Optimization of Warehouse management and Material flows

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Abstract

The subject of this article is optimization characterization, description of warehouse management, organization and material flows of production system. Based on the analysis of production system, technological organization and organization of stocks, areas for improvement have been identified. The main part of the analysis was the choice of production representatives. Materials flow and I-D diagrams were developed for these representatives. The evaluation of the analysis was done using I-D diagrams, also the specific savings on partial material flows and the total savings were quantified. The total savings determined on the basis of the average speed of movement with the time fund of the employee. On the basis of performed analyzes, proposals for optimization solutions were determined together with the recommendations for improving the technological organization of production system.

Keywords: Warehouse management; Material flow; Optimization of stocks; Optimization of production; Savings

1. Analysis of the current state

The subject of this optimization of warehouse management is the production system of the company, which was built 20 years ago. The overall current situation, especially in the area of production, stocks, but also in the area of quality and continuous education of the original employees, especially in the field of technology, corresponds to own age. The first major change was the introduction of the new company's information system – Helios Orange – instead of the older Shoptronic system. This change significantly improved the flow of information in the company.

1.1. Warehouse management

Warehouse management is currently neglected in the company. Individual warehouses and intermediate warehouses are deployed throughout the company, and this deployment usually lacks any system or material flow considerations. There was a personnel problem here because individual warehouses were managed by employees outside of their main job (technologist, purchasing manager, business manager). It isn´t possible for technologist (for example), from the time schedule and economic point of view, to spend ½ of releasing semi-products. Closure of the warehouses (stocks) have therefore only been made for some stocks managed by the purchasing manager, whose previous workload allowed them to accept additional job duties, but this proved to be unsuitable for half a year, especially for a sharp slowdown in material delivery – purchasing manager leaves the area of the company several times a day, and the dispensing of the material is stopped at this time. In the next paragraphs individual stocks will be described.

1.1.1. Stock of metallurgical material (Stock No.1 and 2)

Stock No. 1 contains metallurgical material in the form of rolled bars, thin-walled sections and sheets. Stock No. 2 contains purchased cuts of bar material. These are storehouses where everything is stored on wooden decks or pallets and exposed to external environments.

The stock is located in an outer crane space, which is also operated (together with a forklift). The area reserved for storing materials is 238 m^2 (stock No.1–195 m^2, stock No.2 – 44 m^2). The area of stock No. 2 is used only from about 50%.

1.1.2. Stock of connecting material (Stock No. 7L1, 7L2)

All joining material is collected in this stock. This is a combination of store and shelf stock. The material is stored in shelves, larger sized pieces are stored on pallets in the middle of the room. Dimension of stock is 9x4 m^2.

1.1.3. Stock of semi-product (Stock No. 6, 3, „4")

Semi-finished products made in series of tens to hundreds of pieces are stored here. These blanks enter more products (such as the ground belt, which is part of almost all products) or they are part of the core products that are produced from hundreds to thousands of pieces per year. All parts of the stock are organized as a floor, the material is stored in boxes or pallets that are loose on the store floor. The stock dimensions are 12.7 x 5.4 m^2 (stock No. 6), 6.5 x 5.5 m^2 (stock No. 3) and 1.6 x 2 m^2(stock No. 4).

1.1.4. Stock of electrical material (Stock No.7P)

Storage of electrical material places special conditions on humidity, which must be minimal due to the possibility of oxidation of electrical components and contact surfaces.

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The material is stored in racks or pallets in the storage area. The dimensions of the stock are 14 x 4 m^2.

1.1.5. Stock of wiring accessories for cable ducts and transformer stations (Stock No.4)

Purchased plastic components that are part of some sales assortments of products are stored here. Small parts are stored in a shelf, larger pieces are leaning against the wall of the store or loose on the floor. The dimensions of the stock are 12 x 10 m^2.

1.1.6. Buffer stock

Buffer stocks (M1, M2, M11, M12) are located either in the preparatory workplaces where there are parts that are not produced in stock but are waiting for processing. In addition, the buffer stocks are placed in the free spaces along the aisles - here are semi-products, which are made into stock but are not for them in the stock of semi-products. The subassemblies are assembled into a supplies that is stored in these buffer stocks.

