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USE OF HOLT'S MODEL FOR FORECASTING UNTIL 2023 OCCUPATIONAL ACCIDENTS IN THE METALLURGICAL INDUSTRY IN POLAND

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The article the issue of occupational accidents in the metallurgical industry was presented. The accident analysis included occupational accidents from 2009 to 2018. Based on compiled empirical data (2009-2018), the process of forecasting occupational accidents until 2023 was carried out. The Holt's model with an additive trend was used to carry out the forecasting process. The use of the developed forecasting model allowed to assess the tendency of changes in the number of occupational accidents in the metallurgical industry in Poland. The developed model can also be used to assess accident changes in other countries.

Key words: metallurgy products, occupational accidents, forecasting, Holt's model, Poland

INTRODUCTION

Occupational accidents are events that generate social and economic costs. Consequently, the issues related to their reduction play a significant role for enterprises, including metallurgical enterprises [1]. The concept of accident is specified in Polish law in the Act [2], pursuant to which, an occupational accident shall mean a sudden externally caused event related to the performed work resulting in injury or death of an employee. It must be noted that this definition differs across the countries. It is broadly agreed that an accident is a sudden event caused by an external factor. The occurring discrepancies relate to the further part of its definition referring to damage, injury and loss. In essence, the arising discrepancies come down to three variants in which: the accident is identified with the injury, the accident is the injury alongside its preceding situation, and finally, the injury is one of the possible consequences of the accident [1,3]. Given the above, in order to assess the changes in recorded accident occurrences in the metallurgical industry (i.e. increase or decrease), an analysis was undertaken to examine the trends in the recorded occupational accidents in Poland from 2010 to 2018. Based on empirical data, the values of forecasts of occupational accidents (for the period of 2019-2023) were determined using Holt's exponential smoothing model. The adopted model allows for a specific selection of smoothing parameters (α, β) for the compiled empirical data.

METHODOLOLOGY

The aim of this study is to provide forecasts of the number of accidental events until 2023 and assess the trend in the recorded accidental events. In this context, a three-step research methodology has been selected. In the first stage, empirical data on:

- the characteristics of the sector in accordance with the Polish Classification of Activities (PKD) – in relation to metal production in Poland;
- the number of persons injured in occupational accidents in total and with respect to the severity of the consequences (serious, fatal and other accidents).

The second stage involved the use of the compiled empirical data (for the period of 2009-2018) to build forecasts in accordance with Holt's model. An additive trend model was constructed during this stage. As given in the literature on the subject [4-6], this model assumes that both the level of the forecast variable and its increase are subject to exponential smoothing. Holt's two-parameter additive trend model describes mathematical dependencies (1) and (2):

$$F_t = \alpha \cdot y_t + (1-\alpha) \cdot (F_{t-1} + S_{t-1}) \quad (1)$$

$$S_t = \beta \cdot (F_t + F_{t-1}) + (1-\beta) \cdot S_{t-1} \quad (2)$$

The symbols in the model are defined as follows: y_t – empirical data; F_t – an estimate of the level of the series at time t; S_t – an estimate of the trend (slope) of the series at time t; α – smoothing parameter for the level, $(0,1>$, $(\alpha \neq 0)$; β – smoothing parameter for the trend, $(0,1>$, $(\beta \neq 0)$.

The optimal values of smoothing parameters α and β were determined using the Excel Solver. The mathematical relationships (1) and (2), as well as the specifically defined smoothing parameters (α and β), enabled the determination of the forecasts for the years 2019 - 2023. Since the determination of forecasts does not complete the forecasting process, errors of the forecasting method were identified. The estimation of the error of ex-

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pired forecasts arises from the need to estimate the forecast error and is necessary to implement the forecast itself [4]. For the purposes of this study, Root Mean Square Error (RMSE*) (3) and mean error ψ (4), were determined. These errors were determined using mathematical relationships (3,4) [4,7]:

$$RMSE^* = \sqrt{\frac{1}{n-m} \cdot \sum_{t=m+1}^{n} (y_t - y_t^*)^2} \qquad (3)$$

$$\Psi = \frac{1}{n-m} \cdot \sum_{t=m+n}^{n} \frac{\left| y_t - y_t^* \right|}{y_t} \qquad (4)$$

Where: n – number of elements of the time series; y_t – empirical data; y_t^* – forecasts value; m – number of initial time moments t.

As part of the third stage, ex-ante forecasts of occupational accidents in the metallurgical industry for the years 2019-2023 were assessed and the trend of their changes was analyzed.

