Advanced Logistic Systems – Theory and Practice, Vol. 18, No. 3 (2024), pp. 5-18.
https://doi.org/10.32971/als.2024.024

EVOLUTION AND DEVELOPMENT TENDENCIES OF MATERIAL HANDLING MACHINES

PÉTER TELEK[1]

Abstract: *The tools used during mobilities are very diverse, but their operation and structure can be traced back to the same basic principles that created the material handling machines during the previous centuries. Today, knowledge of material handling machines has become a basic necessity not only for industrial and service processes, but also for people's everyday lives, since our lives are almost unimaginably filled with different means of transportation, or without using the vehicles that transport and load our daily consumer goods. As in all areas, material handling is becoming more and more modern, and equipment that serves social and economic needs at a high level is used. One of the most defining characteristics of today's consumer society is extremely rapid change, which also affects our devices, so the design of material handling machines is also constantly changing. An important question of competitive service is how to meet rapidly changing needs. In my article, I review the development of material handling equipment, or the most important handling machines used in modern systems. Based on the outlined processes and technical changes, I will try to show where material handling is headed, what trends prevail today or are expected in server systems of the near future.*

Key words: *history of material handling, advanced handling machines, development tendencies*.

1. INTRODUCTION

The 21st century is the century of mobility. Everything moves, people travel a lot, the transport of various goods is the most dynamically growing economic sector. This mobility is provided by various devices that are adapted to the high technical and comfort standards expected by consumers.

The tools used during mobilities are very diverse, but their operation and structure can be traced back to the same basic principles that created the material handling machines during the previous centuries. We can state that today the knowledge of material handling machines has become a basic need not only for industrial and service processes, but also for people's everyday lives, since our lives are filled with an almost unimaginable variety of transport applications (e.g. transport and loading machines for our daily consumer goods).

In this paper, I review the development of material handling equipment, and the most important handling devices used in modern systems. Based on the outlined processes and technical changes, I will try to show where material handling is headed, what trends prevail today or are expected in handling systems of the near future.

2. DEVELOPMENT OF MATERIAL HANDLING MACHINES

Material handling has been present in the history of mankind from the very beginning, it was first used manually (transportation and lifting by human power), then in the form of simple tools (e.g. sticks, rods) and equipment (e.g. rafts, boats). Organized material

[1] PhD, University of Miskolc, Institute of Logistics, Hungary
peter.telek@uni-miskolc.hu

handling began with the use of regular water transport (river, sea ships) and animal-drawn transport (carts, sleds, etc.), which have served humanity for thousands of years.

In addition to natural driving forces (water, wind and animal power), after early attempts (e.g. Ctesibius around AD 250, who built machines powered by water and wind), the first artificial propulsion only appeared in the 18th century mode (steam engine), which was already independent of the whims of nature [1]. From then, we are talking about real material handling machines, the very first versions of which were transport cars pulled by steam locomotives and steam ships.

Industrial material handling dates back to the 20th century, mainly thanks to the spread of mass production, where manual material handling no longer met the increased transport and loading needs, and therefore it was necessary to use new, mechanized service tools. It was then that the ancestors of today's material handling machines were created, which in their functional structure are the same as the currently used versions [2].

2.1. Main types of material handling machines

Nowadays, we can find a wide variety of material handling equipment in the industrial and in economic processes, which at first glance are significantly different from each other [3]. Taking a closer look at these machines, many similarities can be discovered between them, on the basis of which we can classify them into different types. Based on the structural and operational characteristics, we can distinguish approx. 15-20 main types. The reason why there are no clear categories is because different specialists consider certain subtypes as separate types (e.g. traveling cranes and jib cranes). Fig. 1 shows a possible breakdown of the main types.

