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HOW MEANINGFUL IS AUTOMATION OF ASSEMBLY LINE SUPPLY?

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Abstract: *Automation of the trolley train process for assembly line feed is a recurring request from manufacturers to material handling engineering providers. This paper introduces those process steps of a trolley train route, which are most worthwhile to be automated regarding to easiest implementation and highest value. By analyzing several applications, it turned out that most of the process time is used for loading and unloading the trailers manually. Not only from economic but also from ergonomic point of view those steps are most critical. The specific application and its conditions always have to be included in considerations; an overall statement about the meaningful use of automation is, due to the large number of specific boundary conditions, not possible.*

Keywords:*Assembly line supply, trolley train, ergonomics.*

1. INTRODUCTION

At present, requirements on manufacturers and suppliers continuously become more complex because of their changing business environment [1]. This development can be attributed to saturate markets, inconstant customer demands and their wish for customized products, shorter product life cycles and increasing numbers of variations of products [2]. In summary globalization is the reason. To address this problem, waste and inefficiencies must be avoided [3]. Therefore, production and assembly lines have to be provided with smaller lot sizes to be as flexible as possible, as value-adding as possible and to reduce costs in shape of space and materials in the workspaces [4]. To make that sure short supply-cycles are necessary, accordingly an efficient and adaptable logistic concept has to be implemented [2]. The Toyota Production System and the idea of lean management provide the basis [5]. Building on that, many manufacturers already converted their material flow between the incoming goods department and the assembly lines from the use of fork lift trucks to so called trolley trains, which drive a defined route and exchange empty for full loading devices [6].

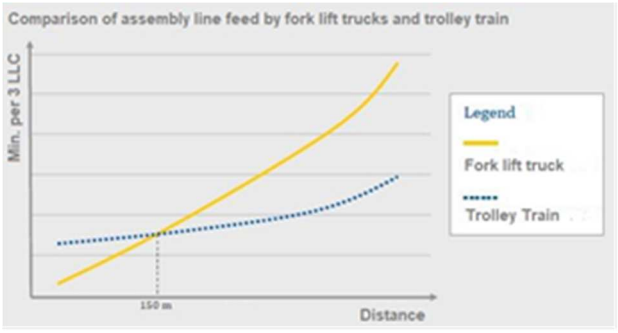


Fig.1: Needed minutes per three large load carriers

At the end of one route the train is completely unloaded and reloaded as required for its next route [6]. By combining several deliveries and a high-frequency just in time supply, a higher operating grade, less empty drives and fewer inventories are achieved, compared to the use of forklift trucks [4]. Furthermore, the volume of traffic is reduced and because of that the risk of accidents decreases [7]. A comparison regarding to the required time for three large load carriers at a certain distance can be seen in the first figure. The longer the distance, the less worthwhile is the use of fork lift trucks [8].
In this context automation is defined as the transfer of functions of the production process, in particular tasks of process control and regulation, from humans to artificial systems [9]. Furthermore, it is differentiated between full and

partial automation [9]. This distinction is relevant for the required employment of staff; the higher the degree of automation, the more the control by and the communication with the humans are reduced [4]. In general, typical targets of automation consist in reduction of costs, standardization of processes, reaching a higher throughput, staff savings and a reduction of physical stress of employees [4]. Within a process different degrees of automation are possible [9]. Especially the material flow engineering and industrial truck manufacturers and providers who have currently a large market share are affected by the changed requirements of the customers who would like to upgrade their existing products. In the industrial truck branch, the "top four" hold over 80% of the market share [10]. On the world ranking of 2016 Toyota, the Kion Group, Mitsubishi and Jungheinrich dominated the market; since year 2013/2014 they all expanded their portfolios by trolley trains and tow tractors [10]. Figures 2 and 3 represent the market development of those products. Their names are in this case composed as follows: E for electric engine, Z for tow tractor, S for seat, G for large load carrier, T for trailer, F for platform, P for portal, E for E-frame, C for super elastic tires, a for automatic, the first number for series and second to last number for towing performance in kg/100.

