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Cost-quantitative analysis of non-compliance in the internal logistics process

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Abstract
Internal logistics is a key element of a production process as it specifies product quality, timeliness and value of orders. The purpose of the research was to determine the amount of non-compliance in the selected production process caused by internal logistics operations. The analysis covers both the quantity and type of non-compliance as well as the cost of non-compliance. One of the basic quality management tools was used in the research - Parteo-Lorenz analysis. An attempt was made to identify potential causes of non-compliance. The significant impact of non-compliance arising in internal logistics operations in production costs was pointed out.

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1. Introduction

Transport is defined as a set of activities related to the displacement of materials in time and space using specialized technical means. The term internal transport is defined as all activities included in the in-house logistics (Bitkowska and Tyszkiewicz, 2016; Da Mota Pedrosa et al., 2012; Dörnhöfer et al., 2016). In-house logistics is an integral element of the production system, because the production of each product involves the use of transport operations, from the delivery of materials to the enterprise, through shipment within the plant, to the distribution of finished products to the customer (Bitkowska and Tyszkiewicz, 2016; Krynke and Mielczarek, 2016; Szatkowski, 2014; Roszak, 2008). In-house logistics within an enterprise includes (Halusiak and Uciński, 2014):

- identification of materials and the place where they can be found,
- synchronization with the production program of all the material instructions,
- implementation of material inventory for production needs,
- optimizing the reaction time to change the production plan,
- integration of information and material flows,
- determining the size of material and production orders,
- providing current information on the production process.

In the field of internal logistics, the issue of quality concerns aspects related to technical characteristics, defectiveness, timeliness and quality costs (Colledani et al., 2014; Da Mota Pedrosa et al., 2012).

The issue of quality may directly relate to such aspects as: inappropriate technical solutions in the field of product protection during transport, handling or storage, use of improper packaging, transport containers, condition of transport infrastructure, qualifications of employees, lack of internal regulations, e.g. packaging procedures or instructions, and many others specific to the product, process and environment of its implementation (Colledani and Tolio, 2011; Dörnhöfer et al., 2016).

Criteria taken into consideration when creating the in-house transport network are (Halusiak and Uciński, 2014):

- proper application of the transport means to the type of cargo,
- application of appropriate technology of applying elements for transport,
- the right way to use technical means,
- the right way to organize, manage and control internal transport,

- application of an appropriate information processing technology.

The purpose of the planned and carried out research is the analysis of non-compliance in intra-company logistics operations and the determination of the size of the company's losses incurred as a result of non-compliance arising in these operations. The research was carried out in an enterprise of the automotive industry.

For comparison, the amount of monthly losses and forecasts on an annual basis, the research was conducted during two separate months of the production line work in 2017 (March, May) at the Machining Department, where the elements are transported manually, using mechanical carts and at the Assist Department, where components are transported in 75% by robots.

2. Experimental

The production process was analyzed, with particular emphasis on in-house logistics operations of steering components with electrical assistance.

The manufactured product consists of the following parts:

- controller,
- motor,
- pinion steering,
- housing rack,
- housing assist,
- upper rotor,
- blank asm worm gear.

Twice (over a period of 31 business days), factors related to internal logistics were examined in the context of product quality assurance, mainly related to irregularities occurring in the transport of components to assembly positions. The research also included cost analyzes for the amount of damaged parts created in in-house logistics operations.

The index of the share of damaged parts in relation to the annual production realized by the enterprise was calculated. The analysis and inference was based on the Pareto-Lorenz analysis (Roszak, 2014; Hys, 2014).

