THE LOGISTICS STREAMLINING OF THE MATERIAL FLOW AT THE PRODUCTION COMPANY

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Abstract: The main practical problem in the Logistics Department at the company is overstaffing in the unit responsible for the flow of materials. Carried out by the authors of the article, some detailed research on the process analysis in the discussed company indicates that the main cause of such a situation is related to an increase in the amount of transported material and a lack of redesigning the material flow in spite of the increased levels of production and acquisition of new projects. At present, at the company the material is prepared and transported by eleven employees whose work is not standardised and impossible to control. Such a large number of people working at the same time at the warehouse and moving through the transport corridors seriously affects the level of safety in a negative way. Therefore, the authors of the publication have suggested three solutions which involve some logistic changes in the existing process in order to increase safety and to reduce the number of staff involved in the transport.

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1. INTRODUCTION

In the 21st century a highly competitive market exerts a lot of pressure on production enterprises. Trying to enhance their attractiveness, enterprises streamline their processes, improve the quality of their products/services and cut down costs. The analysis of the processes taking place at an enterprise requires a holistic approach (Czerska, 2011, pp. 109–112), hence it should refer not only to the optimisation of the main processes but also to the auxiliary processes as well (Franczok & Rudnik, 2014).

Warehousing comes as one of the basic auxiliary processes, which deserves some special attention (Zarandi, Zarani & Saghiri, 2007, pp. 178–196). A modern warehouse is viewed as a place where the optimisation of the stock levels takes place, together with the processes which involve shortening the order cycle time, shaping the customer service level and a decrease in logistics costs (Pacana, Pawłowska, Perłowski, Stachowicz & Zielecki, 2010). The storage process involves the following stages: the receipt of goods at the warehouse, goods storage, order picking and the release of goods from the warehouse (Niemczyk, 2009). Each stage involves a number of manipulation operations by which the efficiency of the warehouse is evaluated (Skowronek & Sarjusz-Wolski, 2008). Manipulation operations include, among others, the processes related to the flow of materials/goods inside the warehouse.

2. THE EVALUATION OF THE CURRENT MODEL OF THE MATERIAL FLOW AT THE COMPANY

The flow of materials at the company was designed some time ago, during the construction of the factory. At that time, completed goods were of a simple structure and of a small size. Employees responsible for material transportation were able to provide all the required materials using one platform truck, during one single pass from the warehouse to the hall of injection moulding machines and from the overprint hall to the main hall.

Nowadays, products consist of a larger number of components and their size has been increased by several times. The size and weight of materials and semi-products required at a particular moment during the assembly process are too big to place them on a standard platform truck. Such an increase in weight and size causes problems in maneuvering the platform truck, and such a situation may eventually end with accidents. There has been an attempt to solve that problem by employing more people to transport the required materials, however this solution has soon proved to be inefficient. Considering the demand, frequent delays in the delivery of the required materials to their hold areas result in micro-stoppages of the assembly lines and consequently in a decrease in productivity. Moreover, the number of people employed only to transport the materials results in additional high costs incurred by the company to provide remuneration for the internal transportation team.

Considering the nested-pipelined character of production (Pisz, Sęk & Zielecki, 2013), it is crucial to provide a proper flow of materials among the particular workstations in order to maintain the continuity of the product assembly. The nods which join the flow of materials between the particular assembly halls are the flow racks where the products made during the previous stage of production are stored and released to the next stage of production.

In the area of the assembly line, where the production is organised, the pipelined flow of materials takes place, and one piece is moved from one workstation to another. In the process which is organised in such a way, there are not any hold areas and the assembly operators move the semi-products between the workstations.

At the company, most of the transport operations at the assembly halls are performed with the use of the platform trucks which are characterised by a relatively small size. In order to deliver the proper number of parts to their destination locations, the material supply paths have been designed, and the particular operators have been assigned to the particular areas. The flows of components and products take place at the warehouses where purchased components and completed products are stored, most often in pallet units, which are operated with the use of high storage forklifts. It is the only area of the company where such vehicles can be operated, in accordance with the internal safety regulations.