1.2. Production system

Production begins with the creation of an internal "production order" that contains basic information such as: product type, quantity and required delivery date (stockpiling). This order is issued with individual production orders that gradually meet its requirements. The production process is shown in Fig. 1.

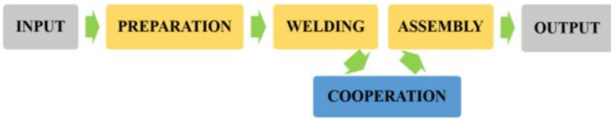

Fig. 1. *Production process.*

Individual workplaces:

- Preparation workplace
- Welding workplaces
- Processing of thin sheets
- Tool-making
- Assembly workstations

1.3. Choice of production representatives

Although the products do not differ from point of view of production (also from economical and logistics perspective), it is necessary to select the main representatives on which the analysis of current material flows and their optimization will be targeted. The weight distribution of points is described in Table 1. The resulting breakdown of individual product points is described by Table 2.

Selection criteria:

- Sales
- Number of sold pieces
- Piece demand–number of parts
- Product weight

1.3.1. Elected representatives of production system

The analysis showed that the three most important products are „Konzola PAŘÁT“, „Provozní žebřík“ (ladder), „Trafostanice“ (Table 2).

Table 1. *Points division.*

Division of points (1000 points for division by importance)	
Sales	300
Number of sold products	200
Technological difficulty – number of parts	100
Weight of the product	100

Table 2. *Result of production representatives analysis (points).*

Product	Sales	Products sold	Diff.	Weight	Total
Konzola PAŘÁT	114	36	36	51	237
Provozní žebřík	19	11	9	8	47
Trafostanice	34	0	7	5	46

As a next step, it is necessary to express the total annual volume of production through the selected production representatives. This means to promote the actually produced number of production representatives by the value that will represent the production of the remaining products. The approximation result is described in Table 3. This approximation can be made due to size and technical similarities of all products. [1]

Table 3. *The result of approximation of representatives on 1-year production numbers.*

Representatives	Approximation of sold products [pieces]
Konzola PAŘÁT	9 106
Trafostanice	278
Provozní žebřík	3 189

1.4. Analysis of material flows

The analysis of current material flows (further in this article also as MF) is realized using the I-D charts of each of the selected production representatives. In order to determine the manipulation distances of the individual material flows, the material flow diagrams related to the annual production were drawn up for each chosen production representative.

1.4.1. Material flow diagram

To the layout of the current production system layout, a diagram of all material flows was created for each production representative. This layout with material is not described in this article.

On the basis of the layout of the current production, the distances of every MF had to be measured. The distances were needed for product evaluation with I-D charts, so the analysis and final drawing of current material flows were also necessary step to validate current state of the production through I-D diagrams.

1.4.2. I-D charts

The I-D chart evaluates the relationships in material flows and serves as a tool for the design of workplace layouts in the production system. The diagram in general expresses the intensity (I-intensity) dependence on the distance (D-distance) of the workplace from the material source. This gives important information about the MF and the efficiency of production.

The horizontal axis is the distance, the intensity on the vertical axis (as shown in Fig. 2). Intensity can be entered in different units, e.g. volume, number of pieces, number of packages. Each movement (single MF) has its intensity and its distance, so the diagram is a point. For individual points, the "bubble label" is a material flow that they represent in described production system.

