ACTA SCIENTIARUM POLONORUM Oeconomia 12 (1) 2013, 45–55

IT SYSTEMS ADOPTION AND ITS IMPACT ON THE FOOD AND AGRICULTURAL SECTOR

Tomasz Woźniakowski, Piotr Jałowiecki
Warsaw University of Life Sciences – SGGW

Abstract. The paper contains an overview of Information and Communications Technology (ICT) implemented in food and agricultural enterprises. The description of the sector summarizes some unique features compared to numbers describing food production aspects in Europe. For better understanding of the whole phenomenon the paper describes an innovative processes and technology progress in general and in the sector as well. Important aspects and potential problematic areas such as factors that influence ICT deployment are shown and analyzed. Main focus is directed on the technologies of e-business and its impact on organizational aspect of the sector. Also the role of ICT in the innovation process and product has been reviewed and certain areas of improved activities compared and summarized. Very forward-looking technology in the agri-food sector is SOA. With a common data exchange standards, it is possible to transfer information between different units.

Key words: ICT, e-business, agri-food sector, innovation, SOA

INTRODUCTION

Agri-food enterprises operate in a complex and dynamic environment. To meet increasing demands of consumers, government and business partners, enterprises continuously have to work on innovations of products, processes and ways of cooperation [Harsh et al. 1981]. Hence, a development towards a more knowledge-based economy is needed. Traditional software engineering approaches are inadequate to address these issues [Wolfert et al. 2010]. Business process management (BPM), in combination with reference information models, plays an important role. Designing and implementing successful business processes can provide important strategic advantages for the business into the next century [Keller and Teufel 1998]. Food production sector will indicate companies that place themselves in the middle of the "from farm to fork" chain, that belong to a group 15 of Polish Classification of Activities and according to NACE rev. 1.1 to a

Corresponding authors: Warsaw University of Life Sciences The Faculty of Applied Informatics and Mathematics, Informatics Department, Nowoursynowska 159, 02-776 Warsaw, Poland, e-mail: tomasz_wozniakowski@sggw.pl, piotr_jalowiecki@sggw.pl

group of 15th DA. In 2005, food production sector of the European Union (EU25) had a turnover of 836 billion over 70% of the processing of agricultural raw materials and employing 3.8 million people in the majority of employees in SMEs [Eurostat, CIAA 2006]. The sector produces processed agricultural products that belong to a group called "non--Annex I goods" that is not specified in the list of CAP (Common Agricultural Policy). However, materials used in this sector are mostly included in the list.

INNOVATION

The new concept is an invention, which properly works in the laboratory conditions. It becomes an innovation only when it can be adjusted in an industrial scale at acceptable cost level. New ideas pass from the invention stage to the phase of innovation. Effort in this direction is the result of independent development achievements in various fields Rogers [2006] defines innovation as "an idea, practice, or object perceived as new by a person or other entity for adoption". This definition is particularly popular in marketing. The most popular definition was proposed by Schumpeter [1934]. It describes innovation as "the introduction of a new combination", that identifies five possible cases:

1. Introduction of the new good;
2. Introduction of new production methods;
3. New market;
4. New source of supply;
5. Introduction of the new organization of industry.

It is not only the research that leads to innovation but also users of technology. This fact is used in EU programs to promote ICT as part of the Competitiveness and Innovation. These programs promote innovation and competitiveness by promoting the wider uptake and best possible usage of ICT by citizens, governments and enterprises, in particular: small and medium enterprises. The European Commission is analyzing the need for policy measures to support and facilitate the dissemination of information and communication technology adoption in particular advanced electronic business (e-business). For instance – projects of eBusiness Watch and eBSN. Among the technological innovations can be distinguished:

1. Product innovation;
2. Innovation Process;
3. Innovation system (business model).

The subject of product innovation is primarily switched to design and create a new product with features that distinguish it from wide range of other products that are offered to customers. An innovation process is the change of technology (the method of processing raw material into the product), which incorporates the content (parameters) and the order of sequence of operations that make up the technological process. Innovation System is in other words a creation of a new solution (the system) – biological and technological organization primarily in the so-called formation technology and communications, leading to changes in the flow of information in logistics processes and management processes. Business model innovation is the most complex incarnation of innovation that combines often radical changes in processes and creation of markets for new products. They require courage, determination and willingness to experiment. They are usually connected to the negation of the accepted ways of thinking and rejection of stereotypes existing in the industry thought. In business, for example, new product management teams, when assessing the feasibility of introducing new products, tend to favor their introduction with a frequency that is unwarranted by subsequent commercial performance. Analysis of many new product failures points to a tendency to both design research, and interpret research results, in a way that does not allow equal opportunity for evidence to arise that runs counter to a new product launch decision [Barabba 1991].