While evaluating the flow of materials in the company, it can be observed that it is optimal at the warehouse and in the area of the assembly line. However, the flow is highly inefficient at the assembly halls, where – considering the low capacity of the means of transport and a chaotic location of the hold areas – there are too many operators employed, whose time is mainly spent on transportation.

3. THE ANALYSIS OF CHANGES SUGGESTED FOR THE COMPANY

The modification process of the material flow at the company is started with an analysis of the location of the assembly lines, warehouses and hold areas for the components. The communication paths for the operators and their means of transport should be shortened and straightened. The time consumed by the preparation and transportation of materials should be measured, adjusted and assigned to each worker; during the distribution of tasks it would be advisable to consider separation of the processes related to the retrieving of materials from the flow racks from the processes related to the transportation and delivery of the components. The means of transportation should be adjusted to the weight and the size of the transported goods. Considering the above-mentioned processes, the implementation of the changes has been divided into two stages (Gryboś, 2016):

- relocation of the assembly lines and hold areas for the materials;
- reorganisation of work performed by the operators who transport the components;

The current location of the assembly lines and the hold areas forces employees to cover long distances from the particular warehouses to the hold areas. In order to save time spent on transportation, the assembly lines should be moved away from each other to create one transport corridor along the main assembly hall. In accordance with the PN-M-78010:1968P standard, the minimal breadth of such a corridor should be as follows (Gryboś, 2016):

- for the two-way traffic of non-self-propelled means of transport and pedestrians $b = 2a + 180$ cm, where b is the breadth of the way and a is the breadth of the means of transport. Considering the use of the platform trucks and pallets which are transported in accordance with the Euro-standard, the a parameter is 80cm, therefore the minimal breadth of the b transportation corridor is 340cm.
- for the two-way traffic of the self-propelled means of transport and pedestrians $b = 2a + 200$ cm, where b is the breadth of the way and a is the breadth of the means of transport. The standard electric trucks are 80cm broad. Therefore, the b parameter is 360cm. Considering a possibility of using electric trucks and the breadth of the main warehouse gate, the breadth of way is assumed as 380cm.

4. THE FLOW CALCULATION

In order to calculate the number of packages required in the workflow between the warehouse, the flow racks and the minimarket racks, a modified ABC method has been applied. The calculations are performed in the Excel, with the use of the data provided by the ERP – SAP 4.6 system and the external databases, and on the basis of some assumptions which result from the specific character of the materials and the frequency of production launching. The data obtained from the reports developed on the basis of the SAP system and the external sources of information are presented in Table 1.

The number of the assembly line is a number assigned to the particular manufacturing nest in the assembly hall, where the completed goods are produced. It is given to facilitate the consolidation and the analysis of the data referring to the production process for the particular group of products.

The type of the components – universal and dedicated – is defined based on the number of the assembly lines where a particular component is used. It is an extremely important parameter, considering further analysis which must be carried out in order to define additional containers or kanban cards in the workflow.

Table 1. Data required for the ABC calculation, Source: a study based on the materials provided by the company and (Gryboś, 2016)

Type of data	Source of data
The number of the assembly line	The SAP report
The type of the component (universal/dedicated)	The analysis of the structure (the SAP report)
Average daily material requirements (Materials Requirement Planning)	The SAP report
A description of a container	PFEP (Plan For Every Part)
The number of components in the container	PFEP (Plan For Every Part)
The amount of material per 1 piece (product)	The analysis of the structure (the SAP report)
The assembly line capacity (piece/shift)	The report on production planning
The number of shifts per day	The report on production planning

The average daily material requirements are based on the MRP analysis. It involves the retrieving of the data on the material requirements for the next four weeks, starting on the date of the analysis and then the averaging of the obtained results.

The basic data of the packaging, such as the type of the container and the number of components in the container, are usually taken from an external database, PFEP (Plan for Every Part), developed in the Excel spreadsheet. This is fundamental information based on which the results of the calculation obtained in retail units are converted into the number of containers required for the workflow. These data are also applied as the basis for the calculation needed to define the workload of the operators who transport materials.

