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

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**Simulacija s celičnimi avtomati – širjenje elektronskega poslovanja v malih organizacijah**

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

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

## 1 Introduction

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

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

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

The probability of unsuccessful introduction of information systems (IT) in a business has been reduced with many years of history of IT projects and efforts put into development of iterative and incremental methodologies

and practices. But the introduction of electronic commerce into small businesses is not the same as previous generations of IT, and it needs a new approach to systems analysis. Due to the complexity of the problem and decisions which demand groups of experts many researchers propose powerful simulation approach and tools (e.g. Kljajić, 2004; Škraba & Kljajić-Borštnar, 2004).

### Small Enterprise in Slovenia

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

### Electronic commerce maturity

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

- Level 1: Getting connected
  The company acquires Internet access and starts exploring the Web with the objective of better understanding the new media. The rising awareness of the business owners towards the potential of the Internet and electronic commerce is recognised.
- Level 2: Establishing a presence
  This involves the use of electronic mail, and using the Web for gathering information, looking at competitors' sites, and similar purposes. The company decides to develop a presence on the Internet, and develops a simple informational company homepage.
- Level 3: Primitive interaction with customers
  The organisation realizes that customers can reach the company via the Internet. They are gaining experience with purchasing, selling and banking on the Internet. The organisation prepares first business plans for electronic commerce.
- Level 4: Transforming the homepage into a service
  The homepage is developed into a full service site where customers can give structured information to the company in order to get assistance in their shopping efforts. Customers can also place orders for the company's products/services online.

- Level 5: Enabling real-time interaction with customers
  The fully electronic commerce mature business will have information and communication technology, including their Internet use and web sites, properly integrated with their business processes and information flows. The Website strives to create personalized relations to every customer, by using database technology, in conjunction with technologies for dynamic Web page generation, to create an informed and personal treatment of each individual customer.

### Electronic commerce diffusion

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

## 2　Methodology

### Research objectives

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

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

### Research phases

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

- study of relevant literature;
- survey and interviews preparation;
- data gathering (survey and interviews) and analyses (descriptive statistics, correlations, parametric and non-parametric ANOVA, factor analysis);
- analyses of data from RIS study (RIS, 2001);

- development of the simulation model that captures the features of opinion dynamic models and additionally biases in the verbalization process. We defined the maturity level of individual organization (positioned in the grid, identified by indexes i,j) in discrete time (t+1) with equation 1:

$$s_{ij}(t+1) = \hat{a}f_{ij}s_{ij}(t) + f_{i+1,j}\ s_{i+1,j}(t) + f_{i-1,j}\ s_{i-1,j}(t) + f_{i,j+1}\ s_{i,j+1}(t) + f_{i,j-1}\ s_{ij-1}(t) + f_{i+1,j+1}\ s_{i+1,j+1}(t) +$$

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

*(Equation 1)*

where:

$f_{ij}$ - strength of influence,

    - one's own strength to keep a temporary state,

$C_{ijk}$ - function of influence of N business partners of organization ij;

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

**Input data**

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

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

**Questionnaires and interviews in small organisations**

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

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

- Business Activity,

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

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

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

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

We do not describe the entire process of these interactions between modelling and data collection here because it is not the focus of this paper. This is why the data

is described first and then the model and results. However, we would like to stress that the process of modelling and data building has been iterative.

