IMPLEMENTATION OF THE SMART SOLUTION TO IMPROVE THE EFFICIENCY OF THE LOADING PROCESS OF PRODUCTS IN SELECTED INDUSTRIAL ENTERPRISE

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Abstract

With high price competition, it is no longer important for enterprises to achieve merely the lowest price but predominantly to gain a competitive advantage using non-financial indicators that include quality distribution, reliability and delivery quality, or cohere supply relationships. The article focuses on introducing the Automated Truck Loading System and its use in the process of loading finished products in a selected industrial enterprise. Further there are mentioned the reasons supporting the decisions about the Automated Truck Loading System. The authors of the article analysed the current state of the process of loading the finished products into trucks and based on the identified deficiencies and requirements of the enterprise; the authors proposed a solution to improve the efficiency of the selected logistics process. As the automation currently plays a key role in logistics, the authors used intelligent/smart technologies that are part of Industry 4.0 in designing the solution. Subsequently, the authors of the paper verified the suitability of the selected solution to the mentioned problem using the Analytic Hierarchy Process method. For multicriteria decision-making, the authors applied Expert Choice software.

Keywords: Automated Truck Loading System, logistics, loading of goods, industrial enterprise, multicriteria decision making, Analytic Hierarchy Process

1. AUTOMATED TRUCK LOADING SYSTEM

The use of advanced technology in the field of logistics provides space for improvement of business logistics processes and thus secures competition of the enterprise‘s logistics capability.

Intelligent/smart technology in industry and logistics is a relatively new concept that entered the market in the last few years. The impact of new trends on the logistics market in Slovakia is evident [1]. The part of intelligent/smart technologies is also Automated Truck Loading and Unloading System which plays a key role in the field of the warehouse - loading and unloading areas, transport and contributes to the optimisation of the logistics supply chain.

Time losses that occur during loading or unloading of the goods cannot be regained on the road. The solution is the Automated Truck Loading System (ATLS), which can significantly save time on the loading ramps [2, 3].

The ATLS is closely related to the handling of material or finished products in industrial enterprises. The ATLS is designed to automate the loading or unloading of finished products by using or without the use of handling units in trucks or trailers. Using several different types of automatically managed equipment or modified belt conveyors that are integrated into lorries [4].

The use of the ATLS brings several benefits to businesses; for instance, it reduces the loading and unloading time, eliminates the truck drivers’ need for the help with loading and unloading, reduces the risk of damage to the handled goods and materials, and has a positive impact on ergonomics and safety.

Like any technology/system, the ATLS also has some drawbacks. The disadvantage of these systems is a higher investment in the introduction of the ATLS, however with a fast return of the investment in applications with high volumes and short driving times, including the need of the trucks and docks' modification [3, 5].

The ATLS consists of two components - the trailer system in the truck trailer and the dock system at the loading ramp [3]. Both systems are shown in **Figure 1**.

