RFID TECHNOLOGY DEPLOYMENT IN THE PRODUCTION LOGISTICS OF BUSES

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Abstract

Paper deals with an issues of tracking a bus movement in production process of the Iveco Czech Republic, a. s. The main purpose of deploying Radio Frequency Identification (RFID) technology is to reduce the impact of human error rate, eliminate manual work of employees when reading barcodes and ensure the accuracy of recording the movement of buses in a paint shop. In case of implementation of tracking technology, it is necessary to meet the requirements of processes related to the issues of bus movements, other production processes and operations or material flow management that remains unchanged. To address the problem, both experimental testing of RFID technology in a specialized laboratory of automatic identification and on-site testing was carried out before the implementation. The proposed options were solved in the context of case study which indicated best option of the RFID technology introduction which improves the processes thanks to accurate information concerning positions and statuses of buses. The aim of the work and subsequently the paper is to address application of automatic identification technology in production process of buses by significant European producer of road vehicles.

Key words: automatic identification technologies, production process, radio frequency identification technology

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Introduction

In recent years, automatic identification of components or products has been increasingly deployed in larger companies with logistics or production processes. Although automatic identification technologies are generally associated with the sale of products or the storage of materials, they can also be usefully applied, for instance, in the management of logistic processes associated with larger objects, such as buses in this case study. Automatic identification technologies (barcode technology, RFID) have important role in various branches of logistics with aim to reduce the impact of human error rate, eliminate manual work of employees, to streamline logistic processes etc. In this paper the case study is a practical example of innovative management: best practices.

1 Theoretical Background

Radio Frequency Identification (RFID) technology works on the principle of object identification using electromagnetic waves on the radio frequency. Unlike barcode, it does not require direct visibility of the identified object, it allows the identification of multiple objects at a time and at greater distance. During identification, communication between the antenna, the reader and RFID tag occurs via radio waves. Information can be written, read or changed in the tag, or the information can also be deleted (depending on the type of RFID tag) (GS 1 Czech Republic, 2016).

Nowadays RFID technology has been widely used in many applications, especially in companies (Kwon et al., 2014). RFID applications are emerging as key components in object tracking and supply chain management systems (Masciari, 2007). RFID technology could improve the potential advantages of supply chain management through reduction of inventory losses, increase of the efficiency and speed of processes and improvement of information accuracy (Sarac et al., 2010). RFID decreases labour costs by making production processes more automated and more efficient (Denuwara et al., 2019). Wang (2014) and Ding, Jiang, & Su (2018) studied RFID-based real-time monitoring systems that made the production process transparent, and material flow and information flow synchronized. Costa et al. (2017) also studied improvement of internal logistics visibility using RFID at an electronics company of the automotive sector. Their aim was to propose a prototype using RFID technology to track and trace (monitoring) materials at selected company. With RFID, it is possible to get the real-time material consumption information in order to provide frequent, smaller batch, and active replenishment service for assembly lines to reduce the pressure on work-in-process buffers (Zheng et al., 2020). RFID enables visibility and traceability of production processes and allows better material management with aim logistic costs (Hardgrave et al., 2013). RFID as one of the key Internet of Things technologies, has been used to collect real-time production data to support the manufacturing decision-making in factories (Feng et al., 2020).

Case study as a method to be used as and when appropriate, depending on the problem under investigation (Gomm et al., 2000). Aim of case study research should be to capture case in its uniqueness, rather than to use them as a basis for wider generalization or for theoretical inference of some kind (Gomm et al., 2000).

2 Analysis of processes in the IVECO bus paint shop

At present, production plant IVECO in Vysoké Mýto produces 19 – 20 buses every day. The paint shop enables more than 900 basic variants of bus painting. Unicolour, e. g. white buses, pass through the paint shop in shorter time than multicoloured buses. The length of the chassis, the type of body and many other influences have also impact on the total time of passing through the paint shop. The movements of the buses in the paint shop are not linear, as it is in case of plants producing smaller road vehicles (cars), but the buses move in space in different horizontal and even vertical directions. Except from mentioned reasons, the issue of indication and position monitoring of buses is even more complicated due to the fact that from the previous workshop (welding shop) the buses are not transferred to the paint shop in the same order in which they leave from the paint shop to the assembly line. For these reasons, it is not possible to effectively monitor the location of buses in the paint shop without the use of modern tracking technologies, respectively automatic identification, in addition to the ever-increasing volume of production.