METALLURGICAL INDUSTRY AND REGISTERED ACCIDENTS

The forecasting of occupational accidents was conducted based on the data from the Central Statistical Office of Poland for events recorded in the group – manufacturing industry – metal production. Events recorded within this group occur during the manufacture of:

– pig iron, ferroalloys, cast iron, steel and metallurgical products, pipes;
– hollow sections and fittings made of steel;
– precious metals and foundry;
– steel products that have undergone pre-treatment, e.g. cold drawn bars;
– cold rolled flat products and wire.

The empirical data on the number of persons injured in occupational accidents in 2009-2018 is presented in tabular (Table 1) and graphic (Figures 1 – 3) format [8]. The collected empirical data was used to carry out the forecasting process – forecast for the years 2019-2023. The number of accidental events occurring in the sector under analysis depends primarily on the number of employees. The literature review shows that a downward trend in the number of employees can be observed in the steel sector [5,6], which is also reflected in the accident statistics. Based on the analysis of empirical data (Table 1), a decline in the total number of persons injured in accidents was recorded since 2013 (fall from its maximum value of 1 127 to a minimum of 887). Moreover, since 2014, an increase in the number of events was recorded in 2014 (889) and in 2015 (899) to be followed by a decline in 2016 (876). In the subsequent years, an increase was recorded in 2017 (955) and a decline in 2018 (930). Similar fluctuations in the number of events are recorded for serious, fatal and accidents with other effects.

HOLT'S MODEL WITH ADDITIVE TREND

On the basis of the compiled empirical data, a forecast variable was determined, which is the number of persons injured in accidents (y_t) in total, serious, fatal and others (y_t). It was assumed for the purposes of the implementation of the forecast that $y_t = F_t$, $S_t = y_2 - y_1$, applicable by analogy to each subsequent issue under consideration – y_2, y_1 are empirical data on the number of persons injured in occupational accidents in total for 2010 (y_2) and 2009 (y_1). The optimal values of parameters α and β were selected using the Solver add-in by minimizing one of the forecast errors, i.e. the mean forecast error by expired "Ψ".

In the case of the forecast of the total number of persons injured in accidents, in accordance with the adopted model, a downward trend is recorded for the projection period. The total number of persons injured in accidents amounts to 923 (in 2019), 912 (in 2020), 902 (in 2021), 892 (in 2022) and 882 (in 2023), as indicated in column 5, Table 1. During the minimization of the mean error of expired forecasts, the values of the smoothing parameters in the developed model were equal to α = 0,66 and β = 0,09, respectively. The analysis of the total number of accidents does not however make it possible to determine which events (serious, fatal, or accidents with other effects) will dominate in the years 2019 - 2023. Given the above, an analysis of accident occurrences was carried out in the group of workers involved in serious (Figure 1), fatal (Figure 2) and accidents with other effects (Figure 3).

As regards forecasting serious accidents using Holt's model, with the mean error minimization of expired forecasts (Ψ = 35,9 %) and smoothing parameters (α = 0,67; β = 0,18), an increasing trend in the number of serious accidents in the year is forecast 2019. However, in the years 2020-2023 it is forecasted that there will be 13 – Figure 1. The analysis showed that employers should pay attention to the occurrence of such events.

Table 1 **Forecasting occupational accidents - total number of people injured in the metallurgical industry in Poland [own research]**

$y_t = F_t$ $S_t = y_2 - y_1$				
1	2	3	4	5
Year	y_t	F_t	S_t	y_t^*
2009	1 081	1 081	-8,00	-
2010	1 073	1 073	-8,00	1 073
2011	1 127	1 106	-4,27	1 065
2012	901	969	-16,34	1 102
2013	887	909	-20,30	953
2014	889	889	-20,30	889
2015	899	894	-18,00	869
2016	876	876	-18,00	876
2017	995	848	-9,76	858
2018	930	933	-10,28	939
2019	Forecasts			923
2020				912
2021				902
2022				892
2023				882

α	β	Ψ	RMSE*
0,66	0,09	0,060	87,404

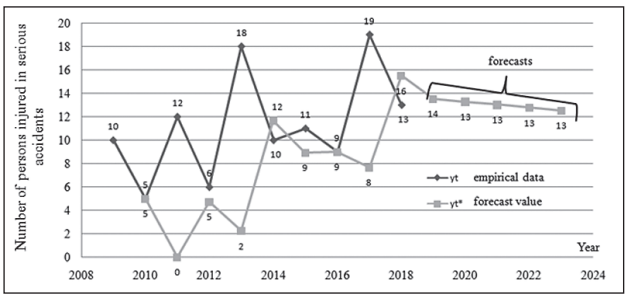

Figure 1 Holt's model for the number of persons injured in serious accidents in the metallurgical industry in Poland (α = 0,68; β = 0,18; ψ = 35,9 %) [own research]

