Advanced Logistic Systems – Theory and Practice, Vol. 17, No. 3 (2023), pp. 24-32
https://doi.org/10.32971/als.2023.020

ROUTE OPTIMIZATION OPPORTUNITIES IN LOGISTICS

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***Abstract**: The article describes the process of warehousing complementing with the definition of concepts essential for warehousing and the various areas that can be found in most warehouses. In the rest of the article, the relationship between the warehouse and production will be discussed, then the presentation of milkrun systems and the related milkrun routes will come to the fore. In the last part of this article, we will introduce how to calculate the optimal milkrun path using the Solver add-in for Microsoft Excel.*

***Keywords**: warehousing, milkrun, optimization, solver*

1. INTRODUCTION

In the life of companies, the process of warehousing is at least as important as the sale or production of profitable products. After identifying the concepts found in the warehouse in the article, we will talk about the problems found here and the purpose of the thesis, the solution of possible problems in the warehouse. The warehouse is a prominent player in the logistics system, which has a direct impact on the entire company structure. In the past decades, warehouse management has undergone significant development, which is also due to complex and constantly renewing logistics processes [1].

After presenting the process of warehouses and warehousing, the article emphasizes the relationship between the warehouse and production. In logistics, these two large parts are physically connected by milkruns. In our article, with the help of the Microsoft Excel Solver add-on, we determine the optimal route of the milkruns responsible for supplying the production lines in the production hall. These two areas are very complex topics, and in our opinion, the article provides a kind of summary and guidelines for logistics for interested readers. We implemented our article based on our own experiences and sources obtained from Hungarian and foreign sources.

2. WAREHOUSE AND WAREHOUSING PROCESS

Traditionally, warehouse can be defined as the part of the corporate logistics system (and/or supply chain) that stores products (raw materials, components, semi-finished or finished products) at and/or between production and/or points of use and provides information about them (e. g. product status, characteristics) [2].

The tasks of storing goods (or storing equipment) can only be solved well if specialized storage rooms are provided for this. Even today, when expanding or modernising a store, new buildings are erected for the sales area and production area, and old buildings are used

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for storage. Such outdated warehouses have high scrap, high cost of warehouse work and unfavourable working conditions. However, there are some basic, common characteristics that are general, the creation of which is absolutely necessary for any warehouse. These requirements are considered fundamental not only for the goods, but also for ergonomics.

The warehousing process therefore begins where the purchasing process ends and ends at the start of production or sales, depending on whether the product is revised or not. There are many raw materials that require special storage conditions (temperature, humidity). There are those that need to be handled during storage. The quality and quantity of the goods must be preserved during storage and protected against contamination, deterioration and contamination. It is also necessary to take into account the rules of storage 5 related to fire and accident protection. All these tasks must be solved during storage [3].

The storage process includes the following sub-processes:

- receipt of the goods,
- storage and handling of goods,
- release (delivery to the place of use) of the goods [3].

Most often, warehousing has a servant role: it is a buffer store for the values produced by businesses. In order to create and develop modern warehousing, of course, it is first necessary to clarify the expectations and demands on it, and to thoroughly assess the given opportunities. As warehouse technology becomes increasingly important within the economy, it matters how cost-intensive and efficient it is. An excellently functioning warehousing system can lay a strong foundation for the future of a successful business, while if it is difficult to trace the path of our products, we can make numerous mistakes in our procurement of goods and receive feedback from our business partners. Therefore, today there is a serious team of specialists, enterprises based on this activity design and organize systems of warehouse management [4].

The purpose of storage is to safely store the raw material until it is used, to preserve its physical properties, and in the case of an independent warehouse, to perform expedition tasks. When designing warehouses, useful layout is important.

Two main warehouse layout types are applied in the practice:

- Head warehouse layout (Fig. 1)
- Through-warehouse layout (Fig. 2)

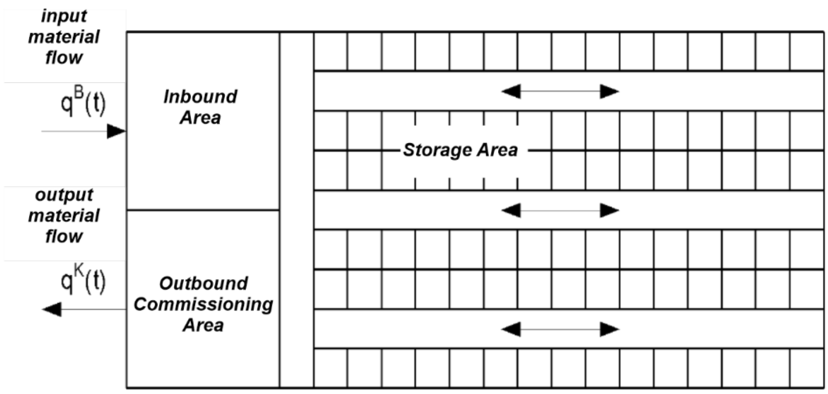

Figure 1. Head warehouse layout

Advantages of head warehouse layout:

- departments are closely interconnected, → less misunderstandings and errors,
- fast progress→, distances are reduced,
- immediate return of return/return products,
- more space-saving.

