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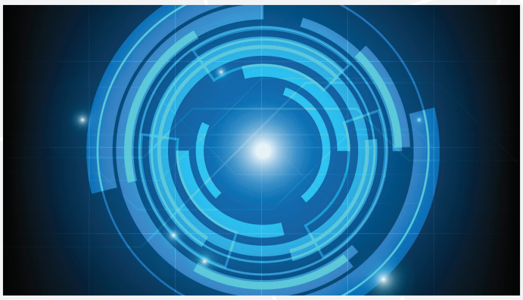


30 January 2019 – 1 February 2019
Stellenbosch, South Africa

Organised by
Department of Industrial Engineering
Stellenbosch University

International Conference
on
Competitive Manufacturing (COMA 19)
Proceedings

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Department of Industrial Engineering
Stellenbosch University

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ISBN No: 978-0-7972-1779-9

Explorative Investigation of Application Scenarios for Smart Bin Systems

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Abstract
Increasing flexibility, greater transparency and faster adaptability play a key role in the development of future intralogistics. Ever-changing environmental conditions require easy extensibility and modifiability of existing bin systems. This research project explores approaches to transfer the Internet of Things (IoT) paradigm to intralogistics. This allows a synchronization of the material and information flow. The bin is enabled by the implementation of adequate hardware and software components to capture, store, process and forward data to selected system subscribers. Monitoring the processes in the intralogistics by means of the smart bin system ensures the implementation of appropriate actions in case of defined deviations. By using explorative expert interviews with representatives from the automotive and pharmaceutical industries, seven practical application scenarios were defined. On this basis, the requirements of smart bin systems were examined. For each individual case of application, a system model was created in order to obtain an overview of the system components and thus reveal similarities and differences. Based on the similarities of the system models, a general requirement profile was derived. After the hardware components of the bin system had been determined, a utility analysis was carried out to find the adequate IoT software. The utility analysis was conducted with a focus on data acquisition and data transfer, data storage, data analysis, data presentation as well as authorization management and data security. The results show that there is great interest in easily expandable and modifiable bin systems, as in all cases, the necessary information flow in the existing bin system has to be improved by means of new IoT hardware and software components.

Keywords
Intralogistics, Smart bin system, IoT Software, Modifiability of bin systems

1 INTRODUCTION

Many companies intend to optimize certain parts of their intralogistics network, and thus their service processes face a variety of technical and business challenges [1, 2]. Of particular interest is the management of bins, including the planning, controlling and monitoring of bins and inventories. The non-transparent flow of material, bins and information, the lack of consistent object acquisition, the unreliable acquisition of bins, missing real-time related data and the shortage of visual support for work processes pose challenges in bin management [3]. According to a study by the Institute of Computer Science and Society at the University of Freiburg regarding the introduction of smart bins, the following obstacles are considered major challenges [4, 5].

According to the survey, 68% of the companies identified the complex integration into cross-company business processes as a central challenge. In addition, the integration into the existing IT infrastructure is perceived by 55% and into the internal business processes by 48% of the participants as a major hurdle. Furthermore, half of the companies do not see the possibility of measuring the benefits of innovative bin systems (50 %). [4, 5]

Integrated bin systems, which generate data at a field level by means of appropriate sensors and actuators and forward the information to the superordinate planning and control systems, hardly exist in intralogistics. A more detailed classification of the role of data in the provision of operational services can be found in a white paper published by Otto et al. [6].

According to Strassner and Fleisch [7] automation must be enhanced in order to reduce manual workload in intralogistics. However, it must be noted that potential savings through the implementation of innovative technologies decrease as the level of automation increases. Figure 2 shows the correlation between costs incurred depending on the degree of automation. The costs are divided into IT costs, workload and potential costs resulting from errors.

A potential benefit of smart bin systems is the increase in process quality, since fewer errors can occur compared to manual processes and permanently automated processes are possible [8]. In the case of less automated processes, e.g. where the use of other Auto ID technologies does not work, savings in labour can exceed the costs of a smart bin system. In this case, the optimum level of automation, without taking into account the potential costs resulting from errors (marked in Figure 1 with 1), is where the sum of the workload and IT costs is minimal. In addition, high potential costs resulting from errors can justify a higher degree of automation. The optimum degree of automation (marked in Figure 1 with 2) is where the sum of all displayed costs is minimal.

