Selection of Handling Equipment in Warehouse Using Multi-Criteria Decision-Making

T. Kučera[1]

[1] *University of Pardubice, Faculty of Transport Engineering, Studentská 95, 532 10, Pardubice, Czech Republic, E-mail:* tomas.kucera@upce.cz

Abstract

The handling equipment are more modern and companies pay more attention to the safety of the warehousing operator every day. Every company which is using handling equipment is constantly renewing them for this reason. Handling equipment are used for professional relocation, loading and directing of material in production, warehousing and cycle. The handling equipment form a whole for a certain area of transport handling, including organization. The aim of this article is the selection of handling equipment in the warehouse using multi-criteria decision-making. Choosing the right handling equipment in warehouse is based on the number of pallets, the position behind the steering wheel, the battery, speed, load capacity and manoeuvrability. Multi-criteria decision-making is a scientific discipline of operational research that deals with the analysis of decision-making situations in which decision-making variants are assessed not only by one but by several conflicting criteria. The article uses the weighted sum method, where alternatives are assigned numbers according to the order of individual characteristics, the highest sequence number has the highest alternative number.

KEY WORDS: handling equipment, multi-criteria decision-making, warehousing

1. Introduction

Material handling equipment, of which transport is an important part, is an integral part of virtually every technological process. It has a significant impact on quality, economy and safety in all areas of business throughout the globalized world. Material handling, as a set of operations required in manufacturing, has become an important field of modern technology. The field began to develop, study and cover other major operations. Thus, all technological transport and warehousing and many other handling operations are routinely included in handling today.

Economic globalization and market liberalization have led to the separation of production and consumption places, which has led to significant growth in world trade and intercontinental flow of goods [1]. Logistics is an area that represents an irreplaceable role in every business and society in today's globalized world [2].

The aim of this article is the selection of handling equipment in the warehouse using multi-criteria decision-making. Choosing the right handling equipment in warehouse is based on the number of pallets, the position behind the steering wheel, the battery, speed, load capacity and manoeuvrability.

2. Theoretical Background

The conditions under which industrial enterprises are evolving today mean that advanced information technologies are evolving intensively and introduced into manufacturing processes to ensure greater flexibility and adaptability to the changing external environment. The problems associated with demonstrating the characteristics of the warehouse process in the relevant supply chains are therefore of particular importance [2]. This is due, on the one hand, to the need to minimize overall aggregate costs in terms of the whole customer satisfaction process to ensure the competitiveness of next-generation production systems and on the other to a high proportion of total logistics costs in supply chains of industrial enterprises [3-4]. Thus, one of the most important goals (from minimizing logistics costs of enterprises) is to document the fleet characteristics of the material handling equipment, which directly ensures the implementation of the material handling process and consequently significantly affects performance indicators of industrial supply chains [5-6]. The problem is also complex because warehouse performance indicators (including transport capacity and operating costs) depend on both the amount of material handling equipment and its technical characteristics [7-8].

The goal of almost every business is to optimize all logistics operations to minimize errors and gain a competitive edge despite other businesses in the industry [9].

Modernization of mechanical structures and structural components helps to mitigate the negative impacts of operating conditions and ensure the desired output [10]. Each moderation should be accompanied by a review of the maintenance strategy. The most effective, but also the most demanding, is proactive maintenance [11]. Warehousing logistics managers are interested in providing high quality services especial in handling equipment to their customers at an optimal price [12-13]. Logistics and express courier services companies have to strive to increase the level of the customer service provided with optimum pricing policy [14].

3. Methods

Multi-criteria decision-making is a scientific discipline of operational research that deals with the analysis of decision-making situations in which decision-making variants are assessed not only by one but by several conflicting criteria. The article uses the weighted sum method, where alternatives are assigned numbers according to the order of individual characteristics, the highest sequence number has the highest alternative number.

The AHP and WSA methods are used in this study. AHP is a decision support procedure developed by Saaty [15] to deal with complex, unstructured, multi-criteria decisions. AHP is based on three factors: model structure, benchmarking of alternatives and criteria, and synthesis of priorities. AHP has been widely used in the literature to address a number of complicated decision-making problems [16-19].