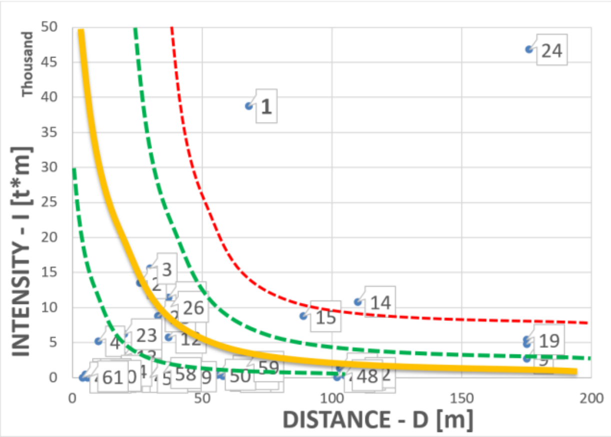

***Fig. 2.** I-D chart for representative Konzola PAŘÁT.*

The yellow curve in Fig. 2 represents selected "fictitious optimal curve" that should ideally approximate MF points. Intermittent curves-equidistant fictitious optimal curves, defining selected areas for I-D diagrams:

Optimal area is located between the green curves (near the fictitious optimal curve). The defined area is intentionally somewhat broader, because it is necessary to take into account the fact that it is a small-series, technologically arranged production where the workplaces are not ideally assembled for only one type of product, but they provide some versatility. Therefore, all points of material flows will never ideally approach one curve.

Partially satisfactory area is an area outside the green curves, which is limited by the graph axes and the second red curve. Material flows located in this area should be taken into account in optimization to bring them closer to the optimal curve. Of greater importance are the points that are found between the green and the red curve - the greater intensity is transferred at a greater distance than the points in the second part of the area. However, even on these points, optimization should not a primary target.

Insufficient area – all points that are in the area between the red curve and the top right corner of the chart are unsatisfactory. The material streams they represent must be the main subject of optimizing the current production system. [1,2,3]

The I-D diagrams were made for all 3 selected representatives, but only chart for Konzola PAŘÁT is depicted in this article. The material flows which ended up in insufficient area of the diagram are described as main optimization suggestions in following paragraphs.

1.4.3. Optimization design of Konzola PAŘÁT

Main optimization suggestions are:

- Move the stocks of metallurgical material closer to production (MF 24 and 14 in Fig. 2)
- Move the assembly workstation closer to stock of final products (MF 1 in Fig. 2)
- Regroup technological workplace of preparation (MF 15 in Fig. 2)

1.4.4. Optimization design of Trafostanice

Main optimization suggestions are:

- Relocate the assembly workstation closer to stock of final products
- Move the stocks of metallurgical material closer to production
- Move stock No. 3 closer to production

1.4.5. Optimization design of Provozní žebřík

Main optimization suggestions are:

- Move the assembly workstation closer to stock of final products
- Approach the stocks of metallurgical material closer to production

1.5. Evaluation

MF analysis with usage of I-D charts showed two major problems in the production system layout:

1. Production hall-stocks of metallurgical material

The average length of MF between workplaces and the stock of metallurgical material (stocks No. 1 and 2) is about 140 meters. The intensity of these flows is also significantly higher in relation to the other MF of the respective production representatives. This fact, taking into account that the metallurgical material is blank for 99% of the products made, is unacceptable.

In the light of these results, relocating of the metallurgical stock in the production system (i.e. its approach to the production hall) will be the main point of optimization.

2. Assembly workstations - Stock of final products

Another problem of the current arrangement is MF between assembly and stock of final products. The average distance here is about 80 m.

Since the complete product assemblies (or transport groups of these assemblies) are transported here, there is a high transport weight that greatly affects MF. Other incentives to improve MF within optimization are MF between stock No. 3 and 4.

2. Optimization design

When designing an optimization of an existing production system, it is necessary to follow two basic points. The first point is the requirements of the company management and the second point is the following main results of the analysis which are suggesting:

- Reduce the distance between stocks 1,2 and production sites
- Shortening the distance between the assembly workstation and the stock of the final products
- Optimization of the technological layout of the production system

2.1.1. Extension to the existing hall

The first step for the reorganization of the production system is the realization of the extension to the existing production hall with external dimensions of 47 x 15 m, which adds about 700 m^2 of the interior space connected directly to the production hall, which will allow the necessary reorganization.