2.1. Characteristics of the analyzed production process

The tests and analysis carried out concerned the manufacturing process of the steering system, including the operations shown in Figure 1. The individual elements of the diagrams show the following operations: 1a - storage of steering and joint elements, 2a - transport of steering wheel elements and joint elements to the drilling station, 3a - drilling holes, 4a - component transport to the joint turning station, 5a - joint turning station and mounting washers, 6a - transport of the joint to the connection station of elements 5a, 5b, 5c, B - buffer, M1- waste storage, 1b - storage of electric motor components, 2b - transport of elements to the brushes assembly station in an electric motor, 2 - transport of electric motor elements to the PCB soldering station, 3 - electric motor brushes assembly, 3b - soldering of a printed circuit board (electronic), 4 - transport of the soldered circuit board to the engine combining station, 4b - transport of connected brushes to the engine combining station, 5 - transport of the finished electric motor to the engine control section, 5b - connecting the electric motor elements, 6b - transport of the finished engine to the connection station ready 5a, 5b, 5c, 7b - control section of the electric motor, M1 - waste storage, 1c - storage of pinion and worm gear and rack elements, 2c - transport of components to the gearbox housing dimensioning stand, 3c - size control of the worm gear housing, 4c - transport of checked elements to the housing and gearbox mounting position, 5c - assembly of gearbox housing and addition of support elements, B - buffer, 6c - transport of components to the assembly station of the rack, 7c - joining of the rack, 8c - transport of components to the connection station of elements 5a, 5b, 5c, M2 - waste storage, 8 - transport of elements to the combination of elements 5a, 5b , 5c, 9 - connection position of elements 5a, 5b, 5c, 10 - transport of connected elements to the switch assembly station and switch mechanism, 11 - switch point assembly and switch mechanism, 12 - transport of the product to the clearance stand, 13 - clearance stand, 14 - transport of finished products to the quality control station, 15 - quality control station, 16 - transport of the product to the finished product warehouse, 16 - finished goods warehouse, M3 - waste warehouse.

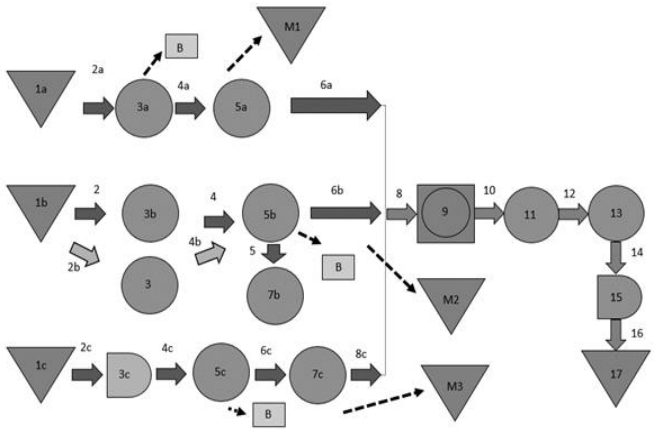

Fig. 1. Diagram of the production process of the electric assisted steering system. The legend: Fig. 1a

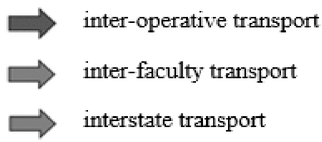

Fig. 1a. The legend Fig. 1

The studied process is characterized by a significant number of internal transport operations.

2.2. Characteristics of in-house logistics operations in the analyzed process

The description of the operation and flow of materials between stations for the analyzed process carried out at the Machining Department is shown in Figure 2 (inter-departmental transport operations are carried out 100% manually), description of the operation and flow of components between stations in the Assist Department is shown in Figure 3 (in-house transport operations are 75% robotic).

Technological and logistic operations at the Machining Department (Fig. 2) include the following: 1 - electric motor brush shop, 2 - printed circuit board (electronic), 3 - electric motor cover storage, 4 - transport of motor brushes to the motor brushes assembly station, 6 - transport of motor cover to the electric motor connection station, 7 - soldering station printed circuit board, 8 - electric motor brush assembly station, 9 - transport of solder plate to the connection station of electric motor components, 10 - transporting the motor with brushes to the connection station of electric motor components, 11 - electric motor assembly station, 12 - electric motor transport to the control section, 13 - control section, 14 - product transport at the Finally Department, A - storage section, B - assembly section for electrical motor components, C - section for connecting and controlling the electric motor.