The paint shop has a box layout of workplaces. At the first workplace, the skeletons are transferred with two cranes to special carriages (skids), which are moved along roller tracks to the pretreatment process and the cataphoresis process. Subsequently, the skeletons are transferred to bogies designed for movements in the paint shop. The bogies are guided by rails. The movement in the axis of the tracks is conducted by manually driven towing vehicles (tractors). Transverse movements between workplaces is catered by traversers. The skeleton on bogies moves on the traverser and it moves on its own track (channel). The paint shop has three channels for a total of four traversers. Two traversers are in one main channel and in each of two side channels is one traverser. These channels divide the paint shop into four parts. In some cases, a skeleton moves directly opposite the previous workplace, so the time necessary for movement is short, in other cases a skeleton moves across the entire paint shop by using more traversers and passes through buffers or through another workplaces. Some skeletons enter the workplace through the same gate as when leaving the workplace, while others pass through the workplace of the same colour in the same direction. The skeletons or subsequently buses are moved among box workplaces by traverser operators.

Technology plan controls the sequence of individual processes. For reliable running of processes, it is necessary to harmonize the flows, resp. supplies of resources (skeletons from the welding shop, parts from the process of gluing components, paints and other chemical material, energy and parts for machines) and personnel for both production and maintenance of machines. Management staff must ensure that all resources are ready for the production of buses in a timely manner and in the required quantities.

An appropriate data must be available to control the processes in the paint shop. The data is used by both management and individual workers and is used to control the sequence of skeletons painting in order to minimize time losses. For effective movement control of the buses in the paint shop, the following data is necessary: bus number, technical documentation, painting pattern, history of processed buses at the workplace, details of the bus movements in the paint shop or additional notes written by employees.

The bar code technology was used to monitor the movements of skeletons in the paint shop. The individual workplaces were precisely defined and marked with barcodes. These codes were placed in front of each workplace, including buffers. A barcode which was placed in the bus paper card, was assigned to each bus identifiable by vehicle identification number (VIN). The assignment was conducted at the previous workshop (welding shop). Barcodes, for marking buses, were generated from Excel files, which contained information on painting requirements. The paint shop used a software program that recorded data on the reading of individual barcodes scanned by traverser operators assigned the data of individual workplaces to individual buses. Four handheld readers located on the traversers were used to read the data.

Operators were for the correct and timely manner transfers of finished skeletons among boxes specially trained. These workers are even in these days the only ones to move the skeletons and to read the barcodes of the workplaces and the moved skeletons. The data is loaded automatically into the paint shop information system.

The system for skeleton/bus tracking in the paint shop based on bar code technology had several advantages. One of them was the availability of information about the status and location of the bus. This information was partly used for production management at the previous (welding shop), subsequent workplaces (assembly plant) and internal logistics department, supplying paints, luggage floors and small plastic parts. Another advantage was the availability of information through the company system for the management of the plant on the course of production (duration of operations on each workplace, total duration times, dwell times). The last advantage was the low acquisition costs of the barcode tracking system and its simplicity, which enabled a quick deployment into operation.

Disadvantages included reading every barcodes by traverser operators, which meant that not every bus was always read in timely manner and in every workplace, especially due to omissions. Therefore, the extra operator who physically checked the actual location of the buses according to VIN codes and subsequently corrected the data in the system, was also used.

Sometimes, it was not possible to easily control the previous and subsequent production processes, due to errors in paint shop tracking system. The last disadvantage was the printing of barcodes and insertion into the paper bus cards in a daily manner, which with a daily production of 20 buses meant a significant consumption of office supplies.

3 Options of RFID based tracking system deployment

The fundamental limits for the deployment of RFID technology are the physical dimensions and properties of the paint shop workplace and at the same time the limiting properties of the RFID technology itself. The following RFID antenna placement options were considered. For each proposed option has been made case study including testing scenarios.

