

An assessment of the relationship between the level of occupational health and safety and the economic effects achieved on a given position

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Abstract: This paper aims at evaluating the relationship existing between the level of health and safety of selected types of working position with their economic value. Ten stationary positions in different branches of economics were studied. Estimated costs associated with the work of man, estimated the risk of environmental hazards and determined the effectiveness of the use of the test job. For all the analyzed work positions, the changes introduced in the area of health and safety led to a simultaneous increase in productivity and a decrease in labour cost. It was also revealed that a strong link exists between the OEE index and the level of occupational risks. The research showed that the level of occupational health and safety and the economic value of a given work are strongly connected. Successive waves of modifications ultimately triggered an increase in the OEE, up to a level much higher than that registered before their introduction, as well as a reduction of the labor cost.

Keywords: health and safety, labor costs, the risk of threats, OEE, modifications job

JEL codes: I5, J8, Q1

1. Introduction

It is widely acknowledged that many factors, be they technical or organizational, have an influence on productivity and quality of products. Taylor's groundbreaking research made it clear that a properly organized workplace and a proper working technique make it possible to boost

productivity (Martyniak, 2002: 5-16; Korulczyk, 2011: 218-225). Deming's (cited in Nieścior, 2000; 1: 27-30) theory on the global governance can be considered as yet another incentive for increasing the quality of products and services. A systemic management was also applied in the area of occupational health and safety. Events such as accidents and work-related diseases came to be seen as business losses, having a negative influence on productivity (Bank, 1997; Cardona and Rey'a, 2009). The vast majority of economic analyses of the impact of health and security levels at work on productivity focuses on the macroeconomic level, or takes into account whole companies or their specific departments (Jasiak and Misztal, 2005; Kowal, 2002; Pacholski, 2004:195-206; Pacholski, 2003: 43-54; Rzepecki, 2007: 3–5). However, analyses concentrating on a particular position are extremely rare (Kowal at al. 2008: 17-26; Rybarczyk and Kowal, 1999: 63-71; Lis, 2007: 151-160). The most popular hypothesis considers that management and participation have the greatest impact on productivity, followed by the typical tasks required for a given position, motivation and the work atmosphere. The list also mentions factors such as workplace ergonomics, work organization and maintenance of order. According to this hypothesis, factors related to work environment - such as lighting, temperature, noise, etc. - have the lowest impact on productivity (Finnish Ministry of Social Affairs and Health and ILO, Febr. 2002). This idea is commonly accepted. Due to this kind of reasoning, employers focus mainly on actions, whose effects can be seen more quickly. Measures changing the work environment seem ineffective and do not guarantee a significant increase in productivity. However, in the hierarchy of actions related to occupational health and safety, priority must be given to the prevention of adverse effects of factors arising from the work environment. As a principle, changes introduced in the area of occupational health and safety must always eliminate first the most significant risk, no matter how important are its anticipated economic effects. Nonetheless, the question arises what is the real influence of corrective measures taken in the area of health and safety at work on productivity (Rybarczyk and Suska, 2004). Do they cause a decrease or rather an increase in productivity? Is there any clear correlation between the reduction of the level of risk and productivity? Any attempt of assessment of health and safety procedures' impact on productivity is problematic, as there is never absolutely no health and safety actions at the initial analyzed moment. Usually, the initial level corresponds to the minimum health and safety procedures required by law. Therefore, the analysis starts at the point when employers do not

expect any positive impact of further changes in the area of health and safety procedures on productivity.

2. Objectives of the analysis

The aim of this paper was to evaluate how corrective measures concerning labour safety and hygiene affect productivity of a work stand, especially how the costs of maintenance of a work stand change as well as the value of Overall Equipment Effectiveness (OEE). Introduction of subsequent technological and organizational changes aimed at lowering the level of professional risk at a working stand.

3. Analyzed material and methods of assessment

The research was done in the period 2005 - 2013 at various medium size enterprises doing business in the Słupsk region (Poland) in the towns of: Słupsk, Ustka, Lębork, Bytów, Miastko. The research included 10 stationary work stands of different branches. The studied positions included: an eccentric press machine operator, a fish gutting position, a fish packing position, a cabbage cleaning position, a strawberry sorting position, an injection press operator, a band-saw operator, a tenoner operator, a pallet nailing position and a pellet fuel packing position.

The main criterion which justified this selection focused on the occurrence of an injury or a disease directly linked to the work performed in a given position. The occurrence of an accident or a disease was a clear signal that working conditions existing for a specific job were not optimal and needed improvement. Another selection criterion took into consideration the fact that the work consists mainly in performing repetitive operations, during which a certain number of harmful or dangerous risk factors occurred, putting into danger employees' life or health. Throughout the evaluation of the selected positions, they were occupied by the same person or a person with similar qualifications, work experience, age, gender and anthropometric characteristics.

The deadline of implementation of the research and the time frame of the research resulted from possibilities provided by the employer and was determined by the moment of implementation of technological and organizational changes at particular work stands. The

research was held in real conditions of working establishments and had no experimental character under simulated laboratory conditions.

In order to evaluate the connection between the level of health and security at work and the economic value of the same work, the human labour cost, as well as the level of environment hazards occurring at the workstation and the efficient use of a given position were determined and assessed.

The costs resulting from human work at the workplace include: remuneration for work (Cs), the cost of monitoring of health and safety procedures (Cbhp), the cost of the collective protection means' maintenance (Cśoz), the cost of equipping employees with personal protective equipment (Cśoi), the cost of preventive medical examinations (Cbl) and the cost of the OHS training (Csbhp) (Smoliński, 2013; Smoliński and Solecki, 2015: 25-27; Smoliński and Solecki, 2016: 8-12). Occupational risks related to work environment factors and occurring at the workplace were measured on a 5-point scale (PN-N-18002:2011), while the efficient use of a given position was determined using the OEE index (Brzeziński, 2003; Hansen, 2001; Productivity Press Development Team. ProdPress.com. 2009). Following the analysis of occupational risks, several modifications, consisting in new measures (allowing to improve the working conditions), were introduced to the selected positions. These modifications did not interfere with the technology used at the workplace, focusing instead on the way tasks were performed. They also required the introduction and progressive use of several new collective and individual protection means, as well as new working devices (with respect to their ergonomic adaptation to the needs of employees). Every modification was carried out independently. Each modification of the workplace gave rise to a new assessment of costs related to work, of occupational risks and to a measurement of the efficient use of work (the OEE index).