Table 2. Data required for the ABC calculation Source: a study based on the materials provided by the company and (Gryboś, 2016)

Type of data	Source of data
Additional containers at the workstation	Depending on the number of workstations where the particular material is used
A	1
B	16
C	2
The number of the kanban cards	2

The productivity of the assembly lines per shift and the number of shifts involved in the production on the particular assembly line can be taken from the Excel spreadsheet run by the Production Planning Department. Such information is required in order to calculate the amount of materials required for the workflow.

Other assumptions required for the calculation of the containers and kanban cards are presented in Table 2.

The main assumption for the ABC calculation is the proper definition of the particular constants of the equation. At the company, the calculation period has been assumed as 1 production day, hence the following values have been assumed for the requirements of the calculation:

A – the number of material retrievals/production per 1 working week. This parameter takes the value 1 for everyday retrievals/production, and up to 5 for weekly retrievals/production. Considering everyday retrieval of materials at the company, the value of the parameter has been defined as 1.

B – the retrieval of materials and transportation to their destination location – every half an hour, that is sixteen times a day.

C – delay in the order completion. Considering the potential separation of the function related to the transportation of materials from the function of retrieving materials from the supermarket rack locations, it is probable that an order collected in the form of the kanban cards and containers during the single operator's route shall not be completed during the same material workflow. The order shall be left for preparation and delivered during the next route. Therefore, the delay parameter should be defined as 2. Other data required for the calculation of the number of transport operators who are needed to move the materials are presented in Table 3.

Table 3. The basic data required for the calculation of the employees' workload Source: a study based on the materials provided by the company and (Gryboś, 2016)

Type of data	Source of data
Supermarket rack address	PFEP (Plan For Every Part)
Minimarket rack address	PFEP (Plan For Every Part)
The method of ordering	Kan-ban/2-bin
The method of retrieving components from the rack	Transferring, a full container, a tray
Route>> Location	PFEP (Plan For Every Part)
The time of retrieving materials	Averaging of the measurements for the method of retrieving components from the rack.

The data required for the calculation of the operators' workload are provided by the PFEP database, or they are dependent on it. The addresses/locations of the supermarket and minimarket racks allow the operators to define the place from which the materials are retrieved and then supplied; the route number assigns operators to the particular areas and allows them to group data in a proper way.

The method of ordering is defined on the basis of the container delivered to the minimarket rack. If it is a kanban container, the delivery of the materials comes in dedicated boxes to which the operator transfers the components from the packages provided by the suppliers. If the components are packed in the way which does not allow operators to transfer them into other containers, the preparation of the material is performed based on the order made with the use of a kanban card. One of the main factors which affect the working time of an operator is the time of material preparation. It is an average value obtained from the measurement of time needed for the retrieval of the material from the supermarket racks, in specified containers, such as trays, full original packaging or by transferring the materials from the original packaging provided by the supplier of the components into a kanban box. The time measurement has been performed for all the operators responsible for the transportation of the materials.

Table 4. The auxiliary data required for the ABC calculation Source: a study based on the materials provided by the company and (Gryboś, 2016)

Type of data	Source of data
Description	PFEP (Plan For Every Part)
Manufactured – M; bought - B	PFEP (Plan For Every Part)

Table 5. The results of the calculations, Source: a study based on the materials provided by the company and (Gryboś, 2016)

Type of data	The method of calculation
The ABC calculation	=A*(1+C)/B
The number of containers required in the workflow.	$\frac{\text{ABC * the amount of the material per 1 piece/product*the productivity of the assembly line}}{\text{The number of components in a container}}$
The size of the requirement/order specified in the kanban card.	The number of containers. The number of the kanban cards
The number of containers at the destination location.	The number of containers+additional containers at the workstation
Average orders per shift	Average daily orders MRP. How many shifts per day.
The number of containers transported during a shift.	Average orders per shift. The number of components in a container
The consumption time of one container (min./pcs)	$\frac{450}{\text{The number of containers per shift}}$
Butterfly's workload (sec./shift)	The time required for the retrieving of the materials * the number of the containers per shift

Another group of data used to define the flow of materials are auxiliary data. In the discussed case, they are applied for better identification of components, and they involve, among others, the name of the components, their classification to the particular groups of materials which are manufactured or purchased. Such a division facilitates the filtering of the data at the warehouse from where the materials (components) are retrieved or at the hall of injection moulding machines/overprint hall.

