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TRENDS IN WAREHOUSING AND MATERIAL HANDLING SOLUTIONS – PAST

KITTI SEPRÉNYI[1], PÉTER TAMÁS[2], ÁKOS CSERVENÁK[3]

Abstract: Today's world is changing and evolving with incredible speed. The constantly growing population leads to large number of demands for increasingly diverse products. Since our main goal in logistics is to make the customer satisfied, so in order to do this, it is essential to develop technology. Over the past few years, mainly due to a pandemic, e-commerce has boomed. However, companies need to store the ordered products somewhere, that is, they need warehouses. We have to choose carefully which warehouse is the ideal one for us, since if we do not choose the right one, the final delivery may even be delayed. Although warehousing is of great importance in today's world, no one has summarized, like this paper, how we got to the warehouses we use today. The paper shows from antiquity to the 2000s how the development took place.

Keywords: logistics, warehousing, material handling, development trends

1. INTRODUCTION

Today's world is changing and evolving with incredible speed. The constantly growing population leads to large number of demands for increasingly diverse products. Since our main goal in logistics is to make the customer satisfied, so in order to do this, it is essential to develop technology. Over the past few years, mainly due to a pandemic, e-commerce has boomed. However, companies need to store the ordered products somewhere, that is, they need warehouses. We have to choose carefully which warehouse is the ideal one for us, since if we do not choose the right one, the final delivery may even be delayed. Although warehousing and material handling are of great importance in today's world, no one has yet summarized in this form, like this paper, how we got to the warehouses we use today. In research, we go all the way back to antiquity and from there we go through the continuous developments. Accordingly, the second chapter shows how development took place from antiquity to the 2000s regarding warehousing, while third chapter regarding material handling equipment. The last chapter makes summary findings about the paper.

2. DEVELOPMENT OF WAREHOUSING - PAST

This chapter covers warehousing and material handling solutions from antiquity to the 2000s.

[1]BsC student, University of Miskolc, Institute of Logistics
seprenyi.kitti@gmail.com
[2]PhD., University of Miskolc, Institute of Logistics
peter.tamas@uni-miskolc.hu
[3]PhD., University of Miskolc, Institute of Logistics
cservenak.akos@uni-miskolc.hu

2.1. From antiquity to the Middle Ages

Modern warehouses today are the offspring of granaries, built by early civilizations to store food to help people survive long winters or famine. About 2200 years ago, the Romans completed the Horrea Galbae, the first "warehouse" in history, which was very similar to the large structures we know today as a place to store goods. It was a huge warehouse complex near the Tiber River, which included more than 140 rooms and was located on an area of about 21000 m^2. The grain reserves of the population were stored here, as well as imported goods, olive oil, wine, food, and clothing [1].

The decision to build such a huge facility so close to the river was deliberate: Roman ships laden with the spoils of conquests ran into the port to unload the treasures, and from there it was only a short journey to the warehouse. The lifeblood of the Roman Empire were the ports. With the advent of new trade routes, these warehouses played an even greater role, as the explorers returned home from their cruises with more and more goods [1].

2.2. From the modern era to the beginning of the XX century

The first known use of the word "warehouse" dates back to the 1300s, from Great Britain. By definition, a warehouse is a construction or room for storing goods or goods. In the centuries when England dominated the waves, warehouses appeared more and more often in port cities of Europe and the world. Larger and faster ships made it possible to establish global trade routes, thus making these ports and warehouses the heartbeats of civilization, pumping trade from the coast to the interior of a given country [1].

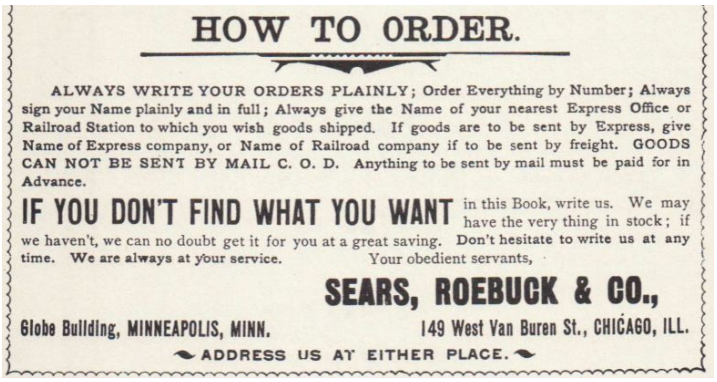
Warehousing became a concept in the late 1700s, during the Industrial Revolution, when it came into vogue as a business practice, such as, "Go and stock those crate shoes." With the invention of textile machines and the steam engine, mass production began to explode in factories, thanks to which there was an increased demand for storing goods before domestic distribution or overseas export [1].