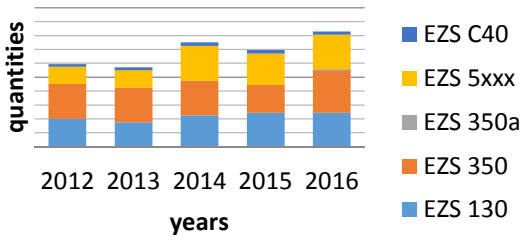


Fig. 2: Sales figures over five years for tow tractors

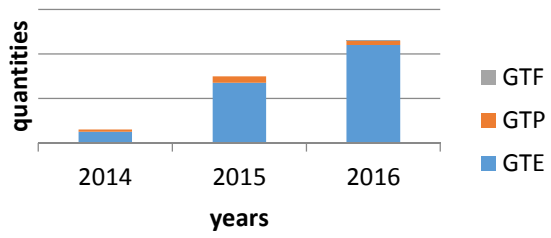


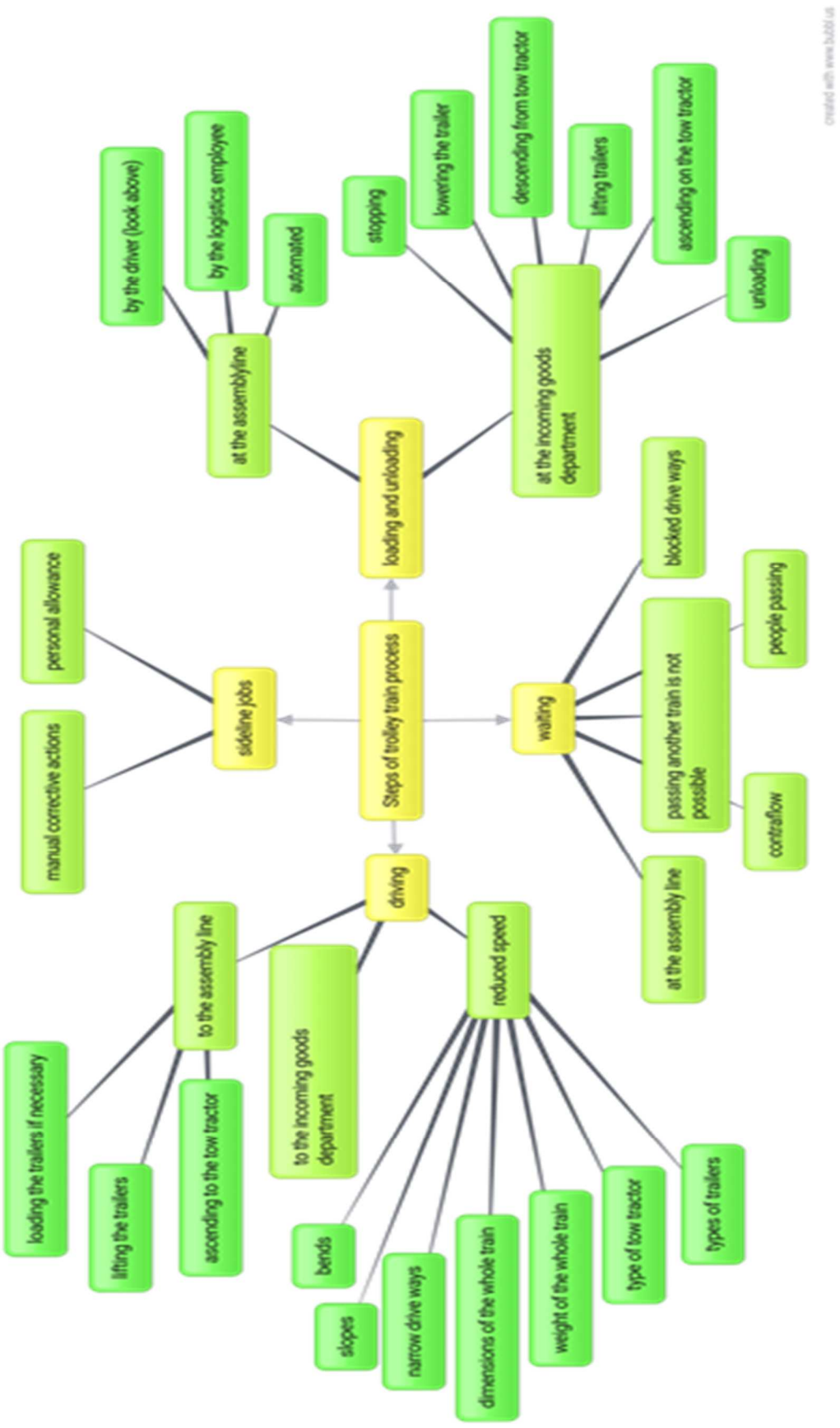
Fig. 3: Sales figures over three years of trolley trains