Disadvantages of head warehouse layout

- in the case of shelving systems, two-way traffic,
- distances may increase → if it is necessary to deliver a product located at the other end of the shelving system,
- With the exception of return products, it is not more profitable than a transit warehouse because, apart from these products, the goods received are never delivered before entry into storage.

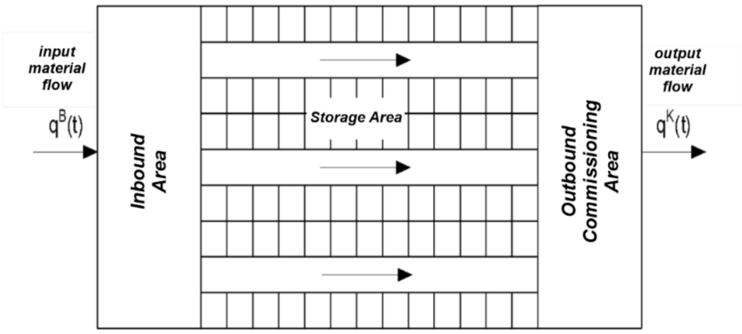

Figure 2. Through-warehouse layout

Advantages of through-warehouse layout:

- more continuous passage → resulting loss times are reduced,
- one-way passage → fewer accidents,
- The routes are even.

Disadvantages of through-warehouse layout:

- longer route, more time in case of return,
- more place-taking,
- There is no close contact → possible misunderstandings are more difficult to eliminate.

3. THE RELATIONSHIP BETWEEN WAREHOUSE AND PRODUCTION

Over the past few years, the relationship between warehouse logistics and production logistics has become so fundamental that people don't even care about it anymore. During our professional experience, we have found that the harmony between the warehouse and production is extremely important, if their relationship does not work properly, it results in serious errors. Upon completion of procurement logistics, the received raw material or component is fully the responsibility of the warehouse until production orders the given raw material or component. After the production line orders the right amount of parts, the warehouse is tasked with delivering them to the production line. Errors due to lack of proper connection can be:

- Production line orders late for the part → not arriving in production on time.
- Warehouse receives / notices late the order → , does not arrive in production on time.
- Ordering or shipping the wrong amount of product.
- Order or ship an unconforming product.
- Human errors.

These errors lead to a line stop or a defective product or an error that cannot be seen with the naked eye, but the computer can detect that the product was delivered correctly, but the part number is not correct. Of course, there are operators on the production line who deal with this, but by eliminating these errors, we can relieve you of extra work. A significant part of the errors listed above belong to the people providing the production. A shorter summary of the production supply was presented at the beginning of the article. The supply of production belongs to the warehouse and is most often carried out by the increasingly common milkruns.

4. INTRODUCTION TO MILKRUN SYSTEM

The technical literature on the design of milkrun-based material supply systems has expanded greatly in the last decade, which was partly due to the fact that these solutions became more and more widespread in the industry [5]. Milkrun is a material handling vehicle controlled by a driver or without a driver, which is most often used to service the production line. Milkrun effectively ensures the supply of materials for production, however, for the delivery of static quantities, it is important to know exactly the demand and its changes [6]. Regardless of the numerous ideas and methods, no general solution for the use of the system has yet been prepared [7]. The constantly growing range of products and the corresponding supply chain are the main challenges of production logistics. Milkrun systems can react dynamically to changes and manage them [8]. The purpose of using the system is diverse, in some researches the goal is to use the capacity while reducing the transportation costs [9] and minimizing inventory costs [10] in parallel. The design and operation of in-plant supply based on the milkrun system involves a wide range of optimization problems, such as installation, flight planning, scheduling, assignment or queuing problems [11].

The task of the milkrun workers is to supply the right production line with the right component in the right quantity. Covering, dropping or any kind of damage is obviously prohibited, but these lead to errors that later result in scrap.

5. MILKRUN ROUTES IN A FICTITIOUS PRODUCTION HALL

In the production hall, based on the top view, on the right side are the production lines for the production of self-starters and related pre-products, and on the left side are the generators. Figures 3 and 4 illustrate the milkrun routes used in the production hall.