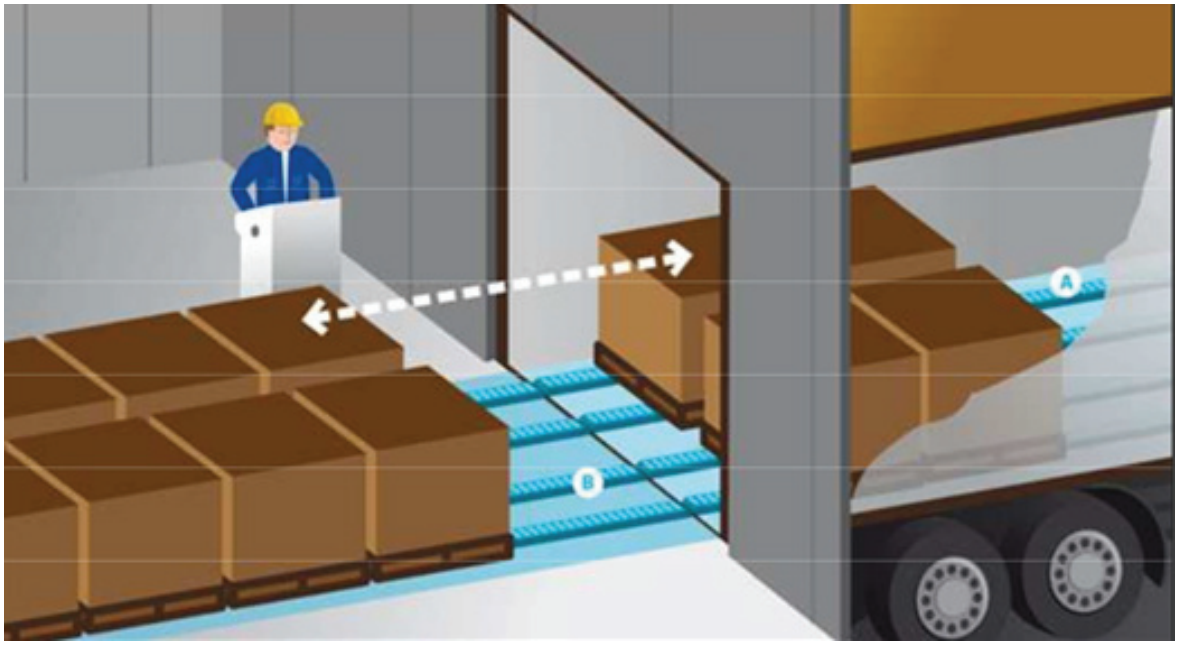

Figure 1 A system in the trailer and system inside the dock [5]

2. STATE-OF-THE-ART ANALYSIS OF THE LOADING PROCESS OF THE GOODS IN A SELECTED INDUSTRIAL ENTERPRISE

The state-of-the-art analysis of the preparation process and the loading of the finished products was carried out in an enterprise in the rubber industry, based on observations and interviews with an enterprise employee.

The process of preparation and loading of the finished products in the selected enterprise is a process that is based on customer requirements that are transferred to the Warehouse Management System. A forklift operator accepts a request for a specific metal column pallet (KSP), which he removes from the warehouse and consequently transfers it to the expedition zone where he unloads the KSP. Another forklift operator with a particular tick grip initially removes the first tires from the KSP, then he places them on the marked area in the dispatch zone, and places the other tires on the first tires to form a CVT chimney (CVT is a type of truck tire).

Stacked CVTs are prepared for the loading process. Loading of the products that will be dispatched shall be carried out from the back side into an in advance prepared lorry. The loading process takes approximately 1.5 to 2 hours. The tire chimney is not sufficiently stable. Therefore, it requires the expertise and experience of the forklift operator. When the forklift truck enters the lorry, the chimney swings. Therefore, the low speed of the forklift truck is necessary to avoid a chimney fall and related increase of the time load or damage to the goods.

Other negative factors that operate between the shipping ramp and the truck and affect the loading process in an enterprise include the following:

- Height divergence between the ramp and the lorry.
- Distance divergence between the ramp and the lorry.

- Suspension and instability of the lorry.
- The weight of the forklift truck.

The enterprise expects increased production and demand for products in the future. Based on the above, the enterprise, like many enterprises, is currently looking for ways to optimise selected aspects of the logistics system, mainly focusing on the Smart Connected System Logistics. Smart Connected System Logistics is formed by the implementation of intelligent/smart technologies, ideas, and concepts in logistics processes. Smart Connected System Logistics is a smartly connected product (e.g. Automated Guided Vehicles, Automated Storage Equipment, etc.) that is organised through the cloud, while the cloud-based solution additionally provides access to information from other factory data sources, such as system planning and management, external logistics etc. [6]. The enterprise intends to introduce Automated Guided Vehicles (AGVs) in the product handling process as a part of the optimisation of logistics processes.

3. IMPLEMENTATION OF AUTOMATED TRUCK LOADING AND UNLOADING SYSTEM IN THE SELECTED INDUSTRIAL ENTERPRISE

The proposed ATLS technology is an appropriate solution for shuttle transport because it allows a several times speed increase of the truck's revolution, for the reduction of the number and operation of a forklift, and also for a reduction of the number of the employees who work on the loading ramp. The hydraulic equipment for the Automatic Truck Loading System consists of the following parts:

1) Chain drive units system.
2) An electric motor that provides chain drive.
3) A place that is intended for unloading of the KSP.

The introduction of the ATLS builds on the introduction mentioned above of the AGVs in the handling of finished products in the enterprise because the combination of these technologies/systems contributes to maximising of the saved costs.

The proposed ATLS operation process will be as follows: using the AGV, a full KSP load will be executed on the hydraulic device by placing the selected number of KSPs in the first position. Subsequently, the steel chain will ensure the shift of the KSP to the second position and the first position will be released for the next KSP. After loading the AGV with the total capacity of the trucks, the loading process that uses automated hydraulic equipment can be started.