Nevertheless, many new smaller providers who just have entered the market must be considered as well, because until now there is no uniform process for a perfectly into customers application embedded trolley train [11].

2. SOLUTION DEVELOPMENT

For this paper, three major customers were visited which already implemented a trolley train process to analyze assembly line feed in practice and identify those process steps which occur repetitive at every customer's process and for whom automation would be meaningful. That was operated by observing the processes and writing down every step and its required time. Additionally, the affected employees and their supervisors were interviewed about the process, its challenges and difficulties, the layout and its conditions, their experiences with the tractors and trailers and their personal ideas and wishes for improvement. In order to find process steps that make the achievement of the targets associated with automation which were already mention in the first chapter possible, the process needs to be considered more closely. Every process step has to be considered independently, even loading and unloading by themselves and at the incoming goods department and at the assembly line, because not all steps has to be automated, for example the unloading can be automated but the loading of empties not [4]. The whole process can be divided into driving, loading and unloading, waiting and, if applicable, sideline jobs. As can be seen on the mind map, all activities are assignable to those four main steps. The mind map reveals that most operations and therefore most of the time fall upon driving and loading and unloading. In addition to that a closer look at the processes preconditions and influencing variables is needed. To achieve an increasing efficiency compared to the use of fork lift trucks the requirements of assembly lines has to be regular and to some degree predictable [12]. They must only consist of small to medium sized and light to medium weight parts, restricted by the driving power of the tow tractor or rather the number of trailers [12]. Due to the fact that the handling is currently mostly done manually, ergonomic aspects must be considered as well [13].

Fig. 4: Overview of the process steps and the belonging activities



In some cases, facilities are available, for example devices for pulling and pushing the trolleys. Accordingly, ergonomic aspects are currently only considered by limitation of the load weight and the height in which it is provided [14]. Besides, the use must be limited to the horizontal plane and the inner area, because driving in lifts, on ramps and outside is only conditionally possible [12]. If the driveways are very narrow, one-way streets have to be planned and the curve ratings have to be checked regarding to the turn radius and the directional stability of the train [12]. Driving backwards is not possible at the moment. The greatest influencing variable is the load; it is carried either on or in large load carriers like palettes or iron-barred boxes which can transport up to 1500kg or in small load carriers that do not exceed a weight of 15kg [11]. For moving the load carriers there are trolleys with rolls below. Often both types of loading devices are used. The duration of the whole process is influenced by the allowed or possible speed and the distances [11]. The speed is, next to the performance of the truck, limited by the appearance of the route with its bends, slopes, the width of the drive ways, whether passing other trains or contra flow is possible and whether people could cross the drive way [11].

2.1 Loading and unloading

The unloading of new required parts at the assembly line can be automated with the aid of so called “shooter racks”, which transfer the load with the force of gravity from inclined shelves or otherwise by powered roll conveyors into the shelves at the workstation [6]. Previously, the trolley train has to be positioned correctly by the driver with the aid of a laser pointer, a stopping point mark or guard rails on the ground as can be seen in figure 5 [7]. After that, the lock of the loads is released so that the small load carriers can slide over the roll conveyors into the designated rack at the workstation [6]. In case of errors, the driver can make manual corrections. That solution requires a precise consignment process in advance, which provides the goods in the position they belong to at the workstation [7]. In the warehouse full automation could have been implemented yet, because of the fact that staff traffic can be excluded. The shooter rack for automated loading of the train is only possible for small load carriers, but there are also solutions for large load carriers already. Powered roll conveyors can be used on both, the trailer and the receiving station at the workstation, as can be seen in figures 6 and 7.
Another possible solution would be forks in the trailer that can be telescoped to push the pallets out on given storage spaces and pull others in [15]. If the storage space is not directly next to the drive way, automated guided vehicles can be established to cover the remaining distance [17] by driving under the large load carrier, lifting it a bit to pull it out of the trailer and carrying it to the correct place at the workstation, as the fig. 8 and 9 show.

