Advanced Logistic Systems – Theory and Practice, Vol. 14, No. 1 (2020), pp. 32-38.
https://doi.org/10.32971/als.2020.007

PRESENTING AN INNOVATIVE PROCESS IMPROVEMENT METHOD FOR THE EFFICIENT FORKLIFT MATERIAL HANDLING SYSTEMS IN THE INDUSTRY 4.0

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Abstract: The rapid adoption of Industry 4.0 principles in the manufacturing sector during the last couple of years has created numerous possibilities for development. One key area related to manufacturing in which Industry 4.0 solutions can have a significant impact is the field of materials handling. However, today the majority of manufacturing companies still overly rely on the utilization of standard forklift material handling systems for supporting their operations. In this paper, our goal is to present a novel process improvement method utilizing Industry 4.0 principles which could significantly aid in the design of efficient forklift material handling systems. We believe that by utilizing the opportunities inherent in Industry 4.0 (in this case mainly sensor systems, big data analysis, digitalization and real-time data transfer), forklift based material handling can be elevated to an entirely new level in terms of efficiency, which could greatly improve the overall performance of the vast majority of manufacturing systems.
Keywords: Industry 4.0, process improvement, forklift material handling systems

1. INTRODUCTION

Traditionally controlled forklift material handling systems often have to deal with a number of inefficiencies. Therefore, the introduction of computer control in forklift material handling is of paramount importance, because it can significantly increase the efficiency of logistics tasks, the performance of the production system and reduce costs. These factors are especially important in a modern Industry 4.0 based production environment.

Computerized control of forklift material handling offers the following benefits: significantly increases the capacity of forklift transportation, warehousing, order picking, increases the utilization and performance of the production and service units served by forklifts by reducing idle time, reduces the waiting time of forklifts, reduces journey times (mainly through improved vehicle routing [1]) and reduces the time it takes to request forklift delivery. Further advantages include:

- make the movement of materials and related goods traceable and integrate their data into the enterprise management system,

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- use ERP databases so management and disposition can be based on near real-time information,
- reduce the number of forklifts required, thereby reducing maintenance costs by collecting diagnostic data.

Computerized control of forklift material handling is a costly investment, especially when it also has to fulfil the requirements of the Industry 4.0 principle (requirements like the deployment of sensor networks, the implementation of machine-to-machine communication, the utilization of big data analysis, etc.), but it does not always require the purchase of new forklifts. With some modifications the problem can be solved by additional automation of existing forklifts (e.g. by installing smart devices and relatively low-cost sensors). In the followings, after a theoretical foundation of computerized forklift control, a novel process improvement method will be presented which allows the deployment of such control solutions for existing forklift-based material handling systems, while also implementing the Industry 4.0 concept.

2. THE CHARACTERISTICS OF COMPUTERIZED FORKLIFT CONTROL

The performance, costs, and competitiveness of production and service processes are significantly influenced by the operation of the logistics system. Management tasks require real-time data. The management of the logistics system – in line with the enterprise management systems – is organized in a hierarchical manner, that is, at the strategic, tactical and operational level, the tasks in different areas of the company are realized (Figure 1). At the strategic level, the ordering of production and service tasks is processed, taking into account the overall strategy of logistics management, the scheduling of production (based on the production processes [2]) and / or services integrated with logistics, the scheduling of deliveries, the preparation of their procurement (based on the relevant sourcing processes [3]), and the administrative activities required for these. This is the level at which logistic controlling data for assets, equipment and capacity utilization arrives [4]. Therefore, the decision about how to implement forklift control is naturally made on this level. However, as Figure 1 clearly shows, the operation of the control system itself is directly connected to the tactical and operational levels, so the proper elaboration of the data connections with these areas has outstanding significance as well.

The described management hierarchy is usually realized through the application of an enterprise computer information system. Therefore, first it is necessary to implement a connection between the previous and the forklift control system, usually through the creation of proper digital interfaces (in an Industry 4.0 environment, the appropriate elaboration of these interfaces from a compatibility and also from a cyber-security standpoint has an even greater significance [5]).

The general principle of computerized control of forklift truck movements is shown in Figure 2. The forklift routing computer provides disposable instructions to the forklift, provides feedback on the forklift's tasks, and provides feedback to the forklift, and can collect data from the logistics system. The forklift can have driver only, driver + onboard intelligence or only onboard intelligence. Thus, the controls can be executed by the driver, onboard intelligence, or both in collaboration. Collecting data from the system and completing tasks can be automatic or offline. The controls can be executed by the onboard intelligence or partially handed over to the driver or transmitted to the control computer.

