The Application of Automatic Identification Technologies by the Czech Post

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Abstract This article deals with the question of practical use of automatic identification technologies in postal sector, with special focus on using barcode technologies and radio frequency identification in Czech Post. After introductory section, which is aimed at description of current situation and analysis of crucial factors of choosing automatic identification technologies, there are subchapters discussing the theoretical base of both technologies, as well as their practical use in postal sector. In the part of practical application of both identification technologies is specified the basic structure of barcodes used by Czech Post and also the description of international project UNEX, which deals with the measurement of the quality aspects of selected postal products and services. Concluding part contains a brief outline of possible radio frequency identification technology application.

Keywords Automatic Identification, Barcode, Czech Post, Logistic Hub, Postal Operator, Postal Sector, Postal Service, Radio Frequency Technology

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1. Introduction

Application of modern mobile communication devices, electronic products and services, and their consequent utilization for substitution, addition, and possible improving of traditional postal services in the last two decades resulted in a marked acceleration, improving and upgrading the overall processing of postal, express and courier shipments. However, the existence of alternative forms of communication and transmission of data, have affected the postal operators also in a negative sense, particularly by decreasing the above mentioned use of traditional postal services by private users. Falling demand for provided postal services by the current user is at least partially compensated by the increase in demand from large companies that use postal services mainly due to the wide coverage of postal networks (compared to the still limited coverage of the Internet and electronic services), or because there is lack of suitable alternatives. For these reasons, postal operators are forced to continually invest in technology and support by them provided portfolio of services, with the aim to maintain, or continuously improve the quality of the postal services, and also their level of competitiveness on the postal market.

Requirements for the provision of adequate postal services by users are reflected in the need to improve the qualitative parameters (time, speed, reliability, availability, real time tracking) less quantitative parameters which influence the process of shipment delivery (number of processed items, amount of handling processes with the postal items, number of post offices, number of postmen, available car fleet, etc.). Conversely in an effort to fully satisfy user requirements, the postal operators must equally take into account the quantitative parameters of postal operation and related technological equipment, because the processing of large volumes of mail under predetermined conditions for the shortest delivery time and the lowest error rate would not be feasible without adequate automation and clear identification.

From a technological perspective, the above mentioned identification of postal items is in practice ensured by implementing the technology of automatic identification and data capture (AIDC, which means the Automatic Identification and Data Capture). Within the AIDC we distinguish several technologies, but not all of them are suitable for identification of the postal items, or their evolution and adaptation to the conditions of the postal sector are still in the testing phase, or only partial deployment. Specific deployment is ultimately dependent on several factors, requirements, properties, or limiting characteristics of each technology.

The main aim and intention of this paper is to briefly describe the automatic identification technologies used in the postal sector, namely the Czech post. There will be also

space for concise definition of the main criteria affecting operation and deployment of these technologies.

2. Main Determinants of the Choice of Automatic Identification Technology

In the present marked by the crisis, the *economic aspects* of development, implementation and operation are the decisive factors in the deployment of new technologies and systems. Each company should consider options, whether it pays to implement new technology, especially if there is an alternative that is indeed cheaper and more often used, but on the other hand, it does not provide such a wide range of application and possibilities for further development. Therefore, it is necessary to calculate not only with input costs associated with the establishment and introduction of new technologies, but also with operating costs in which are included the ongoing operating costs, maintenance costs, the cost of solving unpredictable circumstances, and also the cost of updating hardware or software.

In this situation there is possibility of outsourcing from specialist companies whose portfolio of services is oriented to the providing of overall operation and maintenance of particular technology, often from development, through testing, deployment, operation, maintenance, solving the emergency situations, updating or expansion by additional modules. This eliminates the need to operate their own departments, which should be in charge of all these tasks; the problem remains only the question of what appears to be economically more advantageous at the moment of choice. Last but not least, considering the economic aspects of implementing the new technology, it is also important to consider the extent or corporate level on which the planned technology is going to be deployed. It can be either an application of local character in one branch of the organization, deployment to multiple departments or global deployment affecting the whole network organization [12].

