WIEDZA OBRONNA
2022, Vol. 280 No. 3
ISSN: 2658-0829 (Online) 0209-0031 (Print)
Journal homepage: http://wiedzaobronna.edu.pl
DOI: https://doi.org/10.34752/2022-o280

SŁAWOMIR BARTOSIEWICZ*
Wojskowa Akademia Techniczna, Warszawa, Polska

EFFECTIVENESS OF CONDUCTED PREVENTIVE AND PROACTIVE MEASURES INCREASING THE SAFETY OF THE COMPANY

ABSTRACT: The final part of the developed article presents the results of the conducted research and proposals for the practical use of the developed econometric cost model as a tool for cost analysis. Furthermore, the application of this econometric model enabled the author to analyze the factors influencing the level of costs incurred for preventive measures and for ensuring the safety of the storage system in the company X through the application of preventive and proactive measures adequate to the scale of the problem. As a consequence, such a procedure made it possible to obtain information fully useful in the daily operations of the company X. In conclusion, reference is made to the extent to which the adopted objective has been met and final conclusions are provided.

KEYWORDS: prevention, proactive measures, storage system, cost of measures carried out, probability of effectiveness of preventive and proactive measures carried out

INTRODUCTION

Prevention is understood as a conscious action aimed at individuals or social groups to prevent various problems before they occur. Preventive measures also include identifying individuals or groups at risk in order to intervene early in the development of risky or problem behaviors. Besides, prevention by definition means measures carried out in advance, rather

* dr Sławomir Bartosiewicz, Military University of Technology, Warsaw, Poland
https://orcid.org/0000-0003-2897-6307 slawomir.bartosiewicz@wat.edu.pl

than corrective measures. Proactive measures, on the other hand , are designed to keep the company's employees safe by:

- preventing job-related hazards;
- proper organization of work;
- applying the necessary preventive measures, as well as informing and training employees.

The implementation of this obligation takes into account the principles of prevention of risks posed by the activities carried out, such as:

1. Monitoring the risk of hazards in the company X.
2. Elimination of hazards at the source of their formation.
3. Adapting storage conditions and processes to the capabilities of employees, in particular by:
   - proper design and organization of workstations for warehouse employees;
   - selection of means of internal transport and equipment with appropriate racks for storing goods in the warehouse.
4. Application of new technical solutions within the scope of internal transport and storage of goods.
5. Employee training on regulations – occupational health and safety, and fire safety regulations.

The main reason for this article is the author's interest in the security of logistics systems in management.

RESEARCH PROCESS

The objective the author has set for himself is: Identify a number of relationships between the effectiveness (or, more precisely, the probability of effectiveness of preventive and proactive measures carried out) of certain measures and the costs incurred for these measures. These measures can be applied individually or in specific configurations (systems) to achieve higher effectiveness.

The research problem is: How to determine the relationship between the effectiveness (or, more precisely, the probability of effectiveness of preventive and proactive measures carried out) of certain measures and the cost of these measures, and how to use the results to ensure the required level of security of the company's storage system?

The article assumes the following research hypothesis: Costs incurred for preventive and proactive measures positively affect the probability of their effectiveness, which consequently translates into the security of the storage system at the company X.

The subject of the research was to analyze a number of relationships between the effectiveness (or, more precisely, the probability of effectiveness of preventive and proactive measures carried out) of certain measures and the costs incurred for them to ensure the required level of security of the storage system in the analyzed company X.

The entity was one of the operating business entities where the primary business is storage services. The quantitative data used in the calculations were obtained from the company X under analysis.

The time frame of the research conducted covers the years 2014–2021.

The spatial scope of the research is one of the logistics companies X operating in Poland, where the main area of its activity is logistics services for warehousing and distribution of goods.

The following research methods and tools were applied in the article:

– analysis of literature, applicable laws, and health and safety regulations;
– synthesis;
– econometric model on the example of estimation of structural parameters of the model describing the relationship between the effectiveness of preventive and proactive measures and the costs of these measures;
– data analysis – application in the EXEL package.

The structure of the study includes the identification and analysis of preventive and proactive measures in the functioning of the storage system in the analyzed entity, as well as the measurement and research process aimed at determining a number of relationships between the effectiveness (or, more precisely, the probability of effectiveness of preventive and proactive measures carried out) of certain measures and the costs incurred for them. These measures can be applied individually or in specific configurations (systems) to achieve higher effectiveness.

