

RFID within High-Tech Clusters – Towards a Knowledge-Based Economy

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Abstract – The concept of knowledge-based economy (KBE) in this article constitutes the basis for the undertaken considerations regarding the implementation of Radio Frequency Identification (RFID) technology in the development process of high-tech clusters. It has been indicated in the article that this type of economy is characterised by quick development, particularly, of these disciplines which are related to information processing and science development, mainly the high-tech industry, including the technologies and services of an information society. It has been emphasised that in these market conditions the key sources of competitive advantage of business entities comprise, inter alia, the efficiency of knowledge management as well as various knowledge-intensive undertakings, which create newer and newer value for key stakeholders. The main subject of this paper is to analyse the development and application of RFID within the high-tech cluster. Firstly, the paper aims to present a literature review on the strategic importance of RFID technology for firms located in high-tech clusters through tracing a broad range of literature. Secondly, it constitutes an attempt to characterise the factors determining the decision to implement this technology, by focusing on the research results.

Keywords – Cluster, competitiveness, development, technology.

I. INTRODUCTION

The competition at the level of knowledge acquisition and innovation implementation forces contemporary enterprises to undertake actions within the scope of intellectual capital improvement. Thus, to provide themselves with optimum development conditions, more and more frequently, entrepreneurs decide to cooperate with other entities within clusters. A positive synergy effect achieved as a result of this type of relations in a cluster enables more dynamic and efficient knowledge and innovation generation, contributing to the implementation of the major assumptions of knowledge-based economy. Innovative clusters, knowledge clusters and high-tech clusters are of particular importance in this area. Primarily, it is owing to the fact that they are characterised by entrepreneurs' strong inclination towards the cooperation with R&D sector as well as real activity of these entities within the development of advanced innovative technologies. The support for this kind of clusters, constituting one of the major activities of pro-innovative policy in Europe, contributes, among others, to the achievement of the aims of cohesion policy, including efficient decrease in present economic, social and territorial disproportions, economic growth, and the improvement of the regional competitiveness.

The factors that are conducive to the development of high-tech clusters in the conditions of knowledge-based economy are innovative ICT solutions. The application of a selected type of such solutions, i.e. RFID technology, is analysed within this article. Many researchers stress that RFID as a one of the most common automatic identification technologies is currently used in many different applied fields. This type of technology can

enable redesign of a business process in order to optimise operational efficiency. In the contemporary business environment, the emerging technologies, especially new RFID solutions have provided the security of information management and its application help to develop enterprises in various areas, including members of high-technology clusters. As RFID progresses in its development and application over the next decade, there will be vast opportunities for management researchers to not only study the advancement of this technology, but also to examine its implications from a wide variety of perspectives (Wen, Zailani & Fernando, 2009).

The author of the paper characterises the nature of the RFID technology, its use in high-tech clusters, advantages, and barriers, implications and guidelines for RFID implementation on the basis of empirical research. Primary research was conducted within four months, i.e., from November 2014 to February 2015 by means of a postal questionnaire. The questionnaires were directed to top and middle-level managers who make investment decisions and/or have a decisive impact on them. The research was conducted on managers of 203 purposely chosen enterprises (non-random, purposive sampling). The research was chiefly focused on the enterprises that cooperate with other entities within high-tech clusters. In order to increase the returnability of the questionnaires, information concerning the sources of research funding was included. What was also taken care of were the visual features of the questionnaire and the quality of the prepared and enclosed product data sheet, which explained the significance of the innovative RFID system (with autonomous semi-passive transponder), being currently designed by the scientists at Rzeszów University of Technology. The major aim of the undertaken research was the identification of the determinants in the process of the implementation of RFID system with autonomous semi-passive transponder in Polish enterprises, the assessment of the market potential as well as the possibility of commercialisation of this technology.

The paper presents the selected theoretical and empirical considerations within the subject. They constitute a fragment of the analysis that is currently conducted by the author concerning the conditions of investment decision-making as regards the implementation of RFID technology within cluster companies. This paper was prepared within the scientific project: *"Synthesis of Autonomous Semi-Passive Transponder Dedicated to Operation in Anticollision Dynamic RFID Systems"*.