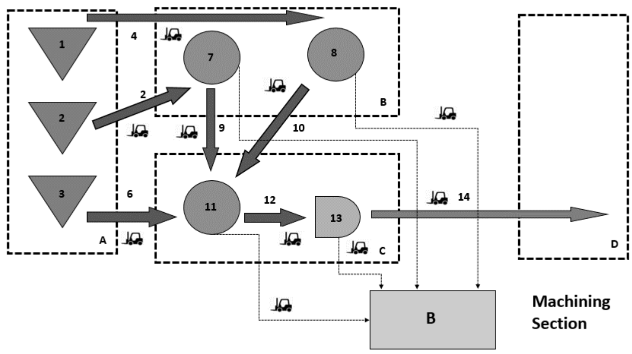

Fig. 2. Technological and logistic operations performed at the Machining Department. The legend: Fig. 2a

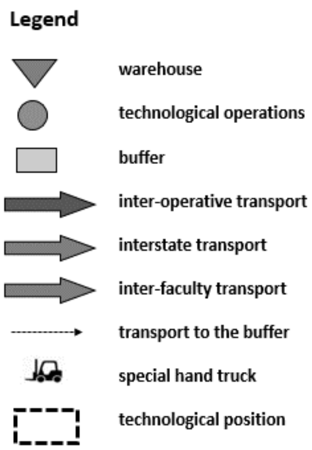

Fig. 2a. Legend to Fig. 2 and Fig. 3

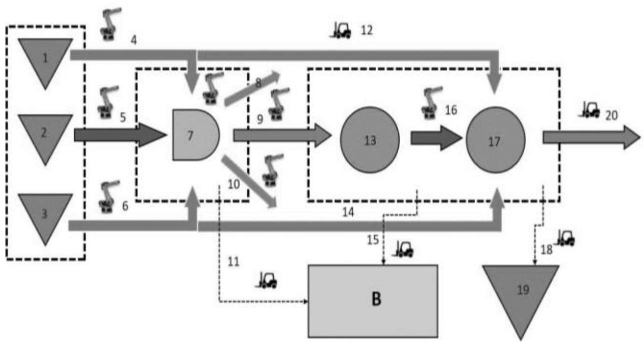

Fig. 3. Technological and logistic operations performed at the Assist Department

Technological and logistic operations at the Assist Department include the following actions: 1 - rack magazine, 2 - pinion gear storage, 3 - worm gear storage, 4 - transport of the strip to the control station, 5 - transport of the teeth elements to the control station, 6 - transport of the worm gear to the control position, 7 - position control, 8 - transport of the slat to the joining station, 9 - transport of pinion elements to the housing assembly and worm gear support, 10 - transport of the worm gear to the housing assembly and worm gear support, 11 - transport to the buffer, 12 - transport of the slat to the station joining, 13 - assembly and support station for the worm gear, 14 - transport to the final assembly station, 15 - transport to the buffer, 16 - transport of the worm gear to the final assembly station, 17 - assembly station of the final rack, worm gear and tooth strip, 18 - transport to the waste warehouse (activities optional), 19 - waste storage, 20 - product transport at the Finally Department.

2.3. Characteristics of the product produced in the process being analyzed

The product produced in the process subjected to analysis and testing is a steering system with electric support for the steering gear (Fig. 4).

The components of the steering system are: steering wheel, steering column, universal shaft joint, control pinion, worm gear, engine bar, electric engine, steering, crossover mechanism.

3. Test results

Chart 1 (Fig. 5) illustrates the results of the analysis of the most common causes of defects arising in operations of the production process at the Machining Department of the enterprise in the first 31-day measurement period (March 2017).