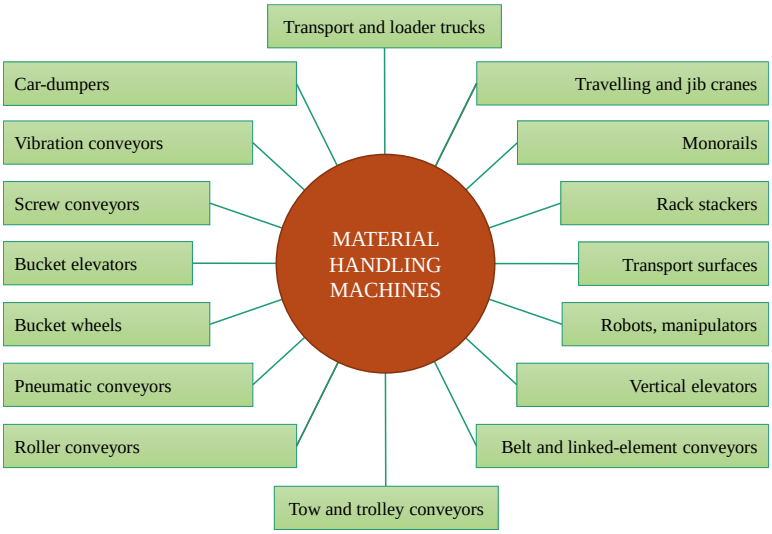


Figure 1. *Main types of material handling machines [4]*

The grouping shown in Fig. 1 significantly facilitates the overview of material handling equipment, but further simplification is also possible. An important question during material handling is how the goods get from one object to another. The implementation of

this is called a goods handling method and it basically determines the structure and operational characteristics of the machines.

In terms of the method of moving goods, we can find four different solutions in material handling [4]:

- mobile handling units,
- installed loading arms,
- transport channels,
- moving by traction elements.

2.2. Development of mobile moving units

Independent, mobile units move goods in discrete quantities, between given objects, in individual cycles. Each piece of equipment is operated individually, according to a separate program, on a specified route. Due to their operational characteristics, we can use them for transport (transportation units), loading (loading units) and storage (storage units) tasks. Mobile equipment includes forklifts, overhead cranes, suspended rail track and conveyor transport cars, elevators and warehouse stackers [5].

The development of mobile handling units can be linked to forklifts, whose history is as old as material handling, since the various aids used for transport appeared in the earliest times. Even before the appearance of the wheel, early humans used means of transportation that fulfilled the function of later forklifts in everyday use. The simplest means of transport was a simple solution, which consist of two poles and some leather strips, and two people could transport different goods and people with it like a stretcher (Fig. 2). A version of this pulled by a back animal (one end was tied to the horse, the other was pulled on the ground) was also used in different areas of the world.

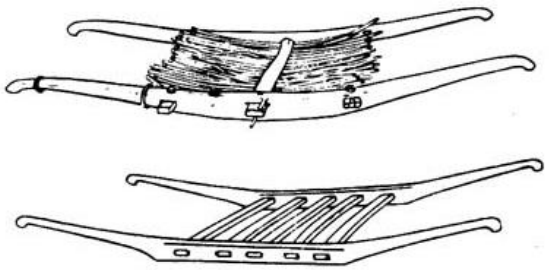


Figure 2. *Simple manual carrying devices [6]*

The real forklifts naturally appeared with the use of the wheel, in its first form with the help of a wheel attached to the pivot. A modern version of this is the one-wheeled wheelbarrow, a means of transport that is still used today. Thanks to human ingenuity, many versions of hand trucks (with one, two and three wheels) have been developed over the millennia, which are still indispensable tools in our daily lives.

The appearance of transport trucks in today's sense is the person, or it is associated with four-wheeled carts pulled by draft animals, which have also served humanity for thousands of years. From there, the development of mechanical forklifts was only a step away, as the horses only had to be replaced with a mechanical drive, the function remained the same.

The history of lifter trucks is a bit shorter, since basically a transport truck and a lifting device must be connected to get a forklift. Lifting equipment mounted on horse-drawn carriages existed centuries ago, but the basic concept is certainly related to ship cranes, where this method of loading goods has been known for a very long time.

Forklifts in today's sense are from the 20th century. were created at the beginning of the 20th century (1923) by combining the column lifting device (1867) and the electric transport truck (1906), this principle is attributed to Eugen Clark [7].

Figure 3. *Yale forklift with a shortened wheelbase (1926) [7]*

Over time, many new types have been born, adapting to the ever-increasing expectations of the industry, but the next big leap was the automation. The first attempts to create automatic transport trucks were made in the 1950s, and by the end of the 20th century, they were widespread in all areas of industry, including automated forklifts.

Forklifts are traditionally non-tracked material handling machines [8], but in some cases (e.g. mining) wagons moving on rails have already been used to perform transport tasks (e.g. wagons moving on railway tracks). A big change was brought by automatic guided vehicles (AGV), most of which are fixed-track devices, primarily due to their simpler and easier controllability.