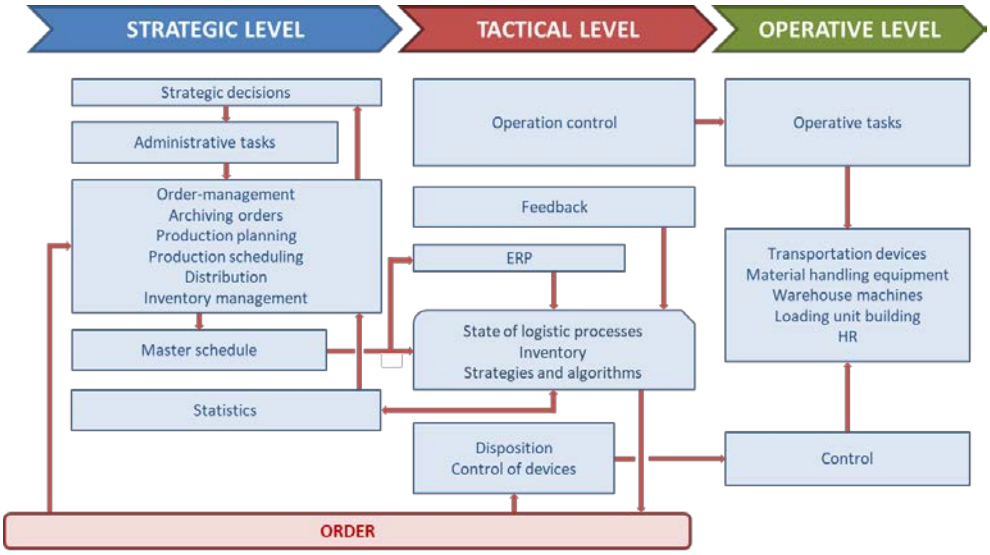

Figure 1. Management levels of the production logistics system

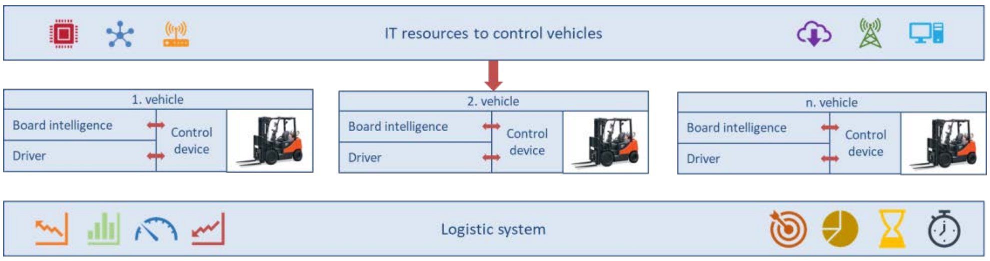

Figure 2. A general model of computer controlled forklift material handling

The information link between the forklift truck computer and the forklifts can be either continuous data transmission (radio frequency or infrared wireless) or offline. The forklift routing computer maintains an information connection with the enterprise management system. The following typical management models can be distinguished:

- Conventional forklifts, offline information link: the job application is distributed by the system controller taking into account the following: manages the job tasks for a given time interval (subject to time window restrictions); manages the available forklifts and their characteristics for this specific time interval; tasks and forklifts are assigned to a specific time window (batch processing). Get the job done on paper through the forklift operator's fixed terminal. Controlling and supervising the operation of material handling tasks here is nothing more than the execution of batch tasks, which can only be intervened in practice in exceptional cases. Confirmation of the execution of the tasks is performed only after the completion of execution of the given task package.
- Conventional forklifts with onboard intelligence but partly offline information connection: Conventional forklifts still communicate with the truck management software in offline mode. The forklift's onboard intelligence is bundled with tasks.

At the interface of the computer network monitoring the system, which is not necessarily a fixed terminal, onboard intelligence is capable of transmitting batch information. The forklift driver receives tasks on the onboard intelligence screen in the order in which they are executed. This allows tasks to be executed in chronological order, without accidental mixing up.