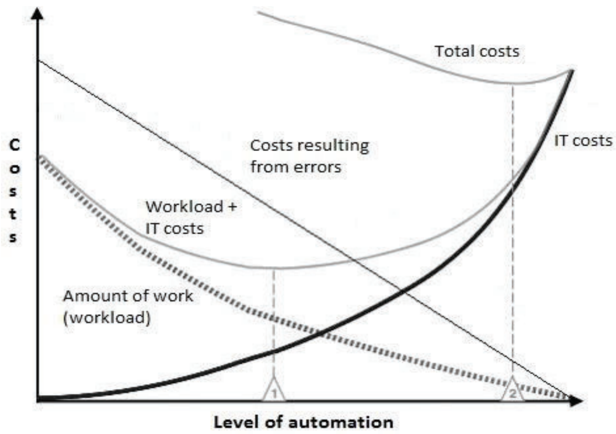

Figure 1 - Correlation between IT costs, workload and potential costs resulting from errors depending on the degree of automation [7]

2 LITERATURE REVIEW

The following sections provide an accurate classification of the terminology used in this paper. In addition, it shows which literature is used as basis.

2.1 Definition of smart bin and smart bin system

The term smart bin used in this research project includes the two definitions given by Bogatu [9]:

- Tagged bin: A reusable bin that can be uniquely identified by means of an AutoID technology and that can receive, store and communicate the relevant process data autonomously, but not entirely without external influence.
- Smart bin: This includes and extends a tagged bin. A smart bin can record process-related information as well as mechanical and hygienic bin conditions independently or through an external influence. At the same time, the bin is able to evaluate both the data received from outside and the data generated independently, to enrich it with further information and to transmit it to the outside via several communication channels.

According to Böhm et al. [10] and Ropohl [11] a smart bin system is a:

- business information system
- socio-technical (human-machine) system in which the system element "machine" consists of the smart bin and the associated supporting IT infrastructure, while the system element "human" includes the employees participating directly in the logistical processes as well as the management who are responsible for the implementation and improvement of logistics processes.

In addition, its primary purpose is to support the planning and operational execution as well as the management levels in the logistics division.

2.2 *Classification of smart bin systems*

The development towards smart products and objects raises the question of an objective system for the evaluation and classification of the level of intelligence. A system described by Tüllmann et al. to determine the level of intelligence of products and objects has been further developed by the authors into a morphological box as shown in Figure 2 [12]. By means of this modified system, it is possible to evaluate and compare the developed smart bin systems.

Morphorlogical Box		Classification of smart bin systems		Date	23.08.2018	ESB
		Application area: ASA and ASP		Editor	Raphael Vogt	INDUSTRIAL ENGINEERING

Characteristics \ Degree of characteristics		Alternatives 1	2	3	4	5
A	Identification and smart data processing	No use of sensors and actuators	Sensors/ actuators are integrated	Bin system continues to process data	Data processing and use of data for analysis purposes	Independent actions based on newly gained data
B	Memory	No data storage	Transponder with electronic data storage	Additional data memory integrated in the bin system	Cloud-based data storage	Cloud based data storage, filtering and sharing
C	Interaction / Communication	No interface integrated	Data input possible	Data input and output possible	Connection to network via Ethernet interface	Connection to net-work (eg WLAN or mobile radio)
D	Additional services	No additional services	Manually via online platform	Manually at the bin system	Automatic by bin system with manual control	Automatic by bin system in real time
E	Control system / monitoring	No monitoring of the operating state	Monitoring of the operating state	Monitoring of operat-ing state and report of breakdowns	Self-diagnosis if error message	Independent error management
F	Networking	No networking	Information exchange via e-mail or telephone	Uniform data formats, rules and interfaces for exchange	Uniform data formats and inter-divisional servers	Inter-divisional fully networked IT solution

Figure 2 - Morphological box for the classification of Smart Bin systems based on Tüllmann et al. [12]

3 CONDUCTING THE EXPLORATORY STUDY

By using explorative expert interviews with representatives from the automotive and pharmaceutical industries, seven practical application scenarios have been defined. On this basis, the requirements of smart bin systems are investigated. For each individual case of application, a system model is then created in order to obtain an overview of the system components and thus reveal the similarities and differences. Based on the similarities of the system models, a general requirement profile has been derived. After the hardware components of the bin system have been determined, a utility analysis is carried out to find the adequate IoT software.

3.1 Practical application scenarios based on expert interviews

Seven experts were interviewed in an approximately one-hour telephone interview. Four of the experts represent the automotive industry and three the pharmaceutical industry. In the selection process, it was ensured that the expert had a background in the strategic management of intralogistics. The main focus of the interview guideline was on improvement potential in bin management, strategic implementation and technological realisation. A particular focus of the present paper is on application scenarios of the automotive (ASA) and pharmaceutical (ASP) industries in Germany.

