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THE IMPLEMENTATION OF THE RFID TECHNOLOGY INTO THE HOSPITAL LOGISTICS PROCESSES: A CASE STUDY

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Abstract
Companies are constantly striving to streamline logistics processes and the functioning of the logistics system as a whole. One of the tools may be automatic identification technology. The aim of the article is to propose the implementation of RFID technology for a selected logistical process within a particular hospital through a case study.

Keywords
automatic identification technology, RFID technology, logistic process

1 INTRODUCTION

Storage is a very important part of the logistics of almost every company, because stocks have a major impact on the satisfaction of customers' needs and wishes. Therefore, it is imperative to store, properly register and manage inventory status. Satisfaction of customer needs ensures profitability for ordinary companies, and in most cases occurs when the customer's needs are not met to his lose and exit into a competing company. However, this is not the case in the health care section to which is devoted this article. Here the dissatisfaction of customer needs may in the worst case cause death of the patient due to insufficient quantity of product or its inappropriate condition. It is therefore important that hospitals always have access to the necessary goods and materials, regardless of whether these goods are from their own warehouses, consignment warehouses or goods that are always delivered at the necessary time under the contract. The aim of the article is to propose the implementation of RFID technology for a selected logistical process within a particular hospital through a case study.

2 THEORETICAL BACKGROUND

Logistics activities are necessary to achieve logistics goals [1]. These activities are part of the supply chain and include:

- Customer Service – serves to promote customer satisfaction.

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- Demand planning – linking production planning and marketing forecasts.
- Inventory management – the objective is to find a compromise between the level of customer service and the cost of holding inventory.
- Logistics communication – is an essential activity for the interconnection and efficient operation of the system.
- Material handling – provides a transfer of material, stocks and finished goods.
- Order handling – receiving and handling orders, communicating with customers.
- Packaging – shall, inter alia trade and marketing function.
- Support services and spare parts – activities under the after-sales customer service.
- Determination of the place of production and storage – is a strategic decision that results in the cost of transporting raw materials and finished goods and also has a significant impact on customer service.
- Purchase – Supplier selection, negotiation of prices and delivery terms, etc.
- Handling of returned goods – a complex and costly process of returning goods from the customer due to his dissatisfaction or malfunction.
- Reverse logistics – deals with the removal and disposal of materials, which are formed during production, packaging and distribution.
- Transportation and transport – own material and goods movement.
- Storage – storage of goods and material for later use. [1]

2.1 Technology of automatic identification – barcodes

Barcodes are the most useful and still cheapest way and therefore are the most widely used for labeling passive elements for automatic identification on the optical principle. Optical sensing is based on the principle of the different properties of dark and light surfaces when irradiated by optical or laser beam. There are about 200 different barcodes that are differ track record and its length coding method used when recording, recording density or way to secure the accuracy of the data. [2]

The most commonly used bar codes today are:

- One-dimensional – these include EAN (European Article Number) and UPC (Universal Product Code). The EAN-13 is the best-known barcode in the business network.
  1D code typically encodes a numeric or alphanumeric string that is the key to identifying the tagged object in an external database.
- Two-dimensional – these include PDF 417 or DataMatrix. 2D codes are less limited by the data capacity they can contain, and therefore usually contain all the necessary information about the tagged item. Both of these types of codes are able to hold up to 2 KB of standard text or raw data (RAW). The DataMatrix consists of dark and light square or rectangular cells. [2-5]

2.2 Technology of automatic identification – radiofrequency identification (RFID technology)

RFID technology is a non-contact automatic identification system for transmitting and storing data using electromagnetic waves. The RFID system consists of a transponder (antenna and chip with data) and a reader. Thanks to the so-called "anti-collision technology," according to the authors, it is possible to read a larger number of transponders at a time, because each of the chips, according to ISO 15693, has its worldwide unique number. [2,6] The advantage of RFID is the ability to read multiple tags at the same time that tags may not be readily visible when read, or the option of additionally editing or adding data [7,8].