- Conventional forklift with onboard intelligence, online, continuous data transfer: A flexible information link can be established between the truck and the system monitoring software using wireless data transfer systems. Here, forklift control tasks are also performed by the driver. The task execution information is immediately sent to the computer monitoring the system when the task is completed. In this case, the execution of tasks can be monitored in almost real time. New assignments are possible depending on the current status of the forklift's transport system.
- Forklift without automatic data transfer: Forklift routing control software transmits disposition data to onboard intelligence offline. Data transfer requires access, automatic positioning and connection of the network connection points from the driverless forklift. Thus, new service tasks and confirmation of completed tasks and automatically collected data are transferred in batches. The minimum amount of batch quantities applied per service task. The more service tasks that are included in a batch, the more inaccurate the data is because data is derived from an older system state.
- Wireless forklift with automatic data transfer: in this version, dispatch, control and data collection can be done online. The forklift is fitted with structural components suitable for the automatic pick-up, drop-off and transfer of unit loads, and of course the pick-up and drop-off points must be fitted.
- Forklift with pick-up robot, automatic data transfer: This cordless forklift not only automatically dispatches, controls and collects data, but also has units that enable automatic order picking.

3. THE PROPOSED IMPROVEMENT METHOD FOR THE DEVELOPMENT OF INDUSTRY 4.0 BASED FORKLIFT CONTROL

Our proposed method consists of six main steps which build upon each other according to the following diagram (Figure 3.).

The first step is the determination of the company goals. As it was mentioned before, the aim of the proposed method is to provide an affordable solution for the large number of those companies which operate a traditional forklift material handling system, but would like to upgrade it according to Industry 4.0 principles. Therefore, the customers are usually looking for flexible, modular solutions that can later be scalable and interconnected with existing systems (for example with the existing computer information system of the company).

After the first step, the most immediate task is to determine the boundaries of the system to be analysed and optimized. Usually this is the simplest step in the method, as every customer necessarily has to have information about the number, type and allocation of its materials handling equipment.

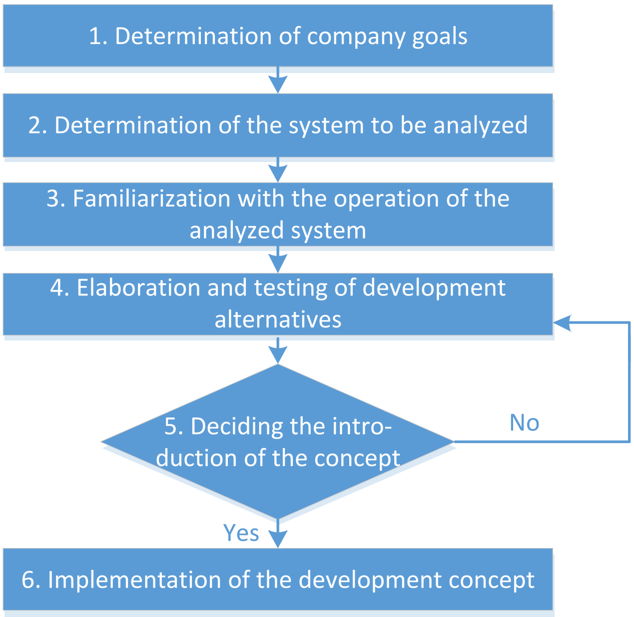

Figure 3. Method for the development of forklift material handling systems

As it is often characteristic of traditional forklift based systems, the tasks and commands for the forklift drivers are usually given through verbal communication, either directly or by handheld telecommunication devices. As a result, most often there is no historical data available in the information system of the company regarding the detailed operation of the forklifts. For this reason, usually large amount of manual data collection is required in order to understand the material handling system in the third phase of the method. In our method, this data collection includes the interviewing of the operators and their immediate supervisors. We propose the following types of datasheets for the manual data collection and for the realization of the interviews:

- half-hourly data sheets showing the daily work of each forklifts,
- questionnaires recording the problems reported by the users requesting material handling by the forklifts and their suggestions for improvement,
- questionnaires recording the problems reported by the forklift operators and their suggestions for improvement.

In the fourth step of the method, the actual elaboration of the development alternatives takes places, together with the testing of design components where necessary. Based on the typical requirements of the customers described in the first step and usual characteristic of the traditional forklift based systems (see the description of the third step), we propose the installation of dual-purpose smart devices (equipped with wireless communication modules) on each forklift which combine touch-screen centered information sharing with Voice over IP (VoIP) based verbal communication. This hybrid solution is very important, as it was mentioned before, traditional forklift-based systems usually lack high level standardization and sometimes even basic connection with the company's information system, therefore a flexible, semi-standardized approach often represents the optimal solution for both the forklift drivers and for the customer. From an Industry 4.0 perspective, it is also very important that this type of solution also represents a quantum leap from a data-analysis stand point, as it allows the real-time monitoring of each machine and therefore creates the basis for the accumulation of historical data. Of course, it is an important question to whether use off-the shelf solutions for the hardware (and software), or to develop custom devices for this purpose. When developing custom hardware and software, the potential benefits and potential risks must be carefully analysed and weighted, often with the help of a comprehensive SWOT analysis. It is worth to look at the solutions and methods that are proven and less successful than the competitors, and then learn from them about the direction and tools of future developments.