Table 5 presents a scheme of the calculation referring to the number of containers or to the kanban cards in the workflow, and the method of the calculation of a butterfly's working time required for the preparation of the material.

Considering the above-presented table, it is possible to notice that the calculations referring to the workload of an operator are not complicated. The main factor which affects the accuracy of the data is the proper identification of the method applied to order materials and the accuracy of the source data.

Apart from the calculations referring to the number of the containers and to the time required to retrieve the materials from their location, it is necessary to consider the time required for transportation in order to provide proper calculation of the total workload of an operator. This time is strictly connected to the organisation of the operators' work. The calculation referring to the transportation of the materials is based on the assumptions presented in Table 6.

The first variant is similar to the current flow of materials. The difference is the shortening of the operator's path from the particular warehouses to the destination locations. The operator's task is to prepare and to deliver the required materials to the assembly sector to which the operator is assigned.

Table 6. Potential methods of the organisation of the operators' work. Source: a study based on the materials provided by the company and [Gryboś, 2016].

	Variant I	**Variant II**	**Variant III**
The method and place of the retrieving of materials	The operator takes the material from the warehouse of components, the hall of injection moulding machines and the overprint hall;	The distribution of tasks for the operators (a particular operator for each retrieval location)	The distribution of tasks for the operators (a particular operator for each retrieval location)
The method and place of the delivery of materials	The operators are assigned to their assembly sectors;	Employees who deliver materials, and who are responsible for all the sectors	Employees who deliver materials, and who are responsible for all the sectors
The means of transport	A platform truck A pallet truck	A platform truck A pallet truck	An electric truck with platform trucks

The second solution refers to the division of tasks performed by the employees into the preparation tasks and material delivery tasks. There should be a group of people who prepare materials, based on the empty containers and the kanban cards, and then they put the materials onto the platform or pallet trucks. The trucks with the components are taken by the operators who are responsible for their delivery to the destination locations. The employees should not be assigned to the particular assembly sectors, and their main task should be the delivery of the prepared materials to their destination locations, the receipt of empty containers and the kanban cards which should be taken to the team responsible for the preparation of the materials.

The last analysed variant assumes the elimination of manual transportation. The functions currently performed by the people who transport the components should be taken over by an electric truck with a train of non-self-propelled platform trucks on which the materials required for production would be transported, after they have been prepared by the team located at the warehouse (Table 7).

Table 7. The time calculation of the operator's path Source: a study based on the materials provided by the company and (Gryboś, 2016)

Delivery sector I	**The number of steps**	**Sec**
The place where racks are located > The warehouse entrance	100	60.00
The warehouse entrance > the gravitational racks of the injection moulding machine	40	24.00
The gravitational racks of the injection moulding machine > the gravitational racks of the overprint	49	29.40
The gravitational racks of the overprint > the upper racks, sector I	85	51.00
The upper racks, sector I > the lower racks sector I	15	9.00
CT pass (sec)		173.40
CT pass (min)		2.89
Pass (min. per shift)		46.24
The percentage of the working time for the pass		**10%**
Delivery sector II	**The number of steps**	**Sec**
The place where racks are located > The warehouse entrance	100	60.00
The warehouse entrance > the gravitational racks of the injection moulding machine	40	24.00
The gravitational racks of the injection moulding machine > the gravitational racks of the overprint	49	29.400
The gravitational racks of the overprint > the upper racks, sector II	105	63.00
The upper racks, sector I > the lower racks sector II	24	14.40
CT pass (sec)		190.80
CT pass (min)		3.18
Pass (min. per shift)		50.88
The percentage of the working time for the pass		**11%**