II. HIGH-TECH CLUSTERS FOR THE DEVELOPMENT OF KNOWLEDGE-BASED ECONOMY

In numerous publications on knowledge-based economy (KBE), it is emphasised that it is an example of an economy

in which knowledge and knowledge-related products constitute the major driving force of economic transformations. This concept of modern economy proves significant for cost reduction and efficiency improvement in transmitting and transacting knowledge and knowledge-related products and services by means of ICT (Hu, 2012).

At present, the KBE constitutes a model of economic development that is based on knowledge and innovations. Various considerations on the significance of KBE are related to the ambitious assumptions of the so-called Lisbon strategy, where the KBE is treated as:

- economy in which production and distribution of knowledge play an important role in wealth creation; in such an economy, the goal is not only the advancing knowledge but also the promotion of the efficient use of knowledge in all economic activities (Mortazavi & Bahrani, 2012);
- production and services based on knowledge-intensive activities that contribute to an accelerated pace of technological and scientific advance as well as equally rapid obsolescence (Powell & Snellman, 2004);
- economy in which the proportion of knowledge-intensive jobs is high, the economic weight of information sectors is a determining factor, and the share of intangible capital is greater than that of tangible capital in the overall stock real capital (Foray, 2004);
- economy based on knowledge and ideas, high-tech industry, information society services, knowledge and education services, in which the key factor of prosperity and economic growth is the superior knowledge capitalisation (Tocan, 2012);
- economy in which organisations and people acquire, create, disseminate, and use knowledge more effectively for greater economic and social development (Kefela, 2010);
- economy in which operating mechanisms lead to the application of knowledge in order to increase enterprise competitiveness and productivity, competitive advantage and economic growth (Kupczyk, 2014);
- a composition of “know what”, “know why”, “know how” and “know who”, which imposes some challenges for the science system regarding the integration of its knowledge creation role and its corresponding role of knowledge transmission (Nacheff *et al.*, 2014).

This type of economy based directly on the knowledge and information production, distribution and utilisation is characterised by the permanent transformation of the knowledge in base material, capital, products, services and production factors essential for the economy, and through economic processes in which the generation, selling, acquisition, learning, stocking, developing, splitting and protection of the knowledge have become predominant and decisive for profit obtaining and for the assurance of the economic sustainability in the long term (Tocan, 2012). It is reliant on harnessing the human and social capital produced by knowledge workers for growth and prosperity (Davis & Evans *et al.*, 2006). With increasing knowledge codification and its transmission via communications, computer and social networks, the continuous learning, organisational learning and cooperation have become essential in ensuring sustainable

economic success (Nacheff & Jantan *et al.*, 2014). A prevailing view in the contemporary economy is that in order to have successful knowledge economies, countries must act simultaneously on their education base, their innovation systems, and their information and communication technology infrastructure, while also building a high-quality economic and institutional regime (Kefela, 2010). Moreover, the KBE requires modern science and national innovation systems to balance between its three important tasks of knowledge production through research, knowledge transmission via education, and knowledge transfer across economic participants and social groups (Nacheff & Jantan *et al.*, 2014).

Taking into consideration the fact that knowledge ensues from human intellectual potential, it is assumed that the process of building knowledge-based economy consists in the creation of the conditions that facilitate the functioning of various entities that base their activity on knowledge and knowledge-related products. One of the factors that are conducive to the process of the development of knowledge-based economy at various levels – macro, meso and micro – is high-tech clusters. Synergy effects that result from the cooperation of the representatives of the spheres of business and science in these structures significantly influence the creation of competitive KBE.

In the contemporary business environment, which is characterised by globalisation, industry convergence, and rapid technology change, high-technology clusters provide opportunities for economic growth, as they can drive the direction and pace of innovation by making innovation opportunities more visible and providing convenient access to complementary resources (tangible and intangible) and capabilities (Zhang & Li, 2010). Therefore, these clusters have become a strategic source of economic development across the advanced industrial economies, and a central focus of technology policy. They can have an impact on legal framework and institutions, infrastructure and also future cluster policy (Palcic, Vadrnjak *et al.*, 2010). However, they also raise concerns due to their energy-demanding nature (Yan & Chien, 2013).