Fig.5: automated loading of small load carriers

Fig. 6: automated loading of large load carriers [16]

In contrast to manual handling, for those solutions a lot of sensor technology has to be implemented and additional space for the empties has to be created [4]. If the next stop, for example for picking up the empties, is only a few meters further and the driver is not on the tow truck in that moment, a so called “easy pilot” has been invented by Jungheinrich. It is a kind of remote control which can be used by the driver to move the train a few meters straightforward.

Fig. 7: automated loading of large load carriers in detail

Fig. 8: example of an automated guided vehicle [18]

Fig. 9: example of an automated guided vehicle [19]

2.2 Driving

The employees are the most expensive part, the so called cost driver, in the whole trolley train process [4]. Without a driver the track guiding gains importance [20]. Currently it is mainly differentiated between two types, on the one hand the visual guidance with the aid of a camera and a track painted on the ground and on the other hand the passive-inductive guidance with a sensor which follows the signals of a metal band on the ground [18]. Either way the route of the train is determined to the track guiding lines. To completely replace a driver and all his senses a lot of sensor technology is necessary.

3. IMPLEMENTATION ANALYSIS RESULTS

The analysis of theory and practice has shown that the biggest opportunities of automation, compared to manual handling, are the increase in speed of operation and handling, the decrease of required time for the affected process steps, the reduction of physical stress and the high availability of the trolley trains. In contrast to that the investment costs, the capital lockup, the payback period and the default risk with its associated costs must not be disregarded [4]. Because of that smaller and medium-sized companies are currently avers to automation [4]. Especially in advance a lot of time and money is required for developing and planning a transparent process and for the implementation of the trolley train due to the fact that most existing processes has to be completely reengineered. [17]. Software and simulation tools are very helpful because of the great amount of cutting sites and interdependencies [21]. In addition to the technical issues it is essential to involve experts as well as employees with their operating experiences for achieving a high quality process and creating acceptance [1]. Extra time for further education and trainings for the employees should also be scheduled [1].
First of all, much standardization is necessary before automation is possible, which implies less flexibility for example by reason of defined stops and fixed track guiding lines. It may also be necessary to invent some special built standardized trailers, load carriers or shelves for the individual application [4]. The most crucial point about a full automated moving train is the safety of people who are potentially crossing the drive way [22]. Therefore, specifically for full automation, a lot of sensor technology is necessary which has to be added to the tractors and trailers as well as the workstations to ensure security and avoid mistakes [22]. In the end all

activities that the staff did with the aid of their senses have to be taken over by the train like checking if the train is positioned correctly, if all trolleys were picked up correctly and are the right ones and if a person crosses the drive way. One possibility to integrate a sensor which detects at least a subarea of the train and its environment is described in the patent an employee of the STILL GmbH, a member of the Kion group, registered [20].

Not least, automation implicates a change in employee composition [4]. More well educated, high qualified and technically well-versed employees are necessary, whereupon the amount of workingmen can be reduced. By reduce of personnel, machine and maintenance costs, last mentioned because of the reduced amount of industrial trucks compared to the use of fork lift trucks, the operating costs decrease and as a result of that the annual overall cost decrease as well [4]. Nevertheless an economic efficiency calculation only would not be meaningful because factors like the operating time, the amount of stops and trains and trailers with their capacities must also be considered, depending on the processes preconditions and influencing variables mentioned in the chapter before. A sensitivity analysis can help to consider the specific, individual conditions next to the technical and financial aspects [4].