The Weighted Sum Approach, also known as the weighted partial order method, is also based on the maximization of utility, but assumes only a linear utility function. Using it, a normalized criterion matrix $R = (r_{ij})$ is created, whose elements are obtained from the criterion matrix Y and its rows corresponding to the ideal (I) and basal (B) variant. The matrix already represents a matrix of utility values of the i-th variant according to the j-th criterion. The option that reaches the maximum utility value is then selected as “best”, or handling equipment are ranked based on a decreasing utility function value [15].

4. Results and Discussion

Electric pallet truck – Jungheinrich

With the designation ESE 533, the electric pallet truck (see Figure 1) is suitable for long-distance transport with a large number of pallets. It can handle up to three pallets at a time and has an operator safety cabin. It is equipped with AC motors for smooth starting and high end speeds, ensuring a powerful 48 V battery with 1,000 Ah capacity. 360 ° steering range facilitates manoeuvrability between racks thanks to low steering wheel speed. The display shows the battery range, cruising speed, program selection, mileage, operating hours and total time. The load capacity is rated at 3,300 kg at speeds up to 20 km/h [20].

Fig. 1 Jungheinrich ESE 533 electric pallet truck; Source: [20]

Electric pallet truck – Still

The OPX 25 Plus from Still (see Figure 2) is designed for horizontal order picking and for transporting multiple pallets at the same time. The weight of the load can be up to 2,500 kg at a speed of 14 km/h. Safe driving through curve speed control, which reduces speed depending on the steering angle, ensuring safe passage between shelves. The battery is 24 V with a capacity of 345 Ah [21].

Fig. 2 Still OPX 25 Plus electric pallet truck; Source: [21]

Electric pallet truck - Toyota BT

The Toyota BT Levio 3.0 t is a specific electric pallet truck (see Figure 3) for two consecutive pallets with a load capacity of up to 3,000 kg and a traveling speed of 19 km/h. It is also designed for transport over long distances. It is equipped with a safety cabin with height-adjustable operator seat. The battery has a capacity of 840 Ah and a voltage of 48 V [22].

Fig. 3 Toyota BT Levio 3.0 t electric pallet truck; Source: [22]

The selection of the Milk run electric pallet truck (see Table 1) for each manufacturer Jungheinrich, Still and Toyota BT is compared by: number of pallets, driving position, battery, speed and load capacity.

Table 1

Comparison of electric pallet trucks for Milk run; Source: Author based on [20-22]

	Jungheinrich	Still	Toyota BT
Number of pallets (pieces)	3	2	2
Driving position	Sitting	Standing	Sitting
Battery (V/Ah)	48/1000	24/345	48/840
Speed (km/h)	20	14	19
Load capacity (kg)	3 300	2 500	3 000

Selecting the electric pallet truck for the Milk run

The selection of the right electric pallet truck is based on the number of pallets, the position behind the wheel, the battery, speed, load capacity and manoeuvrability. For the criterion “number of pallets”, the author defined points 0-10 of the weight of the evaluation. The more pallets, the less points, as the length of the electric pallet truck affects manoeuvrability and passage between racks (see Table 2). The second criterion for points is “driving position” (also points 0-10). The best position is the sitting position, which increases the safety and comfort of the operator. The third criterion is “battery” - again rated by 0-10 weight points. The maximum score is for higher V/Ah. The fourth criterion is “manoeuvrability”. The better the manoeuvrability, the higher the score (0-10).

Table 2
Comparison of electric pallet trucks for Milk run with achieved criteria values; Source: Author based on [20-22]

	Number of pallets	Driving position	Battery	Speed	Load capacity	Manoeuvrability
Jungheinrich	5	10	10	20	3 300	2
Still	10	5	2	14	2 500	10
Toyota BT	10	10	5	19	3 000	7
Weight criteria v_K	0.03	0.35	0.07	0.25	0.20	0.1

For Table 2, the author defined weight criteria v_k ($\sum 1$) according to importance. The weight criteria v_K is the most important to the least important: position behind the wheel v_K 0.35; speed v_K 0.25; manoeuvrability v_K 0.10; battery v_K 0.07 and number of pallets v_K 0.03.