TECHNOLOGICAL PROGRESS

Technology is defined as goods and services produced together with the means of production, respectively in the company, industry or economy. Technological change is a change in manufactured goods, services, or their means of production. Terms: technological change, advanced technology and technical progress are used interchangeably. Technological changes in production of goods and services are called – product innovation. Technological changes in production methods are called – innovation process, which includes for example, changes to production equipment, organization of production, movement of goods or information, or management [Kollinger 2005]. Economic phenomena associated with the usage of technology became popular in the last few decades to become a very important strand of economic theory, such as “patent races”, “new trade theory”, “new growth theory”, “real business cycle”, macro models [Dosi 1997]. We begin to understand the technical progress, not as an exogenous shock that changes the supply curve, but as an explicit part of the economic dynamics and management. The interest of economists to study the technical progress was inspired by Schumpeter, who saw significant technical innovations (“execution of a new combination”) as the main source of long-term economic development. He believed that economic development must be driven by forces that exist in the economy and not only by external influence [Schumpeter 1934]. Specific group of related technological solutions can be associated with each technological paradigm, such as nuclear technology, biotechnology, or Internet technologies. Dosi calls the pattern and direction of technological progress based on the paradigm of trajectory. Technology, in this approach, is seen as a limited set of possible technological alternatives and theoretical future states. We may think of the external borders of the trajectory as the optimum combination of all the relevant technological and economic variables, in other words, the production possibilities frontier for a given technological paradigm. The formation of a new trajectory corresponds to the formation of groups of related technical innovation in the Schumpeterian sense. Movement of the company or the economy along a trajectory can be described by the diffusion of technology within the company or the economy. Numerous technological trajectories can exist in parallel. In addition, they require complementary state of knowledge, experience, skills and so on. When we continue to talk about trajectories or technological paradigms, we will use the definition given by Dosi. It is worth mentioning about the international diffusion of technology models, and models that describe the interactions between the technological leader and imitate others. The probability of successful imitation (adoption of innovation) is higher for less developed imitator, which translates into lower costs and higher demand from imitation to innovation in this country. Higher demand will mean more intensive international exchange and faster diffusion of technology, which, in turn, translate into a higher rate of technological progress in the country imitator and higher economic growth. As a result, the growth rate will converge to mimic the growth leader, as long as the imitator not overtake the leader. However, if the cost of technology adoption in the country imitator will be high, due to such dissimilar economies, the diffusion of technology and international trade will be limited, and the convergence process does not occur. Therefore, a key issue for imitators are all steps to be conformed to the economy of technological leadership. Such actions should aim, above all, the capabilities of the adoptive country, by increasing the pool of potential users of technology.

E-BUSINESS

The concept of electronic business includes an exchange of information between producers, distributors and consumers of products and services, contracting, transmission of documents, videoconferencing, gaining new contacts, search etc. Support of e-business processes enable a B2B (Business to Business – for example, the exchange websites, corporate portals), B2C (Business to Consumer – such as virtual stores and interactive catalogs on the web quotation), often used in conjunction with the CRM (Customer Relationship Management – to streamline your job applications within the enterprise) and SCM (Supply Chain Management – applications implementing supply chain management). It is relatively new to view supply chain as a process, that is a single integrated flow across all business. Internet technology in distributed environment such as food producers can be considered as “the best possible solution” to handle whole problem [Basu and Wright 2007]. However, some constraints arise due to the nature of industry’s products, and the specific structure of the sector. Subsequently, collaboration in the supply chain is often limited to operational issues and to logistics-related activities [Matopoulos et al. 2007]. Depending on the company’s strategy, information systems, e-business can have an open (unrestricted accessibility via the Internet) or closed (extranets available for the selected group with authorization in the form of a password). Policy makers, industry and media have used various terms for the same concepts and also often attributed different meanings to the same terms. The consequence of this were numerous efforts made by various statistical and international organizations (e.g. OECD, European Commission, U.S. Bureau of the Census, Statistics Canada) to find clear definitions of terms as the first step to developing useful statistics to measure the “digital economy” [Mesenbourg 2000].