2.3. Development of installed loading arms

In the case of small moving distances (primarily during loading), the goods can also be moved with arms in a fixed position and rotating around a given axis. Material handling machines of this type move goods in discrete quantities, among closely located objects, in unique cycles, in the vicinity of a fixed point. According to their operational characteristics, we can only use them for loading or transfer activities. We consider rotary cranes, robots and manipulators, as well as car dumpers as installed loading arms [4].

The development of loading arms began with the development of cranes, for which we have to go back to the appearance of simple lifting equipment, because the ancestors of each type of crane developed from rope lifting equipment, and the majority of cranes used today also apply the advanced versions of this [1].

The basic principle of rope lifting is to fasten the goods to the end of the rope, and then pass the rope over a bar located above the goods, so that the goods can be lifted by pulling

the other end of the rope. An important advantage of this method is that the weight of the person carrying out the lifting can help the lifting, which significantly increases the weight of the goods that can be lifted.

Due to its simple structural design and advantageous properties, the rope as a lifting device has been present in the history of material handling for a very long time. In terms of its applicability, the important development was the appearance of the rope wheel, which significantly reduced the frictional resistance during lifting and the wear of the rope (Fig. 4.a). By using several rope wheels, the lifting force could be significantly reduced.

a) Lifting with rope wheel

b) Cable drum [9]

Figure 4. *Rope lifter equipment types*

The first high-performance, efficient lifting devices were certainly rope lifting devices, whose application appeared already in antiquity, where they were used to lift large loads (e.g. on construction sites). However, they were only used to lift the goods, they did not allow for horizontal movement. The appearance of cranes in today's sense (rotary crane) is probably connected to the loading of ships, where the required lifting equipment was attached to a pole mounted to the mast for ease of handling (Fig. 5). In fact, this simple principle is also used in the operation of today's jib cranes.

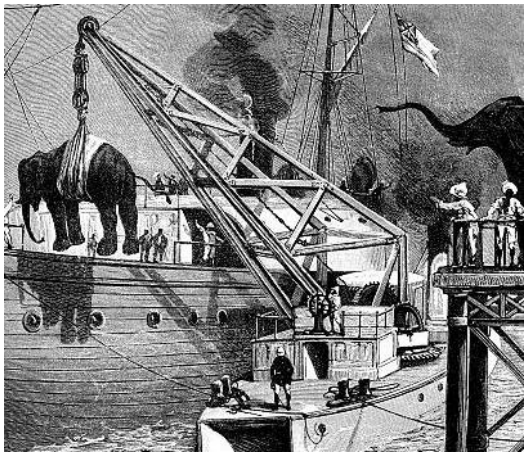


Figure 5. *Ancient ship crane [10]*

The next important element in the operation of cranes is the rope drum, which is used to wind up the rope, enabling the load to be fixed in a given position and the lifting height to be increased (Fig. 4.b). The rope drum, or the large driving drum attached to it made it possible to increase the lifting force even in ancient times (quarry wheel), which was driven from the inside by one or more people with their feet.

The basics of the operation of wheeled cranes (travelling cranes) have been known since the Middle Ages (drawing by Leonardo da Vinci, 1500), but they were used only after the industrial revolution, primarily in connection with increasing production performance [1].

2.4. Development of transport channels

Transport channels are fixed or moving elements for the guidance and continuous movement of bulk materials or piece goods, where the movement of the goods is caused by the movement of the track or an external driving force. The goods are moved along a given path, which determines the characteristics of the movement. Transport channels include chutes, turntables, roller conveyors, belt conveyors, vibratory conveyors, augers, haulage conveyors, en masse conveyors and pneumatic conveyors.

The earliest transport tracks could have been slides on which our ancestors moved all kinds of goods between destinations located on different levels (e.g. unloading ships). The chute, as a material handling device, is still indispensable in some fields (e.g. construction industry).

The earliest versions of driven conveyors were conveyor belts, which appeared at the end of the 18th century, mainly for the continuous transport of agricultural products [11]. In contrast to simple chutes, conveyor belts were able to transport bulk materials both horizontally and on an upward trajectory (see Fig. 6). The initial conveyor belts were hand-powered, the first steam-powered version was used by the British Navy in 1804 for galley transport [12].

Figure 6. *Early belt conveyor [13]*

The transport surface was initially made of leather or textile, but soon rubber straps also appeared. The first steel belt conveyor is attributed to the Sandvik company (1902).