As mentioned, the heartbeats of trade were warehouses, and early railways were the veins that allowed goods to flow to domestic cities. This process led to the construction of even more warehouses at transport hubs, which allowed merchants to transport their goods faster and farther than ever before, opening up new markets and turning smaller settlements into cities [1].

The second industrial revolution, which began in the late 1800s, and electricity led to another expansion in manufacturing. This brought mankind the light bulb, the telephone and the internal combustion engine. Another revolution was started by the invention of the car in both long- and short-haul transportation and trade, as well as the undersea cables and radio waves that connected countries and continents in the global economy changed the world even more. So, throughout history, we have created more and more goods and more and more ways to distribute them, which is how warehouses have become a key link in distribution chains. The longer and more complex these chains became, the greater the need for warehouses, and this need continues to grow today [1].

The postal parcel delivery company Sears, Roebuck & Co. was one of the first businesses to realize the potential of this growing infrastructure. The Sears catalog included thousands of products, such as toys, clothing, medical equipment, household appliances, most of which were housed in a huge 3 million-square-foot Chicago distribution complex.

All year round, hand-filled order forms arrived at the post office, on which customers indicated what products, in what quantity, size, color or style they would like to buy. Such an order form is shown in Figure 1. This process, of course, came with a lot of pitfalls, since a lot of mistakes were made when trying to figure out orders with transcribed catalog numbers or wrong handwritten ones [1].



HOW TO ORDER.

ALWAYS WRITE YOUR ORDERS PLAINLY; Order Everything by Number; Always sign your Name plainly and in full; Always give the Name of your nearest Express Office or Railroad Station to which you wish goods shipped. If goods are to be sent by Express, give Name of Express company, or Name of Railroad company if to be sent by freight. GOODS CAN NOT BE SENT BY MAIL C. O. D. Anything to be sent by mail must be paid for in Advance.

IF YOU DON'T FIND WHAT YOU WANT in this Book, write us. We may have the very thing in stock; if we haven't, we can no doubt get it for you at a great saving. Don't hesitate to write us at any time. We are always at your service.

Your obedient servants,

SEARS, ROEBUCK & CO.,

Globe Building, MINNEAPOLIS, MINN. 149 West Van Buren St., CHICAGO, ILL.

ADDRESS US AT EITHER PLACE.

Figure 1. Sears, Roebuck & Co order form [1]

Many discoveries throughout history have been made by Americans and have played a major role in the development of warehousing. Railroad was key to America's western expansion. These railways had a monopoly on the transport of goods and the manufacturers were forced to pay this high price if they did not want to miss out on sales to a much larger market. Over time, politicians also became involved, which resulted in the interstate trade law of 1887 and the final end of the monopoly on railways. In 1891, the American Association of Warehouse keepers was formed, which successfully attacked the railroad's control over freight warehouses and created the commercial warehousing industry as we know it today in the United States. President Theodore Roosevelt significantly strengthened the work of the Interstate Trade Commission [2], [3], by passing the Hepburn Act in 1906.

2.3. From the beginning of the XX century to the present

The 1900s were a period of remarkable achievements that fueled the spread of global trade. Mechanized factories became more and more widespread, allowing mass production of consumer goods, and the development of transportation meant that the increase in the number of goods offered for sale could actually reach a market that was large enough to buy them all. In addition to land, these goods have already been transported by sea and air to reach as many consumers as possible. Wherever the goods were delivered, there had to be a warehouse waiting everywhere. With the advent of new industries and production methods - such as the assembly line - household appliances, cars and other goods were produced in factories at an astonishing speed. Until the First World War, handcarts were used as material handling equipment. The loading was carried out by hand and thus could be packed at a height of about 2-3 meters. During the Second World War, forklifts and wooden pallets appeared. Thanks to the mass production of forklifts, the loading height has increased up to 10 meters in height and material handling within the warehouse has also become much faster [2, 3].