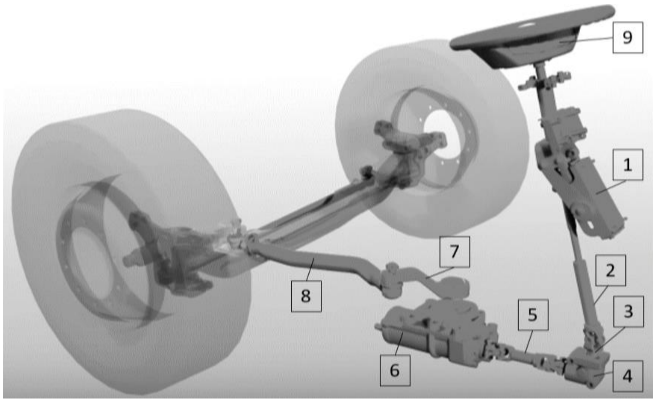

Fig. 4. Power steering elements, 1 - steering column, 2 - shaft joint, 3 - pinion, 4 - worm gear, 5 - engine bar, 6 - electric power assist motor, 7 - steering, 8 - steering mechanism , 9 - steering wheel (Steering wheel System Animation).

The most common causes of damage to the product are the following:

- fall of the component from the transport trolley,
- damage to elements related to the adjustment of the press,
- incorrect arrangement of parts in the buffer.

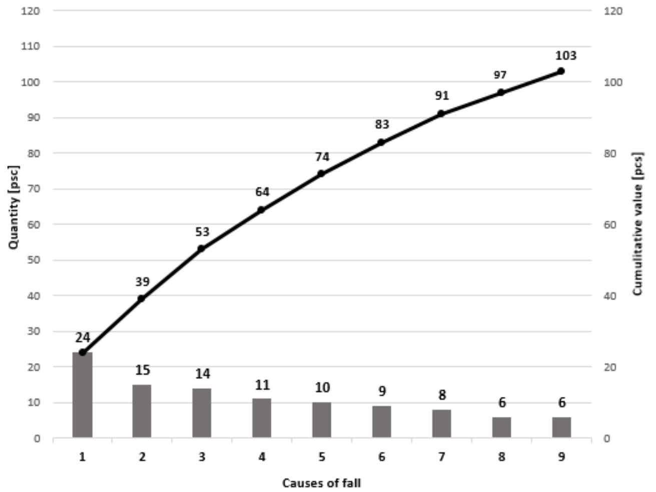

Fig. 5 Analysis of the most common causes of defects in the processing department in first measurement period (March 2017) [own elaboration]. The legend: Tab. 1.

The analysis (Fig. 6) of the number of damaged components of the conducted measurements (March 2017) was carried out at the Machining Department and the result was compared to the cumulative value (marked by a line on the chart).

Then the analysis of the amount of losses resulting from damage to the component components was made. Table 2 summarizes the data on the basis of the cost analysis for specific non-conformities (Machining Department, March 2017).

Table 1. Legend to Fig. 5 and Fig. 8

Number	Causes of fall
1	Fall from the cart
2	Damage during press adjustments
3	Wrong arrangement on buffor
4	Too many elements on the stand
5	Wrong suspension on hook
6	Hooking against tap
7	No bottom separator on the cart
8	Fall from hand
9	Not entirely closed box

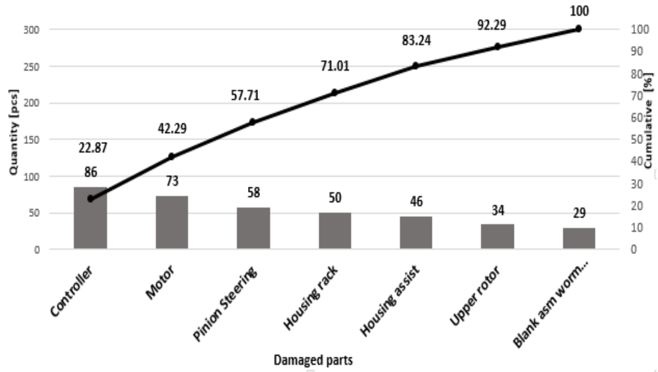

Fig. 6. Pareto-Lorenz analysis - breakdown of damage figures in first measurement period

A graphical summary of the analysis of the amount of damaged components and their financial losses for the enterprise (Processing Department, March 2017). The analysis is presented in Figure 7.