2.2. Optimization of warehouse management

Changes to optimization adjustments affect all warehouses, except of warehouse of final products, and some workplaces. Some stocks only move, others merge or split up to create new warehouses that will optimally link to the rest of the production system. The optimized layout of the stocks and workplaces is more centralized – stocks are closer together – better for logistics – and also closer to connected workplaces. The optimized layout of the production hall is not part of this article.

The size of final product's warehouse also remains unchanged, but it is possible to extend its space. This option will not be realized because the capacity is currently sufficient.

From the point of view of handling devices, two electric fork-lift trucks will be taken for the service of the stocks.

2.2.1. Stock No. N1-connecting material

The stock is created by moving and joining of 3 current stocks. For this new stock an area was used, which currently serves as a collection point for sorted waste and a parking area for bicycles. Each type of material will have its own space, making it easier and faster to find the right material. Smaller material (nuts, washers, screws), which is delivered in boxes, will be stored in shelf shelves, dimensionally more complex materials (e.g. specially shaped bolts) will be stored on pallets in the shelf. The organization of the stock is shown in Fig. 3.

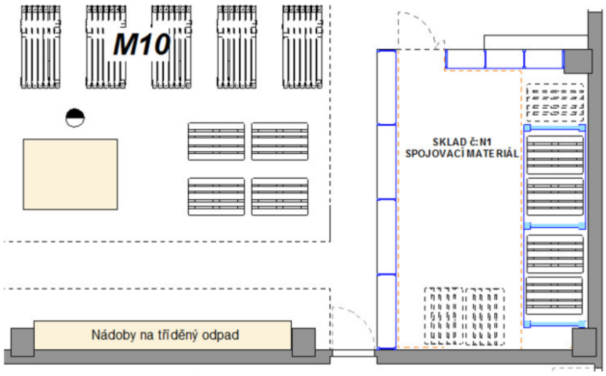

Fig. 3. *Layout of Stock No. N1.*

2.2.2. Stock No. N2-stock of semi-product

This stock must contain semi-product products from the current stock 6, 3 and the stock part 4. Its capacity will again be derived from the current capacity of these three stocks and increased by at least 5 %. The storage units will be mainly standard euro-pallets. The stock will consist of a storage rack with a length of 19 m and a small area for storage stock (10 m^2). Using of certain boxes allows stacking, so if necessary, additional capacity could be provided by further organization.

2.2.3. Stock No. N3–metallurgical material

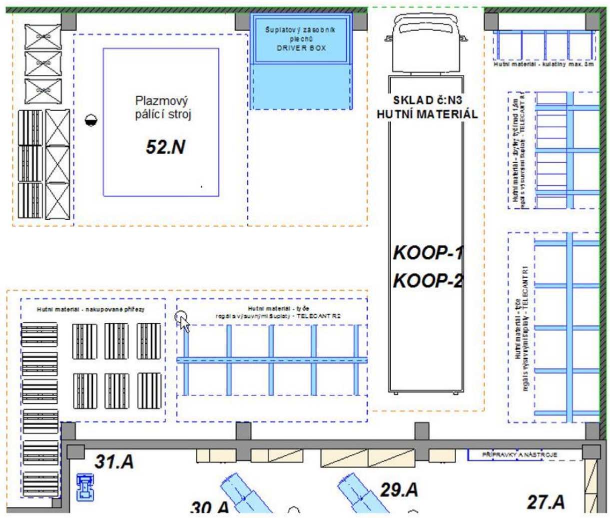

Fig. 4. *Layout of Stock No. N3.*

This stock is relocated in such manner so that when the material arrives, the truck goes directly to the hall, between the shelves for the storage of the metallurgical material. A bridge crane can be used to move the material, and the conveyance path is minimal due to proximity. The loading and removal of material from shelves is possible by means of a bridge crane or a fork lift truck. The bar material of the round cross section will be stored in an existing cantilever rack which will be moved to the N3 stock. Sheets will be stored in the rack specially designed for sheet metal loading. The organization of the stock is shown in Fig. 4.