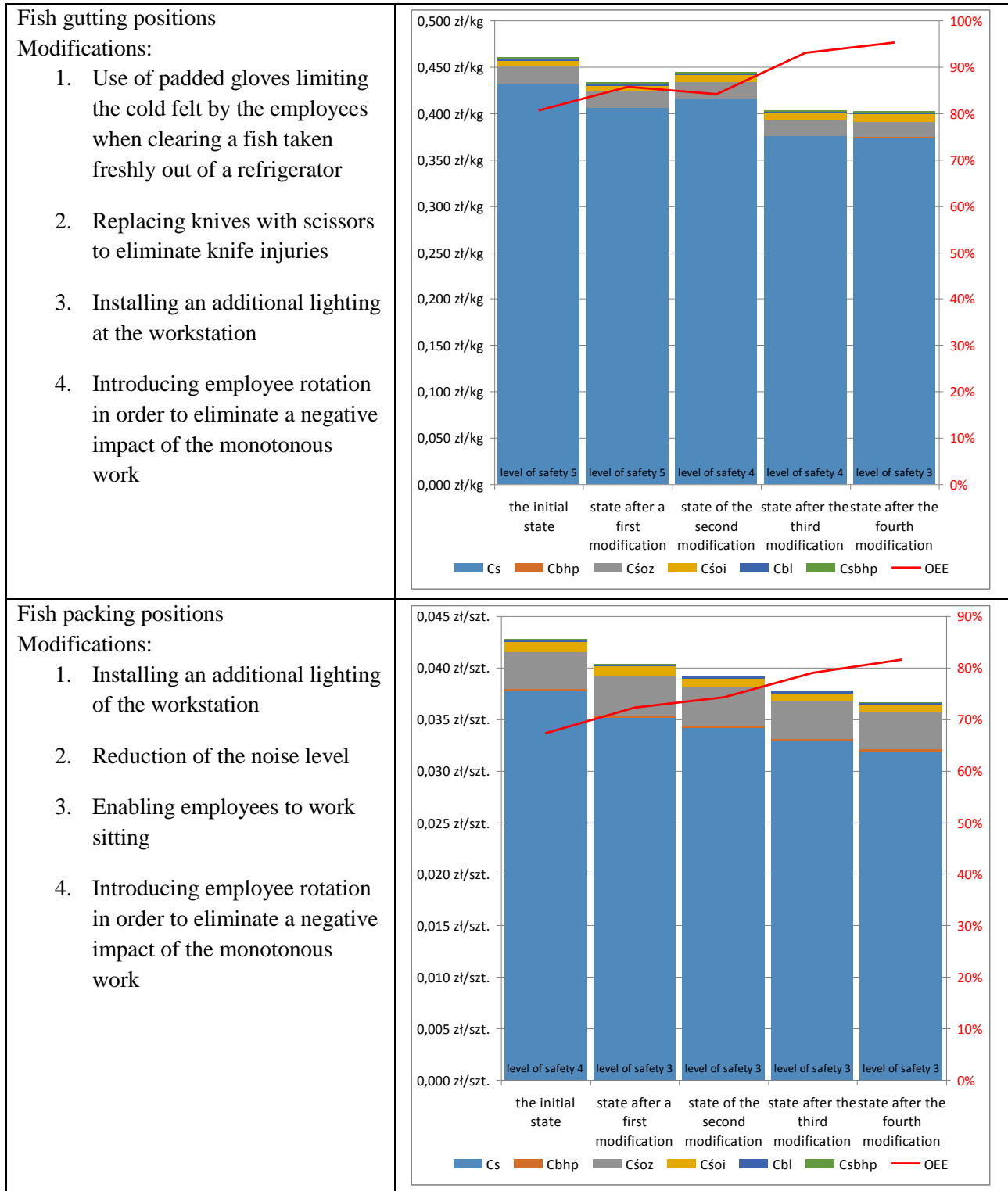
4. Results of the study

The results concerning labour costs and productivity (the OEE index) depending on the level of occupational risks and on the successive changes to health and safety procedures for ten selected positions are all presented in the table chart No. 1.

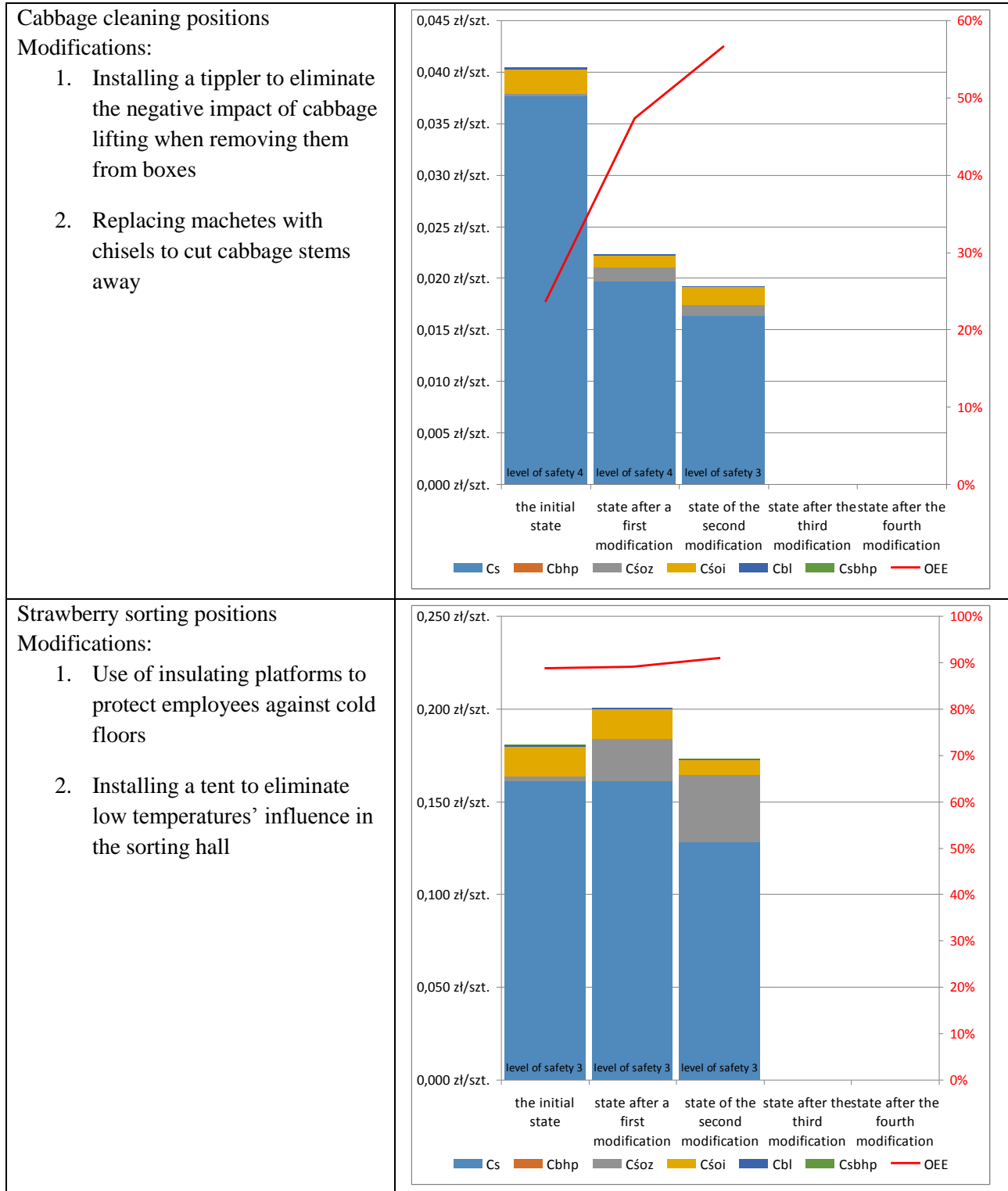
With regard to the eccentric press machine, the first modification, consisting in installing a light curtain to eliminate access to the dangerous zone of the die's work, had no impact on the