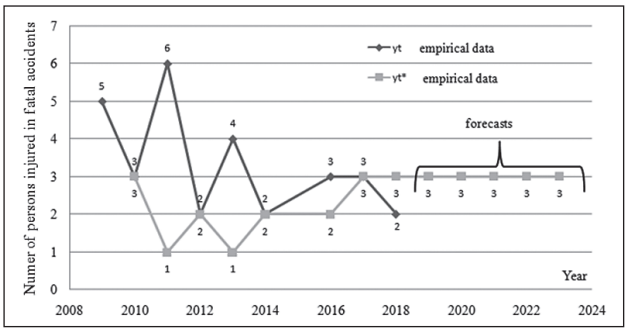

Figure 2 Holt's model for the number of persons injured in fatal accidents in the metallurgical industry in Poland (α = 0,3; β = 1; ψ = 32 %) [own research]

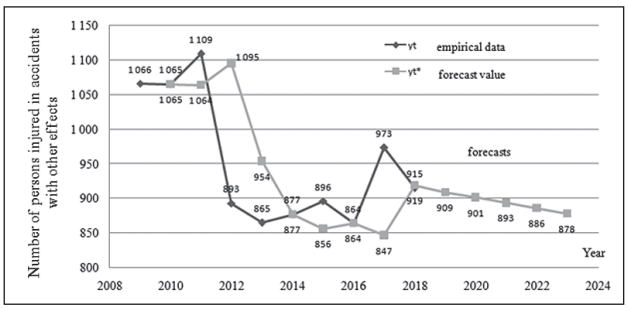

Figure 3 Holt's model for the number of persons injured in accidents with other effects in the metallurgical industry in Poland (α = 0,63; β = 0,13; ψ = 6,1 %) [own research]

These events generate significant absenteeism in the workplace in the steel sector in Poland.

In the period of 2010-2018 under analysis, no fatal accidents were registered in 2015, so that year was not included in the analysis. The analysis of the forecasts reveals that the number of fatal accidents in the projection period of 2019-2023 will remain stable (3 occupational accidents) – Figure 2. Further, 3 fatal accidents are recorded for the years 2019-2023 on the basis of the forecasting process carried out using Holt's model, The optimal values of the smoothing parameters with error minimization (Ψ = 32 %) were α = 0,3 and β = 1. This forecast is not positive and should encourage enterprises to take further steps to reduce occupational accidents, in particular fatal accidents.

The most common events in the metallurgical industry are accidents with other effects (Figure 3). On the basis of the analysis of the obtained forecasts it is found that the number of such events in the years 2019-2023 follows a downward trend – 909 events in 2019, whereas in 2023 – 878 events, i.e. a decline of 3,4 %. The forecast values for 2019-2023 were obtained with the values of the smoothing parameters equal to α = 0,63 and β = 0,13. The mean error of expired forecasts was minimized – Ψ = 0,061 (Ψ = 6,1 %).

CONCLUSIONS

The use of Holt's model in forecasting occupational accidents in the steel sector allows for the identification of trends in the accident rate in the industry in the metallurgical industry in Poland. On the basis of the analyses of the obtained forecasts it was found that:

– the number of persons injured in accidents at work in the metallurgical industry in Poland shows a decreasing trend – it falls by 5,3 % in 2023 as compared with 2018;
– an increasing trend is recorded for the number of serious accidents in 2019, while for 2020-2023, 13 serious accidents are forecast;
– it is recorded that the number of serious accidents for the projected period remains unchanged (3 serious accidents), which is a negative forecast from the point of view of occupational safety;
– due to the high "Ψ" values, the forecasts were used only in the analysis of the trend of changes (serious, fatal and other effects accidents).
– a downward trend in accidents with other effects is recorded – a decline of 4 % as compared to 2018.

Prognostic models can be used to monitor the effectiveness of implemented preventive solutions. The solution proposed in the study can be used by steel enterprises in other countries to assess accident rates and for comparisons with Poland.

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Note: M. Gorgol is responsible for English language, Katowice, Poland