The RFID tag is a carrier of information in RFID systems. RFID tags can also be referred to as transponders, this meaning being created by merging the English words transmit

and response. The basic function of each RFID tag is to store information in the internal memory and to provide the stored RFID data when needed. RFID tags are divided according to the production technology, the type of memory, the power source and the frequency band in which they work. [9]

RFID tags exist according to power source division into two types:

- Active – these chips are equipped with a battery that lasts about 5 years, thanks to which they can transmit the data contained within them. The battery increases the cost of the tag and causes it to become unusable in worse heat and climatic conditions. These chips use very high frequencies and are capable of responding up to 100 meters.
- Passive – for these chips is the energy source reader. Passive tags with a frequency of 125 kHz have a range of up to 2 meters; with higher frequency chips (up to 2.4 GHz) the range is considerably higher. [2]

The tags consist of the antenna, which is the largest part of the tag and thus directly affects its size, and the microchip, which can be less than 1 mm today. It can be said that with the higher transmission frequency used, it is possible to use a smaller antenna. Different tags have different designs depending on their future use. According to the author, in some cases, maximum durability (against temperatures, humidity, chemical or physical processes) is required, and at other times, the lowest possible dimensions, weight, or cost. [9,10]

The tag may be encapsulated in a different way into a PVC card of credit card size or glass tube that fits into a case suitable for subdermal application (used to mark domestic animals, today mostly dogs). Another possible tag application is sticking to the label surface, but it can also be specially encapsulated according to customer's specific wishes. There are, for example, heat-resistant labels that can withstand temperatures from -40°C to +300°C. [9]

There are three basic tag types from the point of view on storing, reading, and writing information:

- RO (Read-Only) tags – this type of tag is already programmed during production, which can not be changed later. Information from the RO tag can only be readed and their memory size is from 40 to 512 bits.
- WORM (Write Once Read Many) tags – these tags are not programmed as RO tags at the time of production but by the seller or vendor. This type of tag is read-only (some types can be overwritten but not guaranteed).
- RW tags (Read Write) – this type of tag has a highly configurable addressable memory (16 Kb to 2 Mb). The RW tag can be overwritten up to a thousand times by any end customer with the appropriate equipment. [9,10]

Combined RO and RWs – for example, a ROM portion of the memory may indicate a pallet and be invariable throughout the service life while the RW memory can be programmed according to the pallet content.

Middleware is software or specialized hardware used to manage, filter, and analyze data from tags that are loaded with an RFID reader. The author also states that the middleware provides communication with individual readers and initially processes the acquired data. The basic functions of the middleware:

- Communication with several readers from different manufacturers and with different communication protocols.
- Filtering data obtained.
- Storing results in the database.
- Providing acquired data via the specified interface of other applications. [9,10]

The RFID reader connects the RFID tag with the control computer and has several basic functions:

- Power supply for passive tags.

- Read the data written on the RFID tag.
- Inserting data into tags (for RW tags).
- Transferring data from the control computer.
- Basic data filtering or control of integrated I / O circuits. [9,11]

There are two basic types of readers:

- Stationary – This type of reader is usually non-transferable (fixed) and is attached at the warehouse entry or at the start of the production line.
- Mobile – These readers are usually portable and have no cable. There are also hybrid readers that can read both bar codes and RFID tags. [9,11]

3 CASE STUDY

The article is dedicated mainly to the storage of operable material and goods associated with the operation of operating theaters and adjacent spaces. The case study is the method of the qualitative research based on the study of one or a small amount of situations for application of the findings for the similar cases [12].

3.1 Current status

There are four main warehouses in the operating halls:

- The warehouse of sterile containers contains material that is ready for actual use in the halls. The stock has dimensions of approximately 3.5 x 5.0 meters. There are various instruments (pliers, peans, scalpels, scissors, etc.), nails and other goods needed during operations. All goods stored in this warehouse are placed in sterile containers (about 50 x 30 x 15 centimeters). Part of the stored items is here within the consignment and the rest is already purchased
- Bone warehouse contains, as its name implies bone implants. There are also non-sterile instruments that are needed for specific operations and, for example, wrinkle to bone surgery. The aforementioned bone surgery instruments are not part of a sterile container store because frequent sterilization of some of them may reduce their lifetime or functionality. Therefore, given their occasional use only, it is unnecessary to be kept sterile in the long term. The stock has dimensions of approximately 5 x 4 meters.
- Warehouse of sterile material includes mainly drains and wrinkle material. Its dimensions are approximately 4 x 4 meters. Things are stored here, including packaging from the manufacturer, and are intended for direct consumption at any moment or left in the hall for later use.
- A non-sterile warehouse is also called a solution warehouse, but this is not entirely accurate, there are also stored medicines, non-sterile caps, wrinkles and bandages. Its dimensions are approximately 5 x 4 meters. Things are stored here, including packaging from the manufacturer, and are intended for direct consumption at any moment or left in the hall for later use [13].