In a hypothetical ranking of the deciding factors, we can place at first place along with economic factors also a group of *technical aspects and rate of their performance*, that is, whether chosen technology meets requirements which we have stated to be performed. The fact, whether the application of the technology is appropriate we find by the comparison of selected factors not only in the experimental laboratory conditions, but also in the real operation, both in normal situation as well as in the increased load. The most important operational factors of the automatic identification technology used in the postal sector are:

- *The accuracy and reliability of measurement and identification* - it is primarily based on the users requirements for the accurate delivery of the required mailings, inserting of exact input data, or processing the data (for example, during manual data entry an error occurs on average with every 300th postal shipment, while when using the barcode technology number of errors is reduced to one in one million). The confidence factor plays an important role in

terms of maintenance when we consider whether there are any unexpected downtimes due to the technical failure or unreliability, or because of unreliability of the sensing methods used under certain conditions [4], [10].

- *The speed of sensing and identification* - the aim of the continuous development of automatic identification technologies in the postal sector, was and still is an effort to accelerate all processes related to the collection and distribution of mail, which would lead to shortening the time needed for the delivery of mail and thus to increasing the perceived quality from the perspective of customer. For the postal operators are particularly important speed of sensing and the associated parameter indicating the operational capacity of the technology; it is due to the large volume of mail handled and number of operation processed. In the postal and logistics services, we can define the work capacity of automatic identification technology according to the number of items scanned per unit of time (minute, hour, day), even if it is necessary to calculate with the human factor and the fact whether the concerned department is fully automated or not.

- *The error rate of sensing and identification* - error rate of sensing can be determined as the percentage of wrong scanned postal items / identifiers (barcodes, RFID tags, etc.) within the total number of scanned items. Causes of errors in reading are of different nature and origin, such as:
  - technical unreliability of sensing technologies, either on the sensor or on the carrier of the code
  - unsuitability of the environment in which the technology is used and its effect on signal transmission and readability
  - damage on the sensor or on the carrier of the code in such scale that will affect the readability (torn, dirty barcode, damaged RFID tag)
  - incompetence in handling with the scanning device or with the carrier of the code [4]

- *The flexibility and mobility* - they are not measurable quantities, such as accuracy, speed, capacity and error rate, but they belong to the important factors influencing the choice of appropriate technology for automatic identification. The term flexibility in this case means that the technology is multipurpose, simple to use, usable in extreme environments and conditions. Mobility is characterized by the independence of existing data, or energy networks, with the potential use of wireless data transmission (Wi-Fi, Bluetooth, satellite links, etc.), thus greatly expanding the available options for operational deployment of selected technologies.

- *The requirements on the working environment* - inadequate working conditions can have significantly negative influence to the physical principles and phenomena on which the selected AIDC technology is based, thus increasing the error rate, inaccuracy of sensing and measurement; it can restrict the devices flexibility and reduce overall suitability of using the device (creating

conflict phenomena by the signal propagation, weak signal transmission depending on the environment, a significant influence of environment on the technical depreciation of the equipment, etc.) [4].

- *The security* - the last, but equally important place among the selected factors has the safety of the technology that can be seen from two perspectives. In terms of safety the technology in relation to human health, there have not been demonstrated negative effects of automatic identification technology to the attendant staff. On the other hand, we can speak of the safety in terms of security of information and data held when the researchers try to find different approaches how to break the security of data and information and get access to them, for the purpose of deterioration, alteration or theft [11].

3. The Technologies of Automatic Identification Used in the Postal Sector

The most important automatic identification technologies used in the postal sector are the technology of barcodes and radio frequency identification technology (RFID, which means Radio Frequency Identification). The origins of both technologies can be found within the fifties of the 20th century, so these are not new technologies, modern are rather the ideas of its various uses in the postal, express and logistics services, as useful tools for fast and safe identification of the goods, packages or shipping units. From different reasons, including, for example, the relative simplicity, economic demands, sophistication of technology, general adaptability, etc., it is more common to use the barcodes rather than radio frequency identification [7].