The most frequently controlled areas of activity within the storage system at the company X, are:

– compliance of the documentation with the facts;
– costs of executing the orders;

– incurred costs of certain measures to effectively conduct preventive and proactive measures;
– occurrence of errors during picking;
– efficiency and mechanization of the measures undertaken;
– efficient use of storage space;
– safe and efficient use of warehouse employees.

Another important element that should be evaluated is the technical condition of the equipment in the storage areas in view of ensuring an adequate level of safety. These activities consist of determining:

– conditions – in which goods are stored, taking into account preservation of their physical and chemical properties;
– conditions – in which dangerous materials of the ADR group are transported;
– fire and burglary protection systems;
– technical condition of the devices and equipment located in the warehouse;
– activities that comply with the occupational health and safety, and fire protection requirements.

APPLICABLE RULES FOR STORING AND SECURING GOODS AND CARGO IN THE WAREHOUSE OF THE COMPANY X

Storage logistics in the company X has a huge impact on the overall operation of the warehouse because the methods implemented and equipment used determine the efficiency of handling the storage area, while the supply and working techniques determine the comfort and safety of the employees. Therefore, it is important to take care of the proper organization of storage processes.

In this warehouse facility, storage space is used for:

– stockpiling – depending on needs;
– cargo consolidation or deconsolidation;
– the organization of space is optimized for specific activities to ensure that warehouse employees can quickly carry out their duties.

To ensure that the facility operates smoothly and that the activities conducted there run without interruptions, the company takes care of:

- provision of means of internal transport for the transport of goods, which are adapted to the specificity of the stored cargo;
- delineation of transport routes in accordance with the principle of their straightness, which ensures the smooth flow of traffic and safety for employees as well as goods and cargo;
- installation of appropriate shelving and racks, and their clear labeling with safety precautions;
- specification of storage methods;
- designation of storage areas for cargo and goods to prevent any kind of disturbance or hazard;
- efficient execution by warehouse employees of order picking;
- The above rules applicable in the company's warehouse facility provide order that translates to:
- efficient implementation of conducted activities;
- safety.
- In this company, the warehouse manager is responsible for:
- compliance with detailed storage rules taking into account the physical and chemical properties of individual goods and cargo;
- ensuring appropriate occupational health and safety, as well as fire safety conditions.

TECHNICAL EQUIPMENT OF THE WAREHOUSE

The different functional areas of the warehouse facility use the correct, compliant with the needs, equipment adjusted to the requirements of the company X. The technical equipment of the warehouse facility consists of:

- transport equipment – elevating and lifting trucks;
- storage structures – fixed racks and holders;
- ventilation and air conditioning equipment – heaters, coolers, fans, humidifiers and air conditioners;
- lighting – natural and artificial;
- fire-fighting equipment – sprinklers, dry powder, foam and snow extinguishers;
- warehouse areas are equipped as required, and internal transport devices used there are operated in accordance with their purpose;

- constant controls and inspections of the technical condition of the technical equipment of the warehouse areas are performed according to the applicable schedule;
- means of internal transport and other technical equipment used to move cargo meet the applicable technical requirements;
- forklifts and other transport equipment are operated only by employees trained within this scope and having valid authorizations;
- warehouse employees strictly observe the permissible weights and heights of formed loads in the order picking area.

STORAGE METHODS APPLICABLE TO THE STORAGE SYSTEM OF THE COMPANY X

In the functional areas of the warehouse of the company, a properly planned storage of cargo and goods has been implemented, which is based on the adopted specific established scheme, where goods and cargo have their designated places according to the ABC method in force in this regard. This solution facilitates:

- memorizing how the assortment is laid out;
- it also allows for creation of a permanent storage plan.

If the delivered goods and cargo have different expiration dates for storage, then their appropriate sorting is implemented. This applies to all products that must be used by a certain date, ensuring easy and efficient rotation. The applicable method for the storage of goods and cargo is the ABC method, which is based on the plan for the location of goods in force and takes into account the frequency of their rotation, where:

- category A – the most popular products are located in the marked area which is situated in a well accessible location to make it easy for employees responsible for order picking to collect them;
- category B – goods that leave the warehouse much less frequently, placed on the lower levels of pallet racking;
- category C – the least marketable goods are located in this area on the highest rack levels due to low customer demand.