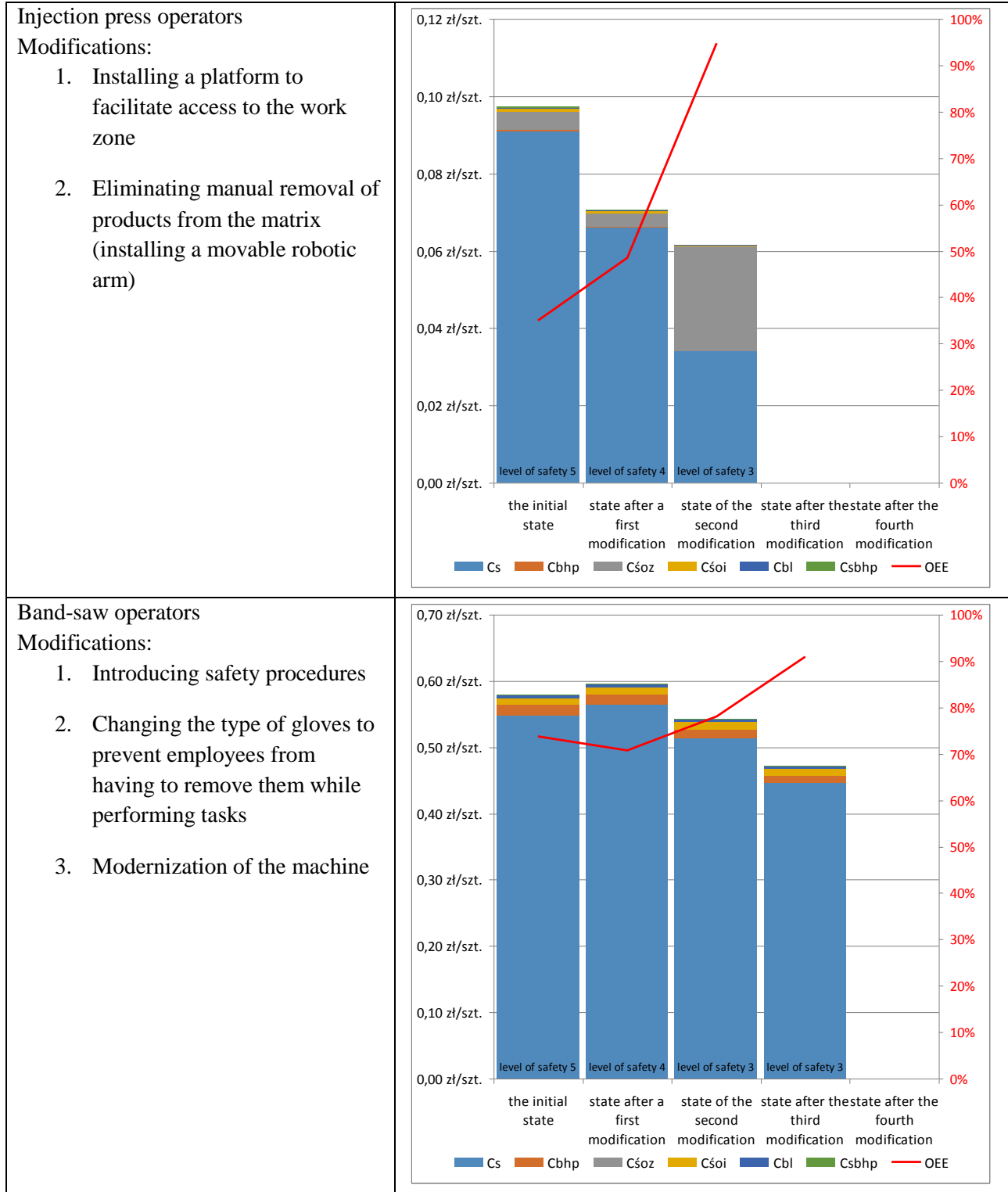
Table 1. Changes in the labour costs and productivity resulting from the modifications introduced in the area of occupational health and safety

Modifications introduced in the area of occupational health and safety	Changes in the labour costs and productivity resulting from the modifications introduced in the area of occupational health and safety
<p>Eccentric press machine operator</p> <p>Modifications :</p> <ol style="list-style-type: none"> 1. Installing a light curtain to eliminate access to the dangerous zone of the dies' work. 2. Renovation of the press aiming at eliminating the risks associated with unforeseen emergencies. 3. Installing an additional lighting of the matrix. 4. Use of boxes with movable bottom to prevent the operator from having to bend down when removing and inserting processed elements. 	<p>The chart displays the following data series:</p> <ul style="list-style-type: none"> Cs (blue): Base labour cost, decreasing from ~0.44 to ~0.33 zł/szt. Cbhp (orange): Additional labour cost, increasing from ~0.01 to ~0.02 zł/szt. Csoz (grey): Safety-related cost, increasing from ~0.05 to ~0.08 zł/szt. Csoi (yellow): Safety-related cost, increasing from ~0.01 to ~0.02 zł/szt. Cbl (dark blue): Safety-related cost, increasing from ~0.01 to ~0.02 zł/szt. Csbhp (green): Safety-related cost, increasing from ~0.01 to ~0.02 zł/szt. OEE (red line): Overall productivity, increasing from ~58% to ~92%. <p>Labels under the bars indicate safety levels: level of safety 5, level of safety 4, level of safety 4, level of safety 3, level of safety 3.</p>