In these 4 warehouses there is usually no loss of goods (theft). If there is an irregularity, it is mostly due to the failure to sign up for the goods during the operation. Near to operating theaters of the Chrudim Hospital, joint-stock company there is also a warehouse of drugstores and foodstuffs, which contain, for example, cleaning products or syrups. In this warehouse, it is not entirely possible to see who has taken the goods and that is why there are losses that are very difficult to quantify.

The weaknesses include poor security in the warehouse of drugs and food, which leads to theft, which has financial losses. Estimation of damage caused by thefts in warehouses is, according to the competent person, 30 000 CZK per year.

In the analysis of the current labeling and identification system there have been discovered weaknesses that are related to the technological backwardness of the current system. These weaknesses are: high time-consuming manual code depictions and personnel costs associated with it, unclear informations on labels, possible human error factor, inability to track inventory at the current time.

The weaknesses are directly linked to threats in the form of automated systems that bring reduction of time and financial costs, a reduction in error rates and the number of staff required to carry out the required agenda. Another threat is litigation with customers who have suffered damage due to human error.

3.2 The proposal modernizing labeling and identification using RFID

A large number of studies recommend the implementation of RFID technology into hospital logistics processes [14-17]. The introduction of an RFID tagging system should ultimately contribute to the elimination of the technological backwardness of the current labeling and identification system that is causing:

- Higher time-consumtion associated to the manual code depiction when depreciating used goods and subsequently ordering them (causing high personnel costs).
- Unclear informations on labels.
- Fault due to human factor.

Inability to track inventory at the current time, which is problematic due to the need to perform inventories, data expiry checks and the impossibility to record the number of instrument use cycles and the consequent worsening of their condition:

- Wrong anti-theft protection in some areas.
- Inventory management difficulties.

The proposal consists of the creation of a comprehensive system of labeling and registration of goods and materials in the premises of the Chrudim Hospital, joint-stock company using RFID technology.

The number stored in the RFID tag would, as with the 2D codes currently being used by some manufacturers, contain unique information for each item. Thanks to this and the resulting automation, it should be a complete refinement and acceleration of the entire system (inventory, ordering and expiry data control).

The advantage of placing a tool tag is to monitor the number of sterilization cycles and their use in operations. This information could be used to avoid situations when too worn tool comes to the operating theater where is stated tool malfunctioning (needle knife does not cut, needle falls out of needle holder, etc.). Doctors or nurses can, based on their experience, set an individual number of cycles for each tool that can be performed on a particular tool without losing properties, and then the tools can be shipped to the supplier to refurbishment.

In the case of RFID-tagging also in the warehouse of drug and food supplies, this measure could greatly limit the theft from these premises because each worker should have his own RFID chip. In the case that only goods without the identification chip were carried out, an alarm would not be triggered, but a CCTV record (Closed Circuit Television) of the warehouse from the time at which it happened could identify the offender. It is to be expected that the number of thefts will be reduced dramatically, because there are thefts of goods worth the tens of crowns that people carry out because they know that the warehouse is not monitored or properly registered and will therefore not be captured.

Another inherent advantage, apart from those already mentioned, would be the possibility of checking the LOT number on the body substitution already used, for example, if is done RFID

markup of operable material, than would be sufficient to attach the reader to the foot of the patient and immediately identify the production batch of the body substitute used and possibly also used nails, etc. This function would be particularly beneficial if, for example, a faulty series was produced, and thus a need for rapid and safe verification of the patients received implants of a faulty batch.