A high-technology cluster is a geographical concentration of the related technology firms including competitors, suppliers and customers; usually around scientific research centres and universities, which is composed of a number of players that work in concert to create a highly innovative and productive environment for the growth of the existing, and the creation of new knowledge, technology and businesses in the cluster (Falah, 2005). It is defined through the practices of the leading and most competitive companies and universities.

The concept of high-technology (high-tech) implies that it is possible to distinguish between different “levels” of technology in the sense that some kinds of industrial activity are based on a more “advanced” technology than other industries, which is often related to the level of “knowledge” on which the technology is based (Spilling & Steinsli, 2003). The category of high technology includes the industries which operate at the contact zone between science and industry by applying the results of scientific research in the industry (Gieranczyk, 2010). Therefore, high-tech clusters are to a large extent dependent on intellectual resources and have a high investment capital, which

make them keep a more intense competition for the domestic and international markets' scarce resources of high-tech R&D capabilities, high-tech talent supply capacity, business growth, development funds, and high-tech products (Yunxia & Huamao, 2010). These clusters are focused on the intellectual and knowledge capital residing within and exchanged among individuals, firms, and other knowledge-creating stakeholders such as universities (Huggins, 2008).

Effective clusters of high-tech industry as a form of network have a number of well-documented advantages for innovation (Bresnahan & Gambardella, 2004; Carlsson, 2013):

- entrepreneurs easier find access to capital in clusters than outside them, and venture capitalists and investment bankers find it easier to locate new investment opportunities;
- entrepreneurial universities with strong technical research capabilities are closely linked to commercial activities;
- geographical proximity also facilitates interactions between active researchers, scientists and engineers and is conducive to a greater number of innovations;
- innovation process within clusters is carried out through strong links between suppliers and users along the value added chain;
- firms in a cluster participate in thick markets for technical labour, managers, and other inputs;
- knowledge spillovers in clusters contribute to an increased rate of innovation leading to the creation and growth of new businesses;
- organisational culture of a cluster is conducive to innovation and entrepreneurship;
- information about new technical and market opportunities flows through a cluster's institutions and through its informal networks very rapidly.

In addition to the four dimensions of the Porter diamond (factor conditions, demand conditions, related and supporting industries, firm strategy, structure, and rivalry), high-tech clusters, as an extension of the industrial cluster concept, possess also: entrepreneurship, a source of innovation, sources of financial capital and social capital (Calzonetti, 2006). A key factor underlying the operation of these clusters is an effective network of relationships that stimulates the permanent creation of new ideas, knowledge, innovation and entrepreneurship (Myint, Vyakarnam *et al.*, 2005).

The process of knowledge and other forms of innovative activity are more effective in these types of clusters, because they usually include, among others, high-tech firms, universities and R&D units (Kowalski, 2013). The effectiveness of the knowledge creation and of innovation processes in this cluster is determined by its innovation abilities, especially soft factors also playing an important role in clustering, such as: high quality of human and social capital, technological advancement of scientific and research units, entrepreneurship-friendly environment, support from business environment institutions, local government and appropriate innovative ecosystem (Kowalski, 2013).

The collaborative and distributed processes of open service innovation within a cluster that combine ideas, knowledge, and resources among a network of actors can be challenging as it calls for a balance between multiple aspects such as: identification of

the rationale for co-innovation; coordination of the processes and mechanisms of co-innovation; maintenance of policies to deal with conflicts between collaborating entities; and maintenance of service quality and consistency (Bughin, Chui & Johnson, 2008). However, high-tech and highly innovative clusters are driven by externalities of various types, customer and supplier relationships, the use of common factor inputs, like specialised labour markets, or knowledge spillovers (Ketels & Memedovic, 2008). A. Kuah (2002) argues that externalities are generally defined as impacts, side-effects or spillovers, which are usually not reflected in the cost or price of a particular product or a service, i.e. not covered by a market mechanism. New technologies within the cluster can facilitate the creation and transmission of tacit and explicit knowledge. R&D externalities associated with learning and transfer of new technological knowledge, which depends positively on the proximity of early users and of technologically close stakeholders, can reduce the costs of undertaking technology embodying capital goods and help facilitate the assimilation of new technologies into the firms' own value chains (Tsai, 2005).