A matrix (F) is created from Table 2 to form a normalized matrix (F´).

$$F = \begin{bmatrix} 5 & 10 & 10 & 20 & 3300 & 2 \\ 10 & 5 & 2 & 14 & 2500 & 10 \\ 10 & 10 & 5 & 19 & 3000 & 7 \end{bmatrix}$$

The same principle as for the electric pallet truck from the column is the highest value that divides the other values in the column.

$$F' = \begin{bmatrix} 0{,}500 & 1 & 1 & 1 & 1 & 0{,}200 \\ 1 & 0{,}500 & 0{,}200 & 0{,}700 & 0{,}757 & 1 \\ 1 & 1 & 0{,}500 & 0{,}950 & 0{,}909 & 0{,}700 \end{bmatrix}$$

For this task, the author also used the method of weighted sum order, where alternatives are assigned numbers according to the order of individual characteristics, i.e. the highest sequence number has the highest alternative number. For example, in the “battery” column, in the order 3-1-2 (see Table 3).

Table 3
Weighted sum method of the electric pallet truck for Milk run; Source: Author based on [23]

i/k	Number of pallets	Driving position	Battery	Speed	Load capacity	Manoeuvrability	$\sum_k v_k f'_{ik}$
Jungheinrich	1.0	2.5	3	3	3	1	4.455
Still	2.5	1.0	1	1	1	3	1.245
Toyota BT	2.5	2.5	2	2	2	2	2.190
Weight criteria v_K	0.03	0.35	0.07	0.25	0.20	0.10	

Calculation: $$\sum_k v_k f'_{ik} \quad [-] \qquad (1)$$

For Jungheinrich $1.0 \cdot 0.03 + 2.5 \cdot 0.35 + 3 \cdot 0.07 + 3 \cdot 0.25 + 3 \cdot 0.20 + 1 \cdot 0.10 = 4.455$
For Still $2.5 \cdot 0.03 + 1.0 \cdot 0.35 + 1 \cdot 0.07 + 1 \cdot 0.25 + 1 \cdot 0.20 + 3 \cdot 0.10 = 1.245$
For Toyota BT $2.5 \cdot 0.03 + 2.5 \cdot 0.35 + 2 \cdot 0.07 + 2 \cdot 0.25 + 2 \cdot 0.20 + 2 \cdot 0.10 = 2.190$

According to the calculation $\sum_k v_k f'_{ik}$ the Jungheinrich electric pallet truck is the best one, but its disadvantage is its size and manoeuvrability. This electric pallet truck is only suitable for transport on long and straight tracks. The Jungheinrich ESE 533 has been selected according to multi-criteria decision-making.

5. Conclusion

High-quality handling equipment is an important part of the future-oriented intralogistics success in every company. Industrial manufacturing processes require a number of special handling equipment. It is currently used to support decision making by appropriate methods such as multi-criteria decision-making. Transport or more generally material handling equipment involves not only solving technical issues, i.e. equipping a business with suitable means of transport and handling equipment, but also problems associated with their purpose of utilizing and solving energy, economic and environmental aspects. The selection of the right electric pallet truck was based on primary criteria such as: number of pallets, position behind the wheel (driving position), battery, speed, load capacity and manoeuvrability. Jungheinrich's electric pallet truck was selected using the multi-criteria decision-making analysis and was recommended for further use.

Acknowledgements

The work was created in connection with the scientific research project of the University of Pardubice no. SGS_2020_010. The author is grateful for their support.