3.3 Technical implementation of the proposal

In this part of the article are facts related to current developments and state-of-the-art trends are still often unused in medicine. Of course, the technical design varies considerably according to the goods to which should be tag attached, therefore will be division to the distribution of the goods as instrumentation, devices, goods packed in a box (medication, etc.), operable material (substitutes, nails, etc.) and absorbent material (tampons, abdominal masks, etc.). [13]

Instruments are today marked with 2D codes by better suppliers, which are used only for a few years to mark this type of goods. However, development has to go forward, and therefore, companies are constantly working on the development of a new, modern generation of chips with resistance to sterilization and their ability to connect with instrumentation. Generally speaking, no medical company dares to put into operation a test series of anything that did not tested beyond the normal conditions.

Three latest designs for RFID chip-to-instrument holding systems designed for medical equipment labeling:

- Putting into the resin mixture directly on the surface of the tool, as shown in Figure 1. For this type of storage, strength tests are still underway, where the basic problem is chemical sterilization and generally the number of sterilization cycles. Chemical sterilization is carried out with a hydrogen peroxide bath, which, due to its purpose, has a strong destructive effect on the resin mixture. Nowadays, chemical sterilization of tools is often not carried out, and only "thermal sterilization" takes place, during which temperatures reach for the resin less detrimental 134 ° C. The problem still makes the number of sterilization cycles, taking into account the durability of tools, which can be many decades, and so hundreds, maybe even more, sterilization cycles are carried out on some tools. Apart from the effects of sterilization, it is also necessary to take into account the mechanical shocks between the various tools. The simulation of these conditions and testing are time consuming and legislative very demanding.

Fig. 1 Putting RFID chip into the resin mixture directly on the surface of the tool [18]

- Create a hole in the tool and insert a tag as shown in Figure 2. This solution appears to be most appropriate to ensure compatibility of old tools with the new system. However, there are still problems with the chip itself (durability, memory and range), and it cannot be forgotten that such structural design is not possible (with regard to strength and other physical properties) for all types of instrumentation.

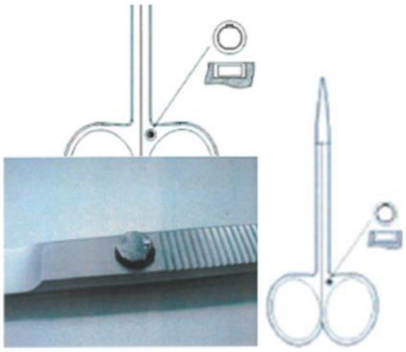

Fig. 2 Putting RFID chip into the hole in the tool [18]

- Create a separate case with a tag that is attached to the tool, as shown in Figure 3. This solution appears to be the best for new tools. In the case of pean, it is a ceramic tag with a frequency of 13.56 MHz (high frequency), a thickness of 2 mm and a diameter of 6 mm. This system is theoretically already ready for practice. The problem with this tag storage is that it would have to buy completely new instrumentation, which is clearly financially unbearable. The second problem is the reading frequency of the used tag, because UHF (ultra high frequency) tag cannot be used here because of its interference. This tag, due to its location in a metal tool and shielding the human body when inserted to a patient, would not read the RFID antenna in the door frames. The same problem also occurs with absorbent material, whose subchapter provides a technical solution to this problem. [13]

Fig. 3 Putting RFID chip into the separate case that is attached to the tool [18]

Devices are, in general, bigger things and with today's technology, is no problem to connect the standard RFID tag with the UHF frequency, which would automatically record their movement when passing through the RFID antennas in the door frames. For the purpose of device labeling, a test set of RFID tags would potentially be purchased and a suitable tag would be selected for that device.

Goods packed in boxes could be marked similarly, as it is already on a large number of products in retail chains (tag standard affixed to the bottom of the bottle with alcohol) or could be used so called smart labels (conventional labels, which include RFID tag). These tags would work on the UHF, and therefore would automatically record their movement when passing through the RFID antennas in the door frames. Operable material cannot be labeled with RFID in today's conditions for several reasons, which are listed in the subchapter evaluating the feasibility of this proposal.