E-BUSINESS TECHNOLOGIES

Existing definitions can be seen as different in the three key elements [OECD 1999, p. 10]:

1. Actions/transactions;
2. Applications;
3. Communication networks.

These three elements coincide with the three dimensions of e-business:

1. Instance (the current implementation of application);
2. One or more applications that use the network infrastructure;
3. Communication technology infrastructure.

Earlier definitions of e-business and e-trade differed, depending on a component/dimension of e-business concern:

1. Activities (for example, sell at retail or supply made electronically);
2. Applications (such as a fully integrated online store or online catalog with a simple form of e-mail);
3. A communication network (such as Internet or traditional EDI).

METHODS OF IMPLEMENTATION

Methods of implementation and development of ICT systems and business processes create new opportunities for managers, and more and more influence on their decisions. The computer system can be supplied as SaaS (Software as a Service), implemented in accordance with customer specifications, may be a diagnostic or prognostic. Therefore, it is important to underline the role of agri-food supply chain networks (further abbreviated as AFSCN). Three basic forms of network governance can be distinguished in AFSCNs [Lazzarini et al. 2001]:

- Managerial Discretion (plan): discretionary actions by a coordinating agent, who centrally plans the flow of products and information;
- Standardization: standardized rules and shared mechanisms to orchestrate transactions;
- Mutual Adjustment: alignment of plans through mutual feedback processes and joint problem solving and decision making.

Multi-dimensional networks put the emphasis on standardization and mutual adjustment, requiring a high flexibility of processes and enterprises. A sequence of actions associated with development of ICT systems in agri-food sector may be of cascading, incremental, iterative, evolutionary, or spiral. The continuous development of information technology and increasing globalization of the economy gives rise to new problems when creating enterprise information systems. Simultaneously, globalization has meant that today's corporations have to be able to connect many of its departments working in different locations, using different hardware and software platforms, as well as different applications into one cohesive body. The problem of creation and development of ICT systems is related mainly to the provision of: system flexibility, interoperability, mechanisms for continuous improvement of the system. In the classical IT project, there are three phases: analysis, design and implementation. Most modern methodology assumes repetitiveness of manufacturing process, which means that the individual phases can (even must) penetrate. In the analysis phase business process model is formed, that specifies the system environment, and on the basis of a model system, maps its functionality in terms of the use-cases, classes and objects. Model analysis stage is a source of knowledge about the problem domain. Design phase develops system architecture. Model elements are added to the technical architecture. In areas particularly vulnerable to changes in design, patterns are used to increase flexibility. System model of the design phase includes knowledge of how the system performs its functionality (ontology). In the implementation phase model is transformed into a skeleton code, which when completed becomes a running system. Most challenging is to address the transformation of the design model to code. Most modeling tools is provided with a code generator that allows you to create skeleton code for various programming languages. There is still a gap between analysis and design stages and it even seems to extend. Technologies that we use when creating the systems are becoming more complex. Moreover, during the design phase, model should be supplemented with elements from different kind of standards, guidelines and standards, such as methods to access attributes and naming conventions. Usually these problems can be avoided by creating a separate analytical model and design that will need to manually update every now and then. This situation is very burdensome and, sooner or later, these models need to be manually fixed if are no longer valid. You cannot create two separate models simply by creating incomplete specification. Integration of information for the farm and food producers as a networked enterprise is complex. At all defined levels and types of integration, one can distinguish three basic approaches:

1. Implementing one standard system that provides all required functionality (requires managerial discretion governance);
2. Developing customized point-to-point interfaces (costly, complexity is growing exponentially if the number of interfaces is growing);
3. Adoption of integration standards that make it possible to plug different systems via standard connectors into a common platform [Lee et al. 2003].

FACTORS THAT INFLUENCE ICT DEPLOYMENT

Efficiency of the operators is determined by many factors, which include information technologies that base on computer technology and telecommunications. Their combination has led to a creation of powerful instrument – computer network, in particular the Internet. This opened great opportunities to build a modern business that bases on almost unlimited information exchange. New technologies have opened new possibilities... but not all of them have already been discovered.

Five different categories of measuring the intensity and impact of ICT can be distinguished:

- The first category refers to a discrete, non-economic measures, in this category. Measures base on data that is collected in respect of quantitative physical parameters such as number of telephone lines, television, Internet users, or personal computers and so on;
- The second category consists of economic measures related to ICT, which are based on studies of various aspects of the economy. This category of measurement technology, is mainly related to growth, productivity, investment and employment;

- The third category is related to technology adoption and diffusion. They characterize the effects of differentiation of the availability and adoption of products and services based on ICT;
- The fourth category refers to the establishment of a single index ranking that measures the progress of ICT;
- Fifth category includes digital divide measures – exclusion of companies and sectors with the usage of ICTs.