The first high-performance belt conveyor system for coal and ores was built by Thomas Robbins for Thomas Edison's ore processing company (1892), and in 1905 Richard

Sutcliffe used a composite belt (fabric and rubber) for underground mining purposes. Henry Ford used conveyor belts for the first time (1903) in car assembly processes to serve workshop-based production [11].

In 1908, Hymle Goddard patented roller tracks [11] by further thinking about the operating principle of conveyor belts. The additional driven (e.g. vibration track), or external driving force operated conveyors (e.g. conveyor auger) was generally known centuries ago (e.g. pneumatic transport) [14], but their regular industrial application could only be made in the 20th century, usually adapted to the needs of special application areas (e.g. escalators) [1].

2.5. Development of handling machines using traction elements

The goods can also be transported by continuous movement between the individual track points, for this purpose endless chain or rope traction elements are most often used. Traction elements move goods on hangers, transport units or in transport containers. The movement of the goods takes place along the traction elements, the trajectory of which determines the characteristics of the transport. The operational characteristics of the movement are determined by the design and drive solution of the traction element. Traction moving equipment includes conveyors (movement of piece goods), bucket elevators (movement of bulk material) and continuous excavators (pickup of bulk material).

Traction element movement as an operating principle began with the use of ropes for lifting and transportation (see Fig. 7). Even before our era, the very first traction element devices were regularly used for the purpose of raising water. In later times, in addition to the rope, various chains appeared, the development of which was intertwined with the development of traction element material handling.

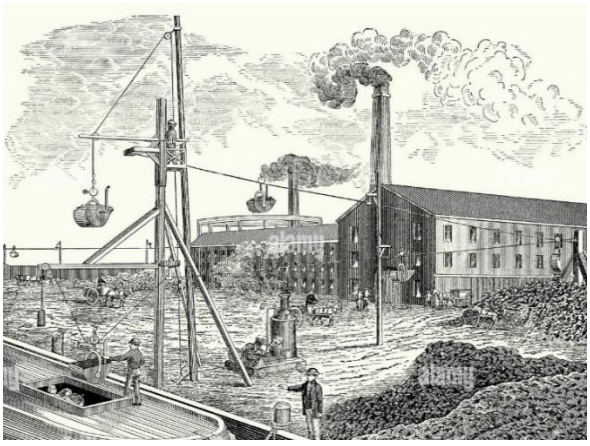
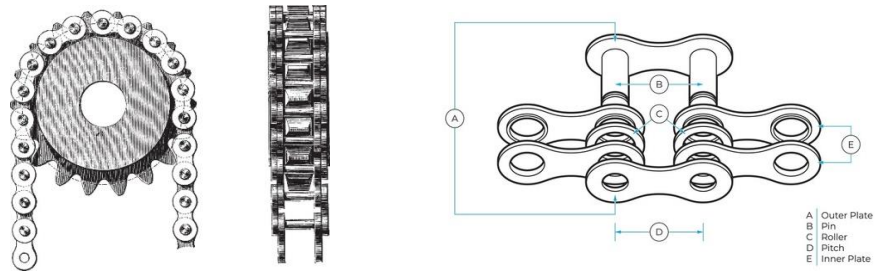


Figure 7. *Early cable way transport [17]*

The first written trace of a chain used as a traction element is attributed to Philo, who made a bucket dredge in Byzantium, B.C. around 225, with which he actually created the ancestor of the elevators and continuous excavators still used today [15]. The first real, steam engine-driven, chain traction bucket elevator was put into operation in 1780 (Oliver Evans) in the USA [1].

Traction-driven transportation of piece goods appeared in written sources in 1411, where a ropeway with transport baskets was used to supply the Vienna court library [1], although the first real ropeway made of hemp rope had to wait until 1644 (England). Passenger cable cars began their expansion in the 19th century, the first urban cable car was built in Lyon in 1862 [16].

The development of modern conveyors required a traction element that could be used to form a closed track system efficiently with little resistance loss. The principle of such chains already appeared in Leonardo Da Vinci's drawings (early 1500s), but the first chain composed of overlapping elements (Fig. 8.a.) was patented by Andre Galle (Galle chain) in 1829 [18]. The next step was the invention of the roller chain in 1864 (James Slater), but wear-resistant, economically operated roller traction elements (Fig. 8.b.) were developed by Hans Renold in 1880 [18].



a) Galle chain [19] *b) Roller chain [20]*

Figure 8. *Conveyor chain types*

The design and operation of today's conveyors required precise and reliable elements that were only made possible by the standardization that became common at the beginning of the 20th century [15].