Upon entering the premises of the enterprise, a driver of the truck reverses the truck to the loading ramp. The truck's driver is alerted about the freehand/ramp by a light signalling. The security equipment ensures the precision that is necessary for the task. The loading process itself can begin following the truck aligning and its subsequent link to the automatic loading system.

The process of the proposed automated loading requires a specific modification of the truck semitrailers. It involves the installation of a particular steel floor with drains that are designed to navigate hydraulic forks.

After starting the loading process, the KSP will be driven forward to the waiting lorry. During the loading process, the trailers of lorries will be equipped with steel drains with entering hydraulic forks that are raised and inflated through an airbag - a system that is located inside the hydraulic forks (**Figure 2**).

The KSP that is stored on the conveyor will be transported to the trailer using the electric motor. After the transport of all KSPs in the semi-trailer, the air from the airbags inside the hydraulic forks will be released, and the KSP will be lowered to the floor of the semi-trailer. Subsequently, the hydraulic forks will be pulled back to the conveyor via an electric motor.

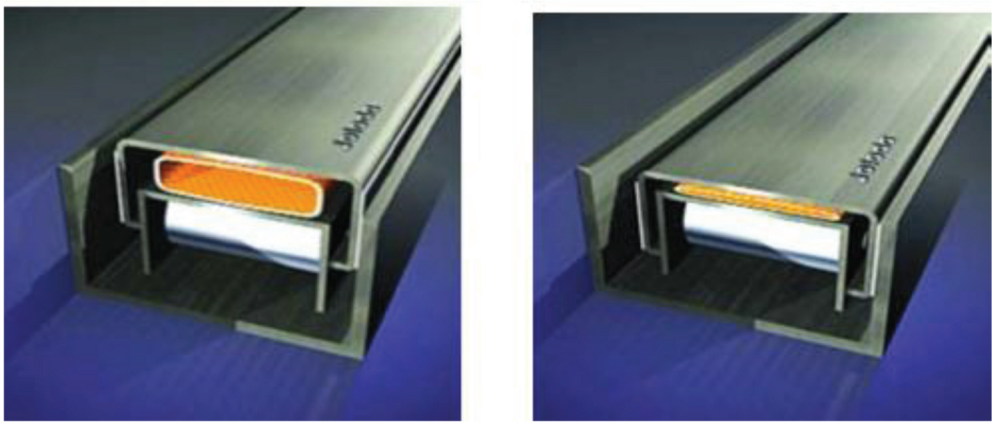

Figure 2 Airbag system inside hydraulic forks [7]

4. THE SELECTION OF THE SOLUTION BASED ON THE AHP METHOD

As mentioned before, the authors of the paper verified the suitability of problem solution based on the AHP method application. Application of the AHP method can be solved in two ways, numerically and using by software. The Expert Choice software (EC software) was used to select the appropriate solution.

The AHP method allows to make an effective decisions in complex situations, simplify and accelerate the natural decision-making process. AHP provides a complete and logical concept for structuring the problem, quantitating its components that are related to the final goals and for evaluating alternative solutions [10, 11].

Decision making within the AHP method is based on three principles of analytical thinking [9]:

- the principle of structuring the hierarchy
- the priority setting principle
- the principle of logical consistency.