Delivery sector III	The number of steps	Sec
The place where racks are located > The warehouse entrance	100	60.00
The warehouse entrance > the gravitational racks of the injection moulding machine	40	24.00
The gravitational racks of the injection moulding machine > the gravitational racks of the overprint	49	29.40
The gravitational racks of the overprint > the upper racks, sector III	125	75.00
The upper racks, sector I > the lower racks sector III	34	20.40
CT pass (sec)		208.80
CT pass (min)		3.48
Pass (min. per shift)		55.68
The percentage of the working time for the pass		**12%**

The ultimate calculation of the number and the workload of the employees who deliver and prepare materials comes as a component of two factors – the time required to prepare materials and the time required to deliver the materials to the particular production sectors. The maximal capacity of a transport truck and the amount of the materials which must be transported in one lot also come as important parameters.

While calculating the number of operators, it should be assumed that the maximal use of the available working time reaches the level of 80% for each of them. This assumption refers to considerable workload which involves physical activity and instability in the demand for the materials generated at the assembly lines.

The number of employees required to handle transportation in Variant I is seven people. Considering the total time required to prepare materials and the time required to transport them in the particular routes, it is possible to notice that in order to deliver the components to the first sector, the workload of an employee is 22%. The second sector must be handled by two employees because the working time of one person would exceed the total working time available during one shift by two hours. In terms of the required working time, there is one employee needed to deliver components to the third sector, in order to ensure its proper operation. Considering the fact that the amount of the materials that should be delivered exceeds 9,5m3, the number of employees should be increased up to four, and the time of material delivery should be shortened from half an hour to a quarter.

Considering the division of tasks into the preparation and delivery of materials, the second variant requires a separate time summary for both these task groups. While considering the total time referring to the physical retrieval of components from the supermarket racks and its transferring into the kanban containers, if necessary, it has been assumed that the required number of employees is two people. The distribution of the whole material to the particular locations takes two and a half hours; hence, taking the amount of the distributed material ($12m^3$) into account, the number of employees should be assumed as four people, and the frequency of the circulation should be increased up to 12 minutes.

The main aim assumed for Variant III is reduction of the number of the staff employed to deliver materials to their destination locations. The current means of transport, a platform truck, is to be replaced with an electric truck with a train of non-self-propelled trucks.

The method of calculation referring to the number of the operators required to prepare the materials (the retrieval of the materials from the supermarket racks and transferring them into dedicated containers) is based on the calculation made for Variant II. The number of people responsible for the delivery of the materials to their destination locations mainly depends on the number of non-self-propelled trucks attached to the electric truck and on the circulation frequency of such a train.

Considering the materials stored in the hold areas located at the production sector, the size of the delivered components and the factors related to the means of transport, namely: the maximal capacity of the truck and the maximal number of non-self-propelled trucks attached to it (which has been assumed as 6 per one train), it has been calculated that in order to provide timely availability of the components, the time of one route should not exceed 15 minutes, if there is one train of trucks used, and it should not exceed half an hour if there are two trains of trucks. The time of delivering and unloading one lot does not exceed the first option, therefore, based on the previous assumptions and measurements, it has been assumed that the components should be prepared by two operators, whereas only one person should be dedicated for the delivery of the components, being responsible for driving the truck and putting the components into the dedicated places.

5. THE PRELIMINARY ANALYSIS OF THE COSTS

The total amount of expenses required to relocate the assembly lines and to cover any possible investments has been assumed as a basis for the preliminary analysis of the implementation costs for the particular variants. The costs based on which the time of the return on investment has been calculated, refer to the difference in the current remuneration of the employees and their remuneration in the suggested solution. The discussed summary is presented in Table 8.

The analysis of the particular variants indicates that the expenditures incurred for the rearrangement of the workstations are the same for all the discussed methods. There is a difference in the investment into the means of transportation suggested for implementation in Variant III. Considering the remuneration costs, it can be observed that the quickest return on investment appears in Variant I, whereas the highest year-to-year savings can be obtained by the company in Variant III, where the main expenditures are related to the purchase of two electric trucks. For the requirements of the calculation, it has been assumed that two second-hand A1 electric trucks shall be purchased with a set of B1 non-self-propelled trucks.