This is due to the fact that the German automotive industry is of great significance for the German as well as the European economy. The number of logistics processes in the automotive industry has been increasing for years. The main goal of automobile companies is to optimize the flow of information between manufacturers, suppliers and logistics service providers. Companies need transparency throughout the entire ordering and delivery process. [13]

The pharmaceutical industry is the third largest industry in Germany after the automotive and mechanical engineering industries (in terms of sales figures). However, the net value added per employee is the highest. The pharmaceutical industry is growing largely independently of economic development and has a high research intensity and innovation pressure because it is an industry of highest complexity. [14, 15]

3.1.1 ASA 1: Monitoring of C-parts

ASA1 describes an application scenario in which bins are stored in drawers of cabinet systems. The C-parts in the bins are monitored. Bins for which monitoring is required are equipped with camera and indoor localisation module, MCU, RFID tag and battery. If a minimum stock level is reached, an automatic message is sent to the warehouse keeper. Hence, it is a consumption- and order-dependent parts procurement.

3.1.2 ASA 2: Condition monitoring in after-sales

This application scenario focuses on the monitoring of high-quality spare parts in after-sales. The primary concern is shock and temperature monitoring as well as theft protection. In addition, the tracking of spare parts from the storage compartment to packaging and preparation for shipment is to be guaranteed. This ensures that on-time delivery can be met. In other words, it monitors whether the part is leaving the plant on time and undamaged after receiving the order.

3.1.3 ASA 3: Tracking of sequence containers

The bin system is used to track empties in the assembly hall to counteract the shortage of sequence containers in supply centers. The sequence containers are stocked in the supply centers with the parts depending on the sequence of the assembly line. The sequence containers are then transported to the corresponding assembly line by a tugger train. The cycle times at the assembly line can be controlled by the use of an indoor localization system. In addition, there is an increased flow of information for the tugger train drivers. The part picking is monitored to obtain additional information on how long the individual assembly step takes and when all parts are taken out to return the sequence container.

3.1.4 ASA 4: Tracking of assembly line stoppers

In ASA4, parts, which are essential for the further assembly of the vehicle, are monitored separately. The purpose is to be constantly informed about the condition and position of the highest priority parts. In addition, the number of stored parts (safety stock) shall be reduced due to the increased flow of information. This enables a position monitoring and an insight into whether the parts are at the correct assembly station.

3.1.5 ASP 5: Condition monitoring of drugs

The first application scenario in the pharmaceutical industry describes the monitoring of drugs, which react sensitively to temperature, pressure and humidity. In addition to room monitoring of the drug storage area, bin monitoring is to be introduced for selected bins. A selective monitoring and recording of environmental changes is possible. In addition, a seamless monitoring of drugs outside the drug storage, like in the dispatch department, is becoming feasible.

3.1.6 ASP 6: Process control & safety in service

The next application scenario of the pharmaceutical industry is the repair of instruments from the Healthcare and Pharma sector. When the instruments are delivered, it is uncertain whether sterilization has already been done. For this reason, the instruments are assigned to a bin with neutral color at goods receipt. The respective process step is indicated or changed optically via a display on the bin. The normal warehouse goods are stored in bins with a blue display, for hazardous goods yellow is used, high-risk goods are marked red and the instruments, which have already been evaluated and cleaned, are marked green. Additional indoor tracking ensures that high-risk goods are handled quickly and correctly. In addition, it guarantees that a complete proof of the process chain can be shown at Medical Devices article audits.

3.1.7 ASP 7: Storage of pharmaceuticals based on action and warning limits

Pharmaceuticals, which are particularly sensitive to temperature, are stored in different bins depending on action and warning limits. A pharmaceutical is a drug used as a medically active ingredient in the manufacturing process of a drug [16]. If a predefined limit is exceeded or not reached, the system displays the necessary action to the manager. If the action is not executed on time and the limit has been exceeded or undercut for too long, the system displays a warning and the pharmaceuticals must be discarded. Managers have the authorizations to make changes/entries in the system. They receive action and warning messages to take appropriate actions.

3.2 Derivation of industry-specific requirements

After evaluating the industry-specific requirements, it is striking that the focus in the automotive industry is on bin management and tracking. Filling level measurement, which means the monitoring of a certain minimum stock level, also represents an important factor. The function of indoor localization is mainly used to monitor process time and adherence to delivery dates.

In the pharmaceutical industry, however, the focus is on environmental monitoring. The continuous recording and storage of process information is particularly important for regularly scheduled audits. If certain environmental parameters are not met, the corresponding action messages must be sent to the responsible employees.