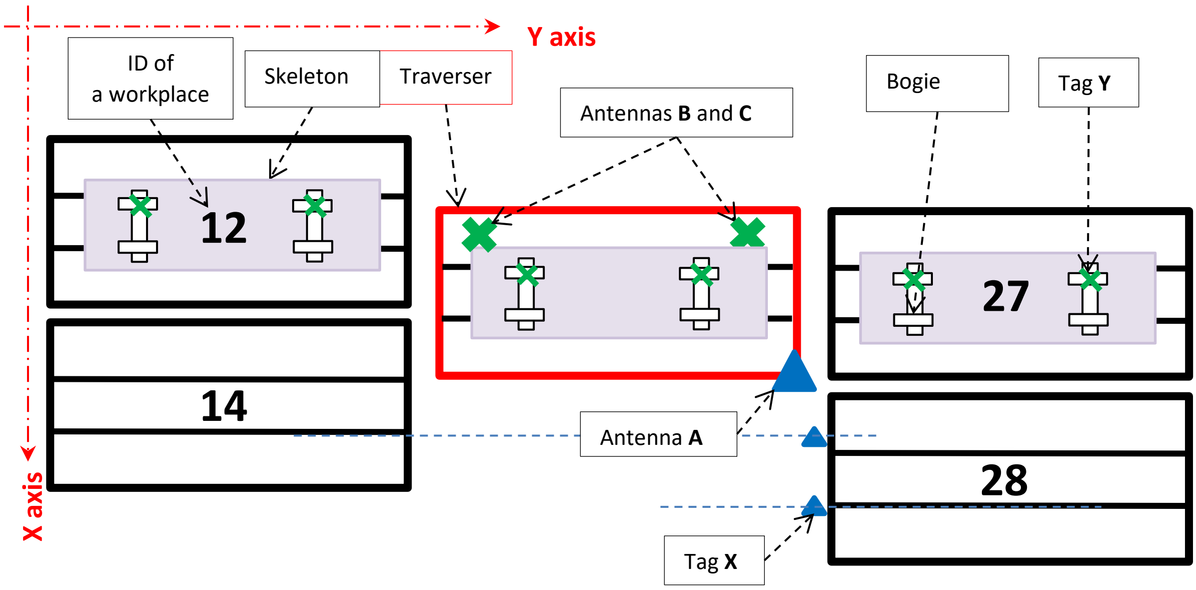
- Hanging RFID antennas under the ceiling of the paint shop.
- Equipment of each workplace with RFID antennas.
- Equipment of each traverser with RFID antennas.

The first option consists in the application of the "umbrella effect", as the antennas would be hung under the ceiling of the paint shop. The option has been thoroughly researched and the main decisive factor was the number of antennas deployed in the paint shop, placement and calibration of them. A network consisting of 30 antennas would have to be set up at a height of 6 meters. For the identification of the bus skeletons would be used up to 100 pieces of tags and one main static RFID reader. The antennas are able to read tags at a distance of about 20m, with a resolution of tens centimetres. The accuracy or ability to accurately determine the position of a tag placed on a bus decrease with increasing distance of an antenna from a tag. The tracking system would not be able to detect movements of tags in the paint shop without adjustment consisting in shielding RFID waves and calibrating the antennas. It is not possible to put a tag on the roof of a bus due to both subsequent painting actions and the difficulty access on the bus roof. Any other place in the lower part of the bus does not allow a tag to be read due to a bus chassis behaves as a cage and prevents of passing waves through. The option was inappropriate in order to characteristics described above.

The second option consists in reading a tag placed on auxiliary bogies used to move buses in the paint shop. Each workplace would be equipped with an RFID antenna. It would therefore be necessary to install 50 antennas, one main static RFID reader and 100 tags would be used in the operation. The advantage of the option is the robustness and reliability of the tracking system. The option was inappropriate in order to its acquisition costs.

The third option consists in the deployment of movable gates as antennas would be placed on traversers. In the process of research were considered physical capabilities of employees, the places on traversers where the antennas would be placed and manner of reading tags placed on auxiliary bogies. The RFID antennas (B and C) placed at both ends of a traverser would enable to indicate the movement (input and output) of the skeleton on one or the other side of a traverser. Other antennas (A) located on the ends of a traverser would read the tags of workplaces, where a traverser stops. Mentioned principle enables exact identification of workplace and recording input and output times of skeleton between a traverser and a workplace. With the number of 20 manufactured buses per day and the average daily number of 35 skeletons painted in the paint shop, would be necessary to deploy 100 pieces of tags on bus skeletons (tags will be placed on auxiliary chassis), 50 pieces of tags identifying the workplace number, 12 RFID antennas (3 antennas for each traverser) and one main static RFID reader. The four pieces of handheld barcode and RFID readers would be still used. The disadvantage of described option is the necessity of extensive cabling to connect static readers and antennas on the traversers. The advantage is the reliability of the tracking system and acquisition costs. The simplified floor plan of the workplaces in the paint shop is shown in figure 1.

Fig. 1: Floor plan of workplaces – the third option



Source: authors

Based on the complex evaluation of case studies of the proposals, the third option was chosen. Natural and economic values are presented by school-like grades see simplified table 1.

