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Automatization in road transport: a review

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Abstract
In this article automatization of road transport is investigated. In the first chapter relevant international trends were identified. In this paper the research hypothesis is that in the case of automatized road vehicles there is a significant likelihood of endangering human life. Secondly, the history of road safety is shortly described, especially focusing on vehicle design and sweep of system's theory. In the third chapter evolution of drivers' assistance systems were elaborated, emphasizing especially autonomous vehicles. Finally, in conclusion the authors warn that new technological solutions could pose new threats.

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1. Introduction

In the last couple of years, a decrease has been observed in road traffic fatalities in many European and non-European countries. It is essential to reduce fatal road accidents independently from economic or social status. The status of road safety or its performance is often connected to infrastructure (Peden et al., 2004), as well as a vehicle or road user's behaviour (Török, 2017). More detailed investigaions were carried out in some countries showing a connection between a number of casualties and road safety measures, compulsory seatbelt wearing (Holló et. al., 2010), drunk-driving interventions, speed enforcement, etc. Economic valuation of road safety measures and its methodical analyses established for numerous road injury prevention measures for future application (Elvik et al., 2009).

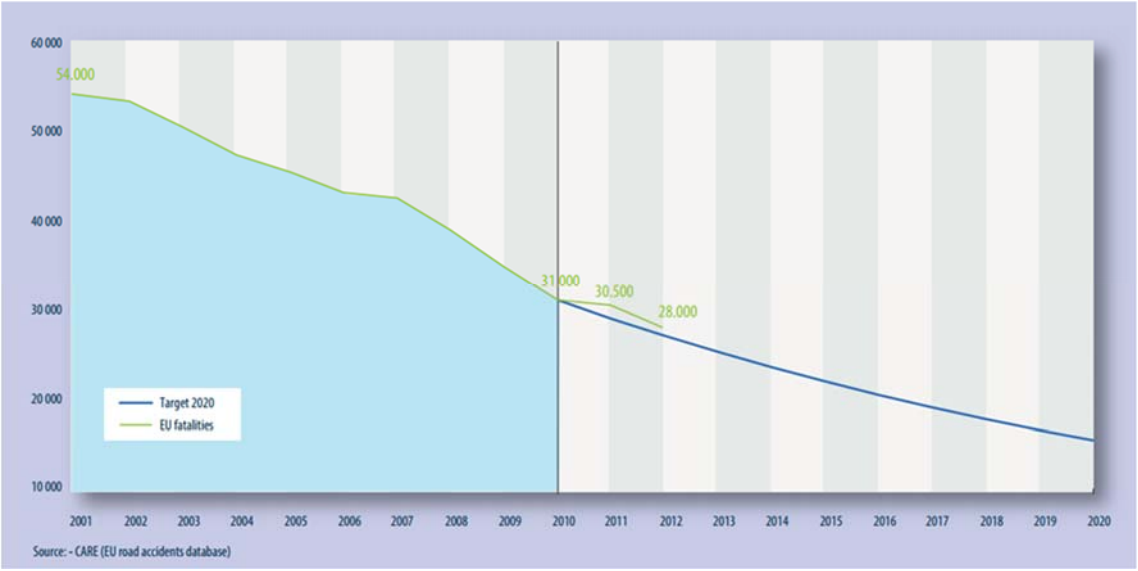

Fig. 1. EU fatalities and targets 2001-2020

Despite the progress achieved, road safety still causes lot of problems. Accidents are still present and cause serious threat to public health. Recent data show that more than 1.2 million people die worldwide per annum as a consequence of injuries resulting from road accidents. In Europe, an ambitious target of reducing the number of road fatalities by 50% until 2020 was set to the basis of status in 2010 (WHO, 2013).

According to recent estimates, there has been an increase in motorisation level since 1970s, meanwhile the number of fatal road accidents in EU decreased by a half. Among the included accident reducing factors, for example, there is the installation of active and passive safety systems (Schulze, Kossmann, 2010).

Moreover, taking into consideration a fast development of electronic devices in vehicles, and intelligent transportation and communication systems, the hypothesis is that additional efforts are needed in order to be able to evaluate the changing market of road vehicles so as to determine the benefits and drawbacks of automatized road vehicles.

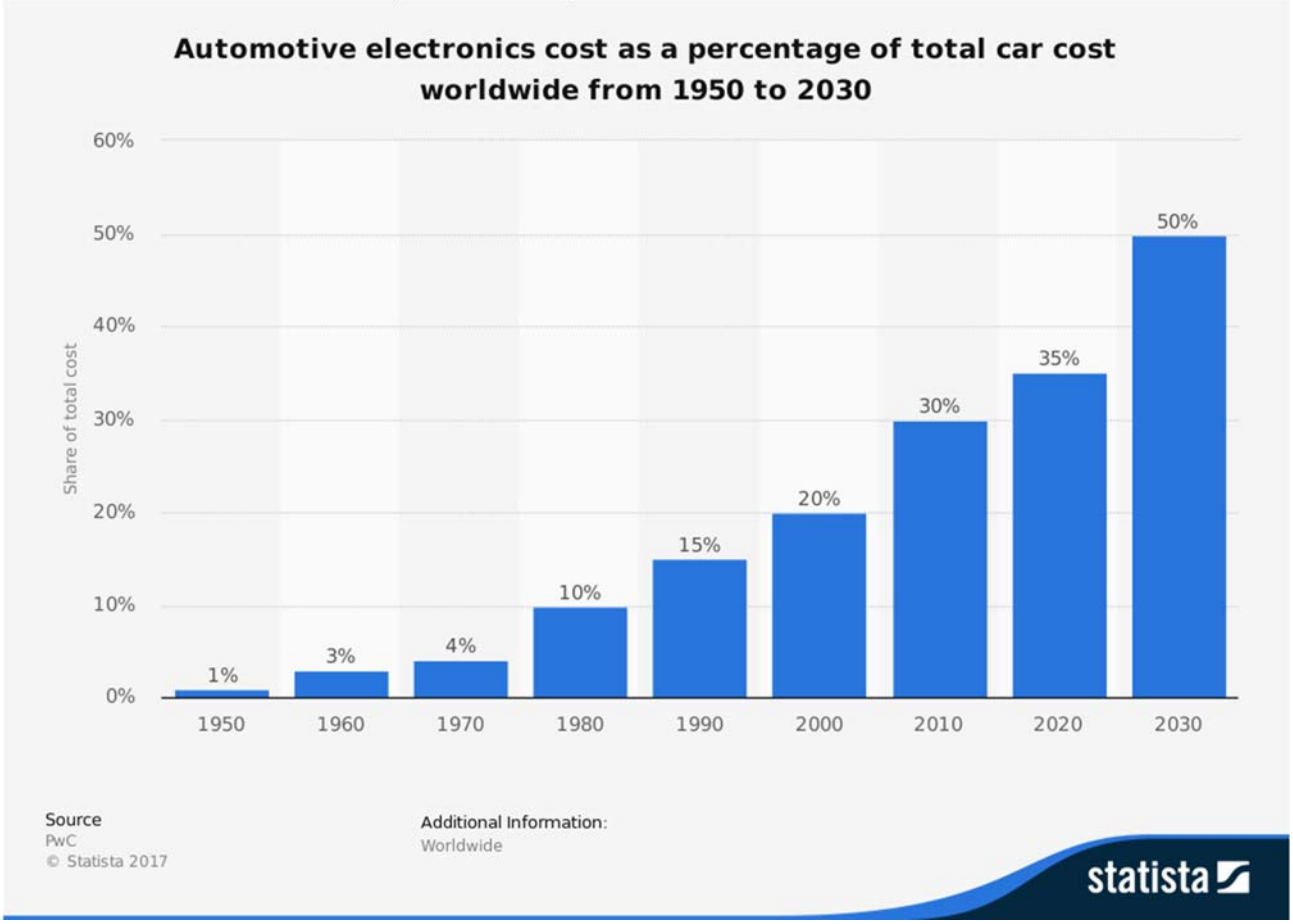

Fig. 2. Automotive electronics cost as a percentage of total car cost

Besides, urgent safety problems in highly populated areas draw more attention to vulnerable road users such as pedestrians and cyclists (Hakkert, Gitelman, 2014; Levulytė et. al., 2016).

2. History of road safety

Road safety research started nearly one hundred years ago. A demand to deal with growing amount of road accidents casualties was recognized. One of the first documented research studies about road accidents was written in 1929. In the last decades, rapid changes have been observed in road transport. Also, the growth (or changes) of population and motorisation, and the expansion of the transport infrastructure were noticed (Farmer, Chambers, 1929; Sipos, 2017).

Furthermore, new trends which influence road safety have occurred, for instance urbanisation and population density, a modal shift from motorised transport to bigger reliance on public transport or an increase in the use of bicycles as well as walking. Fast changes have been noticed in vehicle technologies as well, especially focusing on autonomous vehicles.

Human presence is a factor in more than 90% of road accidents. Importance of an interaction between the road, traffic and vehicle features was highlighted in a the road safety research (Hakkert, Gitelman, 2014).

Before 1960s it was assumed that vehicles on the roads are safe, as they are designed to be safe. Most of accidents that

occurred at that time were drivers' errors. The entire legal system and police investigation are still designed to determine the fault of drivers (Hakkert, Gitelman, 2014).

It has become quite obvious that safe vehicle design and the introduction of safety devices (active and passive systems) cannot be avoided. Automatic safety belt systems, although they had been known since the 1980s, were introduced as compolsory standard equipement much later. The airbag was invented in 1951, but was not considered standard equipment until the last deacde of XX. century to become compulsory standard equipment of todays cars (Somers, Hansen, 1984).

Recently, it has become obvious, that improvements in vehicle safety cannot depend on the automotive industry alone, but that the intervention of the government is also needed, governmental and social pressure is essential. This widely occurs in the US, Japan, Europe and Australia. Road safety research has accompanied vehicle safety legislation. As a result, new standards and automotive legislations have been introduced.

Researchers of road safety and some of the decision-makers started to realize in the 1960s and 1970s, that the monocausal approach was not helpful. In most cases, accidents were not a result of a single cause. Multiple effects and their interconnection lead to accidents. A well-known matrix concept was developed as well by William Haddon, in which an accident is described as a short sequence of events before, during and after the crash, wherein countermeasures can be sought. This can be applied to the human, vehicle and road elements involved in the accident. With this new connection, the idea of a driver's fault has lost its significance (Haddon et al., 1964).

It is recommended to analyse accidents in a multidisciplinary way, taking into account the all the circumstances.

Under these circumstances the government is responsible for providing a safe road transport infrastructure, industry's role is to provide safe vehicles while road users are responsible for their own behaviour. The authorities, as part of the state, could apply enforcement to achieve safe transport to regulate the transportation sector. In the future, it would be possible to substitute most of the enforcement with self-enforcing systems, for instance intelligent and smart solutions (Hakkert, Gitelman, 2014).

3. Driver assistance systems

With the current technology and foreseeable future development, the world will massively switch to automatic individual travel mode. The value and impact of such systems on road safety have became one of the most important research issues (Hakkert, Gitelman, 2014).

In recent years, one of the most important goals in the car manufacturing industry has been to offer passengers the highest level of safety, comfort, and efficiency by partially or completely removing duties related to driving from humans and helping them in controlling their car. Studies have shown that active safety systems (adaptive cruise control, electronic stability control, lane keeping), which are already on standard parts of todays' automobiles, can improve road safety (Magdici, Althoff, 2017).

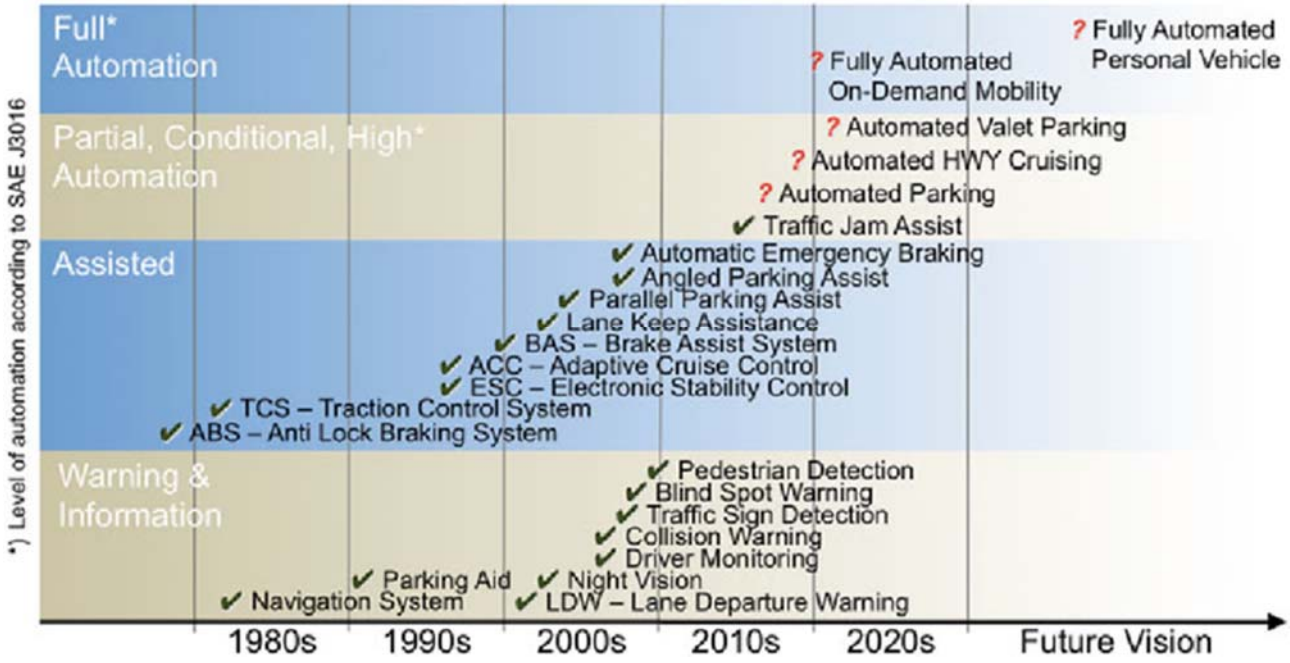

Fig. 3. Timeline for the deployment of advanced driver assistance systems with the vision of fully-automated driving (Beiker, 2016)

The market for advanced driver assistance systems (ADAS) is on the verge of a tipping point, driven largely by requests for improved safety, either via a governmental pressure or the corporate responsibility. Automakers carefully and in a well-planned manner incorporate new technologies and systems that are designed to help drivers

avoid accidents. In most cases, they were first introduced in trucks or heavy goods vehicles, and, later, in premium category passenger cars. Only long time after, it became a serial part of commercial passenger cars. Key components that enable ADAS include, among others, cameras, image processors, system processors, ultrasonic sensors, solid-state lidar, high-end lidar, radar sensors, and infrared sensors.

According to a new report from Tractica, ADAS component will increase in the next decade, rising from 218.1 million units shipped in 2016 to 1.2 billion units by 2025. By that time, the market intelligence firm forecasts that the ADAS component market will have reached $89.3 billion in annual revenue (Tractica, 2016). That will overwrite the market and a shift to more automatization will be noticed. In addition to the technological issues that arise from the introduction of such technologies, there are many ethical and legal issues associated with it. The problems of public acceptance, privacy of the data collected, and legal responsibility of the agency operating such a system have not been solved yet, which can be seen as global challenge.