In the following part of the paper we will discuss brief theoretical characteristics of these technologies, their principles of operation as well as practical use in the postal sector with a focus on the specific application within the Czech Post.

3.1. Barcode

The basic operating principle of barcodes is based on the physical properties of colours in relation to the incident light, which are able to reflect or absorb. Using the optical reflection and mutually contrasting colours (black and white, possibly each other high-contrast colour combinations) arranged according to a specific algorithm, we obtain a system of lines and spaces, which are responsible for accurately encoding of information, thus numeric or alphanumeric characters. Individual lines and spaces may vary in width and they represent the system of encrypted characters, and the encoding of information into the final version is done by a specific coding table relevant to the specific type of barcode [2]. In addition to a combination of bars and spaces, the barcode contains also a numerical combination that makes it easy identification in case of mechanical damage to some parts of the code, or malfunctioning of optical sensing device where you can insert appropriate numerical combination

manually. The length of numerical combination depends on the kind of code and consists of a prefix (numbering system or the international country code), manufacturer code (in the Czech Republic contractually assigned by *GS1 Czech Republic*), product code, which carries given code and check digit used to verify the correctness of the numeric string [1], [4]. In the following Figure.1 is shown an example of barcode Code 128 Set C.
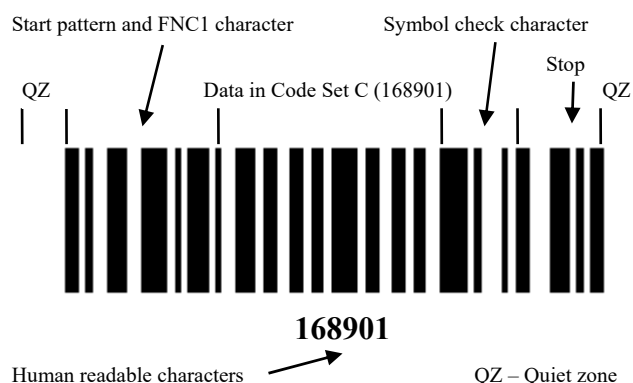

Figure 1. Example of barcode Code 128 Set C.

Nowadays, the use of barcodes is already so widespread that a normal user does not realize all the benefits that come with it. These include:

- the possibility of print in minimum cost
- cheap and reliable sensing
- high safety and effectiveness of data encoding
- international acceptance
- adaptability to use on different materials (carrier of the barcode)
- simplicity of operation and sensing [4], [10]

The technology of barcodes is not perfect and it results in considerable financial investment worldwide that are spent to the further development of barcodes, or to the research of alternative technologies of automatic identification. The main reasons of this fact are following negative aspects of using the barcodes:

- it is not possible to scan barcodes without direct visibility
- the data carriers have less damage tolerance (compared with RFID tag)
- relatively short lifespan
- smaller amount of data which can be stored in the barcode
- static character of the data (data cannot be changed or deleted and reinserted) [10]

The main reason for the further development of new solutions and barcode types is that possibilities offered by alternative technologies are not yet able to fully offset the benefits that accrue from the use of barcode technology.

3.2. The Application of Barcodes in the Postal Sector

For the labelling of postal shipments which are processed by the Czech Post, alphanumeric barcodes type Code 128 (see Figure 1), a fixed length of 13 characters coded, are standardly used. This is one-dimensional barcode with a

relatively high information density [4]. It includes 107 different symbols (103 data symbols, 3 start codes, 1 stop code) and three subsets, A, B and C, which are just different ways of interpreting the data encoded by the barcode. Using the subset A or B Start code you can encode the entire ASCII character set, including control codes. With a subset C Start code you encode high density numeric data. Barcodes Code 128 can be of variable length and they require a checksum.

This code is printed on the posting label (see Figure 2), and depending on the type of shipment, the labelling is done within the enterprise or at the place of submission, thereby facilitating the process of sorting and identification of consignments. All registered consignments are usually marked by barcode at the application site. Ordinary correspondence is marked with the assigned barcode within the automatic processing based on the postal zip code and the delivery location at logistic hub (SPU). There is not assigned an element of automatic identification within the process of manual sorting.