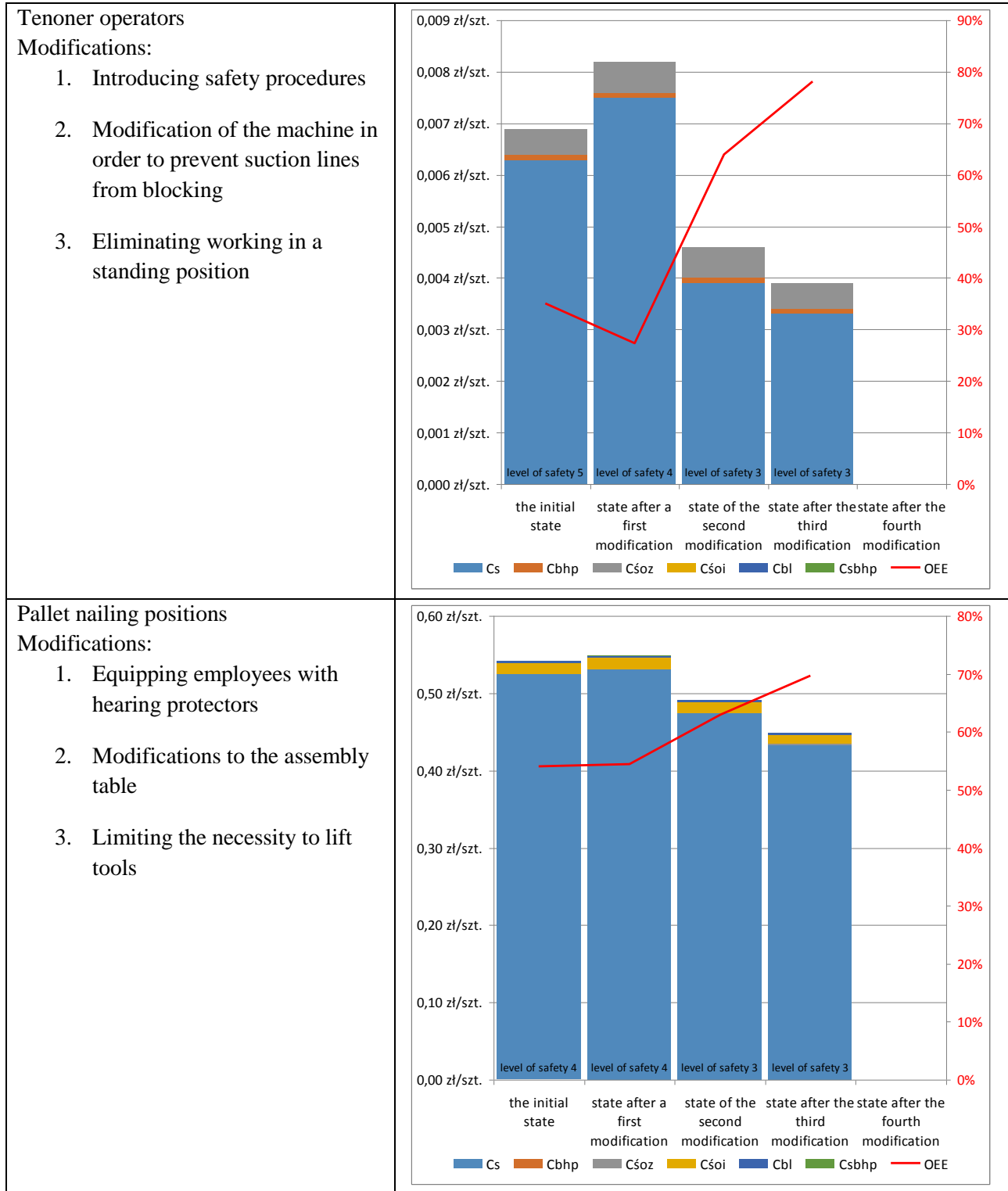


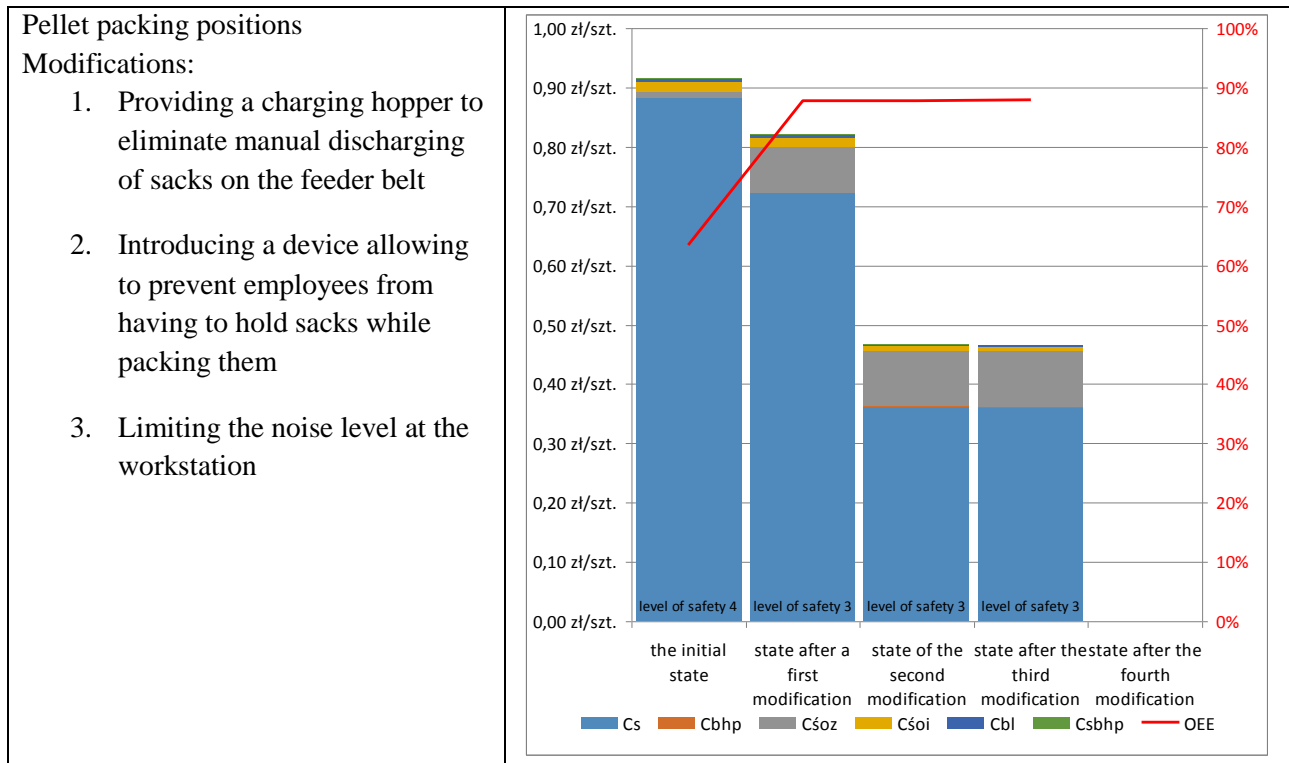
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Source: own research (Smoliński D, 2013)

OEE index' value. It was the next three modifications, namely the renovation of the press machine, the installation of an additional lighting of the press and the replacement of boxes, that has provoked a dramatic increase in the OEE value, peaking after the fourth modification (90%; an increase of 30%). Furthermore, the level of occupational risk dropped from the initial level 5 (the initial state) to level 3 (following the fourth modification). Calculating the labor costs (Cs) also revealed a significant drop (decreasing from 0.45 zł / pcs. to 0.35 zł / pcs.).