This process led to the introduction in the 1950s of the first automated guided vehicles (or AGVs) designed to carry heavy loads in factories and warehouses. It was actually a towing vehicle, but it did not require a driver or a fixed rail system. He navigated following the trail of wires embedded in the floor that generated a magnetic field. Moving heavy materials along specific paths has made the AGV an invaluable work tool that has taken over repetitive and often dangerous tasks, allowing workers to focus on more detailed or complex work. And the fruits of labor, the products produced - toys or electronic goods - were delivered to warehouses located in different cities of the country and the world [2].

Figure 2. Forerunner of forklift [7]

For centuries, people carried out the warehousing of various objects. Obviously, some kind of manual or mechanical device (handcart) was often used, but it was essentially the workers' job to transport the supplies to the warehouse for storage and then take them out for delivery to the dealers or directly to the customers. This was extremely time-consuming and often dangerous work, and since we are talking about people who make mistakes, the number of mistakes in these processes has also increased. Thus, we needed a solution that is cost-effective, productive, can save time, increases safety and customer satisfaction. This is automated warehousing [2].

In the 1960s, automation began to come to the fore. It was during this decade that the first automated storage and retrieval systems (AS/RS) appeared, which were computer-controlled systems and stored and retrieved goods in warehouses and distribution centers. At first it was designed to handle larger pallet loads, but later versions were also suitable for storing smaller batches. Automated storage and retrieval systems have been complex and extremely expensive and usually require either massive infrastructure changes or entirely new facilities to accommodate them. Overall, these systems marked the beginning of warehouse automation as we know it today [2].

The manufacturing industry reached its real heyday in the early 60-70s. As automation – of course, not the level of automation that we have today – began to appear in more and more places, the number of consumer goods produced worldwide and as customer demands also began to change, so too did the variety of products. This, in turn, led to an increase in the demand for warehouse space. At the same time, advances in technology, transportation and communications began to disrupt business as usual. The first handheld mobile phone

call was made in New York and a company called Federal Express made the first overnight parcel delivery. This was the beginning of a change in the "economy on demand" and consumer behavior, which also necessitated a change in the way goods were distributed [4]. In the eighties, the catalog buying success started by Sears, Roebuck & Co. a century earlier was still alive and well, and some companies, such as L.L. Bean and Lands' End, realized that there were buyers who were willing to pay more for faster shipping options and express delivery. The new need for speed has forced companies to think carefully about how they operate. The question was a given: if more workers cannot deliver the products to customers in a shorter time, how can this need be met? Of course, the solution was to invest in new technologies, and cooperation with shipping companies – FedEx or UPS – was essential. In addition to all this, computers began to spread nicely gradually, both at the corporate level and in homes. It was simply a matter of time before this would bring about a new change [4].

The 1990s began to boost computers. Word processors and spreadsheets made work easier, online services made it possible not to have to leave home and no longer had to throw money in arcades, since computer games were also a great success. The boom in e-commerce owes a lot to computer hardware and software companies when they took their first cautious steps online. The welcome screens were full of text and orders were difficult to process. However, the basics of selling and shipping products were already in place when a former Wall Street genius named Jeff Bezos decided to go to Seattle and start an online bookstore with more than 1 million books [4].

Throughout the history of warehouse development, it is important to mention the Amazon effect. Starting in the mid-90s, the company advertised itself as "the largest bookstore on Earth." In the early days, Amazon made deals with book distributors and wholesalers to fulfill its orders, but later it was forced to build two large warehouses, as the product range was expanding, and it had to place these stocks somewhere. Striving to store goods closest to the most profitable customer market, in the richest and most populous states of the country, the company has established a network of more than 100 performance centers throughout the United States. Amazon has invested billions of dollars in rapid expansion and warehouses, building state-of-the-art facilities with carousels, conveyors, and all the automation tools available at the time to deliver orders as quickly as possible. It employed thousands of warehouse workers who walked an average of 20-22 km a day to get the products off the shelves of the warehouse, although finding and retaining skilled workers was becoming increasingly challenging [5].

Retailers like Walmart and Target have been driven by Amazon's explosive growth rate to make significant investments in their own e-commerce operations and warehouse networks if they don't want to disappear from the scene. For companies producing software and hardware specifically for warehouses, this meant a new market. For example, Kiva Systems – now known as Amazon Robotics – a robotics startup that developed a robot that can locate a shelf full of goods in a warehouse, lift off the product you're looking for and deliver it to the person who puts together online orders for delivery [4].