Table 8. The preliminary analysis of the streamlining implementation costs. Source: a study based on the materials provided by the company and (Gryboś, 2016)

Variant	Costs referring to the rearrangement of the assembly line; staff overtime (PLN)	Costs referring to the rearrangement of the assembly line; exploitation materials (PLN)	Staff remuneration costs (PLN/year)	Costs referring to the purchase of machinery and equipment (PLN)	Total investment PLN	Savings (PLN/year)	Time of the return on investment (calendar days)
I	4227.27	1500	182553	0	7090	78237	34
II	4227.27	1500	56474	0	7090	104316	25
III	4227.27	1500	78237	140000	147090	182553	294

6. THE IMPLEMENTATION SCHEDULE

Considering the fact that the continuity of production must be maintained, the relocation of the assembly lines can be done only on Saturdays and Sundays, when the production is stopped. A preliminary plan is to reorganise the production cells in a particular sector during one weekend. It is also assumed that the total time required for the implementation of a new arrangement of the assembly lines shall be three weeks. The company has delegated the relocation tasks to an electrician, a mechanic, two production operators and a process engineer. Working hours have been divided into twelve-hour cycles, starting at 6.00am and ending at 6.00pm, including Saturdays and Sundays. The remuneration of the whole team shall be paid in accordance with the legal regulations, including the additional payment for working overtime and at weekends.

The schedule of the relocation shall be repeated for the reorganisation of other sectors. At first, all the workstations and assembly machines are disconnected from power grid and from the compressed air installation. Next, the operators take all the materials from the workstations back to the racks, which are then moved to the transportation corridor in a way which prevents any collisions with the transported assembly lines. After each workstation is put into its new dedicated location, the machines are again connected to the power grid and the compressed air installation.

Another important step is validation of the workstations and their cooperation in the assembly line.

The verification is done by an assembly operator under the supervision of a process engineer, and it involves a test assembly of a particular number of completed products and their verification at the end testing device. The operation of the testing device is verified on the basis of dedicated error patterns for a particular line. The errors in the operation of all the machines must be corrected immediately by a process engineer with the cooperation of a mechanic. After the reorganisation of each assembly line at a new location in the particular sector, the racks are moved into their dedicated locations near the communication corridor. At the same time, while the workstations and racks are relocated, the process of purchasing a set consisted of an electric truck and six non-self-propelled transport trucks is initiated. The process involves collection of offers provided by potential suppliers, and their verification in terms of prices and delivery date. The next step is the installation of the truck and a training course for the operators.

7. CONCLUSION

Manifested by increased efficiency and decreased levels of production costs, the current tendency in the automotive market forces companies to implement various technological innovations and changes in processes, also in the sector of logistics. In order to maintain its competitive edge in the market, the company must also follow this path.

The main problem in the Logistics Department is overstaffing at the unit responsible for the flow of materials. A detailed analysis of the process indicates that the fundamental reason for such a situation can be found in the increase in the amounts of the transported materials and in the fact that the flow has not been redesigned in spite of the increased levels of production and new acquired projects. At present, materials are prepared and transported by eleven employees whose work is not standardised and impossible to control.

Such a large number of people working at the same time at the warehouse and moving along the transport corridors largely contributes to a decrease in the level of safety. The company has decided to analyse three variants referring to the change of the current process in terms of increased safety and decreased number of workers who are responsible for transportation. Despite the highest investments, Variant III comes as the optimal solution which can guarantee a possibility of quick adaptation if new projects are implemented or the number of orders placed by customers is increased.

While analysing articles in trade press presenting studies on internal logistics, it is possible to observe that the discussed company follows a general trend in the same way as other production companies where internal transportation – organised in the form of singular courses from the hold areas to destination locations – is being pushed out by other solutions which are mainly based on so called logistic trains.

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BIOGRAPHICAL NOTES

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