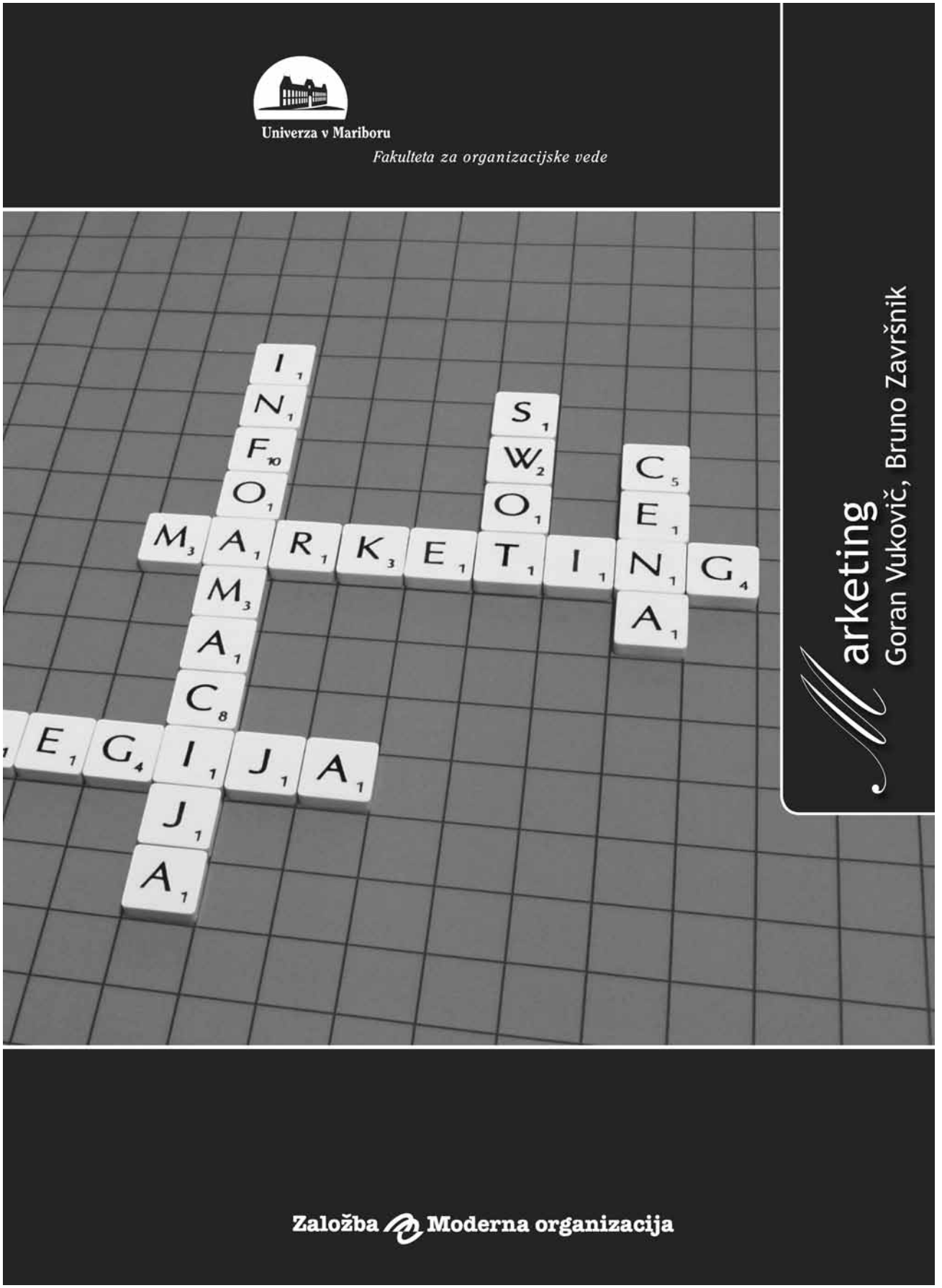
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