## 3 Model

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

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

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

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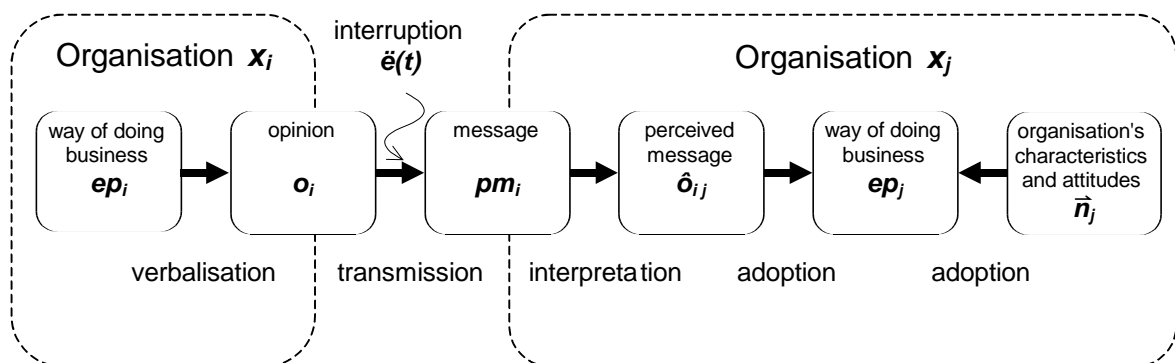


*Figure 1: Simulation model*

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

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

## 4 Results

Experiments on empirical data and different scenarios of electronic commerce diffusion showed that 32 time steps are needed to transit from initial state in 1997 to initial state in 2002 (Figure 2 and 3 – marked with black triangle). Time interval of changes is approximately two

months and it was used as mean transition time. It is interesting that only internal factors cause comparable results of two simulations. There is a little deviation from simulated state (after 32 steps in 1997) and initial state in 2002, which we can assign to other factors of electronic commerce that were not disclosed in this research.

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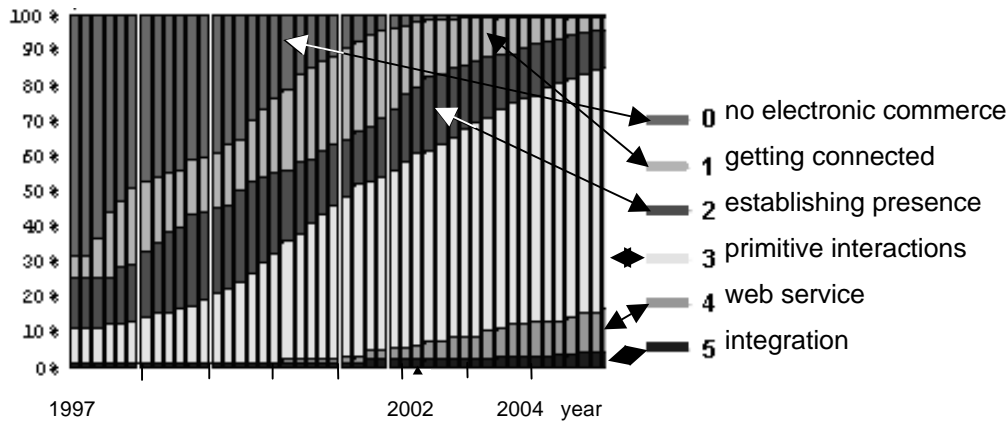


*Figure 2: Dynamics of electronic commerce maturity (initial data for year 1997), internal factors.*
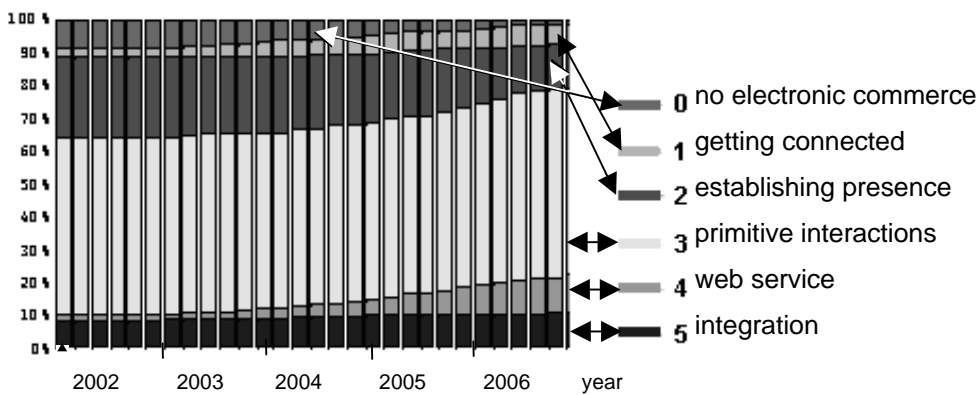