The evaluation of the expert interviews shows that a modular design of the bin system is required in both industries. This makes it possible to modify the smart bin system and adapt it to other circumstances. Furthermore, in the experts' opinion it is important that the module is not firmly integrated into the bin. This allows to equip only certain bins of a bin cycle with the module and to remove the module when the bin is leaving the company and a supply chain monitoring is not required. Another important component is the location-independent use. This mainly concerns the energy supply.

3.3 Hardware selection

The following sections provide a detailed technology selection and the development of a first prototype.

3.3.1 Technology selection

Before the experts were contacted, potential technologies were selected based on an internet research. The technologies highlighted in grey in Tables 1-5 are the selection of technologies that experts consider to be the most appropriate for the use in an operating environment.

Wi-Fi (IEEE 802.11 a/b/g/n)
Wi-Fi Direct à peer-to-peer specification
Mobile communications
ZigBee (IEEE 802.15.4)
Bluetooth (IEEE 802.15.1)
Bluetooth 4.0 LE Technology

Table 1 - Selection of communication technologies

RFID (low, high or ultra-high frequency)
NFC
Barcode, QR-Code

Table 2 - Selection of identification technologies

Laser Tracker & iGPS
Assisted global positioning system
Ultrasound systems (Telocate, Cricket or IMAPS)
Radio-network-based positioning (RADAR)

Table 3 - Selection localization technologies

Integrated camera
Weight sensors
Infrared light barrier

Table 4 - Selection of technologies for filling level measurement

Temperature monitoring
Pressure monitoring
Shock monitoring
Humidity monitoring

Table 5 -Selection of additional sensors

3.3.2 Outcome of the hardware selection

A first prototype, using the selected technologies, was realized with the Rasperry Pi Zero as shown in Figure 3 [17]. Further variants investigated in the course of this project were the Arduino uno, NodeMCU and ZF Tagfinder with deTAGtive TAGs. [18, 19, 20] However, the Raspberry pi zero proved to be the most suitable solution due to the BlueDot sensors available, the CSI camera connector on the board, the Wifi and Bluetooth LE module and the very low energy consumption. Furthermore, the Raspberry pi zero is compatible with the Losant IoT platform described later in this paper.

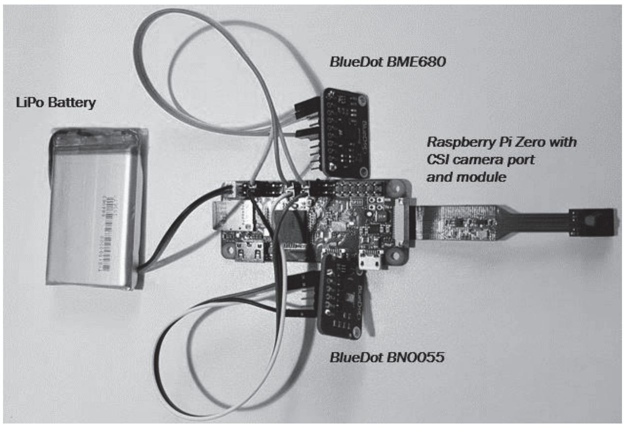

Figure 3 - Setup of the smart bin module

3.4 Utility analysis in order to identify suitable software

The utility analysis aims to identify potential software solutions for the industry-specific applications as described beforehand. By analyzing the platforms available on the IoT market, the work done can serve as a decision-making guide in the selection of a suitable IoT platform. Depending on the application and prioritisation, the benefit analysis can be adapted. However, not all possible platforms are examined. Due to the growing number of products on the IoT market, only the major IT companies are considered in the analysis. In addition, the IoT platform must be well established on the IoT market for a certain period of time.

3.4.1 *Conducting the utility analysis*

The following selection of IoT platforms is examined in more detail in the course of the paper: PTC ThingWorx, Bosch IoT Suite, IBM Bluemix IoT Zone, HPE Universal IoT Platform, Oracle IoT Cloud Service and Losant IoT Platform.

The necessary expertise for the analysis is accomplished by means of Internet research, telephone calls with qualified employees and, if possible, by means of testing using trial versions provided. The analysis of the IoT platforms is carried out on the basis of the following four categories shown in Table 6. The individual categories are divided into more detailed requirements. According to the categories and requirements in Table 6, the IoT platforms are analyzed for advantages and disadvantages, followed by a pairwise comparison and a utility value analysis.