3. EVOLUTION OF ADVANCED MATERIAL HANDLING MACHINES

The development of material handling machines is not a self-serving, random process. All changes that occurred during material handling can be interpreted as a response to the challenges of the industrial, economic or social environment. As a result, it is not possible to draw a linear, always upward development line. The development of these machines can also be seen as a kind of evolution, during which certain directions become stronger or die out. The material handling devices used in today's industrial environment are the results of this evolutionary process. In the following chapters, I will go through the main stages that each mode of goods movement has taken during its development.

3.1. Advanced mobile handling units

Mobile handling units include a wide variety of equipment (see Chapter 2.2), but in today's material handling systems, mobile units occur in three main operational variants:

- free moving handling units (forklift, truck, ship, etc.),
- fixed-track, self-propelled vehicles (travelling cranes, monorails, AGV, stacker, elevator, train, etc.),
- fixed track, towed cars (tow conveyor).

For the modern design, or application specifics required the following development steps:

- integration of the loading operation,
- creation of horizontal movement along the track,
- creation of vertical, inclined path movement,
- the development of drive solutions,
- development of loading techniques,
- development of external delivery methods,
- development of track management solutions,
- development of automatic control and management,
- development of tracking and identification, etc.

In modern material handling systems, the most important features of mobile handling units are fast and trouble-free operation, automatic control and error-free operation (see Fig. 9).

Figure 9. *Automatic Guided Vehicle [21]*

3.2. Advanced loading arms

During today's material handling tasks, we can only come across three types of loading arms, which differ significantly in terms of their function and field of application: rotary cranes, robots and rotary excavators.

Their design is significantly different, but the following development steps were necessary to reach their current form:

- boom structure development,
- development of lifting structure,
- development of the driving system,
- the development of drive solutions,
- development of loading techniques,
- development of arm kinematics,
- development of automatic control and management,
- sensor system development,
- development of tracking and identification, etc.

In modern material handling systems, the most important features of the loading arms are fast and trouble-free operation, error-free operation, or security technology and the possibility of cooperative operation (see Fig. 10).

Figure 10. *Material handling robots [22]*

3.3. Advanced transport channels

The individual transport channels can differ significantly (see chapter 2.4), but in terms of their development, they are aligned with the characteristics that determine their operating principle. Based on this, we have to distinguish three main groups:

- passive transport lanes,
- active transport lanes,
- transport channels using an external driving force.

The operation of passive transport channels (chutes, gravity roller lines) does not allow for significant development, primarily the structure, or it is possible to move forward in the materials of sliding or moving surfaces. The situation is similar in the case of the external driving force (conveyor screw, pneumatic transport, etc), where the principle is given, significant development is unlikely to be achieved.

Real development can be outlined in the case of active transport channels, since the birth of some equipment is also an evolutionary step (e.g. roller track). The most important development steps:

- the formation of the moving surface,
- development of belt transport,
- development of transport surface,
- formation of a roller track,
- development of roller transport
- the development of drive solutions,
- development of special solutions (vibration conveyors, turntables, escalators),
- development of automatic control,
- development of tracking and identification, etc.

Since the transport channels, as continuously operating devices, basically carry out automatic goods movement, the most important direction in modern systems is not their automation, but their integration into the system (see Fig. 11), their coordinated, undisturbed operation, and the reduction of their energy consumption are the most important challenges.

Figure 11. *Advanced roller conveyor system [23]*

3.4. Traction elements in advanced material handling systems

Transport using traction elements also differs primarily in the application characteristics, which are mostly defined by the properties of the transported goods:

- ropeways (transport of people or bulk solids),
- trolley and tow conveyors (piece goods transport),
- bucket elevators (transport of bulk solids),
- continuous excavators (loading bulk solids).

Their design does not differ significantly, the following development steps were necessary to reach their current form:

- rope development,
- development of bulk cargo loading,
- the development of the movement of bulk goods,
- development of passenger transport,
- formation of chains,
- development of chains,
- development of automatic control,
- development of tracking and identification, etc.

Figure 12. *Advanced trolley conveyor system [24]*

Since equipment using traction element is also a continuously operating device, it basically carries out automatic goods movement, so integration into the system, coordinated, undisturbed operation and reduction of energy consumption are the most important challenges here as well (see Fig. 12). In addition, in the case of ropeways, creating and enhancing personal safety is an increasingly important task.