Here are the key factors that determine a success of information systems deployment:

1. Strategic factors: leadership, management, skills, technology;
2. Environmental factors: the level and area of company's interest, the current development of the company.

THE ROLE OF ICT IN THE PROCESS AND PRODUCT INNOVATIONS

The ability to innovate is a key competitive advantage of particular importance because of the increasing globalization of the economy. ICT can play an important role in facilitating the innovation of products/services and business processes. Half of product innovation and process innovation is possible because of ICT. Agri-food sector as a result of these studies can be described as significantly more innovative in relation to all companies. Agri-food sector in Poland, shows an even greater commitment to the introduction of new products/services. 50% for product innovation and 59% for process innovation.

Impact on businesses. The agri-food sector and e-business technologies have their main impact on production and logistics. The marketing activities and sales potential of e-business is not fully exploited for the benefit of the manufacturer. Large retailers want to maximize their direct control over customers. In general, the capabilities of ICT and e-business solutions enable large companies to manage more advanced projects with greater efficiency and savings. Observations of specific activities in the field of e-business perceptions of the importance of ICT show a large variation between large and small companies.

Perceptions of importance of e-business. Approximately 50% of companies of agri-food sector show that e-business is a small area of the business they perform and 15% of the important and vital part of their business. The obtained results of the survey show that there are two different groups: large companies that have implemented ERP systems in daily practice and small companies with low rates, that are about to introduce e-business.

Impact on organization. The impact is seen as important by companies of all sizes and growing with increasing size of the company. More than 1/3 of companies observe an important effect on the organization, as well as in training employees. Most of the companies see two major areas of expected high or medium impact: accounting and marketing (see Fig. 1)

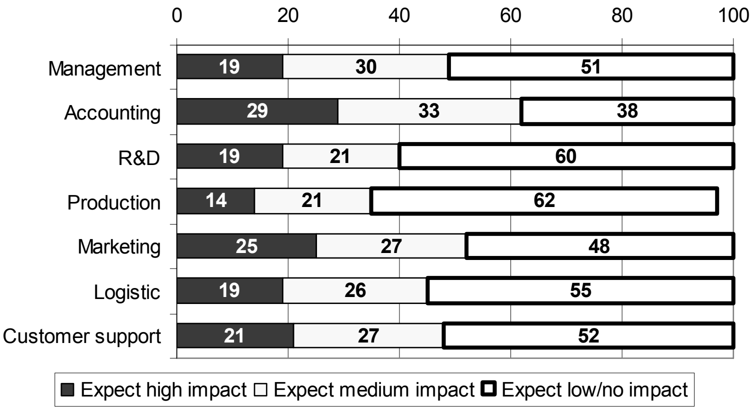

Fig. 1. Impact on organization
Source: Own work based on results of EU e-Business Watch Survey [2006].

HOW AND WHERE DOES IT HELP?

It can be stated without doubts that IT helps us in mastering our everyday existence. Otherwise, we would not tackle corresponding research problems. There are basically three areas of investigation – analogous to production systems for real goods – in which substantial progress has already been made by IT applications, and may certainly be expected in the future.

- IT supports the production process, i.e. by generating information output from data input by means of models.
- IT supports the procurement, i.e. the gathering of data as necessary model input.
- IT supports the logistics, i.e. the transformation of data and information over space and time.

Very forward-looking technology in the agri-food sector is SOA. With a common data exchange standards, it is possible to transfer information between different units. An integration is possible among certain layers:

- Business process management layer;
- Business service layer;
- Application service layer.

The use of BPMN (Business Process Modeling Notation) is a method of illustrating business processes in the form of a diagram similar to a flowchart (see Fig. 2). It helps to visualize business processes for better integration towards webservices and full interoperability.

There are marked advantages of organizing food production in chains of companies exchanging information and workflows for better efficiency, flexibility and quality. There has been the increasing requirement for a flow of information associated with a food product traceability [Hammoudi et al. 2009], the collection of information on its quality and safety for human consumption [Wolfert et al. 2010], and the flow of information associated with consumer demands needed for both production and inventory management decisions.