Kiva was launched in the early 2000s and gained customers like Gap, as well as Zappos.com. Later, Amazon liked Kiva's robots so much that in 2012 it acquired the entire company, depriving its competitors of access to breakthrough technology [6].

To fill the void created by the acquisition of Kiva, new automation and robotics startups began to appear. It is also important to mention third-party logistics service providers (3PL), which offered regional and local storage and transportation services to businesses

wishing to establish an online presence. For businesses that wanted to keep up with large firms in a tight labor market, robotics and automation companies were the sure foundation. From robots that follow workers as they collect products, to next-generation autonomous mobile robots that go out to the warehouse and bring the goods back to the picking station. Going back to the beginning of history: the heartbeats of trade and later online shopping were warehouses, early railways were the blood vessels that allowed goods to flow to domestic cities, and robotics and automation in today's world are the heartbeat of warehouses [4].

3. EVOLUTION OF MATERIAL HANDLING

In order to actually move material, we need material handling equipment. They consist of various complex components. The functions are implemented by components consisting of basic elements, by which it is possible to understand the operation. Such a basic element is a rope, rod, wheel or pan. From a pot, rope and wooden bars you can build a boom hoist. From wooden rods and ropes you can build a boat, to which, if you add a sail, you get a sailing ship. How could these equipment has evolved? In the case of material handling, we can talk about natural and artificial material handling. Natural material handling includes manual handling by simple machine, animal power, wind force and water force [9, 13].

3.1. Manual handling

The driving force behind manual material handling is human power and it is the oldest method of drive. This is still used today for the movement of small goods and small movement distances [8, 9].

Figure 3. Manual handling [7]

3.2. Simple machines

Simple machines can be used to distribute weight, to increase strength. The driving force here is human power and does not require external energy expenditure. Simple machines have played an important role in material handling since prehistoric times [9].

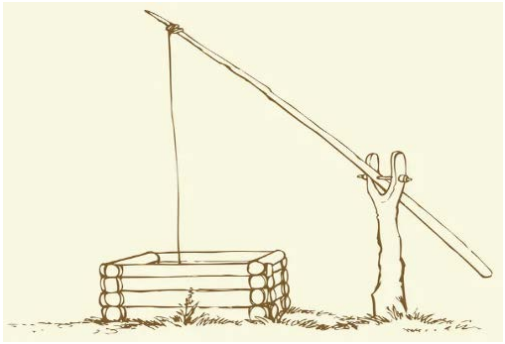


Figure 4. Boom well as a simple machine [11]

3.3. Material handling by animal power

Since prehistoric times, we have been using animals for the purpose of increasing strength. However, unlike simple machines, they no longer play a role in modern material handling systems [9].

Figure 5. Material handling by animal power [12]

3.4. Material handling by wind force

Wind energy can also be used for the purpose of increasing strength. Wind is used in sailing ships and windmills. Modern versions of air movement are pneumatic systems [9].

Figure 6. Material handling by wind power [13]

3.5. Material handling by waterpower

The driving force behind material handling is the pressure of water. Water wheels have been used for lifting and moving since prehistoric times, and they are also used in modern material handling systems, but most of the time in motorized form. Hydraulic systems are modern variants of fluid handling [9].

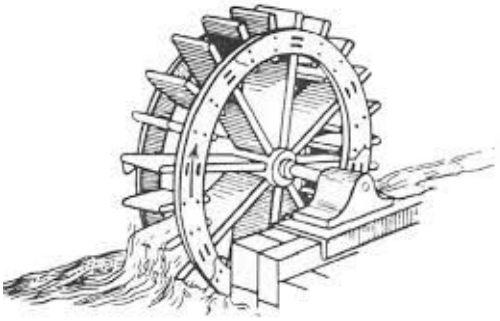


Figure 7. Material handling by waterpower [13]

3.6. Mechanized material handling

In today's world, the movement of goods is carried out mainly by material handling equipment. Different drive modes can be applied to these machines. Thanks to the Ktesibius used hydraulics and pneumatics since about 250 BCE, in the 1st century BCE, Heron created the first steam-powered structure and in 1681 a French scientist invented the steam engine. Since 1829, when electric motors and hydrogen motors were invented, we have been using electric energy and explosive motors, and since 1942 we have also used nuclear power [9].