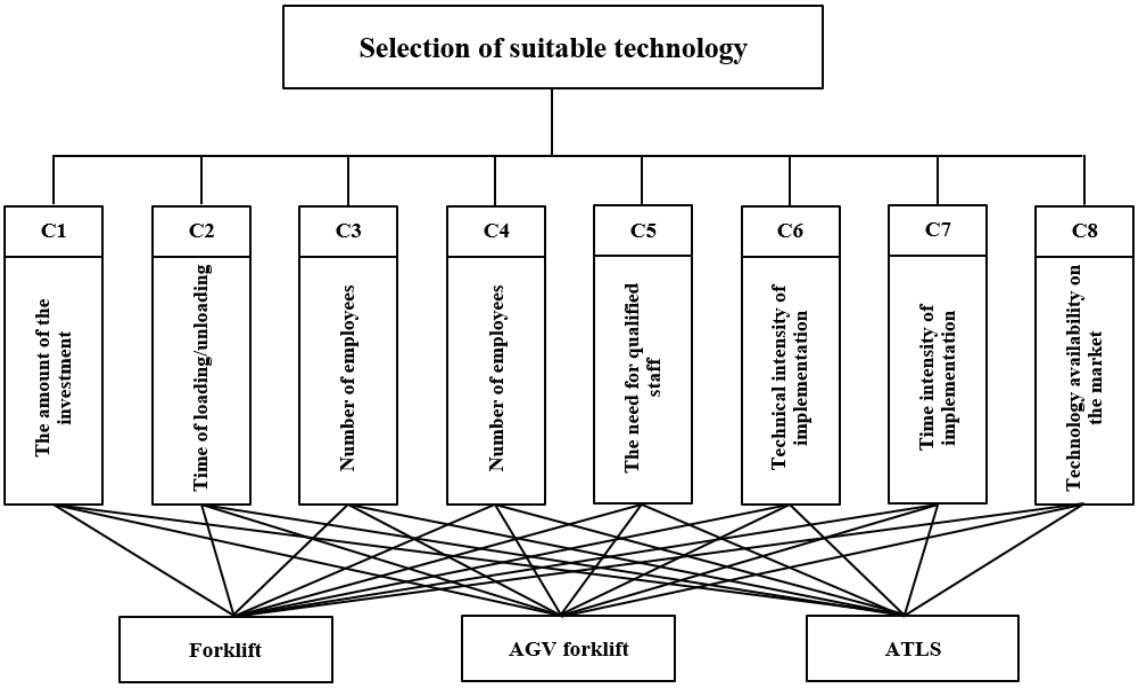

Figure 3 Hierarchical structure

Before the method application, it is necessary to create a hierarchical structure of the problem, which consists of the following elements:

1) To define the goal of the decision problem: The selection of the appropriate solution (appropriate technology)
2) To identify the possible solutions variants of the problem. The authors included the current state of the art to the shortlist of the possible solutions variants (1. the use of forklifts, 2. the implementation of the AGV forklifts and 3. implementation of the ATLS)
3) To determine the criteria for evaluation of the solution variants.
4) To establish the relationships among the goal, variants a criteria and to compile the hierarchical structure (**Figure 3**).

The procedure of the problem solution by using the EC software is as follows:

1) Determination and writing the goal, criteria and variants of the problem.
2) Assignment of weight to individual criteria by pairing comparison of the criteria.

The EC software calculated the weight of the individual criteria (**Figure 4**) based on the pair comparison. The most important criterion is the loading/unloading time and the least important criterion is the availability of technology on the market.