Tab. 1: Results of case studies evaluation

Option	Acquisition costs	Costs of operation	Reliability	Maintenance difficulty	Application difficulty	**Resulting order**
Barcode	1	5	5	4	1	4
1.	4	1	3	3	4	3
2.	3	1	1	2	2	2
3.	1	2	1	1	1	1

Source: authors

4 Discussion

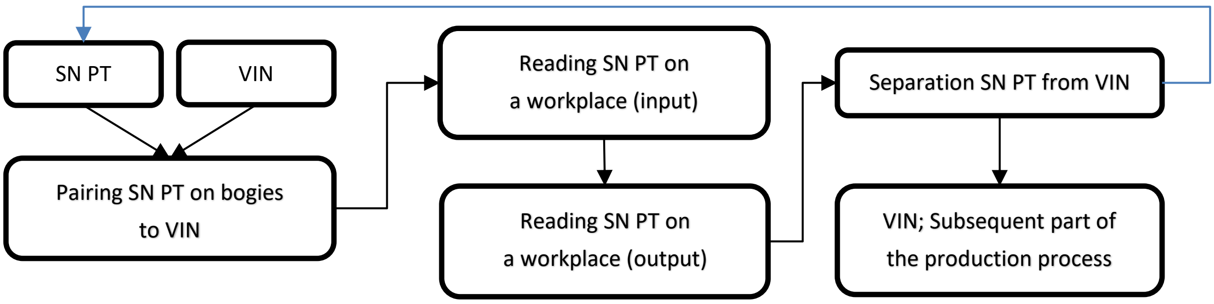
Passive ultra-high frequency 865 to 868 MHz tags (type Omni-ID Exo 600 and Exo 750 with reading range up to 6 and 7 meters) used for tracking and controlling the movement of skeletons meet also the values of the following parameters: thermal and physical resistance to mechanical action, price and reading range of tag/antenna waves. As part of the skeleton/bus tracking process, the action of pairing the serial numbers of passive tags (SN PT) with the vehicle identification number (VIN code) is performed. This means that the tag number is not subsequently displayed in the paint shop information system after pairing, but the VIN number of the bus on which the tag is placed is displayed. The operations consisting in pairing and separating tag numbers from the VIN are performed by a team leader who is near the exit of cataphoresis workplace, where the skeleton is put on auxiliary bogies used to move the bus skeleton in the paint shop. After the skeleton is put on the bogies, the team leader reads both tags placed on bogies by RFID handheld reader. The two serial numbers of the RFID tags read are paired with the VIN code in the paint shop' tracking system. End of moving a skeleton to a workplace and start of painting operations are automatically identified by reading the tags on bogies. The end of the painting operation at the workplace and output from the workplace is recorded by the automatic reading of the bogie tags by the antennas located on the traverser.

After performing all painting operations on the bus, the transfer from the paint shop bogies to the bogies used on the assembly line follows. After the completion of the painting process before leaving the paint shop, the operation of separating SN PT from VIN is performed. Paint shop bogies with tags are after the separation displayed in the paint shop system under their own serial numbers. Then the bus leaves the paint shop. The separation conducts traverser operator by handheld reader. The paint shop bogies are moved to the entry place and wait for the next pairing with the VIN number of another bus skeleton.

In case a bus that has already left the paint shop is sent from the assembly line back to the paint shop (due to repair or modification of the paint), the similar procedure is performed.

It is assumed that the tags are firmly attached to the paint shop auxiliary bogies with metal strips and do not leave the paint shop in any case except in case of maintenance. The described manner caters the identification of the bus movements or bogies movements. A workflow diagram of the tracking process in the paint shop is shown in figure 2.

Fig. 2: Workflow of the tracking process in the paint shop



Source: authors

Based on the identified shortcomings of the tracking system in the paint shop, the replacement of barcode technology by RFID technology was proposed. The new tracking and management system should fulfil several goals. Economic goal – savings of future costs, especially personnel, at the same time with the growing volume of production, the assumption of improving management and control and reducing communication costs. Operational goal – improving production management and control of performed actions affecting the speed of production, i.e. overall savings of time used for handling bus skeletons. Strategic goal – improving of the information flow both within the plant and also towards suppliers and customers. The introduction of RFID technology has eliminated the necessity of manual data acquisition and shortcomings in production caused by the previously used tracking system. The basis for the analysis of utilization of workplaces capacity has been established. The advantage of the implemented solution is the connection RFID based tracking system to previously used paint shop information system which only has been slightly modified. Thanks to the connection of the paint shop information system to the ERP system, it is possible to inform the internal logistics department, external suppliers (paint suppliers, suppliers of small plastic parts and components) or plant management in a timely manner. The paint shop information system also gives a feedback for employees about performed operation.

Conclusion

The new system for monitoring of bus movements in the paint shop using RFID technology has minimized time losses in production, precisely in painting process, arising from the idle times of skeletons in the workplaces of the paint shop. Improved quality and reliability of data and elimination of errors in the process of monitoring of skeletons established the base for better preparation and performing of operations by workers, control of production, adjustment of production plan according to current status, better production process planning and traceability of each bus in production process.

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