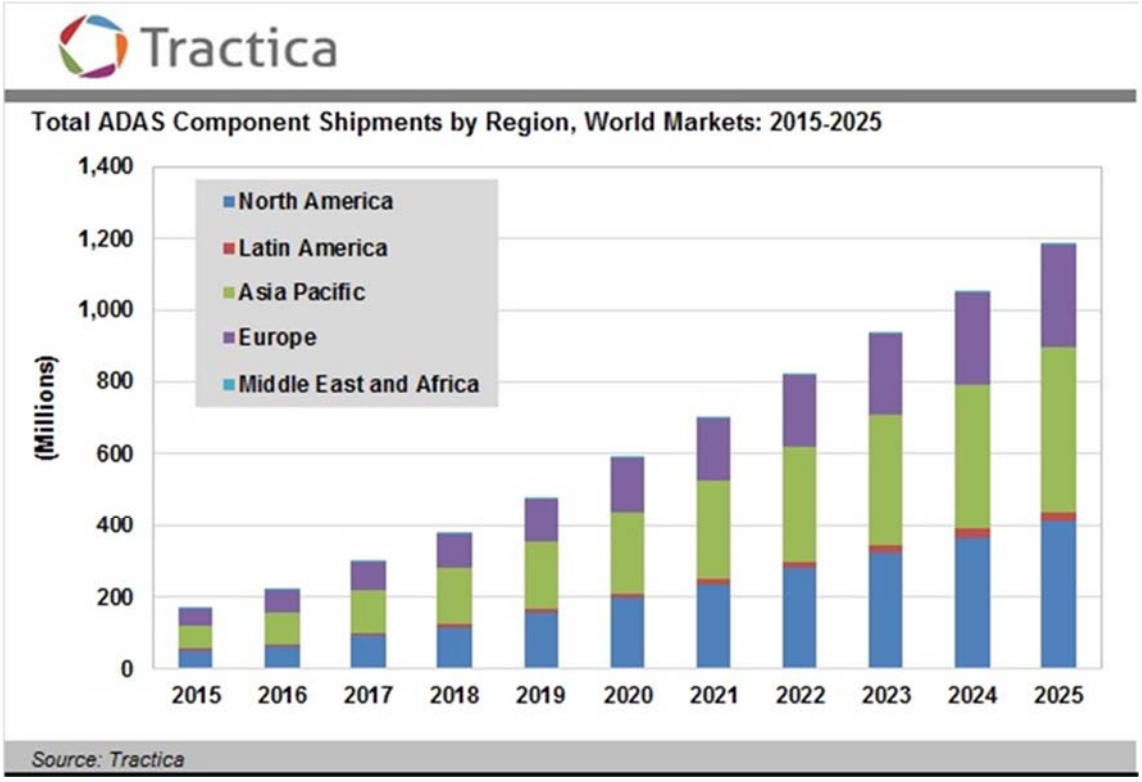

Fig. 4. Total advanced driver assistance systems components shipments prediction

3.1. Autonomous vehicles

Fully autonomous cars without a driver will diminish the risk of accidents, as most of them are the result of a human involvement. Autonomous cars will operate without a human driver, utilising computerised systems to collect information, detect environment and make decisions. Without a human driver, occupants of autonomous cars would become passengers, which could influence the occupancy rate as well and could have effect on modal split.

The concept and practice of autonomous vehicles is not new. It has existed for several decades, an example of it can be a train or metro. It is interesting that the majority of passengers were afraid to use a driverless train or metro. The social acceptance was low, but later people became accustomed to it. However, most of these autonomous shuttles and trains are separated from traffic. Autonomous cars would be used in various situation, and they would interact with other road users, therefore complex interactions and conflicts need to be solved (Hulse et al., 2018).

Driving as a process is very complex. Several cognitive tasks must be performed parallelly, sometimes very quickly in order to ensure the proper vehicular parameters.

Human behaviour is a critical factor in road safety (Holló et. al., 2018). Several forms of road user behaviour have been highlighted recently as increasing the risk of road accidents. Drunk driving, over-speeding, lack of safetybelts and the use of mobile phones while driving. All these elements could influence the reaction time and the time to put a viehicle to a halt (Hulse et al., 2018).

However, to perform the complex task of driving, there must be a mechanism or a computer that supports automatic functions. This need to obey to both the road rules and the social rules (Riaz et al., 2018). The major challenges for such autonomous vehicles are connected with the issue of decision making (Torok, 2017).

4. Conclusion

Autonomous vehicles have a potential to significantly decrease the number of fatal road accidents by eliminating mistakes of human drivers. Autonomous vehicles' driver never become drunk, distracted, or tired. Their performance may also be better than human drivers because of the lack of blind spots.

However, there is a potential risk for autonomous vehicles to cause new and serious accidents, like crashes resulting from cyber attacks. Clearly, autonomous vehicles have an enormous potential for posing risks.

The Americans drive nearly 3 trillion miles every year. The 2.3 million reported injuries in 2013 correspond to a failure rate of 77 reported injuries per 100 million miles. The 32,719 fatalities in 2013 correspond to a failure rate of 1.09 fatalities per 100 million miles (Kalra, Paddock, 2016). For comparison, Google's autonomous vehicle fleet, which currently has 55 vehicles, was test driven approximately 1.3 million miles in autonomous mode and was involved in 11 crashes from 2009 to 2015: Comparing Google's fleet performance with human driven performance one could found that Google's fleet might result in fewer crashes. Unfortunatelly the dataset does not allow to draw the final conclusion. There were not enough autonomously driven miles to make statistically significant comparisons between a man and machine (Kalra, Paddock, 2016)

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公路运输自动化：审查

關鍵詞
道路交通安全
自动驾驶汽车
自动道路车辆
公众接受
风险和劣势

摘要
在本文中，研究了公路运输的自动化。 第一章确定了相关的国际趋势。 在本文中，研究假设是，在自动化道路车辆的情况下，极有可能危及人类生命。 其次，简要介绍了道路安全的历史，特别是车辆设计和系统理论的扫描。 第三章阐述了驾驶员辅助系统的演变，特别强调了自动驾驶汽车。 最后，作者总结说，新的技术解决方案可能会带来新的威胁。

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Irregular operation of autonomous vehicles

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Abstract

Today, with the spread of autonomous functions in vehicles, the role accountability for causing accidents is emphasized. Self-guided functions work in certain traffic situations, but accidents happen, and, therefore, the following article presents an analysis of the issue. Its purpose is to show that vehicles with self-drive functionality do not provide the driver's level of safety that vehicle manufacturers suggest. In this article, four recent events and an analysis whether these accidents could have been avoided a human driver or how they could have happened with appropriate self-drive function. In each of the investigated cases, vehicles equipped with self-drive function are involved. Based on the evaluation and assessment of accidents, conclusions are drawn whether current self-propelled vehicles provide the safety level that drivers and society expect from these vehicles. The reconstruction of the accident process is illustrated with the help of a vehicle simulation program, with the resultant parameters being given a special emphasis, in particular to the avoidance of the accident.

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1. Introduction

In the paper two accidents involving autonomous vehicles are presented, which have been interrupted in autonomous mode during their journey. In the first case (The Guardian, 2018), a situation which involves Volvo XC 90 operated by Uber and the pedestrian is presented , the second case concerns a Tesla Model S and a fire truck (Autoweek, 2018). The paper analyses the cases, determines the reaction points, examines the likelihood of avoiding accidents.

The examples illustrate that current autonomous systems in the real-world transport environment do not yet provide what manufacturers have promised and users have expected.

2. Experimental

In the first case a person pushing a bicycle was crossing a 4-lane road, partially illuminated road cross. The Volvo car was going along the outside lane around at the speed of approximately 40 mph*. There was a crew in the vehicle at the time of the crash, but the Advanced Driver Assistance System (ADAS) was on. The crash occurred in the 4th, outside, lane, the vehicle was caught at a point of ca. 40-50 meters away.

As far as the second accident is concerned, a fire truck was standing on the inside lane of the highway because of an earlier event. The Tesla car was travelling at 65 mph and then collided with the fire truck.

Note: 65 mph = 104 $^{km}/_{h}$
Note: 40 mph = 64 $^{km}/_{h}$

The sites of the accidents

The full reports of the sites of the accidents were not available when the following paper was being written. In the case of the first accident based on the data of the on-board camera presented in the media, the location of the collision could be determined in an appropriate way. The width of the roadway and other environmental conditions were determined on the basis of data available in the media and with the use of the Google Earth program. The trajectory of the accident site, the vehicle and the intended pedestrian pathway could be determined. The accident occurred in Arizona, in the city of Tempe on N Mill Avenue, at 33.436195, -111.942370 GPS coordinates.

The Figure 1 depicts the site of the accident process. The figure shows the direction of the Volvo and the pedestrian path.

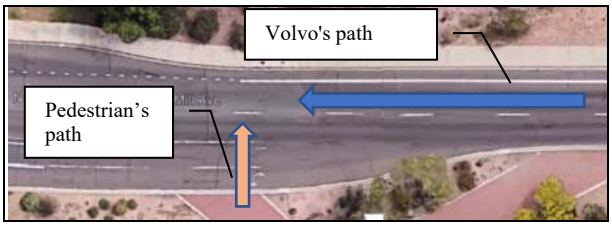

Fig. 1. The accident sites (Google Earth)

Figure 2 shows the street view, where the location of the collision was specified.

Fig. 2. The collision location (Google Earth)

Figure 3 is a screenshot from the video when the pedestrian becomes visible to a driver.

Fig. 3. The moment of pedestrian perception (Youtube, Abc Action News)

The second accident occurred on January 22, 2018, in the morning, in the day-time, dry road conditions. Based on the obtained data, the fire truck was occupying 2 internal traffic lanes of the motorway. The Tesla car in self-driving mode smashed into the back of a fire truck. A personal injury occurred, the case is investigated by NTHSA. The event happened in the US state of California, Culver City, on the 405 freeway.

3. Results and discussion

The calculation of the accidents process

Own accident calculations based on the data collected during the test were used (Burg, Moser, 2009).

The simulation calculation was conducted by the means of Virtual Crash 2.2 software (Virtual Crash Homepage, 2016). This application is intended for forensic experts working in the field of traffic, who specialise in elaborating technical expert reports about causes of road traffic accidents.

In the case of the first accident the process based on the recording of the on-board camera was synchronised. The pedestrian speed was approx. 6 $^{km}/_{h}$, the car was traveling approx. 64 $^{km}/_{h}$. The sync point is the location of the collision that ends the white separating line of the bicycle track. Analysing the video, it can be stated that the vehicle hit the person without braking. The impulse that caused the braking was the collision.

It can be concluded from the established speed that the pedestrian started crossing the road approx. 8.5 seconds before the collision. At that time, the car was 150 meters away from the point of impact. From this distance, the pedestrian is not yet expected to be seen, and the movement of the pedestrian does not pose an emergency as one can still change direction or speed. In the following pictures, typical situations connected with the assessment of hazard are presented.

Figure 4. shows the situation when the pedestrian walked to the middle of the road 4.5 seconds before the collision with the vehicle. The Volvo was 80-85 meters away from the point of impact. From this distance the pedestrian did not pose a dangerous situation because the vehicle with a normal brake manoeuvre can be stopped, before the hitting point.

Fig. 4. The mutual position of the participant's T – 4,5 sec

Figure 5. shows the next situation when the pedestrian reached the lane along which the Volvo car was travelling. The vehicle is then approx. 43-47 meters, pedestrian approx. 4-5 meters from the point of hitting. In this case, a vehicle with an intensive brake manoeuvre can be stopped.

Fig. 5. The mutual position of the participant's T – 2,5 sec

Fig. 6 depicts a simulated moment corresponding to Fig. 5. The vehicle is then approx. 20 to 25 meters from the collision site. From this distance the vehicle with an emergency brake manoeuvre cannot be stopped before the pedestrian's travel path.

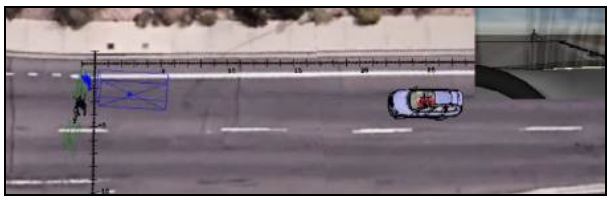

Fig. 6. The mutual position of the participant's T – 1,25 sec

Based on this, it can be stated that the pedestrian became visible to the human driver within the braking distance. The collision was inevitable with normal operation.

The next step was the investigation of the avoidance of the accident. On the basis of expert experience, a pedestrian who is in the area that is marked with different colours represents

the danger to the driver. Figure 7 depicts a different area. The area of the vehicle which is marked with yellow, and the further area are the ones from which, in reality, it would be not possible for the human eye to detect a pedestrian, and in the case of an autonomous vehicle, an earlier detection, independent of the weather and visual conditions, is necessary. With proper detection, the vehicle could be halted by intensive braking before the path line of pedestrian.

Fig. 7. The expected detection distance

In the case under investigation, it may be established that the autonomous system was not functioning properly.

In the meantime, the preliminary report was completed. (National Transportation Safety Board, 2018). Based on the report, the system first registered the pedestrian about 6 seconds before the impact. First as an unknown object, as a vehicle, and then as a bicycle. At 1.3 seconds before impact, the self-driving system determined that an emergency braking manoeuver was attempted.

A significant part of new vehicles have an EDR (Even Data Recorder) system, from which accident data can be read with CDR Softwar. (Darts Group Homepage, 2018; Fourth Cdr User Summit Europe, 2017; Gazdag et al., 2018).

The braking did not happen because "according to Uber, emergency braking manoeuvers are not enabled while the vehicle is under computer control, to reduce the potential for erratic vehicle behaviour. The vehicle operator is relied on to intervene and take action. The system is not designed to alert the operator."

Based on the investigation of the avoidance of the accident, it can be stated that the detection and determining of the self-drive system was correct. According to own calcultions, the Volvo could have been stopped before the pedestrian's travel path, 2.5 to 6 seconds prior to the accident.

Fig. 8. The accident process in the case of adequate autonomous function

It can be calculated in case of 1,3 seconds before the occurrence, if, as a reaction point, the time when the pedestrian is seen on the video for the first time is chosen, or the self-drive system determined an emergency braking manoeuver, and 0.1-0.3 seconds of self-drive system "reaction time" and the slowdown of emergency braking is taken into consideration, then Figure 8 depicts the simulated moment. In the case under investigation, the pedestrian goes out of the path of the vehicle (time avoidance), but if the pedestrian had not even left the lane, then the speed of collision would have been one third of the real speed (about 18-25 km/h).

In the case of the second accident, before the collision, the Tesla was travelling at 104 $^{km}/_{h}$. Based on the damage pictures, the collision speed can be estimated - approx. 40-45 $^{km}/_{h}$. It follows that the vehicle decelerated before the collision. There is no information available that the self-drive system or the human driver brake the vehicle.