The barcodes have important role in the system Track & Trace service, allowing customers to track the real movement of shipments through the internet. The move of the shipment identified by unique posting number (barcode) can be monitored in real time, and the service can be used for domestic or international shipments (sales packages, mail packages, insured parcels, valuable letters, standard parcels and registered mail). In terms of relevance for the postal operator, the main task of the system Track & Trace is the establishment and maintenance of the registry information obtained from the data flow between collecting logistic hubs (information about all operations carried out with the consignment from the submission, through transport to delivery), integration of this registry with the system APOST and also with the operational databases (middleware). Track & Trace system is the basic element of technology for processing and recording consignments with barcode at post offices, logistic transport nodes and post offices of exchange [3], [8].
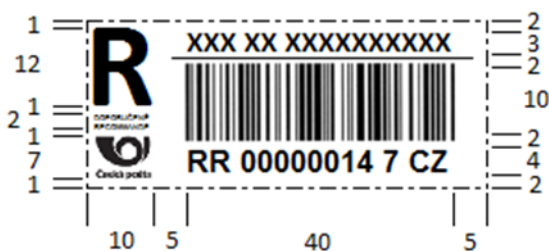

Figure 2. Technical structure of posting label used by Czech Post.

The barcode characters indicate the following information:

- *RR* - prefix for RR shipment
- *00000014* - serial number (range 1 to 99999999)
- *7* - check digit
- *CZ* - postfix (other postfixes for contractual sender: F, M, U, C - for the submitter has the barcode different structure)
- *XXX XX* - ZIP office of origin

- *XXXXXXXXX* - name of the office of origin [3]

3.3. Radio Frequency Identification

The basic principle of radio frequency identification technology is based on transmitting a signal through electromagnetic waves, their subsequent modulation and the use of physical properties of electromagnetic waves by the propagation in free space. The source of the primary signal is a device called a reader device (so-called RFID reader or reader) which comprises a transmitter / receiver circuit with the decoder and antenna. If necessary, the reader is in some cases also equipped with its own operating system providing basic software functionality. The receiver of the emitted signal is a device called transponder (the RFID tag), which is actually an electronic memory circuit containing a silicon chip and an antenna for receiving and transmitting the signal.

In addition to RFID readers and RFID tag, every radio frequency identification system contains a third equally important component part; that is the control software (middleware) which is designed to manage, filter and analyse data obtained from a scanned tag [9]. Last but not least, the middleware provides also process control, communication with individual readers and general data processing. Communication between the reader and the tag takes place at various frequencies. Depending on radio frequency used by sensing, we can identify three main groups of radio frequency systems:

- *LF (Low Frequency):*
  - range of frequencies 125 – 135 kHz
  - characterized by the short reading distance (to 0.5 meter) and has low speed of communication
  - it is particularly suitable for reading through the liquid and partly through the metal
- *HF (High Frequency):*
  - range of frequencies 13,56 MHz
  - distance reading is usually up to 1 meter, higher communication speed than at low frequency range
  - it leads to substantially shorter detection range when reading through the liquid, or when using the tag placed on a metal substrate
- *UHF (Ultra High Frequency):*
  - range of frequencies 860 – 960 MHz
  - reading distances are about 1-6 meters, achieves high communication speed
  - suitable for situations where is it necessary to scan information from objects moving high speed (e. g. toll gate)
  - cannot read through the liquid and scanning through metal is difficult
  - different range of frequency bands within continents [5]

The main advantages of RFID technology over barcode technology are much greater quantities of stored data, as well as the possibility of manipulation with the data (change, addition, deletion, update, etc.). In addition to the above mentioned benefits, the RFID technology has greater speed scanning and sensing range, the possibility of multiple sensing, greater resistance to mechanical damage, longer

life, the dynamic character of data held, programmability, and also eliminates the need for direct line of sight between the reader and the tag.