As a result, especially the activities while loading and unloading are meaningful for optimization, because they are on the one hand most time-consuming and on the other hand also from ergonomic point of view most critical. The two types of loading devices are often used both but with different effects on the later processes [11]. Handling a lot of small load carriers is much more time-consuming than one large load carrier. Accordingly, the average possible speed is higher with large load carriers, because less changes of loading devices are necessary. Furthermore, the required execution time for loading and unloading the trolley train increases with increasing weight of the loading devices [11]. Therefore loading and unloading empties is less critical because the loading devices are lighter, that means decreasing required execution time and less physical stress of employees so that the automation of the activities with full loading devices is for a start more important. Further, the possibility of loading and unloading from both sides of the train would contribute to higher flexibility. Another conclusion is that automation of driving is meaningful especially when the distances are very long or staff traffic can even be excluded.

4. DISCUSSION AND CONCLUSION

Currently, the degree of standardization for tow tractor trains is very low [7]. Not in question of the technical solution either regarded to characteristic numbers for monitoring the materials [23] and evaluating the process [11]. The aim is to connect the industrial trucks with the company's network and the production, so that a precise controlling and timing is possible, not least to provide a basis for fully automated systems [1]. For achieving more flexibility in the use of the trolley trains it is attempted to manage the track guidance independent from assistance on the floor but with the help of the radio-frequency identification (RFID) technology, which identifies and localizes objects and humans contact-free by using radio waves [24].

Also factors like protection of the environment, sustainability and conserving resources gain importance in logistics. The trolley train meets that claims by using energy-saving lithium-ion batteries and electric motor. In addition to that a resource circulation and process-oriented thinking is created via the trolley train process [5]. Moreover, the packaging waste can be reduced trough standardized, reusable load carriers [5]. Also, for that a transparent, well-documented and traceable process is necessary [1]. Characteristic numbers, for example directly at the workplaces, but without violating the privacy of the employees and the specifications of law and the company, has to be identified [1]. That the optimization of the assembly line feed process has a great influence on the employees and their health is definitely a moving spirit, especially regarded to the current demographic change in the European society. The more automation in the shape of automated guided vehicles and robots will be implemented, the smaller the role of humans in the production and assembly environment will become. In return, more jobs in the background are needed with less physical work but more tasks in planning,

controlling and developing complex processes and systems as they are needed for all that.
Experience has shown that successful, far-reaching innovations are no more achieved by a lot of secrecy but through exchange, cooperation and so called “open innovations”, like the “drive-thru” concept shown in figure 6 of Jungheinrich, collaborating with the Technical University of Munich [7]. Special advantages consist in the possible reduction of the time and costs required for development [4]. In fact none of the “top four” released a product yet that could be called a “standard solution” but there are a lot of the small providers who just entered the market who also invented trailers for the trolley train application or solutions for the interfaces between the train and the customer, as shown above. Currently, automation is connected with high technical effort and high investment costs especially because of the sensor technology, but research and development on that topic are expected to generate a higher performance of the sensors and thereby achieve a lower priced and simplified implementation of hardware [4]. Then the realisation of full automated process will become more economic also for small and medium-sized companies.
All in all, the implementation of a trolley train process must not only be an entrepreneurial and procedural but also can be a strategic and by the society conditioned decision.

5. REFERENCES

[1] Dombrowski U 2015 Lean Development: Aktueller Stand und zukünftige Entwicklungen (Berlin-Heidelberg: Springer-Verlag)

[2] Knössel T 2015 Gestaltung schlanker Prozessschnittstellen in automobilen Logistikketten Dissertation Lehrstuhl für Fördertechnik Materialfluss Logistik, Technische Universität München

[3] Jones D T, Hines P and Rich N 1997 Lean Logistics (International Journal of Physical Distribution & Logistics Management)

[4] Martini A, Stache U and Trenker F Automatisierung von Routenzugsystemen Research Gate

[5] Dickmann et al. P 2015 Schlanker Materialfluss: mit Lean Production, Kanban und Innovationen 3rd edn (Berlin-Heidelberg: Springer-Verlag)

[6] Hompel M t, Schmidt T and Nagel L 2007 Materialflusssysteme: Förder- und Lagertechnik 3rd edn (Berlin-Heidelberg: Springer-Verlag)

[7] Günthner, Univ.-Prof. Dr.-Ing. Willibald A. 2012 Stand und Entwicklung von Routenzugsystemen für den innerbetrieblichen Materialtransport: Ergebnisse einer Studie Studie Lehrstuhl für Fördertechnik Materialfluss Logistik, Technische Universität München