Fig. 8 presents the results of the analysis concerning the most common causes of defects arising in operations of the production process at the Assist Department of the company during the second 31-day measurement period (May 2017).

Next, in Fig. 9, the results of analyzes concerning the amount of damaged components and their financial losses for the company over the period of 31 days (May 2017) and the reference of the result to the accumulated value (indicated by a line on the chart) are given. The measurements concerned the Assist Depment.

Table 3 presents the results of the analysis of the costs of damaged parts, in relation to prices and the sum of costs, the relative share of costs and their cumulative shares were determined in the second measurement month (May 2017) at the Assist Department.

A graphical summary of the analysis of the amount of damaged components and their financial losses for the enterprise (Assist Department, May 2017). The analysis is presented in Figure 10.

Table 2. Pareto-Lorenz analysis regarding company‘s losses [in PLN] caused by component damage

Name of the element	Price [PLN]	Quantity	Expense [PLN]	Sum of expenses [PLN]	Relative share of costs [PLN]	Cumulative share
Motor	238.00	73	17 374.0	17 374.0	36.8	36.8
Controller	178.00	86	15 308.0	32 682.0	32.5	69.3
Housing assist	124.00	46	5 704.0	38 386.0	12.3	81.6
Upper rotor	98.00	34	3 332.0	41 718.0	7.0	88.6
Blank asm worm gear	109.00	29	3 161.0	44 879.0	6.7	95.3
Pinion Steering	32.00	58	1 856.0	46 736.0	3.9	99.2
Housing rack	8.00	50	400.0	47 135.0	0.8	100.0

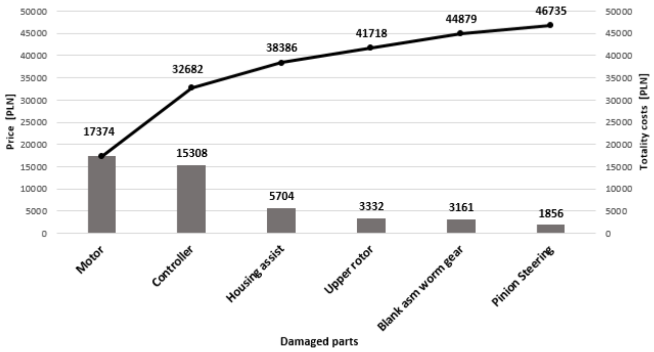

Fig. 7. Pareto-Lorenz analysis - breakdown of damage figures in first measurement period

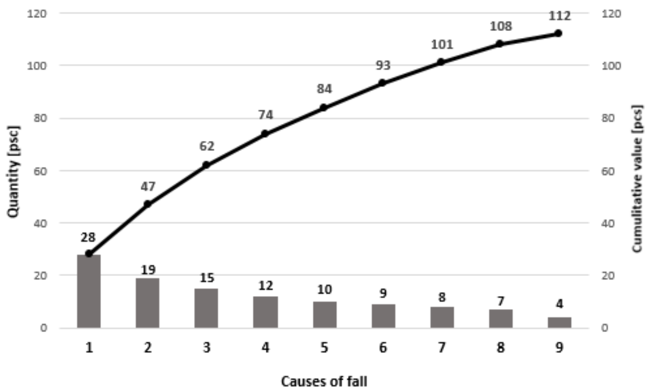

Fig. 8. Analysis of the most common causes of defects in the processing department in second measurement period (May 2017). The legend: Tab. 1