Based on the speed of travel and collision, the Tesla started breaking at approx. 45 to 55 meters before the point of the impact. Figure 9 shows the end position of the collision.

Fig. 9. The end position of the collision

Figure 10 shows the start of braking.

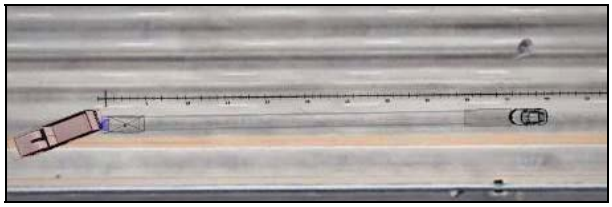

Fig. 10. The beginning of the car's braking T = -2,5 sec

Taking into account the reaction times, if the self-propelled system had started to brake, then the stationary car would have become recognizable 50-60 meters before the collision, if the human driver had recognized the emergency, then the reaction point would have been approx. 73 to 78 meters.

Following the breaking, the Tesla car collided with the left rear corner of the fire truck.

After the likelihood of the avoidance of the accident was calculated.

In order for the Tesla car to stop safely behind the fire truck the self-drive system should have recognized the danger before the point of impact approx. from 62 to 67 meter, the human driver approx, from 82 to 87 meter. Figure 11. illustrates the breaking process with human reaction time.

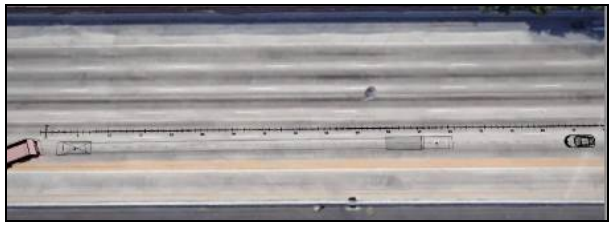

Fig. 11. The case of the safely standstill of the Tesla

It can be stated that the autonomous system detected the obstacle but approx. 15-20 meters, and approx. 1 to 1.5 seconds earlier would have been necessary to detect an emergency.

4. Conclusion

In the first case, the self-propelled system was detected in time but the system did not operate because the emergency brake function was switched off, in the second case, the delay of the detection could be calculated.

In the first case, a human driver could not have escaped the incident because the perceived of the bicycle – subject to visual conditions –was possible only within the braking distance. In addition to properly functioning self-drive vehicle function, the collision could have been avoided.

In the second case, either a human driver or a car with the properly functioning self-driving function could have avoided the collision. As the accident occurred, therefore the self-driving function of the vehicle did not work properly.

In addition to the steady increase in the number of vehicles, the reduction of traffic accidents can only be achieved by the means of the widespread introduction of driving support systems and autonomous vehicle functions. However, the marketing messages of vehicle manufacturers should not lead to excessive expectations with the vehicle's self-driving capabilities, thus creating a false sense of security for an average driver.

It is important to emphasize, that the autonomous vehicle functions have to be provided at least the spatial and temporal emergency expected of the human leader irrespective of conditions of weather and vision conditions.

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自动驾驶汽车的不规则操作

關鍵詞

事故重建，自动驾驶汽车，
自驾车
紧急
车辆运动模拟

摘要

今天，随着车辆自主功能的普及，强调了引发事故的责任。自导功能在某些交通情况下起作用，但事故发生，因此，下面的文章提出了对该问题的分析。其目的是表明具有自动驾驶功能的车辆不能提供车辆制造商建议的驾驶员安全水平。在这篇文章中，最近的四个事件和一个分析是否可以避免这些事故是一个人类驱动因素，或者它们是如何发生的，具有适当的自我驱动功能。在每个调查的案例中，涉及具有自驱动功能的车辆。在对事故的评估和评估的基础上，得出结论，当前的自行式车辆是否提供了驾驶员和社会对这些车辆的期望。

在车辆模拟程序的帮助下说明事故过程的重建，特别强调所得到的参数，特别是避免事故。

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Behaviour Based Safety (BBS) - Advantages and Criticism

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Abstract
Behaviour-Based Safety (BBS) is a popular approach to enhancing occupational safety, with many researchers reporting successes of implementing BBS programs. There are, however, studies that see this approach as illusory, bringing more harm than good. The first goal of this article is to present an overview of literature providing both evidence and elaboration of implementing BBS programs, highlighting both positive and negative views of the approach. The second goal is to discuss the perception of the method, based on a literature review and authors' own research.

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1. Introduction

The importance of occupational health and safety in organizations is highlighted with relevant statistics in introductions to almost every book and research paper on this topic. The perception and approach to safety, however, has greatly changed with time (for a thorough historical analysis see (Swuste et al., 2010, Swuste et al. 2014). In the early industrial era, accidents were attributed to fate or other uncontrolled force, and seen as unavoidable. For some time, they were attributed to "accident proneness", a personality trait of workers who tend to have accidents more often than others (Kerr, 1957, as cited in McAfee and Winn, 1989). Later, accidents were linked to flaws in mechanical or environmental design (Greene 1969, as cited in Sulzer-Azaroff, 1978). More recently, accidents tend to be seen as combination of those two factors, a result of interaction between the worker and the environment. The cause of accidents is still an important question. Behaviour-Based Safety, or BBS, is a popular approach to safety management, that sees the main cause of accidents in unsafe behavior. The seemingly solid theoretical background and widely reported effectiveness make BBS programs quite appealing, as it is shown by the authors' own research. BBS programs, however, are subject to criticism, which should be taken into account before their implementation.

2. Literature study

Unlike many management methods or techniques, it is hard to track down the exact moment of emergence of BBS, or to name the "pioneer" or "inventor"; some of the earliest implementations, however, can be found in the late 70s. of the twentieth century (Sulzer-Azaroff, 1978; Smith, Anger, Uslan, 1978). BBS can be defined as "a set of techniques aimed to encourage or discourage employees from particular behaviour to prevent workplace accidents and illnesses. The implementation of such a program requires setting its goals, establishing observation techniques, recording and analyzing the causes of workers unsafe behaviour and creating an effective communication system" (Pęciłło, 2010). Or, simply, "BBS focuses on what people do, analyzes why they do it, and then applies a research-supported intervention strategy to improve what people do" (Geller, 2001). The roots of the BBS methodology can be linked to the works of Heinrich (1927, 1928, 1929, 1931, 1941, as cited by Swuste, van Gulijk, Zwaard, 2010; Heinrich 1959 as cited by Choudry, 2014), who claimed that around 88% of industrial accidents are caused by worker's unsafe behaviour. Another equally significant background is Skinner's (1938, 1953, 1974, as cited by Geller, 2001) research on applied behaviour, which assumes an antecedent-behavior-consequence (ABC) model. Antecedents work as "triggers" of behaviour, while the consequences – positive or negative – determine the probability of repeating the behaviour in the future. The weight of the consequences is yet another issue, as immediate or high-probability outcomes may outweigh long term or low-probability outcomes, e.g. not wearing personal protective equipment (PPE), while may cause some risk of injury and/or illness in the long run (such as loss of sight/hearing or lung problems) gives immediate and highly probable positive outcome in form of increased comfort, better movement speed, or social acceptance of other workers (Gniazdowski, Sibiński, 1999; Zohar, Erev, 2007). Therefore, providing workers with positive consequences – rewards (positive reinforcement) may enhance the probability of the desired behaviours, while providing penalties (negative reinforce-

ment) can discourage them from the undesired, risky ones. The rewards and penalties may take different forms, from positive or negative feedback, through celebrations and parties for reaching set goals, to financial incentives and even lay-offs.

The actual course of action while implementing a BBS program varies, depending on the author and in particular reported cases. However, it can be summed up to a few main steps. Geller provides an approach dubbed "DO IT" for BBS programs (similar to Deming's PDCA cycle) which consists of four steps: 1) Define – behavior(s) to target, 2) Observe – to collect baseline data, 3) Intervene – to influence target behavior(s), 3) Test – to measure impact of intervention. In a similar fashion, McSween (2003) lists that a successful BBS process (as he argues that ensuring safety should be an ongoing process, not a program) should consist of four basic components: 1) a behavioural observation and feedback process, 2) formal review of observation data, 3) improvement goals, 4) reinforcement for improvement and goal attainment (Geller, 2001; Geller, 2005).

Many literature reviews reported an extraordinary success of implementing BBS in different countries and industries in analyzed papers, for example: McAffe and Winn (1989) – 24 papers, Sulzer-Azaroff and Austin (2000) – 32/33 papers Pęciłło (2010) – at least 8 papers judging from the provided bibliography (particular authors' overall work is generally discussed in the article). The "success" of BBS programs can be defined in many ways, as different measures and rates are used by researchers; the list of reported positive effects includes (but is not limited to): decrease in the number of unsafe behaviours, decrease in the number of injuries/injury rates (e.g. per 100 workers) and illnesses, decrease of absence from work caused by injuries and illnesses, lower costs of treatment, lower insurance rates, increase in the number of "safety behaviour" (behaviour increasing safety of the workplace), more worker involvement in contribution to organizational safety, overall improvement of organization's *safety climate* and/or *safety culture*. *Safety climate* is a term reflecting the overall level of safety in the organization. It was coined and developed by Zohar (1980), and initially included "workers' perceptions of management attitudes about safety and their perceptions regarding the relevance of safety in general production processes" (p. 96). *Safety culture* is considered a part of organizational culture, consisting of employee attitudes towards safety, common norms of safety behaviour, values assigned to safety (Studencki, 1996, as cited by Znajmiecka-Sikora, 2012).

BBS programs, however, are subject to criticism. (DeJoy, 2005) lists three most popular arguments against BBS, i.e.: 1)"victim blaming", 2)minimizing the importance of the environment, and 3)focus on the immediate causes. The arguments are actually strongly interconnected; "victim blaming" or "blaming the worker" is the practice of placing all the responsibility for accidents on individual workers (excluding any responsibility of the management), who are expected to work safely all the time, no matter what the conditions are, even if the working environment is not controlled to ensure safety. Such behaviours are seen as immediate cause of the accidents, and no attention is given to previous steps of the causal change, i.e. what the reason of such behaviour was. This interconnection can be seen in (Pęciłło 2010), as she reveals that "[victim blaming] argument [against BBS] is justified if those programs are not based on finding the cause of unsafe behaviour". Ironically, among examples of unsafe behaviors listed in the same article, we can find: using wrong tools for the job, using tools in a bad condition, without valid inspection certificates, without or with damaged covers and protective gear, using damaged PPE or not using it at all. While a possible fault of the worker cannot be excluded (e.g. laziness, carelessness), one must agree that supplying the right tools and equipment and ensuring its proper condition should be the responsibility of the employer, rather than the worker.

SMITH (1999) as well as Frederick and Lessin (2000) raise many similar arguments against BBS. As they reveal, the "victim blaming" tendency in BBS comes directly from the aforementioned statistic made by Heinrich in the 1930s, which, despite its age, are commonly accepted and cited to this day (see McSween, 2003; Pęciłło, 2011, Chen, Tian 2012; Zhang, Fang, 2013; Choudry, 2014, among others). Heinrich was in fact an insurance investigator, and his conclusions probably lack any scientific proof (Smith, 1999), as he based his data on supervisor reports, which naturally put the blame on the workers (Frederick, Lessin, 2000). Both articles also highlight the limitations of applied behaviourism as the basis of BBS, as many experiments prove that incentives may not always work as expected, or even bring an adverse effect, mostly referring to Kohn's *Punished by rewards* book (1993, as cited by Smith, 1999). They also both point out that instead of contributing the *safety climate* or *culture*, BBS programs actually create the climate of fear. Smith argues that being observed during work can be more stressful than working in normal conditions (and in fact cause more unsafe behaviours). Frederick and Lessin suggest BBS cause reluctance to report injuries (to avoid the label of "unsafe worker"), giving example of one factory, where half of the workers raised their hand when asked if they are afraid to report injuries; an anonymous survey later showed that another 20% were even afraid to raise their hand in public. Smith claims that BBS programs tend to bring only short-term effects (an issue raised already in 1989 by McAfee and Winn), as they focus solely on the results, giving the false assumption that the real problems were solved; Frederick and Lessin claim the only point of BBS programs is to discourage workers from reporting injuries, as it is more profitable for the employer. Finally, both articles highlight that BBS programs are disapproved of by worker unions; Frederick and Lessin also mention the disapproval of Occupational Safety and Health Administration (OSHA).

Brown and Barab (2007) presented a thorough case study of the San Francisco Bay Bridge rebuild project, which proved how BBS programs can result in injury and illness rate manipulation. The BBS strategy held by the consortium behind the project provided all working crews with substantial monetary incentives, while foremen, supervisors and managers of different levels were additionally rewarded with "merit cards" required for career advancement. All rewards were distributed only if no injuries were reported in a given period. The BBS program created an atmosphere of fear, as any injury report of an individual worker would result not only in losing his or her reward, but also rewards of other team members and of its superiors. There were many signs of

workplace harassment, and even a suspicion that the physicians caring for the workers were manipulated to understate the injuries, so there was no need to report them and victims could return to duty. The California Division of OSHA filed a citation against the consortium, as it intentionally did not file at least 13 worker injury reports. According to the OSHA this was not an individual case, as similar problems were found even in several Fortune 500 companies.

3. Results of own research

The BBS approach was discussed in the form of a guided interview with a group of occupational safety experts (n=11), chosen on a criterion of having either professional experience as occupational safety inspectors, experience as a academic lecturer focused on OHS, or a combination of both. Additionally, similar discussion was held with a group of working students (n=60). In both cases the discussions consisted of the following parts: 1) brief presentation of the BBS approach foundations and rules, 2) general questions about the perceived usefulness of implementing BBS programs in Poland ("do you think such programs in Polish enterprises are worth implementing?"), 3) questions about the perceived potential benefits of implementing BBS programs (see **Fig. 1**), 4) questions about the perceived potential barriers in implementing BBS programs (**Fig. 2**).