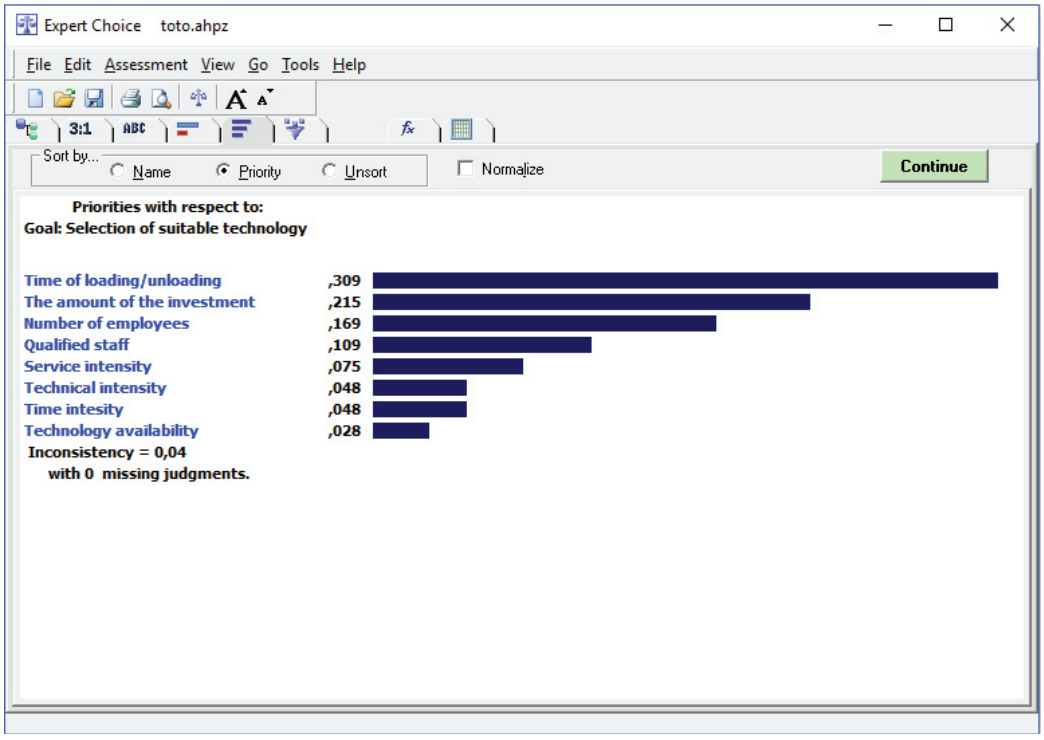

Figure 4 Determination of the criterion weight

The EC software displays decimal numbers by using rows, not the points as it is usual in English. The EC software does not display decimal numbers in the form of 0.XYZ, but it only displays the numbers following the decimal comma, i.e. without displaying a number zero.

3) Evaluation of the variants based on the pair comparison of the individual criteria.
4) The resulting (synthetic) evaluation of individual variants

The order of the individual solution variants of the given problem was obtained based on the AHP method application. The most appropriate solution according to the criteria is the implementation of the ATLS (**Figure 5**).

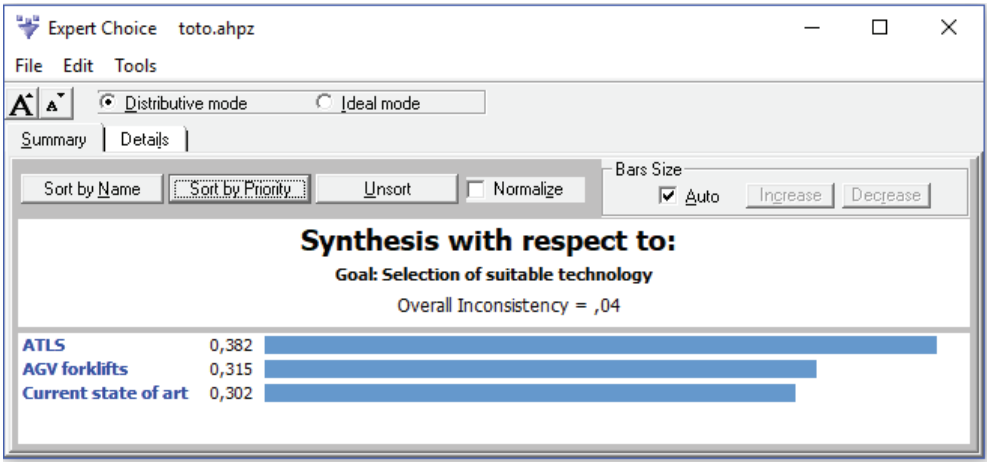

Figure 5 The resulting order of the proposed solution variants

5. CONCLUSION

The implementation of the hydraulic automated loading and unloading equipment will optimise selected logistics processes in the enterprise.

For better clarity, **Table 1** summaries specific examples of strengths, weaknesses, opportunities and threats of the ATLS implementation in the enterprise.

Table 1 Summary of the strengths and weaknesses, including ATLS opportunities and threats [8]

Strengths	**Weaknesses**
Time reduction required for the loading and unloading process	Higher investment in the implementation of the ATLS
Reduction of the number of the employees who may be employed in other jobs	Required warehouse floor modification
Liberation of the space on the loading ramp for other use	The need for newly qualified staff
Minimum semi-trailer adjustment	Increased power consumption
Simple management	
Security of the stability of the goods (elimination of the instability of stacked products)	
The functional existing loading system	
Opportunities	**Threats**
The possibility of increased production	A power cut
Compatibility with other types of automation in the future	Electricity expenses increase
The possibility of obtaining the new customers	ATLS Services
	Extended implementation time

The most significant benefits of ATLS implementation include the reduction of the loading and unloading time that is proven by the following calculation. Based on the protection of sensitive business data, the specific numbers are not used in the calculations.

Decreasing the loading time at full truck capacity is calculated by subtracting the original value from the scheduled loading time. The loading time is reduced by approximately 16 minutes.

The implementation of the proposal to introduce the ATLS into practice will also result in a reduction of the economic costs, for instance by reducing the number of fork-lift trucks that can be sold. Based on the expected cost savings and a specific bid for the introduction of the ATLS in an enterprise, the estimated return of the investment is 3.5 years.

The authors of the paper confirmed the appropriateness of ATLS implementation as a solution to problems related to the cost effectiveness of the loading goods in the selected enterprise. The authors used for selection and confirmation of the most appropriate solution the multi-criteria optimization method - the AHP method.

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