Concerning the fish gutting work, four changes were made, too. The first modification (introduction of padded gloves) and the second modification (replacing knives with scissors) slightly increased the value of the OEE index (5% increase), accompanied by a minor reduction in labour costs. The level of occupational risk decreased by 1 point (dropping to level 4) only after the second modification. Subsequent changes (additional lighting, and the introduction of the employee rotation) resulted in an increase in the OEE index (15% increase), while reducing the labour costs (to 0.37 zł / pcs.). Following modifications allowed to further decrease the level of risk by only one level (from the initial level 4 to level 3).

As regards the fish packing position, four modifications were made (additional lighting, noise reduction, possibility to work in a sitting position and the introduction of the employee rotation) and provoked a reduction in the level of risk merely by 1 point, dropping from the initial level 4, to the final level 3 (after the first modification). The OEE index increased by 15%, while the labour costs dropped to 0.032 zł / pcs.

Regarding the cabbage cleaning position, the level of occupational risk was situated at level 4 in the beginning of the evaluation. Only two modifications were made to improve working conditions: the use of tippers eliminating some of the negative effects of working conditions and the replacement of machetes with chisels. This allowed to reduce the level of risk from the initial level 4 to level 3 (after the second modification). A significant increase in the OEE index was registered (over 30%) and a considerable decrease in the labour costs (a two-fold decrease, down to 0,017 zł / pcs.).

The next studied position (strawberry sorting) also required two modifications: the introduction of insulating platforms and that of a tent. These changes had no effect on the level of occupational risk (level 3). The OEE index did not change either (stable at about 90%), however the labour costs decreased (down to 0,125 zł / pcs.).

In the case of the injection press position two modifications were applied (the introduction of a platform and that of a movable robotic arm), which lowered the level of risk (from the initial value of 5 down to 3), and significantly increased the OEE (by 60% - reaching 95% at the end of the evaluation), while substantially reducing the labour costs (a 3-fold decrease, down to 0.03 zł / pcs.).

On the position of a band-saw operator three modifications were introduced: introduction of safety procedures, replacement of gloves and modernization of the device. Only after the second and the third modifications were made, positive effects were observed. The level of risk decreased from 5 to 3. The OEE index peaked at 90% (a 20% increase), while the labour costs declined to 0,45 zł / pcs.

As regards the tenoner operator's position, three modifications were applied (introducing safety procedures, adjusting the device and eliminating work in a standing position). The third modification triggered a decrease in the level of risk, which dropped from 5 to 3. Meanwhile, the OEE index increased considerably (by 45%, up to 80%) and the labour costs decreased twofold (from the initial value: 0.0065 down to 0, 0035 zł / pcs.).

Concerning the pallet nailing position, three modifications were applied, too (equipping employees with hearing protectors, altering the assembly table and avoiding lifting tools by workers), leading to a minor reduction of the level of risk (from 4 to 3). The OEE index increased by 15% (and was at its height at 70%), while the labour costs decreased down to 0.45 zł / pcs.

The tenth studied position (pellet fuel packing) called for three modifications: providing a charging hopper, eliminating manual holding of the bag and noise reduction; this resulted in a small reduction of the level of risk (from 4 to 3). Meanwhile, the OEE index rose by about 25% following the first modification, and stayed at that level till the end (peak at 90%). The labour costs significantly dropped from the initial value of 0,90 zł / pcs. to 0.35 zł / pcs.

5. Analysis of the results

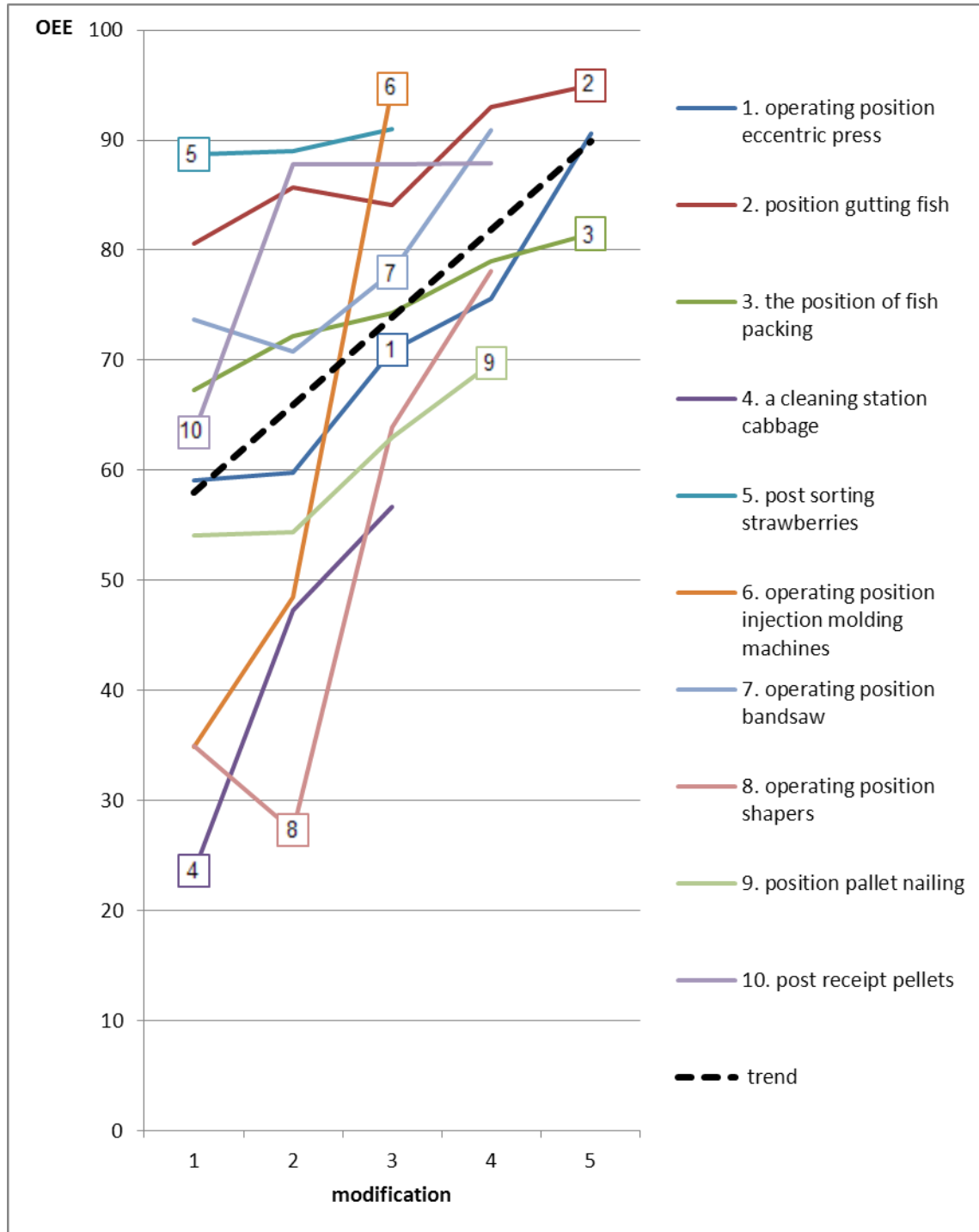
The study showed that the introduction of successive modifications in the area of occupational health and safety, eventually allows to improve economic indicators. For all the studied positions, the modifications of health and safety procedures gave rise to a significant increase in the efficiency index as well as to a decrease in the labour costs. In many cases, changes regarding the rise in efficiency index and the reduction of the labour costs were noticeably significant. One might put forward as an example the results obtained for the tenoner operator's position, for which an increase of nearly 40% was registered for the OEE index, while the social cost of labour dropped by over 40%.