According to J. Yunxia and X. Huamao (2010), high-tech industry clusters are seeking a long-term survival and development, but also contending for continuous resource supply and market share of the open space. Moreover, they are attracted especially to new knowledge, innovative technologies, skilled labour force and R&D investments (Strukelj & Dolinsek, 2010).

III. RFID TECHNOLOGY AS A STRATEGIC FACTOR WITHIN CLUSTER DEVELOPMENT PROCESS

Many researchers and entrepreneurs believe that RFID has great potential benefits for high-tech clusters and the members of a cluster supply chain. This is due to the fact that RFID can significantly reduce the costs, improve manufacturing safety and refine the business process. Although RFID has great potential benefits, the adoption of RFID technology in high-tech industry is still in the emergent phase, not yet high growth phase. This involves, *inter alia*, the high costs of its implementation. Return on investment has not been sufficiently documented in the literature of the subject; however, as the use increases, the cost falls and vice versa (Mamdapur & Rajgoli, 2011). Moreover, still many small and medium enterprises are reluctant to adopt RFID technology because they perceive it unprofitable and risky (Shin & Eksioglu, 2014).

According to the literature and research by academics, RFID is constantly evolving, thereby it is frequently defined in various ways, e.g., as:

- one of the most exciting technologies that revolutionises the working practice by increasing efficiencies and improving profitability (Durani, Bhatt & Mehta, 2014);
- a wireless communication technology that is used in physical markers (RFID tags) to mark products, as well as in bar code technology (Barburski, Czekalski & Snycerski, 2008);
- a system that is based on storing and remotely retrieving information or data as it consists of RFID tag (contains microchips that store the unique identification ID of each

object), RFID reader (generates magnetic fields that enable the RFID system to locate objects – via the tags – that are within its range) and back-end database (Ahsan, Shah & Kingston, 2010);

- a system that transmits the identity (in the form of a unique serial number) of an object or person wirelessly, using radio waves (Kaur, Sandhu, Mohan & Sandhu, 2011);
- one member in the family of Automatic Identification and Data Capture (AIDC) technologies that is now seen as a radical means of enhancing data handling processes, complementary in many ways to other data capture technologies such as bar coding (Ravi, Varun, Vamsi & Pratyusha, 2013);
- a wireless system that facilitates the tracking of objects, primarily for inventory tracking, via a three-part technology comprised of a reader, transceiver with decoder and transponder (Radio Frequency-Tag) and that works in conjunction with an organisation's information technology infrastructure to improve business processes such as inventory management and efficiency in supply chain management (Mamdapur & Rajgoli, 2011).

RFID as a technology that enables wireless data capture and transaction processing can have many different applications in high-tech clusters, thereby provides it with many benefits, e.g. (Barburski, Czekalski & Snyckerski, 2008; Kaur, Sandhu, Mohan & Sandhu, 2011; Peppas & Moschuris, 2013; Ahuja & Potti, 2010):

- it replaces a barcode technology and enjoys the major advantage of being independent of line of sight problems and scanning the objects from a distance;
- it can be used to asset management, including identification, alerting, monitoring and authentication, or access control, such as keyless entry and employee identification;
- in IT systems it helps to improve automatic product or semi-finished product identification during the process of their manufacturing and further on;
- in factories it can be used for the identification and monitoring of a single product;
- it is used to track parts and work in process and to reduce defects, increase throughput and manage the production of different versions of the same product;
- it is an effective method for the identification of counterfeit products by tag authentication to differentiate genuine products, where lightweight cryptography is involved;
- it is used to automatic data capture allowing contactless identification of objects using radio frequency;
- it can be used in closed loop supply chains or to automate parts of the supply chain within a cluster's control;
- it can promote operational efficiency and precision;
- it is a support tool to automate processes and to improve operation management; it reduces labour, eliminates human errors;
- it offers the promise of reduced labour levels, enhanced visibility, and improved inventory management;
- it gives entrepreneurs new opportunities to track the whole course of product existence, from manufacturing and storing through to sale and utilisation.