[8] Schulz R 2017 Methoden und Tools für die Effizienzsteigerung Ihres Unternehmens: Staplerlose Fabrik https://www.ipe-group.de/industrieplanung/kontakt/impressum/

[9] Bergakademie Freiberg Begriffe zur Automatisierung (DIN 19233)

[10] logistikjournal 2017 Weltmarkt Flurförderzeuge 2016: Rangliste nach Jahresumsatz mit Gabelstaplern und Lagertechnik http://www.logistik-journal.de/weltrangliste/

[11] Günthner, Univ.-Prof. Dr.-Ing. Willibald A. 2016 IntegRoute-Ganzheitliche Konzeptauswahl für Routenzugsysteme zur Produktionsversorgung: Integrierte Bewertung von Prozess und Technik Forschungsbericht Lehrstuhl für Fördertechnik Materialfluss Logistik, Technische Universität München

[12] Verein Deutscher Ingenieure VDI-Richtlinien: Routenzugsysteme VDI-Handbuch Technische Logistik

[13] Keuntje C and Günthner, Univ.-Prof. Dr.-Ing. Willibald A. 2017 Considering Ergonomics in the Planning of Trugger Train Systems for Production Supply (Institute for Materials Handling, Material Flow, Logistics, Technical University of Munich)

[14] International Organization for Standardization 2009 Ergonomics-manual handling (ISO 11228-3:2007) https://www.iso.org/standard/26522.html
[15] STILL GmbH Routenzug mit automatischer Be- und Entladung: Nominierungen 2017 (2017)
[16] Mecalux logismarket Routenzug mit automatischem Be- und Entladen: Innovative intralogistische Lösung, um Produktivität zu gewinnen beim Gewährleisten von hohen Flüssen https://www.logismarket.de/manuline/routenzug-mit-automatischem-be-und-entladen/5443524153-7247723016-p.html
[17] Ackermann e 2016 Miniaturized Sibling of OTTO Material Handling Robot Joins Clearpath Fleet https://spectrum.ieee.org/automaton/robotics/industrial-robots/miniaturized-sibling-of-otto-material-handling-robot-joins-clearpath-fleet
[18] openPR 2009 Fahrerlose Transportsysteme: Die Sache mit der "motormouse"
[19] KUKA Group Fahrerloses Transportsystem Carry Pro: optimierter Transport von Paletten
[20] Wittmann T, Viereck V and Krüger-Basjmeleh T 2015 Route train and control method for same EP2848498A1
[21] Dulai T and Werner-Stark A Algorithm for directing cooperative vehicles of a vehicle routing problem for improving fault-tolerance Optimization and Engineering
[22] Bauernhansl T, Hompel M t and Vogel-Heuser B 2014 Industrie 4.0 in Produktion, Automatisierung und Logistik: Anwendung, Technologien, Migration (Wiesbaden: Springer-Verlag)
[23] MCP UP Ltd 2002 Effective Lean Logistics Strategy for the Auto Industry (The International Journal of Logistics Management)
[24] Schönsleben P 2016 Integrales Logistikmanagement: Operations und Supply Chain Management innerhalb des Unternehmens und unternehmensübergreifend 7th edn (Berlin-Heidelberg: Springer-Verlag)

Cât de semnificativă este alimentarea automatizata a liniilor de asamblare?

Rezumat: Automatizarea procesului de troliu pentru alimentarea liniei de asamblare este o solicitare recurentă din partea producătorilor către furnizorii de inginerie de manipulare a materialelor. Această lucrare prezintă acei pași ai procesului de rulare a troleibuzului, care sunt cele mai importante pentru a fi automatizate în ceea ce privește implementarea cea mai ușoară și cea mai mare valoare. Analizând mai multe aplicații, sa dovedit că cea mai mare parte a timpului de proces este utilizată pentru încărcarea și descărcarea manuală a remorcilor. Nu numai din punct de vedere economic, dar și din punct de vedere ergonomic, acești pași sunt cei mai critici. Aplicarea specifică și condițiile ei trebuie întotdeauna incluse în considerente; o declarație generală despre utilizarea semnificativă a automatizării nu este posibilă datorită numărului mare de condiții limită specifice.

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