Data acquisition and transfer	1. M2M device integration 2. Integration of environmental data (e.g. production plan) 3. Integration of IT systems 4. Transformation of data for filtering of certain information out of raw data (ETL process)
Data analysis and processing	1. High compatibility in handling data volumes and diversity 2. Finding trends and patterns 3. Monitoring and reporting 4. Alarm functions (e.g. SMS)
Data presentation via user interface (GUI)	1. User-friendly end-user GUI for presentation of information 2. User-friendly admin GUI (extending IoT platform) 3. Integration of PC or Tablet
Authorization management, data security and protection	1. Encrypted transmission technologies to prevent intruders 2. User and role concept 3. Adherence of data privacy 4. Structure of license model

Table 6 - Defined categories with corresponding requirements

3.4.2 *Outcome of the utility analysis*

If the requirements, elaborated application scenarios and hardware selection are taken into account, the Losant IoT platform performs best with 6.4 out of 10 points. This value includes the weighting of the individual requirements determined in a previous pair wise comparison. The final results of the utility analysis are illustrated in Figure 4.

		PTC ThingWorx		Bosch IoT Suite		IBM Bluemix		HPE IoT Pl.		Oracle IoT Cl.		Losant IoT Pl.	
	Weighting	Average of ratings	Value	Average of ratings	Value	Average of ratings	Value	Average of ratings	Value	Average of ratings	Value	Average of ratings	Value
M2M Device Integration	12.38%	7	0.87	8	0.99	6	0.74	5	0.62	6	0.74	9	1.11
Further environmental data	7.14%	6	0.43	5	0.36	7	0.50	5	0.36	4	0.29	5	0.36
Further IT systems	8.57%	7	0.60	6	0.51	6	0.51	5	0.43	8	0.69	3	0.26
Information filtering	3.33%	4	0.13	7	0.23	6	0.20	6	0.20	7	0.23	5	0.17
Working with Big Data	2.86%	8	0.23	5	0.14	4	0.11	6	0.17	5	0.14	5	0.14
Predictive analytics	2.38%	6	0.14	5	0.12	7	0.17	8	0.19	3	0.07	3	0.07
Monitoring and reporting	8.57%	5	0.43	7	0.60	5	0.43	6	0.51	4	0.34	6	0.51
Alarm function	11.90%	6	0.71	7	0.83	6	0.71	6	0.71	6	0.71	6	0.71
End-user GUI	10.00%	8	0.80	1	0.10	6	0.60	4	0.40	6	0.60	7	0.70
Admin-GUI	0.95%	7	0.07	1	0.01	4	0.04	6	0.06	5	0.05	6	0.06
Integration PC, Smartphone	7.62%	7	0.53	4	0.30	6	0.46	6	0.46	5	0.38	6	0.46
User and role concept	4.76%	7	0.33	7	0.33	6	0.29	6	0.29	7	0.33	6	0.29
Encrypted transfer technology	3.33%	6	0.20	6	0.20	7	0.23	6	0.20	6	0.20	7	0.23
Data privacy	3.33%	4	0.13	9	0.30	5	0.17	6	0.20	6	0.20	5	0.17
License cost model	12.86%	3	0.39	3	0.39	6	0.77	3	0.39	3	0.39	9	1.16
	Sum		**6.00**		**5.42**		**5.93**		**5.18**		**5.37**		**6.40**

Figure 4 - Result of the utility analysis

4 CONCLUSIONS AND OUTLOOK

This paper provides an overview regarding the introduction of smart bin systems for companies in the automotive and pharmaceutical industries. A possible solution is approached from an operative point of view. Based on expert interviews, possible application scenarios and the corresponding requirement profiles were derived. This enabled a targeted technology and subsequent hardware selection. Afterwards, a suitable software was selected by means of an adaptable utility analysis. The methodology presented in this paper can be adapted to specific application scenarios and requirement profiles. The results of the internet research and expert interviews indicated great interest in expandable and modifiable bin systems.

In the next steps of the research project, the prototype will be introduced to the Logistics Learning Factory (LLF) of Reutlingen University for validation. In the LLF environment, the defined requirement profiles will be examined and evaluated in more detail. In this way, the specified requirements can be assessed in terms of their relevance and implementation potential. Furthermore, previously unrecognized requirements for the functionality of the smart bin system are to be reassessed. At the same time, the prototype should point out the limits of the smart bin system and form the basis for further research projects.

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6 BIOGRAPHY

Raphael Vogt holds a B.Eng degree in Mechanical Engineering from the University of Applied Science in Konstanz. He is currently doing his MSc degree in Digital Industrial Management and Engineering at the ESB Business School in Reutlingen. His major field of research are smart bin systems in intralogistics.

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