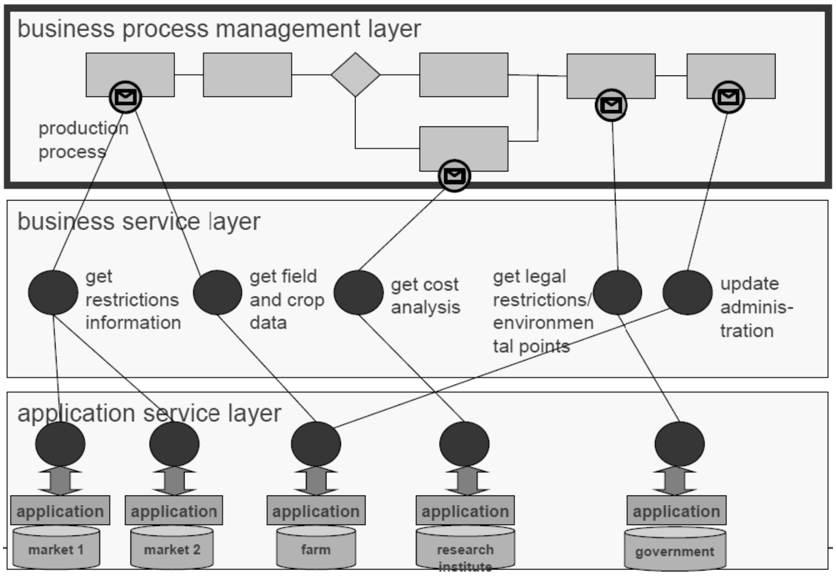

Fig. 2. Business process modeling using SOA
Source: Own work based on [Lee et al. 2003].

CONCLUSIONS

In conclusion, one major application of IT in agriculture will certainly be the development of knowledge-based, bio-economic models which:

- will contain appropriate input-output relationships as generalized production functions;
- will take into account space and time variability by incorporating the relevant, non-controllable yield factors, preferably with their direct values or at least with their probability distributions;
- will contain biological and technological, as well as economic components, in order to provide effective decision support for the agricultural land users.

Obviously, such models will have to be developed by multi-disciplinary teams, comprising subject matter experts from the fields of agriculture and business management, as well as computer scientists and statisticians. In order to guarantee practical relevance and user friendliness, extension specialists and selected professional farmers should be involved in the model building process as early as possible. As a rule, the development of a decision support model may be designed as a stepwise and iterative process. A thorough systems analysis and the establishment of a theoretical concept should lead to the prototyping of a first model version. These steps will be followed by tests on research farms and by extension specialists and farmers, as a base for model enlargements and refinements. After several model adaptations and improvements the final product will eventually be ready for the farming community. While the marketing will typically be conducted by public or private service providers, subject matter research and model development will typically lie in the hands of university groups or specialized institutions for applied research. Since the agricultural sector, being composed of many small business entities is not able to finance these research and development efforts, funds will have to be provided through governmental agencies and research foundations, of course, based on competitive bidding and peer group reviewing of proposals. With such models we will certainly not regain the paradise lost of decision making under certainty by way of instinctive actions, but we will eventually be able to support decisions which yield results being technically and economically less inefficient than they are usually now.

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ZASTOSOWANIE TECHNOLOGII INFORMATYCZNYCH I ICH WPŁYW NA SEKTOR ROLNO-ŻYWNOŚCIOWY

Streszczenie. Artykuł zawiera przegląd technologii informacyjnych i komunikacyjnych (ICT) realizowanych w sektorze przetwórstwa żywności i przedsiębiorstw rolnych. Opis sektora zawiera podsumowanie kilku unikalnych cech oraz liczb opisujących aspekty produkcji żywności w Europie. Dla lepszego zrozumienia całego zjawiska ICT w tym sektorze artykuł opisuje procesy innowacyjne i postęp w technologii ogólnie, jak również w sektorze. Ważne aspekty i potencjalne obszary problemowe, takie jak czynniki, które wpływają na wdrożenia ICT są przeanalizowane i przedstawione w syntetyczny sposób. Główny nacisk skierowany jest na technologie e-biznesu i jej wpływ na organizacyjny aspekt sektora. Również rola ICT w innowacji procesowej oraz produktowej zostały przeanalizowane a pewne obszary poprawy działalności porównane i podsumowane. Bardzo przyszłościową technologią w sektorze rolno-spożywczym jest SOA. Wspólne standardy wymiany danych umożliwiają przesyłanie informacji pomiędzy różnymi jednostkami.

Słowa kluczowe: ICT, e-business, sektor rolno-spożywczy, innowacje, SOA

Accepted for print – Zaakceptowano do druku: 28.02.2013