The positive effect of implemented corrective measures in the area of occupational health and safety can be observed on Figure 1. The OEE index tends to rise for all examined positions as a result of successive modifications introduced in workplaces. It was also pointed out that a strong correlation exists between the OEE index and the level of occupational hazard (as the level of risk lowers, the OEE index increases) (Figure 2).

Nevertheless, a case of a decline of the efficiency index, accompanied by a rise of the labour cost, was also revealed (e.g. after the first modernization of the band-saw), which, from the economic point of view, was highly disadvantageous. A simultaneous increase in efficiency and in the cost of labour was also observed (e.g. after the first modifications of the press operator's work), as well as a case, in which a drop in labour costs without an increase in work efficiency was noted (after the second modification of the pellets packing position) (Table chart

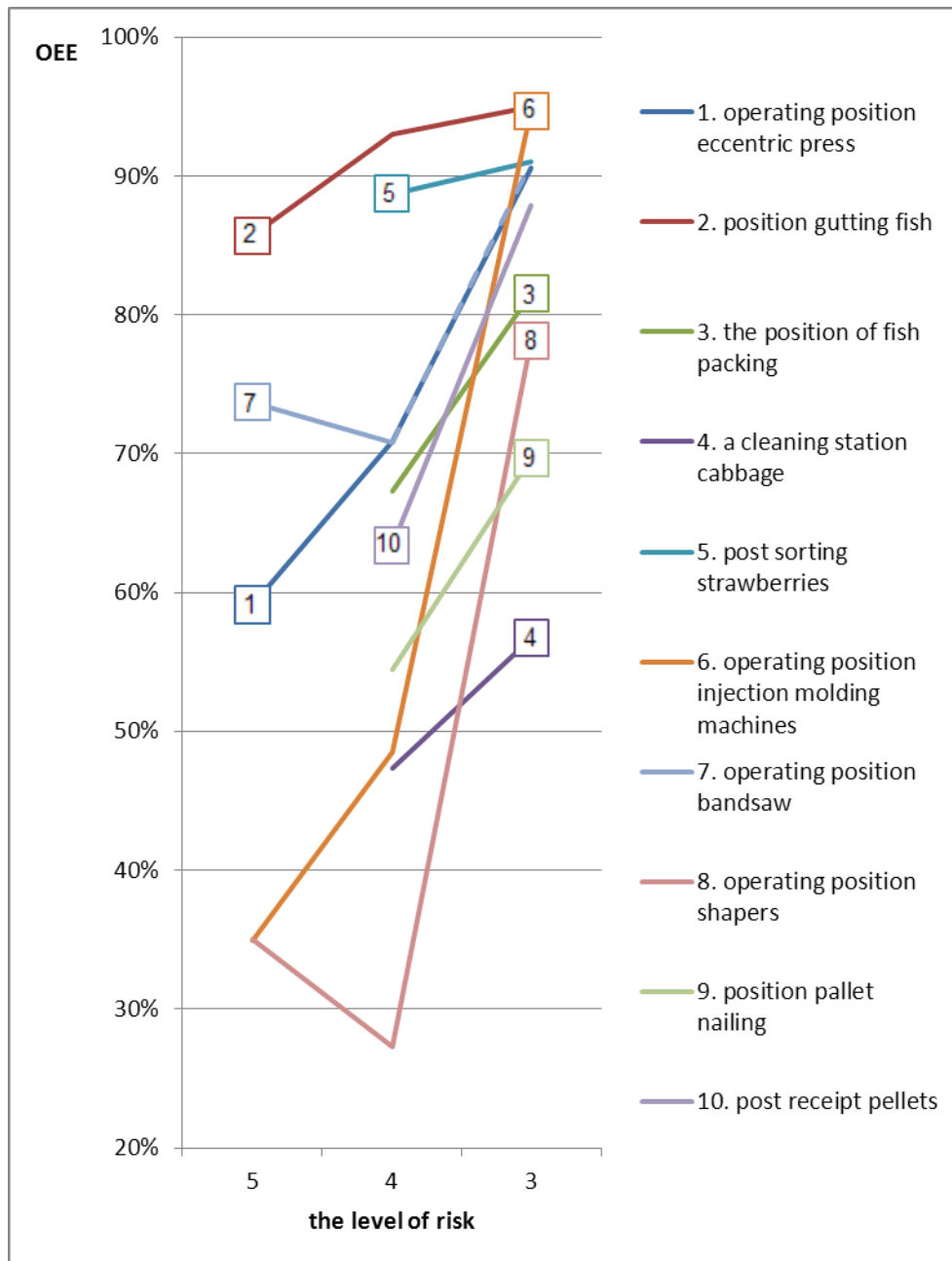
1).

Figure 1. Changes of the OEE, resulting from successive waves of modifications made at workplaces



Source: own research (Smoliński D, 2013)

Figure 2. Changes of the OEE index, depending on the level of risk.