Absorbent materials used during operations (gauze swabs, abdominal masks) are subject of rapid development of marking using miniature RFID chips, similar to instrumentation. The advanced company in this field is the American company Medline Industries. However, this solution is still not commercially available. Available information suggests that these tags will have a low reading distance and therefore will not be good enough to deal with RFID antennas in the door frames after operation, but it will be necessary after every major operation with the suspicion that some absorbent material may remain in the patient, to check patients body by RFID reader. Records in warehouses and during picking will be the same as for other goods packed in boxes that will be marked with a UHF tag.

Labeling of workers could be based on tags that the worker always has with him. However, these should not be not classic tags in the form of keyholes that are used in other enterprises for attendance systems because they are usually at 13.56 MHz and therefore they need to be closer or physically connected to the reader. Zebra offers RFID cards that run on UHF and if these are used, they automatically record employee movement when passing through RFID antennas in door frames. Thanks to automatic staff records, it would always be clear which employee in the warehouse took some goods at the specific time or putted it there. These cards are white, which allows them to print basic employee data and have a similar size as the payment card, which is convenient for inserting into the wallet. From a physician's point of view, the card is more advantageous because he does not always wear keys on which a pendant can hang. From the point of view of management, the card is more advantageous because it can be printed on a photo for identification purposes, and the card is also cheaper than a pendant.

Tag Identification and Information inserting System in Chrudim Hospital, joint-stock company was created on the basis of cooperation with Codeware Inc. As already mentioned, in the premises of the Chrudim Hospital, joint-stock company there are 4 warehouses and 1 adjacent warehouse. In Chrudim Hospital, joint-stock company there is 7 operating theaters. In total, there are 12 rooms for which registration of the goods is required. After selecting a suitable solution, a system consisted of a virtual entry and exit gate for each room was created. Each gate is made of 2 antennas to ensure accuracy. Due to the fact that these 4 antennas will be located on both sides of the door frames, a pair of information will be generated to determine whether the goods were placed in or out of the warehouse. For this solution, Motorola's broadband, one-port RFID antenna was selected. Specifically, the AN480 with IP 54 standard coverage and 2 W transmitting power, which ensures safe coverage of the space by the signal. This antenna is used to read UHF tags. [13]

Antennas would be connected to a UHF RFID reader with four ports. The advantage of a 4-port reader is the ability to connect all four antennas at one point, which, due to the relatively small financial gap between the two-port and the four-port antenna, is not only space saving, but also financial saving. For this purpose, Motorola readers have been selected, specifically the FX7500-4, this, thanks to the built-in USB port, can be easily connected to the whole system via Bluetooth, WiFi or cable.

For upload of informations, Deister UDL5 could be used, with short range and high write speed. The short range is advantageous because there is no risk of accidental rewriting of the remote tags, which could occur during writing over an RFID terminal and a large antenna. Deister UDL5 is both readable and writeable at the same time, and can be connected to any USB device without the need to install the software before. This reader could be used at the central sterilization center of Chrudim Hospital, joint-stock company to write a new expiry date for the instruments and devices. [13]

To check the patients body after bleeding operations (if something was not forgotten in the patient's body), 2 CipherLab CP-9200 mobile readers would be purchased. These readers can work with the whole system via Bluetooth, allowing all information to be handled by the central computer in real-time. These readers are used to read tags at high frequencies (13.56 MHz),

and therefore serve only to locate and register instrumentation and absorbent materials, which are marked by chips at high frequency.

4 CONCLUSION

Logistics processes and activities are at the center of business optimization. Correctly set logistics processes can lead to lower business costs. Logistics processes in hospitals are, of course, very specific. Incorrectly set logistics processes and resulting consequences can lead to patient death. That is why it is very important to pay close attention to this area of logistics.

The aim of the article was to propose the implementation of RFID technology for a selected logistical process within a particular hospital through a case study. In the analysis of the current labeling and identification system, there have been discovered weaknesses that are related to the technological backwardness of the current system. These weaknesses were: high time-consuming manual code depictions and personnel costs associated with it, unclear informations on labels, possible human error factor, inability to track inventory at the current time. The use of RFID technology (including the technical implementation of the proposal) has been proposed under the third chapter to address weaknesses resulting from the analysis.