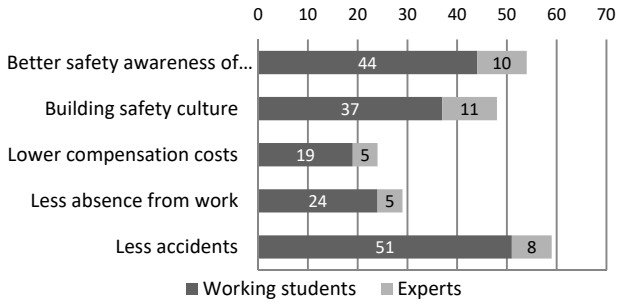

Fig. 1. Perceived benefits of BBS programs

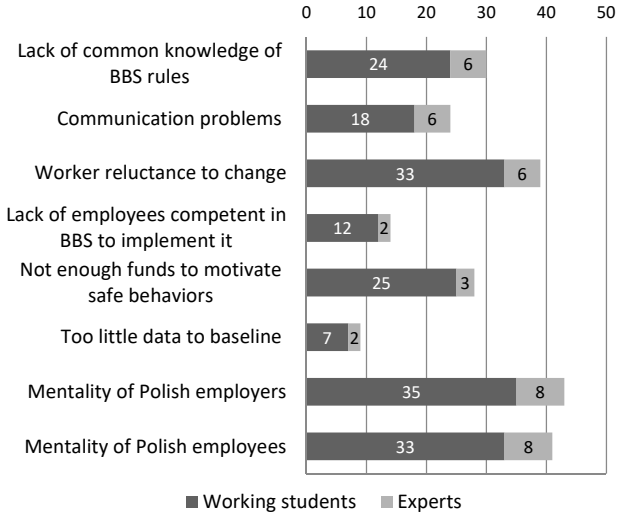

Fig. 2. Perceived barriers of BBS program implementation

The results were quite similar for both groups. Among the benefits, the experts unanimously pointed out the ability to build safety culture (probably due to a good theoretical background and the importance of the matter highlighted in literature); "better safety awareness of workers" was the second most popular answer and "less accidents" was the third; these answers were also the most popular among the working students, but in an exactly reverse order. The influence of BBS programs on absence from work and compensation costs were also popular answers in both groups. Single experts also pointed out the possibility of influence of one worker on another toward safe behaviours and lower insurance rates, while one student also listed lower overall costs generated by the accidents (including potential damage to equipment). As for the barriers, the mentality of both employers and employees in Poland was the most popular answer among both experts and students, the latter also listed "reluctance to change" among the workers as equally strong barrier. While the factor was equally important among the experts as "lack of common knowledge of BBS rules and "communication problems" in enterprises (listed by 6 respondents), the last two were slightly less important to students, which, on the other hand, numerously listed the lack of funds to motivate safe behaviours as a major issue, listed by only three experts.

While motivational incentives varied greatly in the literature and could be both simple verbal feedback as well as monetary rewards, the latter seem to be more convincing to the working students. Only one working student additionally raised the issue of the difficulty in defining clearly the "unsafe" behaviours, as well as the possibly negative and hostile attitudes towards persons observing and reporting them (who can be seen as "squealers"). As for the general question of BBS usefulness, all experts perceived the approach as useful, and only 4 working students had negative attitude towards it. Although they did not list more barriers in its implementation than the average in the group, those barriers had to feel significant, as they perceived the approach as a "waste of time and money" and seen "no point in its [the BBS program] implementation".

4. Discussion

Although almost every respondent saw many potential barriers in implementing BBS programs, they were mainly connected to organizational aspects (most importantly the "fear of change"), none of them actually came to conclusions raised by the critics of the approach, with only one person raising the issue of "unsafe" behaviour definition. It is worth noting, that only the basic aims and rules of BBS were presented to the research participants at the beginning of the interview; they were not informed about its advantages, actual results of implementation (positive, negative or neutral) nor the criticism of the approach in any way, aside their own prior knowledge.

Despite the relatively small sample size, the study shows that the core ideas behind the BBS approach are generally attractive to workers and (perhaps even more) to safety experts. The "charm" of the behavior change programs also tends to affect the academics; together with the sheer volume of reported positive results of BBS programs, it overshadows the criticism and its supporting evidence, as a good number

of researchers in recent years implemented BBS programs with some degree of success (see e.g. Pęciłło, 2011; Chen, Tian, 2012; Boczkowska, Znajmiecka-Sikora, 2014; Choudry, 2014).

While the behavioural aspects of safety are still important in recent studies, more attention is given to the environmental and managerial aspects that may lead to unsafe behavior, building upon Zohar's (1980) safety climate. A popular method to model these relations is structural equation modeling (SEM). For example, Fogarty and Shaw (2010) provide a model in which *management attitude* and *pressure* may lead to safety violations. According to (Vidnokumar, Bhasi, 2010), behaviours (*safety compliance* and *safety participation*) are influenced by safety management practices (*management commitment, safety training, workers' involvement in safety, communication and feedback, rules and procedures, safety promotion policies*) directly and indirectly, mediated by *personal knowledge* and *motivation towards safety*. Model by (Seo et al., 2015) shows that safety climate (expressed by *managerial priority, safety communication, safety regulation* and *safety education*) has the biggest direct effect on safety behaviour; a similar model is presented by (Liu et al., 2015), though they see safety climate as a combination of *management commitment, safety supervision, coworker support* and *safety training*, and safety behaviours as *PPE use*, *safety initiatives* and *safety compliance*. In the model by (Guo, Yiu, Gonzalez, 2016), *safety participation* and *compliance* is influenced by safety *motivation* and *knowledge*, *social support* (similar to *coworker support*), *production pressure*, with *management safety commitment* as a basic factor. Even though the constructs used in those models vary, every model presents the fact that behaviours are very complex, and influenced by many different factors, not entirely dependent on the workers themselves. While the implementation of BBS programs may prove successful, this fact is often overlooked, and too much focus on results, instead of their causes, may in the end bring more harm than good to the safety culture of the organization.

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基于行为的安全（BBS） – 优势与批判

關鍵詞
行为
安全
事故

摘要
基于行为的安全（BBS）是一种增强职业安全的流行方法，许多研究人员报告了实施BBS计划的成功经验。 然而，有研究认为这种方法是虚幻的，带来的弊大于利。 本文的第一个目标是提供文献概述，提供实施BBS计划的证据和详细说明，突出该方法的积极和消极观点。 第二个目标是基于文献综述和作者自己的研究来讨论对该方法的看法。

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Food quality and safety in the brewing industry

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Abstract
The article presents the importance of economic and social responsibility of the brewing industry, pointing to the aspect of synergy related to the brewing industry in the processes of economic development (creation of many jobs in the agricultural sector, retail trade and gastronomy), stimulating specific areas of local and regional development. The principles of organization and supervision of food quality and safety in beer brewing as well as the importance of implementing management systems in the activity of brewing industry companies were presented.

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JEL: L15, J28, M11

1. Introduction

The brewing industry market in Poland is one of the fastest growing industries, which results from changes in preferences of consumers who choose increasingly weaker alcohols. The good condition of the brewing industry is important for the creation of jobs and economic growth.

With the annual production of 40 million hl, Poland is the third largest producer of beer on the Old Continent, and the brewing industry is the largest employer in the domestic alcohol sector and the second payer of beer excise in Europe. The total employment generated by breweries in the Polish economy is 205,000 job places which is twice as high as the number of jobs related to the production and sale of spirit drinks (97,554 - data from the report: Socio-economic impact of the spirits industry in Poland 2013-2014).

The activity of the brewing industry influences not only the labor market but also ~~on~~ the state budget revenues. In 2016, due to the brewing and sale of beer, the state budget gained nearly **PLN 10 billion** (data from the EU Report 2016: The Contribution made by Beer to the European Economy):

- excise tax PLN 3.56 billion,
- VAT (retail trade) PLN 1.29 billion,
- VAT (gastronomy) PLN 3.14 billion,
- income tax (brewing industry) PLN 0.40 billion,
- income tax and Social Insurance Institution (related industries) PLN 1.51 billion.

One third of this amount (PLN 3.56 billion) were excise tax revenues - the second in Europe, after Great Britain and before France and Germany-in terms of the value of excise tax on beer (data from: Beer statistics 2016 edition).

The tendency of the last few years is an increase in the number of contract, craft and restaurant breweries in relation to the decreasing number of industrial breweries. Three biggest beer producers in Poland: Carlsberg Polska, Grupa Żywiec and Kompania Piwowarska are associated in the Employers' Union - Browary Polskie (Polish Breweries). Other beer producers, including restaurant breweries, are part of the Association of Regional Polish Breweries - Polskie Piwo (Polish Beer).

Beer as a foodstuff is covered by European regulations and procedures regarding food safety (as of 1 January 2007, food regulations have been in force in the EU forming so-called **"Hygiene Package"**, that is EC regulations laying down the rules of hygiene of foodstuffs and the rules of conduct of the authorities supervising the food sector.) and its proper health quality, enforcing proper storage and transport conditions and determining the management of supply chains.

2. Aims

The aim of the study is to present the functioning of the brewing industry operating in the global environment. Economic and social responsibility of the company stimulating specific areas of local and regional development is also important. Showing and defining the analysis of critical issues of food quality and safety in beer production is no less important. The determination of the previous issues has a sig-

nificant impact on the proper functioning of the internal quality control system in the Kompania Piwowarska. Considering the above, it is possible to determine the directions of activity of the brewing industry in the era of globalization.

Nowadays, it is justified to supplement the paradigm of Taylor's labor and specialization principle (optimization of use capital-intensive machines and devices in the era of mechanization), by the concepts of logistic and marketing management. The basis for the development of the global economy in the era of globalization are smart organizations, enterprises operating in the areas of developing local, national and international markets. It is more commonly claimed that the real value of an enterprise company is primarily in the "strength" of its participants' minds, which enables functioning in changing conditions as well as the use of volatility as an opportunity for its own development. Issues determining quality and safety in beer production are presented on the basis of published studies of the brewing industry (Sustainable Development Report for Calendar Year 2017 of Kompania Piwowarska).

3. The advantages of implementing a safety system and quality management

Kompania Piwowarska was founded in 1999 and in April 2017 it changed its owner, which is now the Japanese Asahi Group Holdings, Ltd. (however the traditional recipes of Kompania Piwowarska brewing brands have been preserved) and, as a global company, it respects global ecological, economic, quality and social trends and supports local community initiatives and is one of the leaders of responsible business in Poland. In 2017 Kompania Piwowarska maintained its strong position as the leader of the Polish beer market with a sales at 13.8 million hl, which makes for a 36.9% share in the Polish beer market.

It directly employed 3,261 people and in retail sale market around 9,700 full-time jobs depending on beer sales. The company also has a significant impact on the gastronomy - sale of Kompania Piwowarska's products contributes to maintain 13 900 full-time jobs in this industry, and it also has an indirect impact on employment results in the supply chain. Only thanks to the purchases carried out by Kompania Piwowarska, there are 33, 500 jobs. It has been estimated that the total impact of purchases, production and sales of Kompania Piwowarska's products generates over 60,400 jobs in total.

Kompania Piwowarska is the largest beer producer in Poland, which is brewed in three breweries: in Bialystok, Tychy and Poznan. Sales are run by 11 distribution centres, 6 sales subsidiaries and 14 sales branches throughout the country. The portfolio of Kompania Piwowarska's brands includes, among others, the following brands of beer: ŻUBR, TYSKIE, LECH, REDD'S, KSIĄŻĘCE as well as: DĘBOWE, WOJAK, GINGERS and international premium brands: PILSNER URQUELL, GROLSCH, PERONIA NASTRO AZZURRO and MILLER GENUINE DRAFT.

Critical analysis of quality and safety issues in beer production was based on the subject literature and published researches of the brewing industry in particular of the Kompania Piwowarska's Sustainable Development Report for Calendar Year 2017.

Attention to the quality of the products is the result of using the centuries-old traditional methods of brewing, modern technology, care for the highest quality of raw materials used to brew beer and compliance with the rules of production. The quality of all ingredients used in the production process and the product itself is tested at every stage of the life cycle in accordance with the applicable standards restrictions of quality and safety of products. There is also a sensory panel which aim is to test beer samples to ensure consistent quality of the brands produced in the company.

Kompania Piwowarska implements the sustainable development strategy "Bet on beer" which supports saving water and energy, supports the development of business partners and promotes responsibility and moderation in alcohol consumption. Moreover, it trains sellers and small entrepreneurs, working to build the future. Five sources of growth have been identified as part of this strategy: business and community development, responsible consumption, water saving, efficient and friendly cultivation, clean environment - which creates a natural space for achieving business benefits while at the same time maximizing involvement in economic and social development and environmental protection at the local and global level.

The internal control system of Kompania Piwowarska consists of many elements which are the rules of conduct and applicable procedures, structures and processes, internal control services. These are confirmed by the following certificates:

Quality Management System (QMS) according to ISO 9001: 2015 The standard is focused on understanding and meeting customer requirements. The main requirements of the ISO: 9001 standard include: introduction of supervision over documentation and records, management's involvement in building a quality management system, systematization of resource management, establishing product implementation processes, making systematic measurements (customer satisfaction, products, processes).

Environmental Management System (EMS) according to ISO 14001: 2004, is a set of requirements related to the Environmental Management System, created in order to define rules regarding environmental protection, taking into account socio-economic conditions. In Kompania Piwowarska the aspects of operations that affect the natural environment and the elements of potential threats were defined. A system checking program was also implemented to ensure continuous improvement of business procedures.

However, the basic legal obligation for all organizations in the food sector throughout the food chain is to maintain the health safety of manufactured products, according to mandatory management systems which include food safety management according to ISO 22000 and according to the requirements of the EU Hygiene Package and relevant national provisions.

Food Safety Management System (FSMS) takes into account ISO 22000: 2005 (quality management according to

the ISO 22000:2005, includes specific for food safety requirements: communication in the internal supply chain and with suppliers and customers, quality system management-should be included in all activities related to company management, program monitoring- concerning: land and building plans, media supply, services, materials management, measures to prevent cross-infection, pest control, personnel hygiene, verification of HACCP principles - with emphasis on the analysis and monitoring of risk surveillance measures as a key to the effectiveness of the system's functioning), ISO / TS 22002-1: 2009 and FSSC 22000 requirements. This standard defines international and national requirements for food safety, and its implementation supports the realization of Kompania Piwowarska's primary goal - the production of beer which is safe for consumers' health. As part of food safety, the FSSC 22000 system was also certified in breweries, which is an extension of the ISO 22000 standard, providing protection against intentional or accidental contamination of food and bioterrorism. As part of the system the Food Defense Plan was implemented, which describes the appropriate and planned actions and resources to prevent contamination.

Occupational Safety and Health Management System according to OHSAS 18001: 2007, presents requirements concerning the Occupational Safety and Health Management System in order to enable the organization to define policy and objectives in this respect. OSH policy includes the organization's commitment to preventing accidents at work and occupational diseases, striving for continuous improvement of OSH, compliance with legal requirements, continuous improvement of OSH measures, providing adequate resources for implementing this policy and improving employee qualifications and hygiene.

Energy Management System according to ISO 50001: 2011, which specifies the requirements for assessment, implementation, maintenance and energy management - and the purpose of its implementation is to enable the organization to apply a systematic approach in achieving continuous improvement of energy efficiency, including energy efficiency, energy use and its consumption.

Kompania Piwowarska also manages risk, that is, identifies and evaluates risks, qualifies them, takes actions to reduce or eliminate them - through the implemented process of reporting and reviewing existing risks. Risk analysis and assessment covers all areas: strategic, operational and financial.

Kompania Piwowarska has also implemented the Code of Ethics, containing a system of values, which is treated as a guide by making decisions in compliance with regulations and business ethics - both regarding relations at the workplace, as well as cooperation with partners, consumers and local communities. Product packaging contains information about the product's composition place of production, origin and market information such as a bar code, the sign of recycling or the possibility to return the packaging. On all packaging there is also a marketing message and voluntary liability labels: **"I never drive after alcohol"** or **"Alcohol. Only for adults"**.

Supervisory systems are based on international standards and have been combined as part of an I**ntegrated Risk Management Services (IRMS)**, which facilitates the management of all systems and ensures the conscious implementation of their assumptions by all employees to guarantee the quality of beer production processes with minimized negative environmental impact and optimal energy consumption. The implementation of **"Audyt ON"** project covers all eating places that are served by Kompania Piwowarska. The project assumes monthly reaching of external auditors to over 750 eating places serviced by sales representatives and conducting, among others, special surveys to determine TQDB and TQO indicators.