Source: own research (Smoliński D, 2013)

The analysis of cases, in which an increase in the social cost of labour and a reduction of the efficiency indicator were noticed, shows that usually after the implementation of the first corrective health and safety measure economic indicators tend to deteriorate. Such results were noted in positions of a press operator, strawberry sorting, band-saw operator, tenoner operator, and pallet nailing. One might call it the "first modification rule," deprived of positive economic effects. In many cases, the introduction of the first modification arose from the desire to quickly eliminate existing hazards (in particular in situations when the change was provoked by an accident at workstation) through the use of the simplest solutions possible. Consequently, in the case of tenoner and band-saw operators, extremely simple organizational solutions were applied, completely discarding the possibility of tackling the problem through technical solutions. A similar situation occurred as regards strawberry sorting work, where technical changes were introduced only partially.

However, an increase in labour costs is not always provoked by an in application of optimal solutions. The press operator's position can be quoted as an example to this point. The corrective measure, consisting in installing a light curtain, was carefully thought-out. And yet, this advancement resulted in a significant increase in the cost of labour. A similar situation occurred after the first modification carried out for the pallet nailing position, where equipping employees with hearing protectors was followed by higher labour costs. All of these examples clearly show that efforts made to improve safety may bring about negative effects, reducing work efficiency and increasing significantly social cost of labour. The only economic result is a more feeble probability of the occurrence of an accident or a disease linked to the working conditions, and thus the likelihood of having to pay compensations because of a prejudice to the employee's physical health, or having to cover the expenses related to non-working machinery, i.e. factors which were not considered in the study.

Changes in the efficiency recorded for a given position (the OEE index) are directly reflected by the wage component (Cs) (Table chart 1). As a rule, whenever the OEE index rises, the wage component falls. At the same time health and safety modifications alter the costs of the maintenance of collective protection measures (C_{soz}), as well as the maintenance of personal protective equipment (C_{soi}). Depending on a case studied, either positive changes, that is to say a cost reduction, or negative changes such an increase of the same costs, may be observed. The phenomenon of a significant increase in costs related to the maintenance of collective protection

measures have been observed with regard to strawberry sorting, injection press operating and pellets packing positions. It should be noted that in all of the above cases the increase in costs devoted to the maintenance of collective protection measures was eventually neutralized by a reduction in the wage component (Cs), which, in turn, brought about a positive economic effect linked to the reduction of labour costs. However, with reference to the personal protection equipment, the correlation did not exist in all cases. Specific modifications produced changes in the cost of health and safety procedures monitoring (Cbhp), of preventive medical examinations (Cbl) and of OSH trainings (Csbhp). However, these changes were negligible, almost imperceptible.

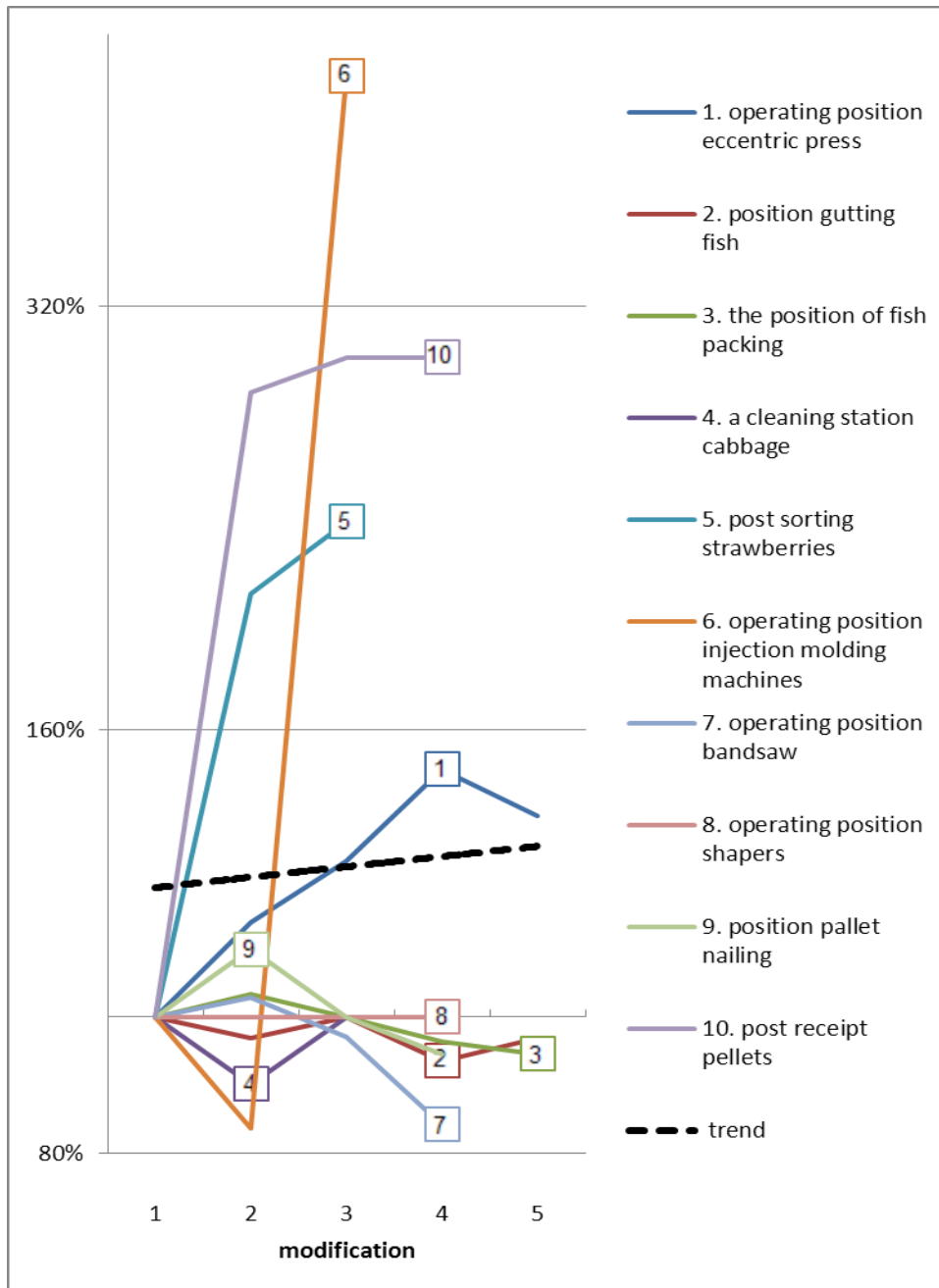
The factor, which significantly improved work efficiency, was a decreasing need for all sorts of breaks at a workstation, in particular interruptions resulting from emergency situations (e.g. second shift workers handling the injection press, second shift workers operating the tenoner). These cases show that the risk of an accident occurring arises very often in emergency situations, when an employee breaks the normal course of work and starts working in an unusual way.