The benefits of the adoption of RFID technology in high-tech clusters are numerous and varied. RFID provides different advantages that are related to resource optimisation, increased efficiency within business processes, enhanced customer care and overall improvements in business operations (Ahsan, Shah & Kingston, 2010). According to D. Hofman, RFID will help manufacturing companies reduce inventory by 15 %, improve the ordering process by 17 %, and reduce the cash-to-cash cycle times by 35 % (Al-Odeh, 2012). Contemporary enterprises perceive RFID as an innovative technology, which can add value to their business operations, supply chain partnerships and customer service relationships (Peppas & Moschuris, 2013). Thereby, RFID technology creates a new way of development. It allows organisations and companies to stay more secure, reliable, and accurate (Ahsan, Shah & Kingston, 2010). RFID has revealed its potential to revolutionise the existing information technology systems in order to enhance their competitiveness, and it is undoubtedly a highly versatile technology that can serve the needs of diverse industries (Ting, Tsang & Tse, 2013).

Owing to the fact that the innovation process, including research and development work, proceeds in a high-tech cluster according to the assumptions of the open innovation model, it creates the conditions conducive to the efficient development and the implementation of RFID in cluster companies. In this model, one can observe an active quest for valuable innovative knowledge from various sources, such as suppliers, customers, universities, research laboratories, consortia, start-ups, business environment institutions or competitors. Moreover, this model emphasises that it is much more beneficial to build competitive advantage through cooperation and transfer of innovation and knowledge between various stakeholders, rather than to follow-up investment only in internal R&D.

The open innovation theories suggest that the generation of innovative outputs is facilitated by greater openness to external sources of knowledge, which in turn stimulates the fluidity of knowledge and information flows between partners (Huang & Rice, 2013). This situation is related, inter alia, to globalisation processes, dynamically developing emerging markets, short life-cycles of products and technologies and also to the increase in human resource mobility. According to the idea of open innovations, it is high-tech clusters, owing to mutual co-operation of various entities within the scope of the creation and development of new knowledge, that can be truly valuable for their members and the economy (spillover effects).

The development process of innovative RFID solutions can be more efficient in high-tech clusters than outside them, as it gives the chance to acquire new knowledge from the partners as well as a chance of its commercialisation in the form of, e.g., the sale of patents and licences. In this case, the possibility of exploiting external and internal technological resources, creativity, knowledge and experience of the partners increases the added value of the new RFID solution being created.

The experience demonstrates that the benefits consisting in the development of new solutions within a cluster are far more valuable than the possible threats resulting from the infringement of intellectual and industrial property rights. Many researchers stress that the clusters are believed to provide an environment

within which the direct costs associated with open strategies (such as contractual, knowledge search costs and indirect costs, particularly in terms of knowledge transmission costs), the uncertainty and risk in cooperative relationships and the conflicts between inbound and outbound knowledge flows could be minimised (Huang & Rice, 2013).

IV. RFID IMPLEMENTATION: SELECTED RESEARCH RESULTS

RFID technology will bring a lot of real benefits when it is successfully implemented; however, this does not denote that it is a perfect solution that fails to have limitations (Ting, Tsang & Tse, 2013). The implementation of this technology in manufacturing organisations is a complicated process for large-scale, in general, and for small-to-medium manufacturers, in particular (Al-Odeh, 2012). Its implementation typically constitutes a complex project, involving a lot of internal and external stakeholders. Entrepreneurs should understand critical success factors to RFID adoption and what RFID both can and cannot do, before making the decision to implement this system. Common critical success factors to RFID adoption identified in the literature comprise (Vanany & Shaharoun, 2008):

- at the strategic level – the creation of strong internal and external motivation to improvement, the development of a clear RFID strategy, partnership with competent RFID providers, the strengthening of mutual understanding in an organisation, top management support and commitment of the leadership;
- at the tactical level – the determination which practice should be incorporated into RFID systems, facilitating equipment vendor's investment, the integration of RFID into the existing IT architecture, proper staff training, starting with a small RFID project, utilising a cross-sectional team;
- at the operational level – the avoidance of major process changes/limitation of process changes, coordination among the departments, continual procedure improvement, integration of the data collected, lack of comprehensive facts and data, use of cost-effective reusable tags.