4. DEVELOPMENT TENDENCIES IN MATERIAL HANDLING

Starting from the history of the development of material handling machines and taking into account the characteristics of the tools currently used in modern industrial service systems, the most important trends that will determine the expected changes in the coming decades can be described. Of course, these changes are not self-serving either, they are always adapted to the ever-changing industrial, economic and social needs and environmental conditions.

Based on the information described in the previous chapters, the most important trends will cause significant changes related to material handling in the following areas:

- full automation,
- cooperative robots,
- maintenance,
- tracking, identification,
- sensors, etc.

Automation is today's prominent technical element, it is being tried to be introduced into every industrial process, but two fundamental problems have to be faced. The first is the social impact, which applies to all affected areas, since automation directly reduces the amount of human resources involved in industrial and service processes. In the near future, this will decrease the number of jobs and consequently, it entails a decrease in consumption, which can cause a significant social and economic problem [25].

As a solution to the above problem, the possibility of cooperative automation (cooperative robots) arose, of which numerous examples can already be found in the literature [26]. This is a promising initiative, but it raises further questions, e.g. the number of real application possibilities, or reduction in the efficiency of automation as a result of the integration of human resources.

The other important element is the issue of automation, which can arise in several places in material handling (e.g. handling of goods). If the manual implementation is significantly simpler or cheaper, then exploiting the advantages that can be gained through automation may encounter problems. A solution can be the so-called use of semi-automatic equipment (e.g. picking), which actually work cooperatively [27].

One of the key issues in the coming decades will be maintenance. The maintenance of automated machines is inherently more complex and critical than that of simpler, manual machines, but due to the ever-increasing expectations for computer control and error-free operation, it is an even greater task. At the moment, the question is whether the maintenance should be carried out by human maintainers or automatic machines? Both cases involve dangers. The increasingly complex maintenance tasks require an increasingly high level of knowledge from professionals, which is difficult to achieve in the light of current social and educational trends. Modular maintenance (replacement of entire subassemblies) can be a solution to this, but the high cost of this can threaten the economy

of production and service processes. The use of automatic maintenance equipment can be effective in the case of certain processes and errors, but the vision of machines that maintain machines seems quite a paradoxical solution.

Another important area of today's material handling is the widest possible implementation of identification and tracking for both goods and service machines. This is not only related to certain operations, but is a source of information that spans entire processes and can be used for all purposes. Here, the goal is currently to establish complete tracking, for all elements (even very small goods), which requires a complex sensor system, high-level data management (collection, storage, transmission, processing, etc.) and software. This is also a general trend, both in terms of goods and people, but it is a particularly complicated task when handling materials.

5. SUMMARY

Nowadays, material handling, or knowledge of material handling machines has become a basic need not only for industrial and service processes, but also for people's everyday lives, since our lives are filled with an almost unimaginable variety of means of transport, i.e. without using the vehicles that transport and load our daily consumer goods.

As in all areas, material handling is becoming more and more modern, and equipment that serves social and economic needs at a high level is used. One of the most defining characteristics of today's consumer society is extremely rapid change, which also affects our devices, so the design of material handling machines is also constantly changing. An important question of competitive service is how to meet the rapidly changing needs.

In this article, I reviewed the development of material handling equipment, and the handling devices used in modern industrial systems. Based on the outlined processes and technical changes, I tried to show where material handling is headed, what trends prevail today, or are expected in server systems of the near future.

Of course, such predictions are always subjective, but they can help determine the research directions in which it is worth investing energy in the coming decades.

REFERENCES

[1] Paturi, F. R. (1991). *A technika krónikája*. Officina Nova Kiadó. Budapest
[2] Felföldi, L. (ed.) (1975). *Materials handling handbook (in Hungarian).* Technical Press, Budapest
[3] Ten Hompel, M., Schmidt, T. & Nagel, L. (Eds.). (2007). *Materialflusssysteme. Förder- und Lagertechnik.* Berlin: Springer, https://doi.org/10.1007/978-3-540-73236-5
[4] Telek, P. (2023). Transport channels in advanced material handling systems. *Advanced Logistic Systems - Theory and Practice* **17**(3), 43-50, https://doi.org/10.32971/als.2023.022
[5] Telek, P. (2024). Mobile handling units in advanced Material handling systems. *Advanced Logistic Systems -Theory and Practice*, **18**(1), 75-90, https://doi.org/10.32971/als.2024.008
[6] Arcanum. *Magyar Néprajzi Lexikon*. Retrieved from https://www.arcanum.com/hu/online-kiadvanyok/Lexikonok-magyar-neprajzi-lexikon-71DCC/s-739B6/saroglya-csin-739FE/
[7] Conger (2024). *Forklift History: The Complete Story.* Retrieved from https://www.conger.com/forklift-history
[8] Kulwiec, R. A. (ed.) (1985). *Materials handling handbook*. John Wiley & Sons. New York, https://doi.org/10.1002/9780470172490
[9] Mighty cranes. *The History of Cranes.* Retrieved from https://mightycranes.com.au/the-history-