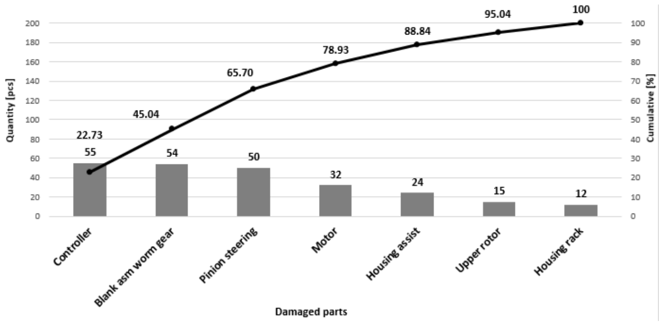

Fig. 9. Pareto-Lorenz analysis - breakdown of damage figures in second measurement period

4. Quantitative analysis of non-compliance

The research and analysis allowed to draw the following conclusions related to the quantitative aspect of the defined causes of defects.

Table 3. Pareto-Lorenz analysis regarding company‘s losses [in PLN] caused by component damage

Name of the element	Price [PLN]	Quantity [pcs]	Expense [PLN]	Sum of expenses [PLN]	Relative share of costs [PLN]	Cumulative share [%]
Controller	178.0	55	9 790.0	9 790.0	33.24	33.24
Motor	238.0	32	7 616.0	17 406.0	25.84	59.08
Blank asm worm gear	109.0	54	5 886.0	23 292.0	19.69	78.77
Housing assist	124.0	24	2 976.0	26 268.0	10.11	88.88
Pinion Steering	32.0	50	1 600.0	27 868.0	5.24	94.12
Upper rotor	98.0	15	1 470.0	29 338.0	4.89	99.01
Housing rack	8.0	12	96.0	29 434.0	0.99	100.00

Analysis of the obtained data, from measurements made at the Machining Department, where the transport is 100% handmade (Tab. 2, Fig. 5, 6, 6) showed that the company's losses, with annual production of 100.000 pcs steering units amount to: 376 pcs - monthly, which gives an annual result of 4.512 pcs. Another analysis carried out at the Assist Department, where the transport of components takes place in 75% robotic way (Tab. 3, Fig. 8, 9, 10) showed the company's losses, with an annual production of 100.000 pcs steering parts are: 242 pcs - monthly, which gives an annual score of 2.904 pcs.

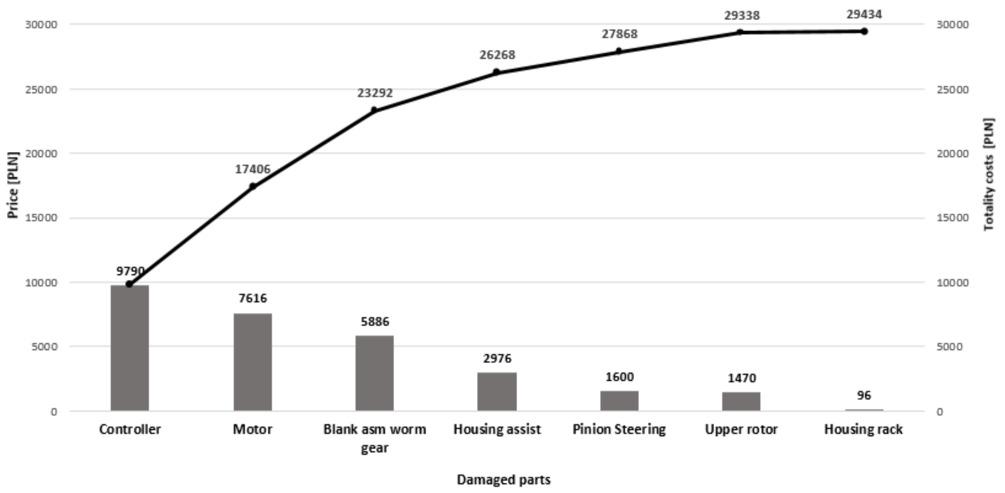

Fig. 10. Pareto-Lorenz analysis - breakdown of damage figures in second measurement period

The difference in the number of damaged components (in pcs) in both departments amounted to 1.608 a year, to the disadvantage of the Machining Department.