These factors can be classified by (Ting, Tsang & Tse, 2013): technological dimension (selection of appropriate hardware and software, effective testing, sufficient technical support, clear process, data routing, clear performance measures), managerial dimension (clear vision, good project management skills, good risk management skills), and social dimension (teamwork, trust, effective communication). Al-Odeh (2012) argues that the most important factors that need to be considered during the process of implementation of the RFID technology include strategic thinking about the importance of developing this technology. Moreover, this key factor includes the process of identifying the consistency between the technology and the organisation's goals and objectives taking into account the potential opportunities and threats.

It ensues from the author's research that an RFID system has been implemented in 41 % of the surveyed enterprises (Table I). This system has been so far applied to the entities for, among

others, production management, stocktaking, working time control, product shipment, electronic security identification, product identification, product quality measurement, and storage logistics. However, in the majority of the surveyed companies, the system has not been implemented yet.

The respondents enumerated the following key factors that according to them determine decision-making concerning the purchase and implementation of an RFID system: the improvement of sales, storage and transport processes (62 %), the quality of the transponder (56 %), the costs of the implementation of this system (55 %), awareness of the benefits for the user (49 %), transponder's price (48 %), compatibility of the RFID system with other systems used in the enterprise (47 %), payback period of such investment (47 %). The factors indicated by the respondents as the least important comprise: the possibility of the measurement of pressure, humidity, gas, lightning, temperature, vibrations and stress, or other physical quantities. It is all the more interesting in view of the fact that the RFID technology proves to be very useful in buildings, in which there is a high level of dust, humidity as well as low temperatures, which frequently make barcodes unreadable.

TABLE I
THE USE OF RFID SYSTEM IN THE SURVEYED
COMPANIES: OPINION OF RESPONDENTS

Answers	[N]	[%]
Yes	83	41 %
No	120	59 %

Source: the author's own research.

What is significant for the respondents in the process of knowledge development, including the acquisition of information about innovative RFID solutions, are chiefly websites of RFID systems' producers, comprising detailed information on the functioning of these systems, direct conversations with entrepreneurs, buzz marketing and the participation in exhibitions and trade fairs. The least popular sources of information based on the survey are: advertisement (TV, press), social media, professional blogs, or research and development institutions. It ensues from the research that the entrepreneurs' awareness of the possibilities that result from complete RFID implementation is still low. Certainly, it is dependent on the size of an enterprise – the bigger the enterprise, the greater the awareness of the management.

According to the respondents, the factors that will decide on the final choice of the supplier of RFID system in their case are: financial and organisational conditions of the supplies, supplier's credibility, which is created by their reputation and financial condition, the quality of services, the scope and the attractiveness of the offer (Table II). What is least important for the respondents in the process of choosing this system is the possession of research and development facilities.

It ensues from the conducted research that, while taking decision to implement an RFID system (particularly the one with automatic semi-passive transponder), entrepreneurs expect to obtain such measurable benefits as: time saving, increase in the efficiency of quantitative and qualitative control and stocktaking,

the possibility of a multiple record of a substantial amount of information, the improvement of object transfer and stocktaking, elimination of waste, increase in customer's satisfaction. At the same time, the respondents assessed the potential influence of the implementation of this system on the improvement of the enterprise financial condition, the improvement of partner relationship with customers, suppliers, employees and competitors.

TABLE II
FACTORS THAT DETERMINE THE CHOICE OF RFID
SUPPLIER: OPINION OF RESPONDENTS

Factors	[N]	[%]
Conditions of cooperation	160	79 %
Supplier's credibility	121	60 %
Service professionalism	117	58 %
The scope and attractiveness of the offer	113	56 %
After-sales services	109	54 %
Recommendation of trusted persons	105	52 %
Supplier's R&D facilities	40	20 %

Source: the author's own research.