of-cranes/
[10] iStock by Getty Images. *Antik illusztráció az elefánt hajón szállításáról.* Retrieved from https://www.istockphoto.com/hu/illusztr%C3%A1ci%C3%B3k/ship-cranes-pictures
[11] Spantech. (2020). *Who Invented the Conveyor Belt & When?* Retrieved from https://spantechconveyors.com/2020/10/27/who-invented-the-conveyor-belt/
[12] SpeedRack West. *The Fascinating History Of Conveyor Systems.* Retrieved from https://www.speedrackwest.com/blog/history-of-conveyor-systems/?srsltid=AfmBOorWkT3k5V8G64Ac8EAtHJDFsphVw0iqLm_yrN637SfIWYhL0-FC
[13] Mercurio. (2022). *How did conveyor belts come about?* Retrieved from https://www.correiasmercurio.com.br/en/how-did-conveyor-belts-come-about/
[14] Klinzing, G. E. (2018). Historical Review of Pneumatic Conveying. *KONA Powder and Particle Journal*, **35**, 150-159, https://doi.org/10.14356/kona.2018010
[15] Concord Engineering. *History of chain.* Retrieved from https://www.conkordengineering.com/history-of-chain.php
[16] Leitner. *The evolution of ropeways.* Retrieved from https://www.leitner.com/en/company/useful-information/evolution-of-ropeways/
[17] Alamy. *An old engraving of a wire rope way, wire-way or aerial tramway in the 1800s.* Retrieved from https://www.alamy.com
[18] Acorn. (2021). *The history of roller chain.* Retrieved from https://www.acorn-ind.co.uk/insight/the-history-of-roller-chain/?srsltid=AfmBOopxhY9_y-0BH4ifZeJQi-ZDXb2PnTVKrdI1O1Iz4XfOow3T-0sk
[19] VecTeezy. *Galle chain on his nuts, vintage engraving.* Retrieved from https://www.vecteezy.com/vector-art/35073710-galle-chain-on-his-nuts-vintage-engraving
[20] Shutterstock. *Chain Drive vectors.* Retrieved from https://www.shutterstock.com/search/chain-drive?image_type=vector
[21] Schaefer. *Weasel AGV.* https://www.schaefershelving.com/t-warehouse-automated-guided-vehicle-weasel.aspx
[22] Trapo. *Articulated arm robots.* Retrieved from https://www.trapo.de/en/products/robotics/
[23] Uline. *Heavy Duty Gravity Roller Conveyor - 24" x 10'.* Retrieved from https://www.uline.com/Product/Detail/H-3412/Heavy-Duty-Gravity-Roller-Conveyors/Heavy-Duty-Gravity-Roller-Conveyor-24-x-10
[24] Bastian Solutions. *IntelliTrak Overhead Conveyors.* Retrieved from https://www.bastiansolutions.com/solutions/technology/conveyor-systems/overhead-conveyor/intellitrak/
[25] Telek, P., Bányai, T. (2018). Advanced Materials Handling Processes and Devices in the Automotive Industry. In: Jármai K., Bolló B. (eds) Vehicle and Automotive Engineering 2. VAE 2018. *Lecture Notes in Mechanical Engineering*, 315-328. Springer, Cham, https://doi.org/10.1007/978-3-319-75677-6_26
[26] Lawson, G., Salanitri, D. & Waterfield, B. (2016). Future directions for the development of virtual reality within an automotive manufacturer. *Applied Ergonomics.* **53**, 323–330. https://doi.org/10.1016/j.apergo.2015.06.024
[27] Telek, P. (2023). Automation features of material handling machines. *Advanced Logistic Systems - Theory and Practice* **17**(4), 41-50. https://doi.org/10.32971/als.2023.029