The disadvantages include the previously mentioned financial performance (cost per tag), less general prevalence of use in comparison with barcodes, or technical sophistication especially in terms of device compatibility, standards and protocols [5], [7], [12].

3.4. The Application of Radio Frequency Identification in the Postal Sector

The national postal operator Czech Post uses the RFID technology in the system of international performance measurement (quality) of postal operators - so called UNEX project. The system was initiated by the *International Postal Corporation* (IPC) and the main aim of this project is help the national postal operators, particularly in the area of monitoring and improving services (international letter-post items) provided to their customers. This project also has specialized coordinators, who are able to provide help to postal operators in their native language.

UNEX system is based on a network consisting of more than 4,500 volunteers in 43 participating countries, who are chosen by an independent organization *TNS Research International*. Volunteer participants have to, according to pre-established weekly schedule, send and receive "test letters", and subsequently they have to record into the central computer system the time period in which they received the letters. In this way, they can each year send and track over half a million international priority letter mail, thus providing a picture of actual geographical samples and physical characteristics of the transport process. The main emphasis is on quality aspects of mail delivery, a speed and reliability.

3.4.1. The Methodology of the UNEX System

The movement of the test letters is monitored by RFID technology. Each letter has a built-in RFID tag (carrier of the data), which enables to track where goods are situated, how fast they are delivered to a post office, where was the postal item processed. Data are sent through information systems to global IPC centre, where the system describes and analyses either progress or delays of test letter from the country of origin to the country of delivery. UNEX provides measures on both ends (the so-called end-to-end) international postal network (see Figure 3) [6].

Figure 3. The string "end-to-end" in the UNEX measurement system.

Quality measurement of postal services by UNEX system operates at three levels:
- it measures the performance between IPC member countries and cities in order to improve operating parameters of postal transport,
- it measures the performance in form of final payments (payment for postal item delivery from one postal operator to the other) connected with the qual-

ity of provided services,
- it provides data about the performance of cross-border postal streams, which are – based on postal directive of the European Union – required for annual evaluation of accumulated system efficiency.

Limits of particular quality indicators, which have to be met by postal operators participating in UNEX system, are set on basis of the revised Directive 97/67/EC of the European Parliament and of the Council on common rules for the development of the internal market of Community postal services and the improvement of quality of services. For speed indicator (D+3 period) the value is set to 85%, and for reliability indicator (D+5 period) the value is 97% of all international consignments.

Within the UNEX measurement, the average number of days required for delivery to the addressee is monitored as well. This number is indicated as D+n, where D (Day, sometimes also J as for Jour) refers to the day of the nearest collection from the time of sending or posting the consignment; therefore, for example, D+3 (J+3) means the number of days (n = 3) before final delivery to the addressee, including all phases of the consignment relocation: from collecting, sorting, national and international transport up to the actual delivery of the consignment. The method of calculating the transport period (D+n) for the date of the shipment is based on a five-day working week (from the point of view of postal operator), excluding Saturdays, Sundays and all national and regional holidays, during which the post office in the destination country is closed. In 2012, some countries involved in the UNEX system introduced delivering and processing of consignments on Saturdays, resulting in a slight change of the method of calculating the period of consignments transport. Methodology of administration and collection of the consignments can be illustrated by the following D+n performance matrix for a five-day (black) and six-day (red) working week (Figure 4).

MON	TUE	WED	THU	FRI	SAT	SUN	MON	TUE	WED	THU
D/D	D+1/D+1	D+2/D+2	D+3/D+3	D+4/D+4	-/D+5	-/-	D+5/D+6	D+6/D+7	D+7/D+8	D+8/D+9
	D/D	D+1/D+1	D+2/D+2	D+3/D+3	-/D+4	-/-	D+4/D+5	D+5/D+6	D+6/D+7	D+7/D+8
		D/D	D+1/D+1	D+2/D+2	-/D+3	-/-	D+3/D+4	D+4/D+5	D+5/D+6	D+6/D+7
			D/D	D+1/D+1	-/D+2	-/-	D+2/D+3	D+3/D+4	D+4/D+5	D+5/D+6
				D/D	-/D+1	-/-	D+1/D+2	D+2/D+3	D+3/D+4	D+4/D+5
					D/D	-/-	D+0/D+1	D+1/D+2	D+2/D+3	D+3/D+4
						D/D	D+0/D+0	D+1/D+1	D+2/D+2	D+3/D+3

Figure 4. D + n performance matrix.