Despite the fact that the benefits stemming from the implementation of RFID technology appear to have strategic importance for further development of a company, there are still numerous barriers, which to a large extent prevent investors from this type of complex implementation. As the major barriers within this scope the respondents indicate typical financial barriers (considerable costs of the implementation of this system, high costs of transponders, long payback period of this investment) and organisational barriers (e.g., problems concerning the compatibility of RFID with other systems used in a company, lack of cohesive systems in the supply chain). The fact remains that RFID tags are significantly more expensive than barcode labels. This situation translates directly into the time and possibility of the payback period of this investment. According to the expert forecast, in the near future the standardisation, the production scale and the use of printed electronics will enable a significant reduction of a unit cost of a radio transponder (the price of a tag). Moreover, experts are of the opinion that RFID technology will become an operational standard.

One of the factors that more and more frequently determines the need for the implementation of RFID systems is the fact that this type of systems is used on the market by competitors. Competitive pressure within this scope has not been felt only by 17 % of the surveyed companies.

37 % of the respondents were convinced that the competitive companies used an RFID solution, 13 % considered that their competitors still did not have this type of solution implemented, and one in two respondents had no knowledge as regards this issue. The results are similar as far as the use of RFID by the customers of the surveyed companies is concerned. In the opinion of every fourth respondent, the customers of their companies use this technology, whereas 26 % of them took the opposite view. Also in this case half of the respondents possessed no information on the use of RFID by their customers. It results from the research that in the vertical value chain it is chiefly suppliers of

the surveyed companies that use RFID solutions. Furthermore, the research shows that the analysis of the key stakeholders of the surveyed companies, including competitors, suppliers and institutional customers, is frequently performed at a too general level and fails to take into account their technological advancement.

In the majority of the surveyed enterprises (56 %), no available substitute of RFID technology is applied (Table III).

TABLE III
THE USE OF RFID SUBSTITUTES IN THE SURVEYED
COMPANIES: OPINION OF RESPONDENTS

Answers	[N]	[%]
Yes	30	15 %
No	113	56 %
I don't know	58	29 %

Source: the author's own research.

Such substitutes are used in 15 % of the surveyed companies. The implementation of the substitutes of RFID technology ensues chiefly from the fact that they are cheaper than the solutions of RFID class. Moreover, at present in Poland, the cases of complex implementation of automatic identification systems based on Electronic Product Code are still rare (Jankowska-Mihulowicz & Jankowski-Mihulowicz, 2014).

The respondents were aware that the implementation of an RFID system in their enterprises would entail the training of the managers due to the implementation of a change of technological, organisational and procedural nature. On the other hand, it would require the development of an appropriate way of communication, by means of which all participants of this process would be efficiently informed. What is also interesting is that in the opinion of the majority of the respondents, the implementation of this system in an enterprise will neither cause misunderstandings and conflicts between the management and the personnel, nor will it meet employees' resistance to the changes or require a common agreement with various stakeholders in an enterprise. It has been stated during the research that human resources, including knowledge, qualification and openness to changes, do not constitute a potential barrier for the implementation of any RFID system in the surveyed entities; actually, it is a factor facilitating this type of implementation.

It undoubtedly ensues from the empirical and theoretical research that the RFID technology can potentially be implemented in every area of enterprise functioning. However, the pace of its implementation in Poland is still slow. According to IDTechEx, in 2014, the total RFID market was worth \$ 8.89 billion, up from \$ 7.77 billion in 2013 and \$ 6.96 billion in 2012. This includes tags, readers and software/services for RFID cards, labels, fobs and all other formal factors. IDTechEx forecasts that it is going to rise to \$ 27.31 billion in 2024 (Das & Harrop, 2014). The global industry for the RFID technology has been growing steadily since past few years and is expected to grow rapidly before stabilising and settling on a steady growth path (Wen, Zailani & Fernando, 2009).

RFID applications could have a profound effect on both the industries that produce them and those that use them, and

on the competitiveness of European companies. The future competitiveness of Europe in RFID depends crucially on its ability to innovate, which is in turn partly driven by R&D efforts (Panizza, Lindmark & Rotter, 2010).

The RFID systems are basic factors of development of a universal information system for different objects, called the Internet of Things, and platforms for connected smart objects of things. The huge progress in electronics technology and RFID solutions gives the opportunity to implement additional features in transponders (Jankowski-Mihulowicz, Kalita, Skoczyński & Weglarski, 2013). The experts indicate that along with the continuous social and industrial evolution, the major area of RFID implementation within the next years in Polish enterprises will be Supply Chain Management. The demand for RFID technology among the entrepreneurs who wish to improve business process management will systematically increase along with the economic changes.