2.2.4. Stock No. N4 and buffer stocks

The stock No. 4 moves only from areas, which had to retreat to the construction of a new part of the production hall, into the loose space after stock No. 6. When inventory management was optimized, some stock items were moved to stock N2, so the required capacity of the stock was reduced. Due to this fact and also better organization of the stocks, reducing the area for stock N4 from 122 m^2 to 70 m^2 (40%) won't affect its efficiency.

In an optimized layout, most of the manufacturing buffer stocks were centralized into one main buffer stock. This stock is strategically located in the center of the hall, in the vicinity of the divisions and material bending. In these workplaces, most of the preparatory work is carried out, after which the semi-finished products are moved to the intermediate store where they are waiting for further processing (the material flow is therefore very short).

2.3. Optimization of workplace layout

Before the reorganization of the individual workplaces starts, it is necessary to complete the construction of the new hall. First of all, all the machines included in the production preparation are has to be moved to optimized position. The shortening of the distance between assembling and final products stock was completely accomplished by this move because the stock final product can't be moved - it is directly dependent on the portal crane that provides the vast majority of the logistics of this stock. The average distance between these "workplaces" has dropped from 93 m to 50 m. As regards the area capacity of workplaces, the work area increased from 142 m^2 to 219 m^2.

2.4. Evaluation of suggested optimizations

In order to objectively compare the existing arrangement with the optimization design, it is necessary, as in the analysis of the current state, to evaluate material flows production representatives in an optimized layout design of the production system. As in analysis of current state, distances of each MF were measured from optimized layout and then used in I-D diagrams. I-D diagrams were made again for all selected representatives, but in this article, only diagram for Konzola PAŘÁT is described.

During analysis of the material flows, only a one-way flow was considered for simplicity – that means no back moves were taken into account ("free" movements). The ideal example of moving "empty" is to move the finished products to the final product's stock, the back path is then a typical empty move, but it must be done.

In practice, these moves can't be neglected and therefore the calculated savings need to be promoted. This backward movement, however, occurs only in some material flows, but it is mostly ones, on which the optimization has resulted in a highest saving. Taking this fact into consideration, the total annual savings were increased by 15% to reflect this fact.

The annual savings on the total distance of all material flows are 17 376 703 m (17 376.7 km). Individual overall evaluations of savings are described in Table 4 (MU stands for "measured unit").

Table 4. *Overall savings through material flow optimization (without added 15%).*

	Savings [%]	Annual savings [MU]	MU
Total number of MF	0,9 %	18 117	[flow]
Sum of MF distances	32.6%	15 110 177	[m]
Average distance of MF	32%	244 847.9	[m]

2.4.1. Evaluation of Konzola PAŘÁT

At first glance, it is clear that the problematic MF 14 and 24 (between stock of metallurgical material and preparation) have moved from the non-compliant region to the optimal area, only MF 1 (between assembly and stock of final products) has almost moved to a non-compliant and partially satisfactory range, but this is also a significant positive shift (Fig. 5). The remaining flows have completely moved to the optimal area in optimization design.

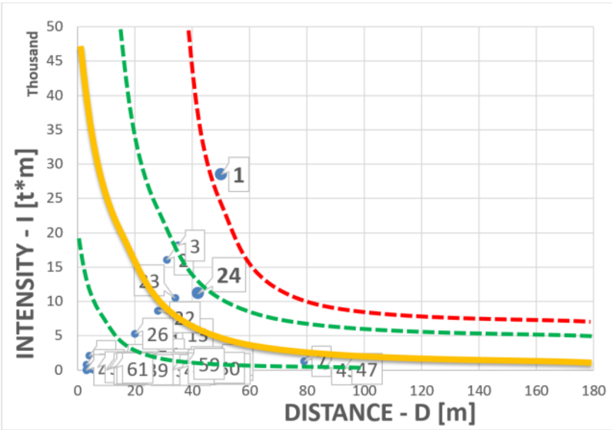

Fig. 5. *Optimized material flows of Konzola PAŘÁT.*

2.4.2. Evaluation of Trafostanice and Provozní žebřík (ladder)

For both these representatives, the material flow between stock of metallurgical material and preparation workplaces was also improved and moved to satisfactory area of the I-D diagram. Only the improvement of MF between assembly and stock of final product wasn't enough for reaching satisfactory area. The reason is that the position of neither assembly or stock of final products can be easily changed, and also the transport batch can't be increased easily (mainly because of the nature of the products). Through further optimization designs, it could be possible in the future to transport final products of Provozní žebřík in bigger batches. The other MFs were also moved to more satisfactory areas of their diagrams.