The modernization carried out through introducing ergonomic measures at workstations also brought about a significant improvement in economic indicators (Table chart 1). One may quote as examples the fourth modification of the press operator's work (preventing the operator from having to bend down), the first modification of the cabbage cleaning position (introduction of a tippler) and the third modification of the pallets nailing position (preventing workers from lifting devices). Improving working conditions due to such modifications helped to increase efficiency, and thus to significantly lower the wage component. By the same token, other modifications in the area of ergonomics consisting in providing a seat during the third modification of the fish packing position and the third modification of the tenoner operator's position and the installation of a platform during the first modification of the injection press operator's position, of a mounting system for bags during the second modification of the pellets packing position, and of a nailer support system during the third modification of the pallet nailing position, showed that expenditure on these upgrades has positive economic effects. Thus, from the economic point of view, the ergonomic modernizations of workstations produced excellent results.

In the same way, replacement of human labour allowed to achieve similar results. One

can quote as an example the first modification of the pellets packing position or the second modification of the injection press operator's position. In both cases there was an interference in the work process amounting to replacing employees by a machine in performing some tasks. Such actions, directly related to the mechanization of the work process, go slightly beyond the typical changes introduced in the area of occupational health and safety. It should be noted, though, that the above examples suggest that an improvement of the level of safety is not necessarily achieved through measures strictly related to the occupational safety. Gear replacement and mechanization of work are generally aimed at reducing the cost of work performed by man, including in the context of reducing the level of safety (of risk). Such changes lead to a significant drop in the wage component of labour costs. At the same time the cost of preventive measures, above all related to the maintenance of equipment, which replaced the work of man, increases. The rise in the preventive actions' cost was not higher than the decline in the wage component, which, in turn, had a positive effect of reducing labour costs (Figure 3). At the same time, the OEE increased in both cases.

Figure 3. Changes of the preventive measures' cost (Cr), resulting from successive waves of modifications made at workplaces



Source: own research (Smoliński D, 2013)

The modifications consisting in replacing tools had mixed results. Replacing knives with scissors, during the second modification of the fish gutting position, caused a regression of economic indicators. In this case expenses which were incurred by the company were not compensated. A completely different situation occurred in the case of the cabbage cleaning work,

where the machetes were replaced with chisels. This modification brought about a significant increase in the OEE index and a decrease in the labour costs (Table chart 1).

Another type of modification in the area of occupational health and safety required the company to take measures to meet the work environment standards. One can quote as an example the improvement of lighting at the workstation (the third modification of the press operator's work, the third one of the fish gutting position, and the first one of the fish packing position); of microclimate (the first and the second modification (combined) of the strawberry sorting position); noise reduction (the second modification of the fish packing position, the third of the pellets packing position). Those efforts to improve lighting produced small positive changes as regards the economic indicators. A similar situation occurred in the case of changes of the microclimate. Modifications involving the reduction of the noise level at workstations yielded mixed results, whereas changes concerning the fish packing position had a clear-cut positive economic impact. In contrast, noise reduction for the pellets packing job practically did not bring any changes in the economic indicators.

Introducing the employee rotation for specific jobs, in order to reduce work monotony, that applied to the fish gutting and packing positions, produced positive economic results, in particular by boosting the OEE index.

The last type of modification in the area of occupational health and safety relied on the introduction of personal protective equipment. These changes - typical for actions undertaken in the area of safety at work - occurred as a result of the first modification introduced on the fish gutting position, the second modification on the band-saw operator's position, the first modification on the pallet nailing position. The last of these modifications had adverse economic effects, as the OEE index did not evolve, while the labour costs increased. A completely different situation occurred in the case of protective gloves, whose introduction provoked a positive evolution of economic indicators. This means that the introduction of personal protective equipment does not in itself suffice to improve the economic results of a given position. This applies in particular to situations when personal means of protection (as was the case with hearing protectors) plays merely a protective role. In the case of PPE, which - in addition to their protective properties - have a utility value as well, making it possible to perform a work or facilitating it (as was the case with gloves), it can be reasonably expected that this modification bring a positive final economic effect.

The study shows that the best results can be obtained through changes, introduced in the area of occupational health and safety, which are closely linked with the elements of process management at the workplace. Observations of the selected positions allow to state that a low level of the OEE index is considerably related to inadequate working conditions. Workers were required to perform a series of unnecessary tasks or their work was slowed down by inadequate devices at their disposal. However, these problems were not taken into consideration by the company management, who focused entirely on "strict technological issues". Neglecting the human aspect in the work process, an inadequate organization of work and lack of satisfactory devices were largely due to a generalized indifference to such problems.

6. Conclusion

1. The study clearly showed that there is a significant relationship between the level of health and safety at the workplace and the economic results obtained on the same work position.
2. The indicators used to evaluate the cost of labour (the wage component and the cost of preventive measures) and the efficient use of a position allowed to determine the economic changes occurring on a given work position, and resulting from the modification of health and safety procedures.
3. Improving conditions in the area of occupational health and safety has a positive influence on economic performance of a given work position. In most cases, a decrease in the level of occupational risk leads to an increase in the OEE.
4. Introducing successive modifications ultimately brought about an increase in the OEE, up to a level much higher than the initial one, as well as a decrease in the cost of labour.

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***Ocena relacji zachodzących między poziomem bezpieczeństwa i higieny pracy
a ekonomicznymi walorami stanowiska pracy***

Streszczenie

Celem pracy była ocena relacji zachodzących między poziomem bezpieczeństwa i higieny pracy na wybranych stanowiskach pracy a ekonomicznymi walorami pracy. Badaniami objęto 10 stacjonarnych stanowisk pracy wybranych z różnych branż. Dla zbadania relacji zachodzących między poziomem bezpieczeństwa i higieny pracy na stanowisku pracy a ekonomicznymi walorami pracy, przeprowadzono ocenę kosztów związanych z pracą człowieka, szacowano ryzyko zagrożeń środowiskowych oraz określano efektywność wykorzystania badanego stanowiska pracy. Na wszystkich badanych stanowiskach roboczych, końcowym efektem wprowadzania zmian w obszarze bhp było podwyższenie wskaźnika efektywności i obniżenie kosztów pracy. Stwierdzono także występowanie istotnego powiązania wskaźnika OEE z poziomem ryzyka zawodowego. Istotną poprawę wskaźników ekonomicznych przyniosły także modernizacje wprowadzające ergonomiczne rozwiązania na stanowiskach pracy. Badania wykazały, że istnieje istotna zależność między poziomem bezpieczeństwa i higieny pracy na stanowisku pracy a ekonomicznymi walorami stanowiska pracy. Wprowadzanie kolejnych modyfikacji przyniosło w końcowym efekcie wzrost wskaźnika OEE do poziomu znacznie wyższego niż początkowy oraz obniżenie kosztów pracy.

Słowa kluczowe: bhp, koszty pracy, ryzyko zagrożeń, OEE, modyfikacje stanowisk.