Generally accepted rule is that a consignment posted on Saturday or Sunday in the five-day variant and on Sunday in the six-day variant of the calculation is considered to be posted on Monday. Consignments posted on a public holiday or any other non-working day is considered to be a consignment posted on the following collection day.

3.4.2. The Deployment of the RFID Technology by the Czech Post

The required prerequisite for participation in the project UNEX was the installation of RFID technology implemented in 2005 at selected post offices providing foreign postal services. It was at the post offices Prague 120 and Breslau 120 (see Figure 5, marked in green). The planned extension of the implementation of RFID technology started in 2012, namely the post offices Prague 022, Brno 02 and Plzen 02 (see Figure 5, marked in blue). While in 2005, installed RFID technologies at logistic hubs Prague 120 and Breslau 120 were used to sensing and capture of the arrival/departure of test letters with RFID tags, with the introduction of RFID technology in the other three branches Czech Post will get an overview about the catchment area for logistic hubs Prague 022, Brno 02 and Plzen 02. The expanding of the monitored area allows the Czech Post to obtain more detailed information regarding the operated area with the possibility of further improving the overall quality of the transportation process, processing of mail, as well as provided services. The information obtained by monitoring may also serve as background information for the future deployment of technology of radio frequency identification within major transportation network of the Czech Post. In economic terms it is an appropriate tool to estimate additional costs needed to completion the RFID technology in the rest of the transport nodes. Red marked postal nodes in Figure 5 graphically interpret the logistic transport nodes of Czech Post, which are good candidates for future completion with the RFID technology [3], [8].
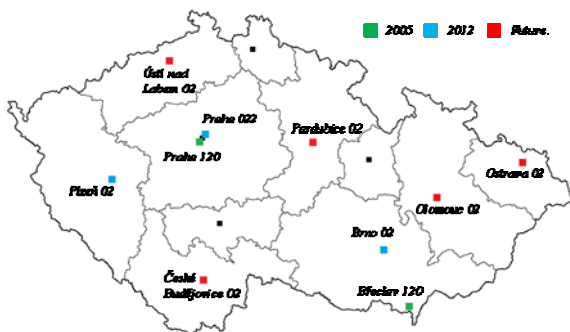

Figure 5. Graphical representation of the post offices of Czech Post, equipped with RFID technology.

With the complex deployment of radio frequency identification technology to track shipments can the Czech Post gain a competitive advantage over other postal operators, in particular by the increasing the efficiency of processes, refine the identification and registration of consignments, meeting the limits of transport deadlines, acceleration method of delivering items, to prevent of damage and loss of items. This information can be evaluated by each department management, thus they provide valuable knowledge about the functioning of the individual collecting transportation nodes, or when planning future development [12].

3.4.3. The Analysis of the Results of Czech Post in the UNEX System

The Czech Post, as the representative of the Czech Republic, participates in the international system of UNEX quality measurement since 2005, and it has always fulfilled the limits of each quality criteria, as we can see on Figure 6 (the performance of the Czech Post is marked blue).
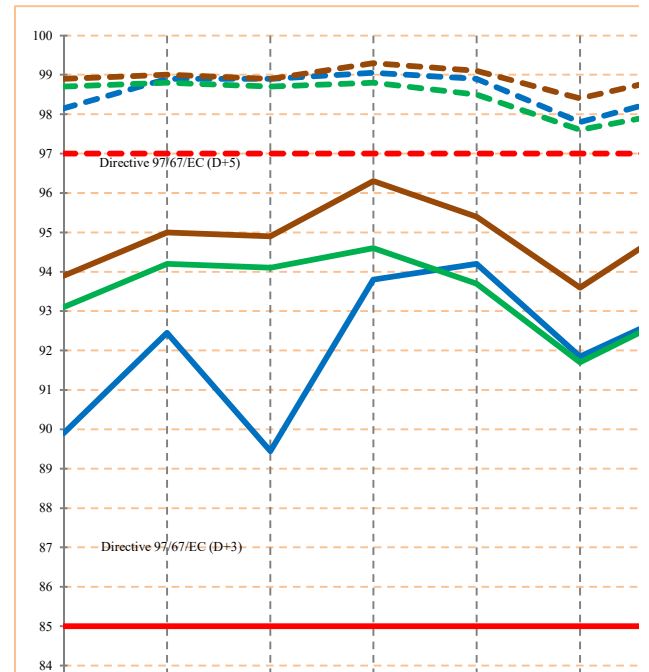