TQDB (Trade Quality Draught Beer) is an indicator of beer quality in kegs and method of mounting and placement of equipment, evaluation of keg time, proper rotation and sensory.

TQO (Trade Quality in Outlets) is an indicator of the quality of beer in cans / bottles in gastronomy with elements of the assessment of the quality of beer storage in premises. Thanks to these measurements a reliable sample of the TQDB and TQO indicator is obtained.

4. Summary and conclusion

Determining the safety and quality of food in the processes of company management in the food industry is a prerequisite for undertaking production activities of enterprises. The selected determinants of safety and quality management presented in the article on the example of Kompania Piwowarska indicate that normative EU and international requirements concerning quality and safety in food production are met and management creates the possibility of distribution channels with access to global networks. An important determinant for obtaining competitive advantages are activities related to the implementation of the traceability of a full product chain, starting from sources of origin of raw materials to the final product. Ensuring the quality and safety of food products through the introduction of formalized ISO 22000 / HACCP quality management systems and the QMS system as well as environmental management in the EMS system is a prerequisite for the synergy of activity in the brewing industry.

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酿造业的食品质量和安全

關鍵詞
酿造业
区域发展
食品安全
管理

摘要
文章介绍了酿造业经济和社会责任的重要性，指出了经济发展过程中与酿造业相关的协同作用（在农业部门创造了许多就业机会，零售贸易和美食），　刺激地方和区域发展的具体领域。介绍了啤酒酿造中食品质量安全的组织和监督原则，以及在酿酒行业公司活动中实施管理制度的重要性。

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Rotation related problems of personnel services in outsourcing companies

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Abstract
The subject of outsourcing of personnel services are functions and auxiliary tasks in the operation of a given enterprise. It is based on outsourcing specific tasks and entire personnel processes, as well as hiring employees who carry out tasks entrusted by a client. The main problem faced by enterprises is employee turnover caused by numerous absences, sick leave and holidays, and, as a consequence, employees have more and more delays and do not keep their deadlines. Consequently, they are frustrated that they have to perform more duties from other positions and listen to complaints about continuous decline in work efficiency. The problem of employee turnover is becoming a common phenomenon. Therefore, each company should analyse this problem. Starting from identifying the problem and, as a result, implementing appropriate measures to prevent excessive fluctuation of employees. It is also important to enable employees to develop and organize appropriate working conditions, which will ensure the comfort of work and attachment to the employer.

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1. Introduction

Outsourcing of personnel services has become an innovative solution. One of the main advantages of this management method is the reduction of costs related to the staffing of employees in individual departments, inter alia in the Human Resource department, by delegating the tasks of this department to a team of specialists from an external company. Another possibility that outsourcing companies use is the ability to delegate one or several personal functions (recruitment, training, selection). The solution provided by the outsourcing company results in a significant increase in the effectiveness of these activities in the company. Outsourcing companies, thanks to an individual approach to each employer-client, provide the opportunity to plan activities and tools that will meet the requirements of the company and at the same time will increase the competitive advantage with the help of properly managed personnel strategy, including cooperation with specialists in a given field. The subject of outsourcing of personnel services is certain post-executive tasks in the operation of a given organization. This method involves outsourcing tasks and entire personnel processes to external companies. This strategy applies mainly to processes related to human resources management as well as to the staffing of various positions. It should be noted that outsourcing can be used while using internal human resource management departments at the same time (Sidor-Rządkowska, 2011). This is to improve the quality of the company's services and focus on the main business objectives and, as a result, to lower the economic costs on which the enterprise depends to a large extent. A negative effect may be the dismissal of some employees who previously performed their tasks and which have been delegated to outsourcing companies. Managing via outsourcing is a method often used by SMEs (Krejner-Nowecka, 2002). The employment of a full-time specialist raises the cost depending on how high the specialist has. They can be effectively minimized thanks to the personnel outsourcing. Employing people in specific, short periods of time enforces employee turnover. Such a state results in a significant reduction in the quality of services. Personnel outsourcing is the possibility of employing the appropriate team of specialists in periods convenient for the company. Outsourcing is a long-term and strategic activity that requires a complete reconstruction of HRM on the enterprise and the need to redefine relations between individual entities of the organization.
We distinguish the following types of personal outsourcing:

- total outsourcing which involves outsourcing (external) the entire personnel tasks in the organization. This is a characteristic strategy for SMEs (small medium-sized enterprises). For large enterprises the service

provider should cooperate, at least through an internal department of External Human Resources (HR),

- partial outsourcing which consists in transferring only selected parts of tasks to an external entity recruitment.
- outsourcing of employee services which is based on the fact that companies decide to organize their own Human Resources (HR) department, however, they abandon recruitment of their own employees, and in return hire them on the basis of subemployment, from an external company (outsourcing),
- outsourcing of the division of specialized tasks consists in organizing the service of their specialized tools and machines by renting a personnel from an outsourcing company.

Process outsourcing allows organizations to optimize costs. This method brings a lot of savings by using the services of suppliers who, with their offer, are able to ensure high quality of key processes for the efficient operation of the company (Kraśnicka, 2002). Regardless of how effective planning of company's resources is, internal solutions still involve hidden costs, such as: sick leave or holidays. It is assumed that the reduction of costs by introducing the method of outsourcing processes should drop by approx. 30%, mainly due to the use of the economies of scale, which relies heavily on the client and the resources of the service provider, among others better technologies, trained employees or better equipment and machines. These are the advantages of external entities specialized in given services. Another advantage and benefit is a flexible adaptation to changes that force the market, as well as the ability to focus on the key business tasks of the organization, and at the same time specialization in the chosen field. Outsourcing of personnel processes gives the opportunity to implement the concept of "making something" rather than "doing everything". It creates the possibility of objective and extensive use of knowledge, including in the area of training, recruitment and selection. Employee rotation means the resignation of employees at a given time. Employees can give up for various reasons that have unpleasant consequences for the employer (Stawicka, 2012). We distinguish between voluntary and involuntary rotation. Uninvited departures are initiated by the management in a situation of dissatisfaction from performing professional duties by a hired employee, which may be caused by a change in the company's organizational structure. In the event of a resignation from work, it is much more difficult to analyse voluntary departures. Two kinds of beneficial and negative departures can be distinguished. A departure is beneficial when a worker brings no added value to the result and negative when it is a person who achieves very good results and has specialist knowledge, and is difficult to be replaced with another employee. Therefore, it is worth taking an attempt to analyse and properly diagnose the problem in order to prevent the resignation, especially of an employee with specialised knowledge or skills. (Trocki M. 2011; Azizi N. et al., 2010; Ayough A. et al., 2011)

2. Rotation costs

Guitting of an employee, especially the one who achieves very good results in his / her work, can be very costly for a company. Employee rotation costs consist mainly of the costs of leaving and replacing one employee with another and the costs of training a new one. Quitting costs are, therefore, all expenses related to the departure of an employee from the company. Included in this group are the costs of cash severance of quitting or dismissed employees and administrative costs. Replacement costs are, however, expenses related to the recruitment of candidates for a vacancy, including the costs of recruitment advertisements and expenses related to recruitment, e.g. participation in labour and selection costs. On the other hand, the costs of training include all expenses related to transferring the necessary knowledge to the newly hired employees and skills needed in a specific place of work. However, indirect costs may be the most severe. They are associated with lost future income and unused opportunities. Also important are the consequences for the employer due to the high turnover of the staff: loss of revenues related to leaving to competitive companies, as well as the fact that new employees are much less productive than previous employees who knew their tasks very well. This may be due to a lack of knowledge of a company's specific activity or its small experience. Another source of lost revenue is job vacancies. This phenomenon occurs almost in every enterprise from the moment of dismissal of the employee and new employment (Trocki, 2011).

Table 1. Employee rotation costs (Cybulski, 2008)

Quitting costs	Training costs	Replacement costs	Intermediate costs
▪ administrative costs ▪ loss of intellectual capital ▪ the cost associated with the payment of severance pay and other benefits ▪ the cost of preparing a conversation with a dismissed or quitting employee	▪ the cost of transferring the necessary skills at the workplace ▪ the cost of health and safety training	▪ costs related to the recruitment and selection process (advertisements, participation in job fairs)	▪ lost future revenues of the company ▪ the cost of unused opportunities

If the problem of employees fluctuation in the enterprise is significant and as a result the costs associated with it are very high, employers should implement appropriate corrective actions. In the first place, they should look at the recruitment process in the company. During the selection of candidates for the position employers should pay attention to the appropriate qualifications and competencies of employees and to be able to adapt to the organizational culture prevailing in the enterprise to which employees are recruited (Krejner-Nowecka, 2002). During interviews, candidates should be presented with a realistic description of the activities and terms of remuneration, which significantly

overcomes the discrepancy between expectations and actual obligations and working conditions. Subsequent recruiters should accordingly design a process of employee adaptation to the given data. The new employee, for the first months, should be supervised by the supervisor and, if possible, quickly implemented in the job duties. A very good idea consists of frequent job interviews among employees. The results of the analysis will allow for quick identification of sources of dissatisfaction and implementation of corrective actions (Trocki, 2011).

3. Benefits of outsourcing of human resources management processes

A big advantage of external companies is the opportunity to cooperate with consultants, external specialists, supported by huge experience through participation in many projects, often competing with the client. The client, therefore, introduces innovative and crucial solutions for specific goals and tasks. The company employing the contractor also benefits from the most modern communication infrastructure and technology that increases efficiency. The education technique through gaining knowledge during the process change involving group-based solving of challenges the organization has to face increases the organization's efficiency in the implementation of the tasks and objectives of the enterprise. Employee outsourcing also brings benefits in the form of increased employee capacity in a situation of quick adaptation to changes in the internal and external environment, and at the same time recognizing the role of joint problem solving (Krejner-Nowecka, 2002). Another benefit is the increase in the level of employee loyalty and the improvement of the quality and at the same time the effectiveness of the company's operation through the increase of employees' motivation. Internal employees of the organization are willing to engage in cooperation with external consultants. The basis for such involvement is the will to develop or sometimes the desire to pacify the "enemy" (Power et al., 2004). Modern outsourcing of processes, aimed at increasing the efficiency of the company's operations is the best solution for SMEs. Achieving a consensus between lowering costs and increasing HR effectiveness enables the employer to control the development of the company as well as the implementation of the organization's key tasks. Management based on outsourcing brings tangible results, however, only after some time, because the cooperation of the organization and the external company requires time to get acquainted with the specificity of the company's operations and to set out detailed expectations as well as requirements of both parties (Harland et al., 2005).

4. HR departments functions

The functions most often carried out by HR departments are usually outsourced to training. These are trainings in the field of supervising, perfecting the managerial staff, as well as conducting trainings in the field of occupational health and safety, training in the field of computer services, and testing the effectiveness of training programs. Another function is recruitment for positions, among others conducting job interviews, looking for new employees, verifying references and qualifications of candidates, placing job advertisements, employing temporary staff for physical work, introducing new employees to work. The next function is the calculation of remuneration under which the preparation of reviews, the valuation of jobs, and the creation of remuneration systems are carried out (Essinger et al., 2002).

Another important personnel related function is shaping the occupational safety and health conditions in the area of conducting and organizing training courses on occupational health and safety and preparing reports on health and safety tasks, managing the employee compensation system, preparing reports required by law. Another function is the service of employees posted to work abroad as well as foreigners' administrative service. Activities in the implementation of this area relate to the creation of specific procedures for the posting of workers abroad, the creation of systems and the handling of remuneration and bonuses for posted workers abroad. To decide on the implementation of outsourcing in the area of the personnel function, there are many determinants, as well as expectations from the company of the recipient and the client undertaking such activities (Power et al., 2004). These include mainly the reduction of fixed costs, the probability of creating new jobs due to the development of the enterprise, especially in the area of auxiliary functions, administrative functions, functions subject to repeated changes of legal regulations, fast and expansive development of the organization and the resulting problems with the continuous training of new employees as well as transformation of fixed personnel costs into variable. One of the many directions of the restructuring of the personal function has been the separation of specific personal tasks and entrusting their implementation to external companies. The process of separating certain areas of operation from the organization's structure is defined by the term outsourcing and is treated as a strategic restructuring undertaking, which in fact leads to depletion and flexibility of the company's organizational structure (client), which in turn means the reconstruction of activities company and focusing on key activities. Hence, the object of outsourcing is primarily the functions and tasks of the auxiliary activity of a given enterprise (Essinger et al., 2002).

5. Employees rotation

Managers frequently cannot cope with the decline in implementation quality of tasks and goals. Employees have more and more delays and do not keep the deadlines for executing orders. They must perform more duties from other positions and listen to complaints about a continuous decline in work efficiency. Managers also failed to perform their own duties because they fulfil goals and tasks in vacancies or are responsible for the recruitment process. They supervise the investing of company funds for marketing purposes, i.e. advertisements, recruitment agencies, etc. as

well as the implementation of new employees through training and implementation at the workplace, and after a few months they leave (Exact System, 2014). Taking away the company's "know-how". Managers usually do not understand the essence of the recruitment process and staff selection. They do not attach particular importance to creating the profile required from the candidate, employing someone who impressed them but without verifying the level of motivation or competence appropriately (Harrison et al., 1993). If they only have the opportunity to try to pass the largest possible amount of recruitment to the HR department, taking the responsibility out of themselves. A frequent phenomenon is also to downplay the process of implementing the employee in an appropriate position, without providing him with adequate support (Holweg, 2005) The most common problem of the managerial staff is the lack of ability to diagnose employee competences as well as employees who are already employed.

If they manage to observe deficiencies in some areas, they cannot develop the skills of both experienced and new employees and, above all, how to build their involvement. The managerial staff cannot lead the implementation process on their own. Managers should first of all diagnose the causes of problems related to employee rotation (Santosh et al., 2016). The manner in which the diagnosis will depend on the size of the problem as well as the characteristics of the functioning of the organization. The analysis may concern individual departments e.g.: anonymous survey in the department in which a large employee rotation was diagnosed or may concern the audit of the entire organization, among others, analysis of strategy, policy of implementing new employees, regulation regarding recruitment and selection, procedures related to the professional development of employees, and the examination of employee opinions and the periodic assessment system. In the event of analysis, we can create tools to deepen the diagnosis of the situation, among others, a competency test (Anderson, 1997) .Competence tests are tools that allow one to diagnose employee competences. They consist of short questions with the best or worst answer options in a specific situation. They allow diagnosing the level of competence of an employee. The next step should be the selection of remedial actions allowing to significantly reduce employee rotation in the enterprise and prevent such problems in the future. Solutions should always be based on the characteristics of the company and its specific situation (Santosh et al., 2016). Examples of remedial actions may include workshops, training for managers, as well as all types of interviews with employees and training programs at all levels of management, including career paths, on-line training, language courses for immigrants and communication with personnel. The essence of remedial procedures are also implemented, among others: management of absences (in the form of an electronic system, recording holidays and other absences) and establishing disciplinary actions in situations of undesirable employee behaviour (Babjak et al., 2012). Research conducted by CBOS shows that only 25% of Poles changed jobs in the last five years. A work position was more often changed by men and young and better educated people. The change of a work position mainly concerned people who were employed on a civil law contract or a fixed-term employment contract and work in the shadow zone. When analysing specific professions, the decision to leave the job was more often made by technicians and middle personnel and service employees. In turn, Central Statistical Office data indicate that the main reason for changing work positions among Poles is to take a better-paid job. Over 24% of respondents changed their job due to reasons beyond their control, and, therefore, as a result of termination of the contract by the employer. However, another 23% of Poles were forced to leave due to the termination of a fixed-term employment contract (Central Statistical Office, 2014).