The decision regarding the introduction of any of the development alternatives is done in step 5. Overall, we believe that the decision in this step is usually positive, as according to our findings, the proposed approach for solving the problem provides numerous advantages, which are the following:

- Reduction in the number of forklifts used, which can result in significant annual savings.
- A performance-based bonus system can be introduced to increase work efficiency.
- Increased service standards (no need to search for a forklift).
- Possibility of analysing and developing processes.

The reduction of the forklifts can be realized thanks to the real-time monitoring of the machines, which usually help in levelling out the downtimes for each forklift. For example, in Figure 4 we can see a typical example for a daily load of a forklift without the utilization of the levelling.

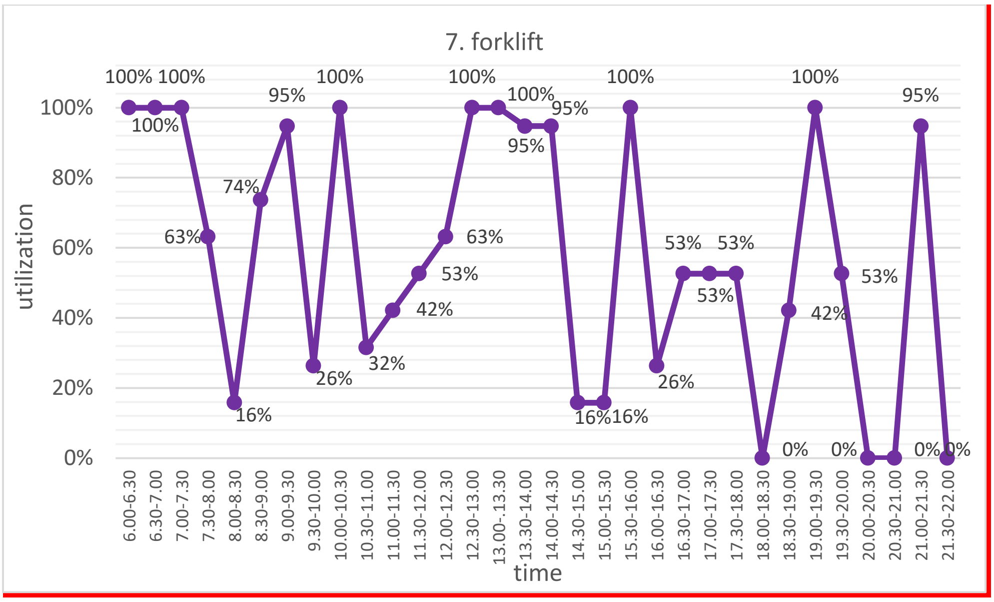

Figure 4. The utilization of one of the forklifts in the base case for an average day

As can be seen, without computerized forklift control, the load is often very hectic with numerous peaks and downtimes. By properly distributing the workload between the individual machines through the upgraded smart communication system, the downtimes can be usually reduced by such an extent that facilitates the reduction of the forklift fleet by several units.

The final step of the method is the implementation. In this phase, a good project manager can greatly improve the dynamics of development and reduce risks. He is the link between the customer and the contractor / developer, coordinates and organizes the work, constantly communicates with the parties, monitors deadlines and cost developments, assists in decision making and supports decision making, monitors and evaluates external and internal feedback. The final stage of implementation is not only finishing, but also evaluation. We compare the expectations and the results achieved and see if the investment has achieved its goal. It is important to get a realistic picture of the work we have done, the successes and the mistakes, so that we can draw conclusions and use our experience in our next work.

4. SUMMARY

In the paper, we introduced a novel process improvement method for the development of computer-controlled forklift material handling systems based on Industry 4.0 principles. The efficiency gains achievable with this approach are also described, proving that the method could be useful in a large number of cases, especially because many companies are looking for ways to upgrade their material handling systems according to the Industry 4.0 concept.

We are looking forward to further develop the process improvement concept, for example by expanding it to other standard areas of materials handling. As the digitization of production is taking place at a constantly accelerating rate, we believe that the interest in such process improvement methods will continue to grow in a parallel manner.

Acknowledgements

“The described article was carried out as part of the EFOP-3.6.1-16-00011 “Younger and Renewing University – Innovative Knowledge City – institutional development of the University of Miskolc aiming at intelligent specialisation” project implemented in the framework of the Széchenyi 2020 program. The realization of this project is supported by the European Union, co-financed by the European Social Fund.”

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