REQUIREMENTS FOR THE WAREHOUSE OF THE COMPANY X[1]

1. Clear storage height – 10.0 m.
2. Floor carrying capacity – 5.0 t/1 m^2.
3. At least 1 loading dock per 1,000.0 m^2.
4. At least 1 entry gate from level "0" per 5.000.0 m^2
5. Fire protection system – sprinkler system.
6. Maneuvering area with a width of – 30.0 m.
7. High-class office space – its average share in the total area of the warehouse facility is 5.0% ÷ 10.0%.
8. Lighting system, light intensity – at least 150 lux.
9. The most desired column grid – 12 m x 24 m or 12 m x 22.5 m.
10. Minimum distance between elements of the truck from all sides and racks or walls – 500.0 mm according to PN-EN349.
11. The width of the corridors of 1.5 length of the means of transport with the greatest length, that is – 2.7 m ÷ 3.5 m.
12. Maximum distance of up to 10.0 km from highway or expressway and surrounding area, excluding residential development.

OCCUPATIONAL HEALTH AND SAFETY REGULATIONS APPLICABLE IN THE FUNCTIONAL AREAS OF THE WAREHOUSE

Organization of work in the functional areas of the warehouse ensures full safety to the employees present there as well as to the third parties in accordance with the applicable principles of the occupational health and safety and the Labor Code. Warehouse employees are properly trained, undergo on-the-job training and are properly authorized to operate means of internal transport. Activities conducted in the various functional areas of the warehouse are organized so as to[2]:

- provide warehouse employees with access to necessary job instructions, including material storage;

[1] Basic principles of occupational health and safety in warehouses - legal status of CIOP, (accessed on April 21, 2022).

[2] B. Krzyśków. (Central Institute for Labor Protection - National Research Institute), Occupational Safety - Science and Practice, No. 1, 2013, pp. 4÷6.

- carry out the storage of all kinds of goods and cargo in accordance with the rules of the company;
- keep transport routes in the functional areas of the warehouse clear;
- blocking of all security exits and escape routes is forbidden, including access to fire-fighting equipment (sprinklers, fire extinguishers);
- maintain technical equipment for transporting and storing goods in perfect technical condition, in accordance with the manufacturer's recommendations;
- ensure that warehouse employees have quick access to personal protective equipment, including first aid kits;
- transport materials in accordance with the permissible total weight of the means of internal transport;
- maintain the continuous and uninterrupted supervision over the course of tasks and activities carried out in the functional areas of the warehouse by warehouse employees.

POSSIBLE HAZARDS IN THE FUNCTIONAL AREAS OF THE WAREHOUSE

The major hazards that may occur during activities conducted in the individual functional areas of the warehouse facility include:

- slips caused by wet pavement;
- impacts and crushing with goods and loads that are transported by means of internal transport or that are on the racks;
- falls from heights, which may be caused by internal means of transport for high storage not complying with the regulations in force;
- fires of all kinds, caused by:
- damaged electrical system;
- improper storage of dangerous goods of the ADR group.

LEGAL PROVISIONS IN FORCE TO PREVENT ACCIDENTS AT WORK AND OCCUPATIONAL DISEASES AND TO ENSURE THE SAFE AND HUMANE WORK OF WAREHOUSE WORKERS[3]

The Act on occupational health and safety (ArbSchG) requires the company director to prevent accidents at work and to ensure safe and humane work (§§ 2, 3 of the ArbSchG). Specifically, this includes workplace design, development of work procedures, flow and organization of work. The director of the company X is obliged to determine what occupational health and safety measures are necessary to avoid accidents at work by means of a risk assessment in accordance with § 5 of the ArbSchG.

Next, DIN EN 15635 requires the warehouse manager to regularly inspect racking systems that are operated by means of internal transport. This applies mainly to pallet racking.

DGUV 208-043 "Safety of racking systems", in turn, provides important information on the prevention of accidents at work, for all types of steel racking used in commerce. Section 4.7 of the information, in turn, states that "In corner areas of racks that are loaded or unloaded by unguided conveyors, a protective barrier anchored to the floor must be installed, which must not be connected to the rack supports. The height of the protective barrier must be at least 400.00 mm. Section 8. "Enhancing safety in the warehouse" recommends the use of shielding elements for the column grid in the storage area.

MEASUREMENT AND RESEARCH PROCESS OF THE COMPANY X[4]

In order to illustrate the case studied, the author used calculations with the use of an econometric model on the example of estimation of structural parameters of the model describing the dependence of the effectiveness of preventive and proactive measures carried out and incurred costs of certain measures.

In the research conducted:

– the names of the measures and the principle of their operation have been omitted;
– the focus was on how the results were obtained, which means on:
  - model estimation;
  - an attempt to assess the model's consistency with empirical data;

[3] Study with the use of: BITO Warehouse technology, www.prevention of accidents at work by warehouse mployees intralogistics expertise (bito.com), (accessed on April 21, 2022).
[4] A. Goryl, Z. Jędrzejczyk, K. Kukuła, J. Osiewalski, A. Walkosz, *Introduction to econometrics in examples and tasks,* Polish Scientific Publishers, PWN, Warsaw,2007, pp. 25-31.