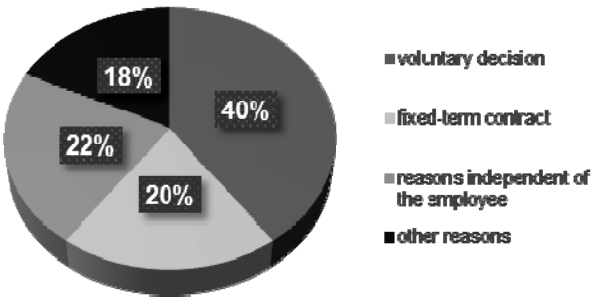

Fig. 1. Reasons for changing jobs by Poles (in %) (Central Statistical Office, 2014)

From the analysis of the causes of job changes of Poles (Figure 1) it is worth stressing that the highest percentage of employed Poles decides to leave their jobs voluntarily. Therefore, employers should pay more attention to better relations with employees in order to limit the employee fluctuation. An increasingly frequent tool is an interview with a quitting employee, the so-called exit interview (Fine et al., 1996). During such interviews, employers should find out what the main reasons for his/her resignation from the job were and what the employee was satisfied with, and what had a negative impact on his/her work comfort and whether he received sufficient support from his/her superiors and whether he/she would like to work in this enterprise in the future (Mueller, 2009). A very important aspect is also communicating and transferring in a transparent way the expectations of the company and offering opportunities for development / training and promotion. The research carried out by one of the outsourcing companies showed that most companies are satisfied with the service of outsourcing companies (Capgemini, 2008). Based on telephone interviews conducted by an outsourcing company on the number of 115 companies, it appears that the majority of customers do not intend to give up orders for outsourcing services, and some plan to expand their cooperation. The main benefits resulting from the services are: professional service, increase in the quality of products, reduction of costs, which is shown in the chart below.

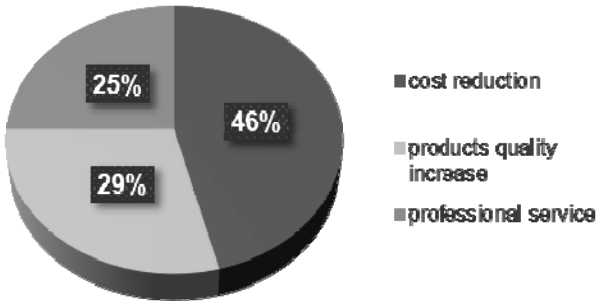

Fig. 2. Benefits from outsourcing services demonstrated by a survey on 115 companies (Exact System, 2014)

The analysis indicated that 94% of service providers are satisfied with the services provided by the outsourcing company. The most popular areas of outsourcing services are production / assembly and quality control. The study shows clearly that more than half of companies use services on a permanent basis, while ad hoc, if needed, it is used by 33% of companies from among 115 respondents, while the remaining 10% use it cyclically. Participants in the study responded that they plan to expand with outsourcing companies about 23%, while 10% said they want to reduce the number of services, and 67% do not want to change anything and continue to use existing services. It is estimated that production in the next three months in 50 percentages will remain at the same level, in 48% it will increase, while in 2% it will fall. In reference for employment it is estimated that 59% will remain at the same level of employment while 38% will increase and 3% will drop. It follows that outsourcing services will grow. What also suggests positive social and economic effects in the future (Exact System, 2014).

6. Summary

The optimization of enterprise processes is a very current topic. The probability that this development trend will end is low due to the innumerable benefits that result. Each company has a unique set of processes that are often neglected. The organizational role in the enterprise plays the foremost management role, often manifesting itself as a patchwork of decisions of former management boards. However, it should be emphasized that the organization's structure should be applied to processes, not vice versa. Therefore, the essence of the outsourcing companies' activity is the reduction of employee fluctuation, which is the key activity point. Outsourcing consists of entrusting specialist external companies (service-recipients) with the support of selected business processes and internal functions of the company, which are not crucial for its operations, but they support the core business. Hence, rotation of employees is an undesirable phenomenon creating additional costs. Entrusting service of selected processes to external companies, still in some of the Polish companies is considered unnecessary or likely to bring about the danger of access to confidential company data and unjustified expenditure. Personnel outsourcing, however, consists of renting employees from an external company that only performs the tasks entrusted by the client. Therefore, the contractor does not bear the costs of recruitment, employee dismissals or holidays. They pay only for services that are less interested in the client's strategic activity. So that outsourcing companies can prosper, managers in the first place should look at the recruitment process. When selecting candidates for the position, employers should pay more attention to the appropriate qualifications and competences of employees and be able to adapt to the culture of organization prevailing in the enterprise which they make recruitment for. During job interviews, they should provide candidates with a realistic description of the activities and terms of remuneration, which will significantly reduce the gap between expectations and actual obligations and conditions in future work. In the second place, they should properly design the process of employee adaptation for a given position. The new employee, for the first months, must be placed under the special care of his superiors and, if possible, quickly implemented in new duties. A very good idea is to conduct employee satisfaction surveys periodically. Getting to know employees' opinions will allow to quickly identify the source of dissatisfaction and implement corrective actions. A satisfied employee in the long run will bring numerous benefits to the company.

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轮换与外包公司人事服务有关的问题

關鍵詞
外包
人事管理
员工轮岗
工作成本

摘要
人事服务外包的主题是特定企业运营中的功能和辅助任务。它基于外包特定任务和整个人事流程，以及雇佣执行客户委托任务的员工。企业面临的主要问题是因缺勤，病假和假期造成的员工流失，因此，员工的延误越来越多，并且没有按时完成。因此，他们不得不从其他职位履行更多职责，并听取有关工作效率持续下降的抱怨。员工流动问题正在成为一种普遍存在的现象。因此，每家公司都应该分析这个问题。从确定问题开始，并因此采取适当措施防止员工过度波动。让员工发展和组织适当的工作条件也很重要，这将确保工作的舒适性和对雇主的依恋。

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Statistical control of the production process of rolled products

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Abstract
The article presents the results of the use of SPC tools, i.e. control charts and indicators of the qualitative capability to assess the stability and capability of the production process of rolled products - I-sections. Statistical analysis of the collected data regarding the selected feature of the analysed product - the width of the foot, and the normality of the distribution were done, which showed that the obtained distribution of measurement results is not a normal distribution. As a result, appropriate SPC procedures for non-normal distribution were used. The Pareto-Lorenzo diagram and FMEA method were also used to obtain information about the structure of non-conformities of the analysed product and the level of risk associated with them. This information was used to propose corrective actions and improve the production process of rolled products.

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1. Introduction

Each process requires inspection, supervision and control in order to ensure the highest quality of offered products or services. Statistical Process Control (SPC) is the most important set of tools used in quality assurance systems (Hryniewicz, 2000). The SPC covers various activities aimed at stabilising the production process and ensuring its capacity, which allows to standardise the quality of manufactured products and reduce their level of defectiveness (Greber, 2005). In the implementation of SPC, two phases can be distinguished: achieving and improving control (engineering phase), and maintaining control (operational phase) (Amaral, 2012). One of the basic tools of SPC are control charts (Fouad, Mukattash, 2010). The control charts enable constant supervision of the process and enable its on-line control thanks to the provision of information on its progress. Application of c.ch. allows to “early sight” when the given process starts to behave in a “non-standard” manner and, if needed, to react quickly (Ignaszak, Sika, 2012).

One of the most important goals pursued by a manufacturing company is the ability of the process to meet customer requirements (specifications) (Iwaniec, 2006). This ability can be assessed using another SPC tool - capabiity indicators (Cp, Cpk, Pp, Ppk) (Hamrol, 2017).

Each modern production plant that wants to improve the quality of its products, optimize production processes and minimize the costs of poor quality should implement a program of SPC of the production process. SPC is an effective and powerful methodology for analysing, monitoring, managing, and improving process performance (Uçurum, Çolak, Çınar, Dışpınar, 2016.). If the SPC is performed properly (understanding of the nature of the statistical stability), and the process is assumed to adequate qualitative capability, the risk of producing product incompatible - due to the controlled characteristic - it is kept to a minimum (Hamrol, 2017). It should be noted that in order for SPC's to show its full potential, it need to be properly implemented and applied, respecting certain principles and assumptions which ensure that SPC tools provide accurate information on the state of the process (Greber, 2009). As Deming claimed, "*the use and understanding of control cards (SPC tools) by management is more important than their use by linear workers*" (Wheeler, 2000).

The aim of the article is to present the results of the use of SPC tools: control charts and capability indicators to assess the stability and capacity of the production process of rolled products in a metallurgical enterprise. The SPC analysis was supported by the analysis of qualitative data on nonconformities in order to propose corrective actions and improve the rolling process.

2. Experimental

The examined object is a company from the metallurgical industry located in the Silesian Voivodeship in Poland (it is one of the branches of this company in Poland). The tests were carried out on the "Large Rolling Mill" (one of the departments) in relation to the production process of wide alloy sections, type HE 400, hot-rolled, which is one of the products in the range. The assortment of manufactured products is very wide, it consists of 15 different types of products, which will be available in different varieties, versions (from 4 to even 49 versions within a given assortment group). The tested product is a the I-section wide beam of HE 400 type. The basic dimensions, which required inspection (in accordance with PN-EN 10034:1996) are shown in Fig. 1.

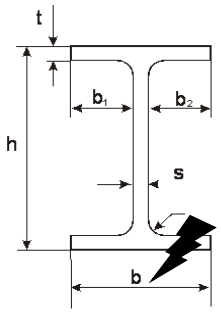

Fig. 1. The controlled dimensions of the I-section European wide beam, in accordance with PN-EN 10034:1996. Dimension *b* - width of the foot - the subject of the research

The dimension used in the SPC research was the width of the foot - "*b*". The "foot" was taken into account, which was shorter. The dimension was selected because of the differences depending on the place of the band from which the sample is taken. The width of the foot is also significantly influenced by the temperature factor, and therefore, along with the change in temperature, the dimension *b* also changes. For the other dimensions, except for the weight of the current meter of the band, the rolling temperature does not affect so much. Other factors also influence dimension *b*, such as incorrect adjustment of settings, hydraulic, mechanical or electrical malfunctions on the rolling stands or operator error.

The permissible dimensional deviations and deviations in shape and mass for hot-rolled parallel wall of I sections of structural steel with medium wide feet (I) and wide feet (H) are given in PN-EN 10034:1996. PN-EN 10034:1996 (Structural steel I and H sections - Tolerances on shape and dimensions). This standard requires that the target width for this type of I-beam section (variety A) should be 300 mm with a tolerance of ± 4,0 mm.

During sixteen hours of production of the analysed products (during two shifts of work), samples were taken from twenty bands, 4 samples from each band. Individual samples were taken as follows: 1 - beginning of the band, 2, 3 - middle of the band, 4 - end of the band.

3. Results and discussion

Firstly, the collected data on the width of profile rates (80 measurement results) were subjected to statistical analysis using basic statistical parameters such as: mean, range, standard deviation, coefficient of variation, skewness and kurtosis (Knop, Borkowski, Czaja, 2008). The results of the analysis are shown in Table 1.

Table 1. Basic statistical parameters of the foot width dataset

	Descriptive statistics							
Variable	Mean	Minimum	Maximum	Range	Standard deviation	Coefficient of variation	Skewness	Kurtosis
Foot width	300,3800	296,0000	303,8000	7,8	2,052240	0,683225	-0,216860	-1,06887

The analysis shows that the average width of the profiles' feet was 300.376 mm, with an average variation of the results of ± 2.05 mm, the minimum width is 296 mm, while the maximum is 303.8 mm, hence the range of results was 7.8 mm. 68% of the average value is a standard deviation. Negative skewness and its value indicate that the distribution of results is slightly asymmetrical on the left (the numbers focus on high values of features), negative value of kurtosis and its value means that the distribution is more flattened than normal.

A box plot of the median-quartile-range type was used to analyse the distribution of data by these statistics (Fig. 2).

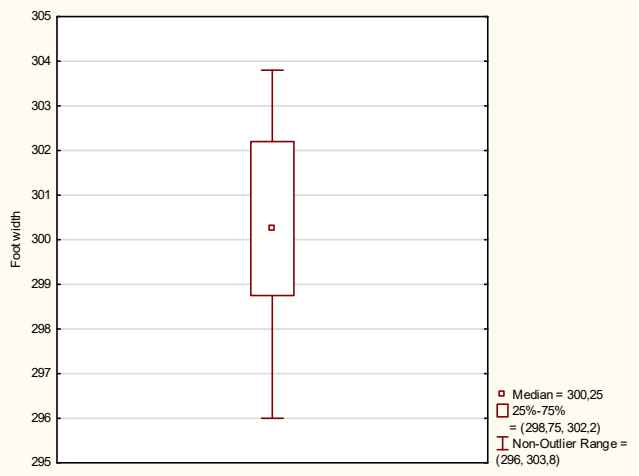

Fig. 2. Box plot of the widths of the foots.

The median is equal to 300.25, which means that the width of the feet in 50% of profiles is at most 300.25 mm. The bottom quartile is 298.75, which means that in 25% of profiles the width is at most 298.75 mm, while the upper quartile is 302.2, i.e. in 75% of profiles, the width is at most 302.2 mm. The shorter upper than lower whisker confirms the left-sided asymmetry of the entire data set, while the location of the median inside the box indicates the symmetry of the distribution of 50% of the middle results.

Next, the consistency of the collected data with the normal distribution was evaluated using the histogram shape analysis, statistical tests of Shapiro-Wilk and Lillifors as well as normality graph (Stanisz, 2007). The results of this analysis are shown in Figure 3.

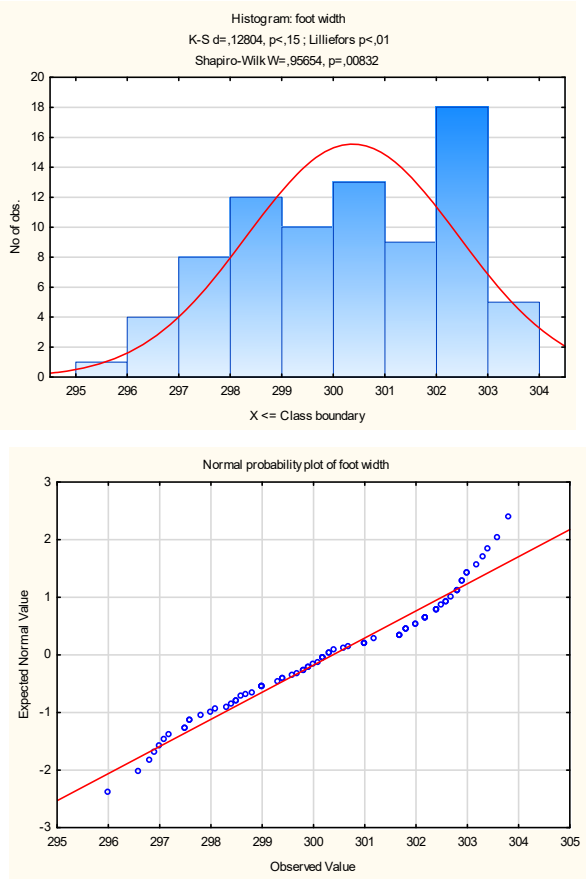

Fig. 3. Histogram with the results of statistical tests and a normality plot as a tool for assessing the conformity of the distribution with the normal distribution

The analysed characteristic does not have a distribution consistent with the normal distribution. This has been proven by all normality tests and normality graph. The characteristic has an asymmetric distribution - negative (left-sided), multimodal.