Figure 6. The comparison of measurements results by the UNEX system in the years 2005 - 2012.

Based on the analysis performed, we can conclude that the average results of reliability indicators (D+5) reflect total values of the extended UNEX29, or UNEX34/35 system (marked green), as well as the results of the original number of countries involved in the system, so called UNEX18 (marked brown); on the other hand, when talking about the speed indicator (D+3), we can observe significant deviations, especially in the results from the period of 2007 – 2009, and also from 2012. While the average results of the UNEX34/35 (93.1%, that is +0.1% compared to 2011 and +1.4% compared to 2010) and the UNEX18 (95.6%, that is +0.3% compared to 2011 and +2.0% compared to 2010) have an increasing tendency, so the average results of the Czech Post for the 2012 on the input and output declined by -0.85% compared to 2011, while the speed indicator increased by +1.2% between 2010 and 2011.

Despite this, there is still apparent high quality level of delivering by the Czech Post, especially when comparing specific values of annual results, where the results of the Czech Post were as follows: the speed indicator (D+3) reached the final average values 91.85% in 2010 (difference of +0.15% compared to UNEX34/35 and -1.75% compared to UNEX18), 93.5% in 2011 (+0.05% compared to UNEX34/35 and -2.25% compared to UNEX18) and 92.2% in 2012 (-0.9% compared to UNEX34/35 and -3.4% compared to UNEX18). Within the scope of the reliability indicator

(D+5), average final values were 97.8% in 2010 (difference of +0.2% compared to UNEX34/35 and -0.6% compared to UNEX18), 98.5% in 2011 (+0.4% compared to UN-EX34/35 and -0.5% compared to UNEX18) and 98.65% for 2012 (compared to UNEX34/35 +0.25% and -0.45% compared to UNEX18).

4. Conclusions

Nowadays barcodes play an essential role in the identification and registration of postal items. In view of the increase in the number of processed postal items, increasing quality requirements for provided postal services, as well as the need of establishing an effective system for records of transport units, there are assumptions that despite the constant technical development, the technology of barcode will not have sufficient functionality to ensure the future needs of the postal sector. It would be appropriate to use an alternative solution based on the radio frequency identification technology, which offers a greater range of options and features. In terms of global deployment, the situation is such that current financial and technical requirements rank this technology only to the position of laboratory scale technologies or partial tool utilized concurrently with the barcode technologies.

The experience gained by the research and experimental implementation in the conditions of the national postal operators constantly expand knowledge base and thus they create assumptions for further development and practical deployment of radio frequency identification technology in the mass scale. In the conditions of the Czech Post, it is mainly about involving in UNEX project which is focused on quality measurement in relation to the international transport of mail, as well as in retrofitting of the other postal transport hubs with radio frequency identification technologies. The results obtained by measuring with the technology of radio frequency identification provide the postal operators with valuable tools which allow them to find an appropriate solution for simplification and optimization of the processes of handling and transport of postal items.

As we could see in several past years, Czech Post is able to meet the requirements set by the Directive of the European Parliament and of the Council 97/67/EC. The trend and expanding utilization of RFID technology will continue to improve the quality of postal services, eliminate errors and bottlenecks in the processes of postal operations and they will progressively evaluate existing infrastructure not only in relation to international as well as domestic transportation of mail.

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