– for this reason, the values adopted in the model, although they are empirical values, come from the data obtained from the analyzed company X and are treated as real data.

The purpose of this measurement and research process was to determine a number of relationships between the effectiveness (or, more precisely, the probability of effectiveness of preventive and proactive measures carried out) of certain measures and the costs incurred. These measures can be applied individually or in specific configurations (systems) to achieve higher effectiveness. The obtained relationships are presented in Table 1.

Table 1. Probability of effectiveness of preventive and proactive measures carried out and the costs incurred for them

No.	Combination of possible measure options	Probability of effectiveness of prevention and proactive measures carried out P(S) Variable X_i	Cost of measures carried out $K_{p,z}$ PLN Variable Y_i
1.	Single measure (No. 1)	0.30	4,900.00
2.	Single measure (No. 2)	0.40	5,500.00
3.	System consisting of two measures (no. 1 and no. 2)	0.58	10,400.00
4.	System consisting of two measures (no. 1 and no. 3)	0.61	24,560.00
5.	System consisting of two measures (no. 2 and no. 3)	0.66	25,160.00
6.	System consisting of three measures (no. 1, 2 and 3)	0.76	30,060.00
7.	System consisting of three measures (no. 1, 2 and 4)	0.83	50,100.00
8.	System consisting of three measures (no. 2, 4 and 3)	0.86	64,880.00

Source: Own elaboration.

The next step was to determine the functional relationships that exist between the given values, which are shown in a graphic form in Figure 1.

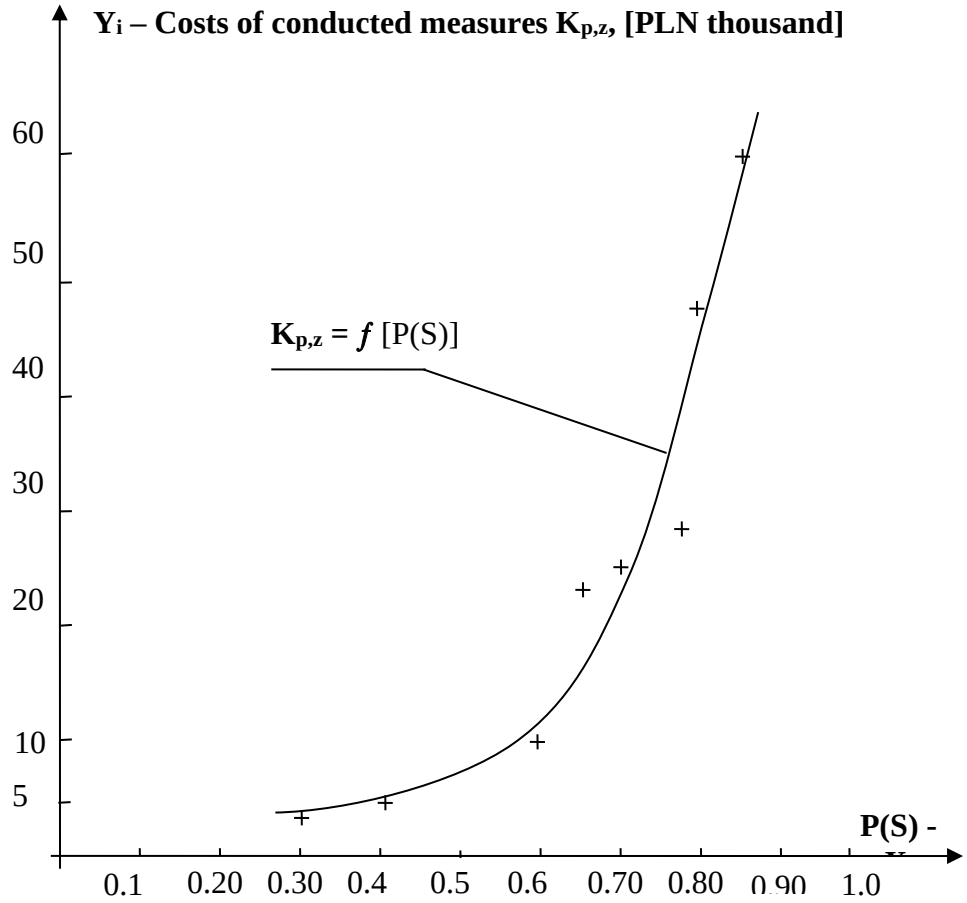

Fig. 1. The relationship between the probability of effectiveness of preventive and proactive measures and the costs incurred for them
Source: own study.