Due to the lack of conformity of the distribution with the normal distribution in order to assess the stability of the process, the $\bar{x}$ and R chart was used, in which control limits were calculated based on so-called Johnson curves, based on skewness and kurtosis (Montgomery, 2012). The results of the construction of the $\bar{x}$ and R chart are shown in Figure 4.

By analyzing the control card $\bar{x}$, you can see that the process is unstable. The results obtained from the first and sixth samples are outside the lower control limit. If in the case of the first sample this is normal (setting the profile after rebuilding), then in the case of the sixth sample it is the so-called "red light" for the employee and the process should be stopped at this point. Although there are no trends, the runs tests (Table 2) indicated 8 points outside the C zone (from 6 samples to 13). This test indicates that the samples taken are influenced by two different factors with a binomial distribution. This is a different, additional signal about the process deregulation. The process should be stopped in order to identify the causes of the disturbances and to take appropriate corrective actions. Analyzing the R chart it can be assumed that the process is stable from the point of view of variability. The results obtained from twenty consecutive samples are between the upper and lower control limits.

Table 2. Runs tests

A/B/C Zone: 3,000/2,000/1,000 *Sigma Runs tests	Foot widht; Runs tests X-Bar chart	
	from sample	to sample
9 points in Zone C or beyond (on one side of central line)	OK	OK
6 points in a row steadily increasing or decreasing	OK	OK
14 points in a row alternating up and down	OK	OK
2 out of 3 points in a row in Zone A or beyond	OK	OK
4 out of 5 points in a row in Zone B or beyond	OK	OK
15 points in a row in Zone C (above and below the center line)	OK	OK
8 points in a row in Zone B, A, or beyond, on either side of the center line (without points in Zone C)	6	13

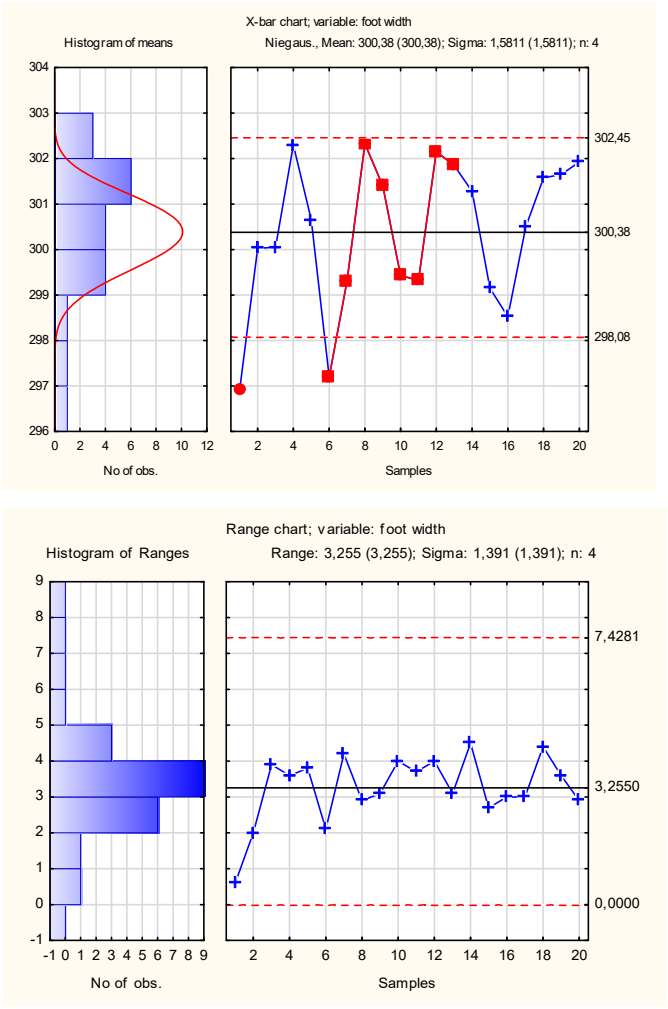

Fig. 4. The $\bar{x}$ and R chart for data regarding to the analysed characteristic - the width of the profile's feet

The EMWA chart was used to quickly detect small changes in averages and trends (to check whether there was a shift in the average process). This card is less sensitive to data that is not normally distributed (Sałaciński, 2009), which is its advantage in this particular case. The result of the application is shown in Figure 5.

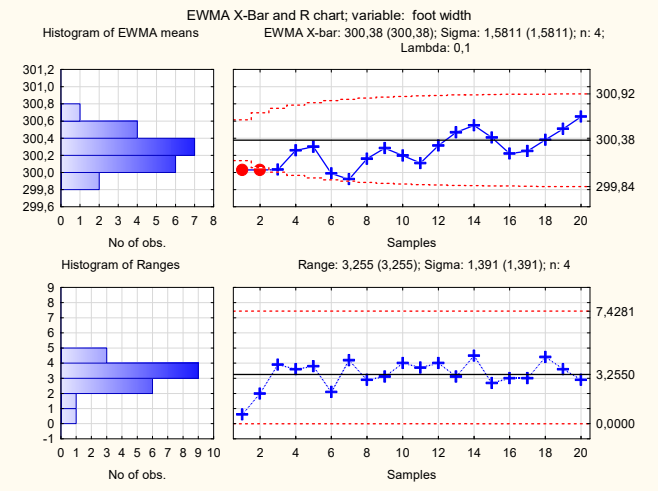

Fig. 5. The EWMA chart as a supplement to the $\bar{x}$-R card for data concerning the analysed characteristic - the width of the profile's feet

The chart showed two signals of deregulation (for samples 1 and 2). Subsequent samples show alternating upward and downward trends, as well as a shift of the average of the samples obtained towards higher values. This relationship can be seen even better if we construct the CUSUM chart (Figure 6) for individual observations (not samples). On the CUSUM chart, you can see a lot of different trends - the average takes values larger or smaller than the target, a large number of samples also goes beyond the control limits, which proves and confirms the fact that the process is unregulated.

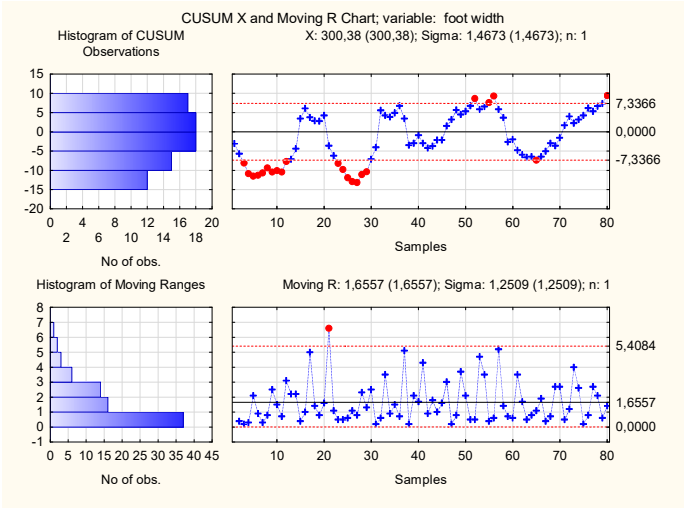

Fig. 6. The CUSUM chart together with a Moving Range chart for data regarding to the analysed characteristic - width of the profile's feet

In order to assess the process's ability to meet the requirements, Cp, Cpk capability indicators for non-normal distribution were used (Ryan, 2011). The results are shown in Figure 7.

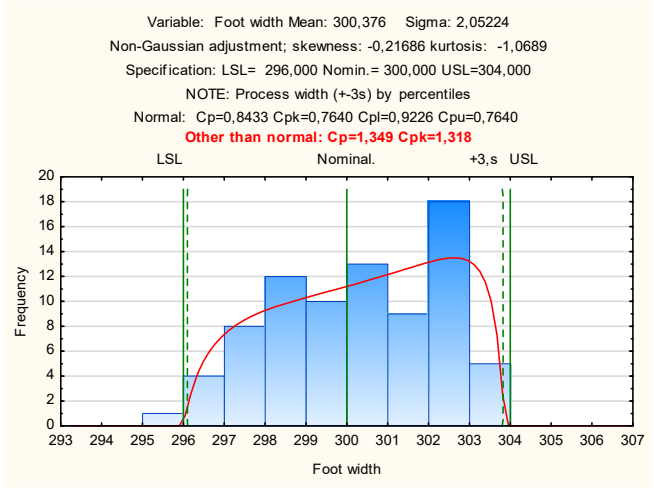

Fig. 7. Analysis of process capability for non-normal data distribution using Cp, Cpk indicators

While assessing the process using Cp, Cpk indicators, it can be concluded that the process has the ability to meet customer requirements, while the level of this ability should be considered relatively good. None of the individual observations went beyond the specification. More values of the width of the profiles are greater than or equal to the nominal value (55 out of 80, 68.75%). One should strive in the process to further reduce the dispersion of obtained values and to improve the process's centering.

The problem of the examined enterprise are nonconformities related to the analysed product. It was decided to analyse this problem using the Pareto-Lorenzo diagram and the FMEA method (Knop, 2017, Hamrol, 2018).

The Pareto-Lorenz diagram was used to analyse the structure of nonconformities occurring during rolling of sections during one year. 14 non-conformances resulted in the creation of 4726,3 tons of scrap. For each nonconformity the symbol was assigned and a ton was adopted as the unit of measure. For individual nonconformities, the percentage and cumulative share were calculated and the results are presented in the form of the Pareto-Lorenz diagram (Figure 8). On the X axis, the nonconformities in the descending order are marked, on the Y-axis on the left the number of defective products expressed in tons, and on the right-hand side the cumulative frequency of occurrences expressed in percent. The nonconformities analysed are: ŁP – Flakes and cracks steelmaking N – Non-rolling, F – Wavy finish, ND – Inadequate length, UM – Mechanical damage, K – Curves, Z – Cold shut, AŚ – Web asymmetry, PS – Foot gradient, RW – Separation, SW – Sprains, twist, NW – Not filling, PP – Longitudinal cracks, R – Abrasion marks.

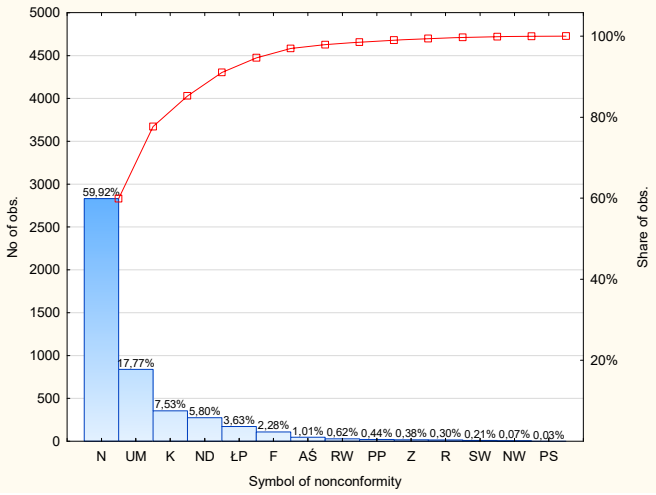

Fig. 8. Pareto-Lorenz (P-L) diagram to capture the structure of nonconformity in the rolling process.

Analyzing the P-L graph, it can be seen that two nonconformities are the cause of 77.7% of quality problems. These are non-rolling (N) and mechanical damage (UM). The remaining 12 nonconformities generate only 22.3% of qualitative problems. After the P-L analysis, it is known that the causes of non-rolling and mechanical damage should be searched for first and then eliminated or minimized.

Non-rolling is all the defects arising in the rolling process due to mechanical, electrical or technological reasons. They are continuously updated on the production report. In order to reduce their occurrences, it is necessary to increase the discipline of work and to ensure timely repairs.

Mechanical damage are nonconformities arising during the production process. They are detected most often during inspection at the finish section where such products are regenerated, reclassified or scrapped. Regeneration on a cold cut saw involves cutting out damaged pieces of material. Shorter lengths are then obtained, for which there are often no orders. If there is no customer for such a product within a certain time, it is scrapped. The view of mechanical damage is shown in Fig. 8. Mechanical damage also occurs frequently during material transport on grates, roller tables, trolleys or during material loading by an overhead crane. If the damage is small, it is difficult to detect it. This nonconformity is of great importance for the client. In order to improve the quality, it is necessary to introduce more frequent inspections of devices and to ensure timely re-pairs. The quality control staff should also be trained to improve the detection of this type of non-conformity.

The FMEA analysis was used to assess the degree of criticality of the nonconformities under investigation and to take corrective actions aimed at reducing the value of their risk. The result of the analysis is presented in Table 3.

The adopted criticality level (RPN = 120) was exceeded for 4 discrepancies: inadequate length, mechanical damage, cold shut and web asymmetry. For these nonconformities, corrective actions should be taken, which are, above all, employee training and repairs. These 4 nonconformities should be addressed first, but one should not forget about nonconformities that occur less frequently and are less important for the client.

Fig. 9. Mechanical damage of the foot.

Table 3. Simplified FMEA analysis

Type	Effects of nonconformity	Causes	O	D	S	RPN
ŁP	Defective product	Inadequate quality of the charge	5	3	7	**105**
SW	Defective product, regeneration	Improper setting of the rolling mill or straighteners	2	3	7	**42**
N	Scrap	Failures during the process	9	1	6	**54**
ND	Regeneration, scrap	Employee's incompetence	5	6	7	**210**
UM	Defective product, regeneration	Employee's incompetence, no repairs	6	4	7	**168**
K	Scrap, regeneration	Improper setting of the rolling mill or straighteners	7	2	7	**98**
Z	Scrap, regeneration	Improper setting of the rolling mill	4	5	8	**160**
AŚ	Defective product, regeneration	Bad fixture adjustment, no repairs	6	4	6	**144**
PS	Scrap, regeneration	Improper setting of the rolling mill or straighteners	2	6	7	**84**
RW	Scrap, regeneration	Inadequate quality of the charge	2	6	7	**84**
NW	Defective product, regeneration	Improper setting of the rolling mill	2	3	7	**42**
PP	Scrap, regeneration	Improper setting of the rolling mill, charge defect	2	2	9	**36**
F	Scrap, regeneration	Improper setting of the rolling mill	6	2	5	**60**
R	Regeneration	Bad fixture adjustment	7	3	5	**105**

4. Summary and conclusion

The evaluation of the I-section rolling process based on the stability and capacity analysis of this process, additional-

ly supported by the analysis of the nonconformity structure and their risk, allowed to obtain a lot of valuable information useful for managers in improving this process.