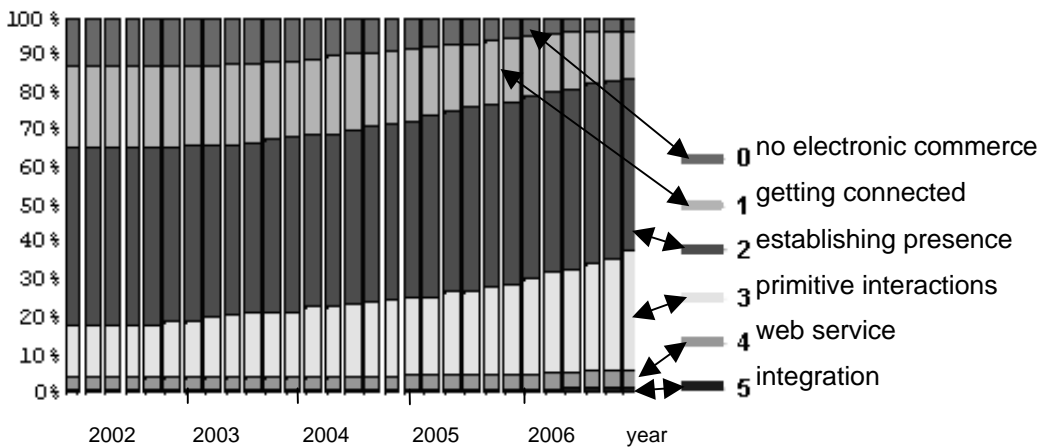*Figure 3: Dynamics of electronic commerce maturity (initial data for year 2002), internal factors.*



*Figure 4: Dynamics of electronic commerce maturity (initial data from RIS 2001), internal factors*
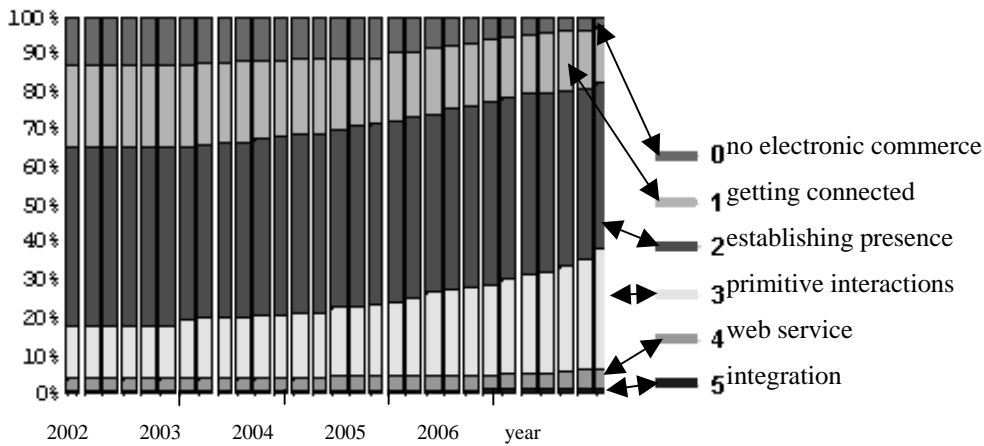
*Figure 5: Dynamics of electronic commerce maturity (initial data by RIS 2001), internal and external factors are in ratio 3:1.*

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

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

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

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

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

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

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

## 5   Conclusion

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

bal economy, uncertainty modelling and fuzzy model embedding along with real-time data collecting system over the Internet.

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