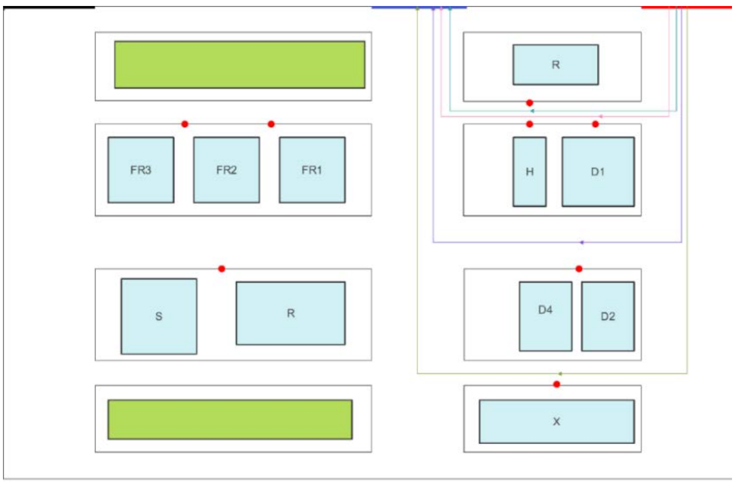

Figure 3. Self-starter page milkrun flights [own editing]

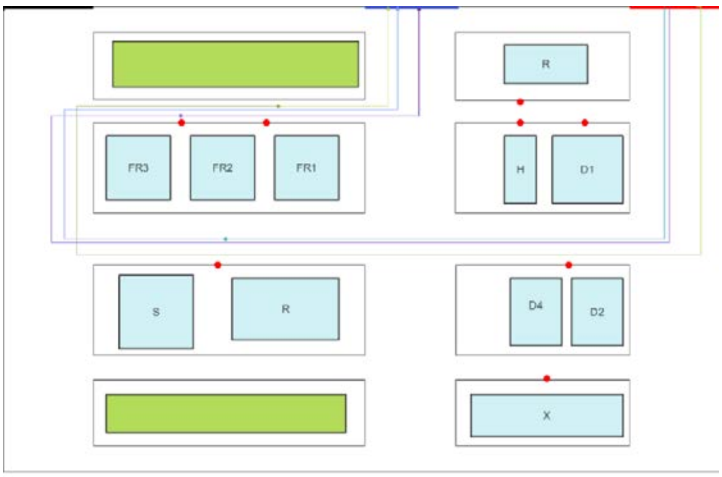

Figure 4. Generator side milkrun flights [own editing]

5.1. Determining the optimal milkrun route

The optimization of milkrun paths in Excel in the Microsoft Office family was created by using the Solver add-in. In the example, the notations involved in Fig. 5 were used.

Production lines have been marked separately, intentionally not using their original name/initial for possible future use. After the production lines, the starting point, which is simply marked with the word "Start" and the arrival point, which is marked with the word "End" have been marked, these points and their coordinates must be included in a table. The starting point is the point (0;0), all other points are relative to this point.

When determining the optimal route, the capacity of the production lines and the quantities delivered and able to be delivered by the milkruns were not taken into account at all.

Number ID	Production line name
1	FAQ1
2	FAQ2
3	FAQ3
4	FAQ4
5	FAQ5
6	FAQ6
7	FAQ7

Notations 1.

0	Initial
8	End

Markings 2.

Figure 5. Notations and markings

We only took into account the routes that were taken and could be taken, and as a result, the time required to complete the entire route was taken into account, which was calculated using the average speed of the milkruns.

The goal of the task is to determine an optimal route that not only satisfies the travel time of the previously reported 15-minute milkrun routes, but also results in the shortest distance travelled according to the routes taken.

5.2. Using Solver

To determine the optimal milkrun route, the points outlined in the previous paragraph should be written in a table called the Road Matrix, where the distance between each point is indicated using a certain function (Fig. 6).

L *[m]*	Initial	GY1	GY2	GY3	GY4	GY5	GY6	GY7	End
Initial	0	27,2029	34,0588	63,8905	106,301	107,075	82,0061	97,5141	51
GY1	27,2029	0	10	39,1152	82,2192	81,8841	63	79	33,121
GY2	34,0588	10	0	39,6232	82,0975	73,2462	53	69	38,9487
GY3	63,8905	39,1152	39,6232	0	43,1045	69	71,5612	85,4225	21,4709
GY4	106,301	82,2192	82,0975	43,1045	0	78,7718	99,8649	109,786	57,3847
GY5	107,075	81,8841	73,2462	69	78,7718	0	40,025	39,6232	88,5664
GY6	82,0061	63	53	71,5612	99,8649	40,025	0	16	84,1546
GY7	97,5141	79	69	85,4225	109,786	39,6232	16	0	99,3277
End	51	33,121	38,9487	21,4709	57,3847	88,5664	84,1546	99,3277	0

Figure 6. Road matrix [own editing]

Each cell in the completed Road matrix table contains the following function: VLOOKUP. By using VLOOKUP, Excel finds the coordinates of the corresponding production line or point in a row and column in a cell, and Excel uses the SQRTS function to calculate the distance between the two points according to the mathematical relationship. The distance to the same point is clearly 0. Next, add the Result table, which includes the Route Order, Production Line Name, Road Distance, and Order columns (Fig. 7).