The purpose of the following activities, however, was not to estimate a specific cost model, but to outline the procedure to be followed and the range of results obtained when the calculations were carried out with adequate tools. To illustrate, a simple econometric model of the following form was used:

$$Y_i = A_1 + A_2 \frac{1}{X_i} + e \quad \textbf{(1)}$$

For this type of model, whose structural parameters were estimated by the classical method of least squares (CMOLS), a computer program was used in which the observed X_i and Y_i values were given.

After calculation, CMOLS structural parameter estimates were obtained. In model (1), these are calculated parameters A_1 and A_2, for the four functions:

– linear;

– hyperbolic;

– exponential;

– power.

For each of these functions, in order to check the validity of the estimate (or choice of function), the table includes the two most commonly used measures for verification of the degree of matching of a particular function to the empirical data, these are:

– coefficient of convergence φ^2;

– mean errors of estimation (evaluation) of parameters.

– Based on the calculations, the analytical form of the model was adopted:

$$K_e = A_0 A_1^{P(S)} \quad \textbf{(2)}$$

In order to estimate the structural parameters and to assess the consistency of the model with empirical data, the application "EXEL" was used, the input data of which were prepared and included in Table 1 (last two columns).

After the calculations, a table was obtained that includes, in addition to the auxiliary calculations, the estimated structural parameters of the model, the mean errors of estimation (evaluation), and the coefficient of convergence $\boldsymbol{\varphi^2}$.

Based on measures of the degree of matching of the function to the empirical data, the exponential function in the following form was selected:

$$\boldsymbol{\hat{Y} = 987,7 \cdot 113,2^X} \quad \textbf{(3)}$$

The criteria for selecting the analytical form of the function are usually the coefficient of convergence and the mean errors of the parameter estimates. For the estimated function (3), these quantities are:

– coefficient of convergence $\boldsymbol{\varphi^2}$ = 0.052;

– mean errors of parameter estimation:

$$S_{a_0} = \pm 9,8 \text{ i } S_{a_1} = \pm 1,6$$

The obtained estimation quality can be considered satisfactory as the coefficient of convergence $\boldsymbol{\varphi^2}$ is close to 0 and the mean estimation errors S_a are less than 10.0% of the estimated parameter values.

The estimation of the cost model given here, as an illustration, is actually an attempt to determine the analytical function capturing the effectiveness of the measures carried out and the costs incurred for them. In practice, knowing the form of this function can be useful when designing and evaluating the cost of these measures.

SUMMARY AND CONCLUSIONS

The purpose of this measurement and research process was to determine a number of relationships between the effectiveness (or, more precisely, the probability of effectiveness of preventive and proactive measures carried out) of certain measures and the costs incurred for them. These measures can be applied individually or in specific configurations (systems) to achieve higher effectiveness.

In the research conducted:

– the names of the measures and the principle of their operation have been omitted;
– the focus was on how the results were obtained, which means on:
  - model estimation;
  - an attempt to assess the model's consistency with empirical data;
– for this reason, the values adopted in the model, although they are empirical values, come from the data obtained from the analyzed company X and are treated as real data.

The following final conclusions were made based on the own research conducted:

1. The presented example of cost model estimation is an attempt to determine the analytical function that includes the effectiveness of conducted activities and the costs incurred for them.
2. The econometric cost model used in the body of the article is the cost analysis tool that was used in practice.
3. Besides, the application of this econometric model enabled the author to analyze the factors influencing the level of costs incurred for preventive measures and ensuring the safety of the storage system in the company X through the application of preventive and proactive measures adequate to the scale of the problem.
4. As a consequence, such a procedure made it possible to obtain information fully useful in the daily operations of the company X.

REFERENCES LIST

Basic principles of occupational health and safety in warehouses - legal status of CIOP, (accessed on April 21, 2022).

Goryl A., Jędrzejczyk Z., Kukuła K., Osiewalski J., Walkosz A., *Introduction to econometrics in examples and tasks,* Polish Scientific Publishers, PWN, Warsaw, 2007,pp. 25÷31.

Krzyśków B,. *(Central Institute for Labor Protection - National Research Institute), Occupational Safety - Science and Practice*, No. 1, 2013, pp. 4÷6.

Regulation of the Minister of Labor and Social Policy on general health and safety at work regulations Legal status valid as of: June 11, 2022.

Study with the use of: BITO Warehouse technology, www.prevention of accidents at work by warehouse employees | intralogistics expertise (bito.com), (accessed on April 21, 2022).