3. Economic evaluation

The evaluation in chapter 2 of this paper showed that the total annual material flow savings for the proposed solution is 17 376.7 km. This value has to be put into economic perspectives – finance. Input data for calculation of the savings are described in Table 5.

Table 5. *Input data for savings calculation.*

Data		Values		MU
Savings from MF		17 376.7		[km]
Time fund of employee (shift = 7.5h)		1 875		[hours]
Average movement speed	Walk	4	4.3	[km/h]
	Bridge crane	3		
	Forklift	6		
Average supergross wage of welder		29 521		[CZK]
Average supergross wage of preparation worker		21 263		[CZK]

- Savings saved in hours: $S_{hrs} = 17376,7/4,3$ = <u>4010 hrs</u>
- Savings expressed in human resources: $S_{hum} = 4010/1875$ = <u>2,14</u>

In simple terms it means that 2 employees (welders) can be dismissed and the remaining 14% fund can be used to cover the fluctuations in production. In this case, annual savings would be as followed:

- Annual savings: $S_{fin} = 29\,521*2*12$ = <u>708 504 CZK</u>

But in the company, there were monitored insufficiencies of manpower in preparatory phase of the production. So other option, how to handle with 2 redundant employees is to relocate them to production preparation, where they will receive lower wages. In this case, the savings will be lower – as followed:

- Financial savings by relocating employees (annual): $S_{finreloc} = (29\,521-21\,263)*2*12$ = <u>198 192 CZK</u>

This result is presented as a minimum financial savings for the proposed optimization solution. These savings don't include the fact, that with less traveled distances, there will be also savings in operation of forklifts.

The decision whether to release two welders, or release two welders and accept two less qualified employees or just move two existing employees and reduce their wages is a matter for the company's management.

3.1. Estimate of the investment

Based on the real prices of suppliers and inner wages, list of needed investments for realization of designed optimization was made. Main investment categories are described in Table 6. The total investment estimate is 21 634 781 CZK. Biggest part of the investment is investment for construction of new production hall.

Table 6. *Estimate of the investments based on optimizations designs.*

Investment		Price [CZK]
Whole optimization project of production system		**21 634 781**
Construction of hall		**21 158 906**
Reorganization of stocks		**100 250**
	Establishing stock No. N1	65 000
	Assembly of shelves in stock No. N1, N2, N3	15 000
	Relocating material	7 875
	Establishing of workplace for material division	12 375
Other activities		**375 625**
	Relocating of parking lot	10 625
	Construction of garages	365 000

4. Conclusion

The subject of this article was the optimization of stock and warehouse management and material flows in an industrial company. Before the optimization itself, it was necessary to analyze the current state of the production system. The main part of the analysis was the choice of production representatives and the subsequent analysis of their material flows on current production layout. Main output of the analysis of current state were I-D diagrams for selected representatives. By the results received through these diagrams, critical material flows were found. These were mainly material flows between the stock of metallurgical material and the production preparation workplace and between the workplace of completion and the stock of finished products.

According to these results, optimization solutions have been proposed, the main points of which are the extension to the existing production hall, the relocation and optimization of most of the existing stocks and relocation and reorganization of certain workplaces. The optimized production layout was analyzed with the same tools as current production – with I-D diagrams.

Through all the suggested optimization features, the achievable real savings by optimization of material flows, warehouse management and production organization were calculated. The annual savings on material flows are 17 376.7 km, which is annually 198 192 CZK with relocating employees or 708 504 CZK with releasing them. Due to nature of current state of the company, the expected result of the optimization is not primarily the profit from it, but rather the ability to sustain and improve capability of production for future years.

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