In the Production Line Name column in the cells, enter VLOOKUP. VLOOKUP finds the production line name for that cell in the Order column and prints it. The values of the cells in the Road Distance column are calculated using the following function: INDEX. By using the values in the order column, the Index function prints the value that corresponds to the order from the path matrix table.

Results			
Route Sequence	Travel Distance	Name of Production Line	Sequence
1	Initial	27,20294102	0
2	GY1	10	1
3	GY2	39,62322551	2
4	GY3	43,10452412	3
5	GY4	78,77182237	4
6	GY5	39,62322551	5
7	GY7	16	7
8	GY6	35,60898763	6
9	End	51	8

Figure 7 Result table [own editing]

The next step is to use Solver. There are 3 mandatory fields to fill in in the add-in: Target Cell, Target and Changing Cells.

- Target cell: The cell in which the distance between paths is summed.
- Goal: Minimize.
- Variable cells The cells that you can change to minimize the target cell. In this case, this is the cells in the Order column.
- Limitations: Milkruns pass through each production line only once, so the restriction must be specified so that each value is different.

5.3. Solver's result

Method of solution: Evolutionary. In the evolutionary solution method, the Solver selects the optimal solution through n stages. In the first step, you select the optimal solution from random sets formed from the input values. In the second step, it generates new sets from this selected set and selects the optimum value from it as well. This algorithm (Fig. 8) repeats until Solver can refine the solution within a specified time parameter [11].

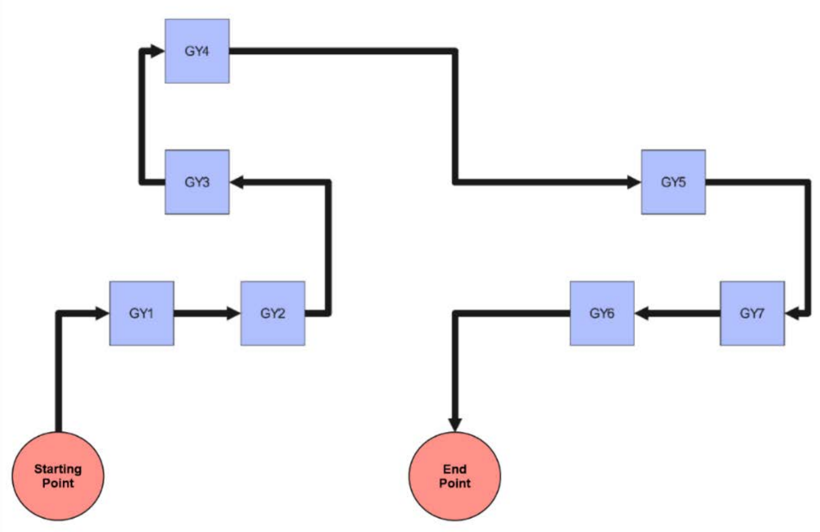

Figure 8. The route of a milkrun flight [own editing]

According to the readings in the Results table (Fig. 9), the journey time for milkrun is more than 17 minutes, plus 2-3 minutes spent loading and packing on the production lines. Based on the calculated data, the future measure would be to calculate the optimal milkrun route for two milkrun flights as well. If the 2 milkrun trains do not meet our needs, the milkrun services should be distributed until they meet the requirements in terms of the shortest time, the shortest route, and the use of as few milkrun coaches as possible.

Minimum distance to travel:	340,935 [m]
Minimum travel time:	17.0408 [min]

Figure 9. Results

6. SUMMARY

The processes presented in our thesis are responsible for everything working well in companies. The number of problems is indeterminable, there are a lot of unrecognized problems, so you can only prepare for them in a conditional way. Some of the problems are present, but they cannot be corrected due to various properties. In general, everyone in logistics strives to be prepared to adapt according to current needs, that is, logistics is always changing. In the future, the research could be supplemented with routes in the warehouse, which would result in new problems.

Route optimization is essential in the life of companies. The effective use of milkruns and the use of the optimal route means profit both from a logistical point of view and from a financial point of view. The calculations presented in the article could easily be used as templates in the future.

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