References

1. **Krstic, M.; Tadic, S.; Brnjac, N.; Zecevic, S.** 2019. International Terminal Handling Equipment Selection Using a Fuzzy Multi-Criteria Decision-Making Model, Promet-Traffic & Transportation 31(1): 89-100.
2. **Kučera, T.** 2019. Application of the Activity-based Costing to the Logistics Cost Calculation for Warehousing in the Automotive Industry, Communications - Scientific Letters of the University of Zilina 21(4): 35-42.
3. **Radaev, A. E.; Leventsov, V. A.** 2018. The Methodology for Substantiating the Materials Equipment of a Unit Load Warehousing System, International Journal for Quality Research 12(4): 989-1016.
4. **Leventsov, V. A.; Radaev, A. E.; Nikolaevskiy, N. N.** 2017. The Aspects of the “Industry 4.0” Concept within Production Process Design, Saint-Petersburg State Polytechnic University Journal. Economics, 10(1): 19-31.
5. **Ahmad, M. Z.** 2006. The Application of Fuzzy Expert System to Preliminary Development Planning of Medium Size Container Terminal. University Teknologi, Malaysia.
6. **Ertugrul, I.; Güneş, M.** 2007. Fuzzy Multi-Criteria Decision Making Method for Machine Selection Analysis and Design of Intelligent Systems using Soft Computing Techniques, Advances in Soft Computing, 41. Berlin: Springer.
7. **Shymchenko, A. V.; Tereshchenko, V. V.; Ryabov, Y. A.; Salkutsan, S. V.; Borovkov, A. I.** 2017. Review of the Computational Approaches to Advanced Materials Simulation in Accordance with Modern Advanced Manufacturing Trends, Materials Physics and Mechanics 32(3): 328-352.
8. **Zobacheva, A. U.; Nemov, A. S.; Borovkov, A. I.** 2017. Multiscale Simulations of Novel Additive Manufactured Continuous Fiber-Reinforced Three Component Composite Material, Materials Physics and Mechanics 32(1): 74-82.
9. **Kučera, T.; Suk, A.** 2019. The application of ABC analysis in the logistic warehousing processes, Transport Means - Proceedings of the International Conference, 548-554.
10. **Bosnjak, S.; Petkovic, Z.; Simonovic, A.; Zrnic, N.; Gnjatovic, N.** 2013. Designing-in Failures and Redesign of Bucket Wheel Excavator Undercarriage, Engineering Failure Analysis 35: 95-103.
11. **Moczko, P.; Pietrusiak, D.** 2019. Experimental - Numerical Method for Assessing the Condition of Opencast Mining and Material Handling Equipment, Australian Journal of Structural Engineering 20(4): 248-258.
12. **Kučera, T.** 2017. Logistics Cost Calculation of Implementation Warehouse Management System: A Case Study. 18th International Scientific Conference-Logi 2017. MATEC Web of Conferences 134: 1-7.
13. **Kučera, T.** 2018. Calculation of Logistics Costs in Context of Logistics Controlling, Transport Means - Proceedings of the International Conference, 22-27.
14. **Sommerauerová, D.; Chocholáč, J.; Jirásková, A.; Polák, D.** 2019. Improvement of Distribution Logistics Processes Using Vehicle Routing Problem with Pickup and Delivery with Time Windows Algorithm, Transport Means - Proceedings of the International Conference, 1191-1196.
15. **Saaty, T. L.** 1980. The Analytic Hierarchy Process. McGraw-Hill: New York, USA.
16. **Dagdeviren, M.; Yavuz, S.; Kilinc, N.** 2009. Weapon Selection Using the AHP and TOPSIS Methods under Fuzzy Environment, Expert Systems Application 36: 8143-8151.
17. **Kulak, O.; Durmusoglu, M. B.; Kahraman, C.** 2005. Fuzzy Multi-Attribute Equipment Selection Based on Information Axiom, Journal of Materials Processing Technology 169: 337-345.
18. **Chan, F.T.; Kumar, N.** 2007. Global Supplier Development Considering Risk Factors Using Fuzzy Extended AHP-Based Approach, Omega 35: 417-431.
19. **Shen, C. W.; Peng, Y. T.; Tu, C. S.** 2019. Criteria Decision-Making Techniques for Solving the Airport Ground Handling Service Equipment Vendor Selection Problem, Sustainability 11(12): 3466.
20. **Jungheinrich**. 2020. Vozíky s bočním uložením sedačky 3,3 t [online cit.: 2020-03-07]. Available from: http://www.jungheinrich.cz/produkty/elektricky-paletovy-vozik/ese-533/
21. **Still.** 2020. Vychystávací vozík OPX 20-25 Plus [online cit.: 2020-03-07]. Available from: http://www.still.cz/opx-20-25-plus-cz.0.0.html
22. **Toyota BT.** 2020. Vozíky [online cit.: 2020-03-07]. Available from: https://shop.toyota-forklifts.cz/webshop/cz/elektricke-paletove-voziky/bt-levio-30t-sedici-ridic-a-zdvojene-motory-pojezdu
23. **Dudorkin, J.** 2003. Systémové inženýrství a rozhodování. Praha: Vydavatelství ČVUT, 161 p. (in Czech).