V. CONCLUSION

In the conditions of knowledge-based economy, there is an increase in the awareness of entrepreneurs that knowledge, as an element of intellectual capital constituting a key source of competitive advantage, influences the efficiency of creating values in various areas and dimensions. At the same time, there is a strong conviction that in order to gain competitive advantage in the conditions of knowledge-based economy it is not sufficient to streamline organisation internal processes, yet there is a necessity of permanent cooperation with all business partners. Thus, what is more and more frequently emphasised is the need for building social capital to enable effective transfer of knowledge and technology, serving the improvement of innovativeness, and hence of the competitiveness of the economy. The efficient flow of knowledge between business entities and many other stakeholders, e.g., universities or business environment institutions, as a strategic factor of the development of knowledge-based economy, represents the new quality in strategic management of contemporary enterprises.

The literature indicates that in the line of knowledge-based economy, a reliable way to support business development is to create high-tech clusters, using the knowledge and the resources of the region (Piasny, 2009; Rychen & Zimmermann, 2008). High-tech clusters, which constitute an example of knowledge-based clusters, are mainly characterised by the fact that within their structure there are dynamic innovative companies belonging to the high-tech sector on the basis of the knowledge ensuing from the cooperation of "business and science". The members of this kind of regionally rooted structures notice customer's needs more quickly, or even create them themselves. They adjust to market needs more efficiently as they have an easy access not only to their partners within the vertical value chain but also to R&D centres, business environment institutions or local government. A great concentration of so many various partners having the key role from the viewpoint of the innovation process creates a real chance of further development of information and communication technology, including RFID.

RFID technology has a great market potential and a wide range of application possibilities. The basis of RFID is EPC (Electronic Product Code), i.e., a system which is continuously improved within the scope of the open innovation model (co-operation of various partners, among others, trading networks, manufacturers, logistics companies, R&D institutions). The EPC is based on the specifications required in the standards of a protocol, such as: communication between transponders, manual scanners and information systems. Owing to EPC, there is a real possibility of coding a selected object and its automatic identification (e.g., place of manufacture, storage and transport conditions, temperature, pressure, humidity, vibrations, etc.).

The key advantage of the RFID system in the area of manufacture is the possibility of minimisation of the role of human factor and its interference in the transfer of innovation through automatic registration of every separate product and a collective package. It can be done, among others, owing to interrogators placed under the production line. Numerous scientific publications also emphasise the capacity of RFID within the scope of the efficiency of the transfer of information and knowledge between the partners in a supply chain, delivery control, management of product life-cycle, or a broadly understood process management. This technology can transpire a significant incentive to the creation and implementation of innovative process changes facilitating the increase in the enterprise efficiency. Moreover, RFID influences economic development, operational activities and financial results within the scope of: enterprise productivity, employment, innovation development, structure of the market of goods and services (Schmitt & Michahelles, 2008).

Radio Frequency Identification technology is a cross-cutting and enabling technology and is considered to be the next wave of the IT revolution (Schmitt & Michahelles, 2008). This technology is still in the developing phase and in the pipeline in terms of new applications. In spite of the fact that it is attractive to business and can be applied in various areas, it has to be further improved to enable its common use. In terms of its mass application, the crucial factors are a relatively low price and possibility of its efficient integration within the scope of a complex IT system of an enterprise.

The potential of RFID technology and the new solutions that have been created on this basis is enormous, and it substantially exceeds a simple record and readout of tags. More and more innovative RFID solutions aim at a full object identification with the accuracy of one unit in the whole supply chain and also the possibility of tag intelligent response to various kinds of user's questions concerning, e.g., the assembly, essential components for production line, storage conditions. What has a particular value for the users is a new class of RFID, i.e., autonomous, semi-passive RFID transponders, providing extended information on the object and its environment, which are powered by energy recovered from the environment. Thus, the quality of the new class of RFID technology constituting an example of eco-innovation can stimulate permanent improvement of enterprise competitiveness in the conditions of a turbulent environment. It can also facilitate further development of knowledge-based economy.

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