4.1. Cost analysis of non-compliance

The analysis carried out allowed to draw the following conclusions related to the cost aspect of the measured causes of non-compliance and the level of business losses (tab. 2) as a result of damages, the Machining Department reaches PLN 47.135 - monthly, which translates into PLN 565.500 per year. The level of company losses due to damages at the Assist Department (tab. 3) is PLN 29.434 - monthly, which translates into PLN 353.228, on an annual basis. The difference in the cost of losses incurred as a result of damage to components is PLN 212.292 to the detriment of the Machining Department, where the transport of components takes place manually.

5. Summary and conclusion

Identification of incompatibilities for the enterprise resulting from in-house logistics operations was the goal of the analyzes presented.

The conducted analysis indicates that the internal logistics process significantly affects the quality of the product. In the analyzed production process of the steering system, damages in the vast majority occur in the Machining Department, where the transport of components takes place entirely in a manual manner, with special transport trucks being used as the carrier. In Assist Department, where component transport was 75% robotic, there are fewer disadvantages, so replacing manual transport with automated or robotic means will save the company (in the prior analysis of the feasibility of introducing robots or conveyors belts that may be subject to other tests).

The analysis showed that robotization and automation in logistics operations inside the plant has a beneficial effect on minimizing the number of generated non-conformities. The use of logistics in 25% of operations within the factory automation in 25% allows at the same time to reduce the volume of production by 35% the number of non-compliances recorded.

The research and analysis showed that the average cost of non-compliance per one piece of product manufactured for the analyzed production line is over PLN 9,0.

The identification of non-compliance also concerned the identification of potential causes of their occurrence and proposing solutions in order to limit the number of defective products and thus ensure the quality of both the process and the product. After analyzing the above-mentioned reasons, in order to eliminate them, the following actions were proposed:

- the use of foam containers or separators separating transported parts,
- increasing the frequency of controlling the correct loading of components for transport,
- analyzing the possibility of introducing transport boxes with separate compartments for each finished component,
- analysis of modification of shelves in transport trolleys,
- analysis of the use of additional trolley safeguards against the possibility of falling parts,
- introduction of detailed instructions on the preparation of transport elements for employees,
- conducting additional training for employees responsible for the transport of items,
- taking steps to optimize the use of other mechanized means of continuous transport (e.g. belt conveyors).

The above-proposed measures to eliminate the potential causes of non-compliance were the result of analyzes in the field of improving in-house logistics operations, resulting from the interest of the management staff in the identified significant level of incompatibility resulting from the conducted analyzes. The analysis results presented in the analysis have been taken into account in this respect for non-compliance transactions in the audited enterprise, so far it has not been conducted separately in this scope of analysis. In the available scientific literature, there is no reference to exact data related to the level of non-compliance costs associated with in-house logistics operations.

This article indicates the need to implement effective methods not only in the field of process monitoring and diagnosis of non-compliance in production processes with particular emphasis on in-house logistics, but also the implementation of technical and organizational solutions that minimize their occurrence.

Due to limitations related to access to source data, no repeat tests were performed.

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内部物流流程中不合规的成本定量分析

關鍵詞
质量
成本
内部物流流程
Parteo-Lorenz分析

摘要
内部物流是生产过程的关键要素。 指定产品质量，及时性和订单价值。 该研究的目的是确定在选定的生产过程中由内部物流操作引起的违规数量。 该分析涵盖了不合规的数量和类型以及不合规的成本。 研究中使用了一种基本的质量管理工具-Parteo-Lorenz分析。 试图找出不合规的潜在原因。 指出了内部物流操作不合规对生产成本的重大影响。