Chronology of the appearance of transport machines [9:

- 210 BC – In Byzantium, Philon makes a bucket excavator
- 1411 – A Viennese library operates a cableway with a transport basket
- 1644 – The first ropeway made of hemp ropes is completed in England
- 1767 – The first pair of iron rails for steam locomotives is completed
- 1780 – The first elevator for bulk materials is completed in the United States
- 1810 – A pipe mail is installed in England to transport cylindrical parcels
- 1820 – Riverboats are towed with the help of chains (conveyor)
- 1843 – The first steam-operated excavator is commissioned in the United States
- 1963 – The first industrial robots go to work
- 1965 - Transport on railway containers

Chronology of the appearance of lifting machines [9]:

- 1550 BC – Boom aquarists are used in Mesopotamia and Egypt
- 1510 BC – The rope roller appears in Mesopotamia
- 20 BC – Vitruvius describes the principle of operation of cranes.
- 1500 – Leonardo da Vinci draws the principle of the running crane
- 1546 – Water-powered lifting stations are used in mines

- 1616 – Faustus Verancsics creates the first grabber
- 1688 – A ship-lifting device is built in the Netherlands
- 1857 – The first elevator for passenger transport is commissioned in New York
- 1920 – The first escalator is commissioned in New York

3.7. The development of mobile movers, lifting trucks

To date, manual lifting is used for some storage systems, however, this work was facilitated by the appearance of simple machines. In 1913, the predecessor of today's forklift appeared and advances in technology resulted in forklifts in use today. These were further developed, and special forklifts were created, such as the forklift truck or the swivel column lift truck. Today, we also use AGV lifting trucks [13].

3.8. The development of mobile movers, transport trucks

It all started with manual transport, which was replaced by the handgun. Later, material handling equipment transporting complete palettes, transport flights appeared, and now AGVs are becoming more and more widespread. However, we have a more advanced, but quite expensive, material handling equipment, the AMR (autonomous mobile robot). The AMR is more versatile than the AGV and, thanks to its on-board intelligence, is able to plan a new route due to an obstacle and also perform emergency braking [13, 14].

3.9. The development of mobile moving units, warehouse service machines

The development of warehouses also requires the development of warehouse service machines since manual handling and forklift trucks cannot be used at all in a high-bay warehouse. Therefore, loading machines appeared, and then, as automation progressed, automatic loading machines. In some warehouses, automatic warehouse wagons are now also used [13].

3.10. Evolution of installed moving equipment, material handling robots

Since science is developing at an incredible speed in today's world, we should definitely mention robots, since it is in them that the future lies. It all started with the man, and then the manipulators appeared that helped the people in their work. The next step was gantry robots, as they surpass the restrictions that stop other robots. And there are also humanoid robots that make work even easier and faster [13].

Material handling equipment for static and dynamic storage modes are mainly forklift trucks, except for example in the case of the shelving system, where the service is done by manual force. Over the years, people have tried to produce types of forklifts that can achieve the highest lifting height with as little width as possible. At the first stage of development, after the forklift with a front fork, forklifts with sliding columns were created. The lifting column of these forklifts can be pulled back thanks to a hydraulic cylinder, thus reducing the structural length of the forklift. Thus, they have already reduced the width of the road. These two forklifts also handled materials within the warehouse in addition to loading and unloading. As a next step, forklifts that only handle loading and unloading have been developed, as storage retrieval forklifts. They do not need to turn 90°, they travel on

guide rails or are guided by an induction wire in the floor. They travel along the corridors only longitudinally. A forklift truck is the most common unbound track machine requiring narrow road widths. The machine that requires the smallest road width is the forklift truck, which can rotate its fork structure in both directions. The latter two forklifts are only used for serial rack storage [15].

4. SUMMARY

The paper dealt with the development of warehouses and material handling equipment from antiquity to the present day, how we got from the Horrea Galbae and boom well to the automated high-bay warehouse and loading machine. We have seen what technological developments have been required by the expansion of trade, the emergence of railways or rapidly changing demands. These technologies are the basis for the technologies we use today and in the future. Of course, these technologies are constantly being improved, which means that they will be even more advanced in the coming years, and it is difficult to predict what exactly is expected in terms of the future of warehousing.

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