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Bibliography

[1] LAMBERT, D., STOCK, J., ELLRAM, L. *Logistika*. Praha: Computer Press, 2000. ISBN 80-7226-221-1.

[2] SIXTA, J., MAČÁT, V. *Logistika teorie a praxe*. Brno: CP Books, 2005. ISBN 80-251-0573-3.

[3] *KODYS: Čárový kód* [online]. KODYS, 2009a [Cit. 24. června 2018]. URL: <http://www.kodys.cz/carovy-kod.html>.

[4] *KODYS: EAN 13 a EAN 8* [online]. KODYS, 2009b [Cit. 26. června 2018]. URL: <http://www.kodys.cz/carovy-kod/ean-13-a-ean-8.html>.

[5] *KODYS: DataMatrix* [online]. KODYS, 2009c [Cit. 27. června 2018]. URL: <http://www.kodys.cz/carovy-kod/datamatrix.html>.

[6] HUNT, V. D., PUGLIA, A., PUGLIA, M. *RFID: A guide to radiofrequency identification*. New Jersey: John Wiley & Sons, 2006. ISBN 978-0-470-10764-5.

[7] *KODYS: RFID* [online]. KODYS, 2009d [Cit. 29. června 2018]. URL: <http://www.kodys.cz/rfid.html>.

[8] FINKENZELLER, K. *RFID Handbook: Fundamentals and Applications in Contactless Smart Cards, Radio Frequency Identification and near-Field Communication*. Chichester: John Wiley & Sons Publishing, 2010. ISBN 978-0-470-69506-7.

[9] *RFID Laboratory* [online]. RFID Laboratory, 2018 [Cit. 10. července 2018]. URL: <http://rfid.vsb.cz/export/sites/rfid/cs/informace/RFID_pro_Logistickou_akademii.pdf>.

[10] SWEENEY, P. J. *RFID for dummies*. Hoboken: Wiley Publishing, 2005. ISBN 978-0-7645-7910-3.

[11] ROUSSOS, G. *Networked RFID Systems, Software and Services*. London: Springer-Verlag, 2008. ISBN 978-1-84800-152-7.

[12] NIELSEN, L. B., MITCHELL, F., NØRREKLIT, H. Management accounting and decision making: Two case studies of outsourcing. In *Accounting Forum*. Čís. 1 (2015), s. 64–82. ISSN 0155-9982.
[13] POLÁK, M. *Skladování a související logistické činnosti v Chrudimské nemocnici, a.s.* Pardubice: Univerzita Pardubice, diplomová práce, 2017.
[14] BOLIĆ, M., SIMPLOT-RYL, D., STOJMENOVIĆ, I. *RFID systems: research trends and challenges*. Chichester: John Wiley & Sons, 2010. ISBN 978-0-470-74602-8.
[15] OLIVEIRA, V., FONTGALLAND, G., RODRIGUES, R., SILVEIRA, T., MELO, C., FONTGALLAND, I. Design, Simulation and Fabrication of Low Cost UHF RFID Reader Antenna for Hospital Applications. In *11th German Microwave Conference (GeMiC)*. IEEE, 2018. S. 36–39. ISBN 978-3-9812668-8-7.
[16] LIU, Y., CHENG, B. H., ZHAO, W. A management system based on RFID technology for valuable instruments in hospitals. In *Basic & Clinical Pharmacology & Toxicology*. Vol. 121, No. 5, November 2017, s. 15–15. ISSN 1742-7835.
[17] MARTINEZ PEREZ, M., VAZQUEZ GONZALEZ, G., DAFONTE, C. Safety and Traceability in Patient Healthcare through the Integration of RFID Technology for Intravenous Mixtures in the Prescription-Validation-Elaboration-Dispensation-Administration Circuit to Day Hospital Patients. In *Sensors*. Vol. 16, No. 8, August 2016, s. 1–23. ISSN 1424-8220.
[18] *MEDIN* [online]. MEDIN, 2017 [Cit. 24. dubna 2017]. URL: <https://www.medin.cz/>.