Process evaluation using control charts showed that it is not stable. However, only one dimension (width of the foot) was included in the SPC analysis. The results from the $\bar{x}$ chart are a warning signal for process managers, despite the fact that all values were within tolerance. As a result, the process showed a good qualitative capability, this capability was determined based on the procedure for a non-normal distribution, because the process did not behave according to this distribution (the distribution of results was oblique, clearly flattened and multimodal). The cause of such a disturbance shall be indicated.

By analyzing the structure of nonconformities, the basic quality problems, i.e. non-rolling and mechanical damage, were identified. Corrective actions have been proposed which mainly consist in a better policy of repairing machinery and increasing the number and quality of training provided.

Summing up, it should be emphasized that the company under study invests all the time and strives for full automation of the process, which improves the quality. However, most of the rolling mill machinery and equipment is still obsolete, which means that in order to maintain the appropriate quality level, the steel mill is forced to incur higher maintenance costs. Effective repairs and trainings (their quality and quantity) are a critical element requiring improvement, which will increase the quality and repeatability of the obtained results from the rolling process.

SPC tools are an invaluable source of information about the rolling process and its results, which can be used to improve the process. By analyzing the behavior of the process over time, knowledge about the predictability of the process was obtained. The results were not satisfactory. The process is unpredictable and can give managers a headache. It is much easier and faster (and often cheaper) to eliminate the source of disruption than to remove its effects. The goal of the managers of the rolling process should be to minimize sources of process variability, which will be resulted in process improvement and cost reduction. It is really difficult to control the stability of the rolling process. What counts the most is above all the experience and high involvement of workers at each working stand (ULEWICZ, 2003).

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轧制产品生产过程的统计控制

關鍵詞

SPC
轧制产品
稳定性分析
能力分析
定性分析

摘要

本文介绍了使用SPC工具的结果，即控制图和评估轧制产品生产过程稳定性和能力的定性能力指标剖面图。对所分析产品的所选特征的收集数据进行统计分析足的宽度和分布的正态性，这表明所获得的测量结果的分布不是正态分布。结果，使用了适当的非正态分布SPC程序。Pareto-Lorenzo 图和FMEA方法也用于获取有关分析产品的不合格结构和与之相关的风险水平的信息。该信息用于提出纠正措施并改进轧制产品的生产过程。

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A study on the Utilization of Lean techniques/tools in Indian SMEs

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Abstract
The Small and Medium Enterprises (SMEs) are the backbone of all the major economies around the world. Majority of these industries are facing tough environment for existence. The present study explored the most common and easily implementable Lean Tools/Techniques amongst the SMEs. This has been achieved via a detailed survey of SMEs in India. Study concludes with nine most common Lean Tools/Techniques implemented across the surveyed population of Indian SMEs.

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1. Introduction

SMEs focus on acquiring a high sales turnover with strategies that strongly emphasize increasing market share or entering new markets with current products. Small enterprises are constrained by capital, labor and limited resources to improve their technology. With a rapidly changing environment and successes, it is necessary to create certain "tools" for small enterprises with a limited budget. These tools should be implemented quickly and, most importantly, they should have a significant impact on the company at the time of implementation. There are more than a hundred common tools available and that there is no way to systematically undermine the production organization for its problems and possible tools to address these problems (Mathur et al., 2014). Bhasin and Burcher (2006) suggested that the company should implement all or most of the lean practices to succeed in the implementation of Lean. At the same time, the reviews show that SMEs cannot simultaneously implement all methods (Gunasekaran et al., 2000, Rose et al., 2011).

In India the enterprises other than Large are categorised as micro, small and medium enterprises and are addressed as MSME. However, these industries are addressed as SMEs in most of the countries and in research literature. Hence, the terminology used in this paper to address the enterprises under the study is SMEs.

2. Methodology

The present study on Lean tools/techniques used in Indian SMEs is a part of a survey based on the study which focused on the current status of Lean Implementation in the Indian small and medium enterprises (SMEs). The larger study has been conducted during and under the doctoral study by the authors amongst the SMEs in India.Owing to the size of questionnaire the sample size chosen was large.

A total of 149 feedbacks are received from Indian SMEs as a result of the survey conducted via internet and personal visits to the industries in central and west part of India.

The data collected is being analyzed using statistical methods.

3. Lean Tools

In order to simplify ensure effective implementation of Lean its fundamental concepts must be clear. Lean relies on several fundamental concepts:

- Customer focus – value is determined by the customer values.
- Eliminate waste – if anything does not add value then it is waste and must be eliminated.
- Smooth flow – level out any variations in process steps to achieve consistent flow of processes.

- Continuous improvement – continually find ways to make any type of improvements.

These principles are achieved using a set of tools focusing on any of these principles. The most commonly used tools (NSW Department of Education and Training, 2009) include:

Value Stream Mapping (VSM), 5S, Six Sigma, Kaizen (continuous improvement), Visual Workplace, Just in Time (JIT), and Poka-Yoke, or mistake proofing.

Rose et al. (2009) summed up the Lean practices suggested by various researchers as follows (Table 1).

Table 1. Lean Practices (Rose et al., 2009)

Research-er	Large organization			Small organisation	
	Mclahlin (1997) and Shah & Ward (2003)	**Bhasin 2006**	**White, 1999**	**Lee, 1997**	**White, 1999**
i	Set up time reduction	Set up time reduction	Set up time reduction	Set-up time reduction	Set up time reduction
ii	Kanban	Kanban	Kanban	Kanban	Kanban
iii	JIT/continuous flow production	Continuous improve-ment	Total Quality Control	Total Quality Control	Total Quality Control
iv	Small lot	Group technology	Group Technology	Small lot	Group technology
v	Total quality manage-ment	Process mapping exercise	JIT Purchasing	Multifunction Em-ployee	Multifunction Em-ployee
vi	Continuous improvement programs	Step change/ kaikaku	Multifunction Em-ployee	Group Technology	JIT purchasing
vii	TPM	5S and visual mana-gement	Quality Circles	JIT purchasing	Quality Circles
viii	Multifunction employee	Value and seven waste	Uniform workload	Uniform Workload	Uniform Workload
ix	Self-directed work teams	Supplier development	TPM	TPM	TPM
x	Focused factory	Supplier base reduc-tion	Focused Factory	Focused Factory	Focus factory
ix		TPM			

Pirraglia, A., Saloni, D., and Van Dyk, H. (2009) in a detailed study on the Status of Lean manufacturing implementation on secondary wood industries, have reported the results in the form of a figure (Figure 1). The researchers have found a high usage of 18 workplace organization (5S) technique as 73.3 percent respondents have validated its usage.

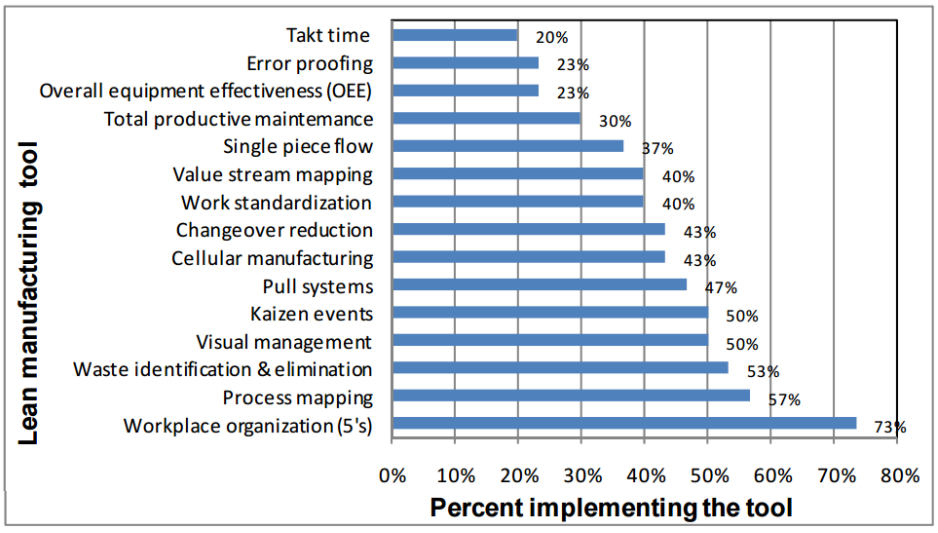

Fig. 1. Lean Manufacturing tools usage (Pirraglia et al., 2009)

Following are the definition or explanation of the key or the technical terms used in this thesis from a variety of Lean resources (Claire Biggs, 2009, Bicheno, 2000; Hines et al., 2004; Hines and Taylor, 2000; Womack and Jones, 2003; and Vorne Industries Limited at-

http://www.Leanproduction.com, 2011-16.)

5S - A simple tool to make a workplace suitable for Lean production and visual control. It consists of five steps. The name of each stage begins with S in Japanese, the place of its origination and the same have been translated into 5 words in English that also begin with letter S to maintain its essence.

- Seiri – Sort - eliminate that which is not needed.
- Seiton – Set in order – put the remaining items in sensible locations, and mark them.
- Seiso – Sweep and shine – cLean and inspect work area.
- Seiketsu – Schedule - create standards for above.
- Shitsuke – Stick to it - maintain the above system and arrangement.

5S Eliminates waste that results from a poorly organized work area (e.g. wasting time looking for a tool).

Cellular manufacturing – An arrangement of production floor where all the work centers required for manufacturing one family of products are arranged in order in one area or cell, enabling better flow of the processes, reducing travelling within the factory and making one-piece flow easier.

Gemba (The Real Place) – A philosophy that reminds us to move out of our offices and spend time on the plant floor – the place where real action occurs. It promotes a deep and thorough understanding of real-world manufacturing issues – by first-hand observation and by talking with plant floor employees.

Heijunka (levelling) – A form of production scheduling that purposely manufactures in much smaller batches by sequencing (mixing) product variants within the same process. It reduces lead times (since each product or variant is manufactured more frequently) and inventory (since batches are smaller).

Jidoka (Autonomation) – To design equipment to partially automate the manufacturing process (partial automation is typically much less expensive than full automation) and to automatically stop when defects are detected. After Jidoka, workers can frequently monitor multiple stations (reducing labor costs) and many quality issues can be detected immediately (improving quality).

JIT – Just in time – closely related to pull systems. Minimizing inventories and work-in-progress, synchronization of processes.

Kaikaku (sometimes known as Kaizen blitz) – Large "shake-up" changes such as a shift to visual control, changing to cellular manufacture, implementing one-piece flow.

Kaizen (Continuous Improvement) – by virtue of which many small improvements can collectively result in large benefits. Kaizen seeks ideas for improvements from people on the job, using their experience, knowledge, common sense and intuition to understand the process, identify the value-add and identify wastes.

Kanban – It is pull-system for components and subassemblies, setting maximum and minimum limits for the inventory, visually. A method of regulating the flow of goods both within the factory and with outside suppliers and customers. Based on automatic replenishment through signal cards that indicate when more goods are needed.

It eliminates waste from inventory and overproduction. It can eliminate the need for physical inventories (instead relying on signal cards to indicate when more goods need to be ordered).

Lean – A strategy for doing business efficiently, with the workforce involved in making improvements continuously, making exactly what the customer wants when they want (and not before), and minimizing waste of all kinds.

Muda – the Lean term for wastes. Anything in the manufacturing process that does not add value from the customer's perspective. The elimination of muda (waste) is the primary focus of Lean manufacturing.

Poka-yoke – "Mistake Proofing" or "Error Proofing" - designing tools etc. in such a way that mistakes are impossible to happen (e.g. making a jig so that it is impossible to put a part into it the wrong way around).

Pull / push – In a pull system, customer orders "Pull" work through the process, in a push system, work is "pushed" through in batches to build up stock, and is then held pending orders.

Rightsizing – Making equipment the right size for the flow of work, so that batch flow is not necessary.

Root cause analysis (five whys) – A problem solving methodology that focuses on resolving the underlying problem instead of applying quick fixes that only treat immediate symptoms of the problem. Go for gemba (wherever the problem is occurring) and a common approach is to ask why five times, each time moving a step closer to discovering the true underlying problem..

Single piece flow – Products are made one by one instead of in batches. Reduces inventories, reworking and scrap (because mistakes are caught after only a few products have been made wrongly rather than a whole batch), handling, errors in identification.

Six Sigma – Under this tool statistical analysis is availed to find ways to improve process capability.

SMED (Single-minute exchange of dies) – Reduce setup (changeover) time to less than 10 minutes. Techniques include:

- Make setup steps to be external (performed while the process is running).
- Easy internal setup (e.g. replace bolts with knobs and levers).
- Eliminate non-essential operations.
- Create Standardized Work instructions.

Smoothing – Planning production levels so that there is the same amount of work every day and everyone is always busy but all orders leave on time.

Takt time – The pace of production (e.g. manufacturing one piece every 34 seconds) that aligns production with customer demand. It is calculated as Planned Production Time / number of products demanded by Customer Demand. It provides a simple, consistent and intuitive method of pacing production. Is easily extended to provide an efficiency goal for the plant floor (Actual Pieces / Target Pieces).

TPM (Total Productive Maintenance) – Planned maintenance schedules are devised to keep all equipment running at 100% of the time. It's a holistic approach to maintenance that focuses on proactive and preventative maintenance to maximize the operational time of equipment. TPM blurs the distinction between maintenance and production by placing a strong emphasis on empowering operators to help to maintain their equipment.

Turn-back analysis – Analysis of how often work is turned back to an earlier stage of the process for reworking.

Value stream mapping – Value Stream Mapping (VSM), where value (what is valued by the customer) is identified throughout a process and non-value (waste) can be reduced. Identifying families of products, then for each fami-

ly identifying each step in their manufacturing process and highlighting which steps are not adding value and thus constituting a muda in one of the categories.

Visual control – All controls and measures (eg. flow of work, order progress, stock levels, call for replenishment of stock) are done visually, using control boards (including Andon boards), coloured cards and markers, kanban/two-bin etc.

Visual Factory – Visual indicators, displays and controls used throughout manufacturing plants to improve communication of information. This makes the state and condition of manufacturing processes easily accessible and very clear– to everyone. These may be figures, painted lines, signs, signals or shadow boards to indicate where things should be stored, diagrams showing correct procedures, real time displays of productivity data, visual systems for scheduling and progressing work flow.

Based on the literature review and ease of implementation following tools have been included in the survey questionnaire prepared by the research scholar of this study:

- Value Stream Mapping (VSM),
- Kaizen,
- Work Standardization,
- Six Sigma,
- Error Proofing (Poka Yoke),
- Workplace Organisation (5S),
- Visual management,
- Kanban (Pull),
- SMED,
- Process Mapping.

The application of tools or techniques requires understanding and expertise in the area of its application. As the present study is focused on SMEs, a thorough understanding of the definition, scope, importance, impact of SMEs on industry and economy need to be addressed.

3.1. Lean Tools suitable for SMEs

A number of Lean tools have been developed by researchers and implementers in last three to four decades. Having automobiles as the source of these initiations, many of the tools are mass production specific. In order to make Lean implementation a success story with the SMEs, the tools specific to mass production and which are resource hungry need to be identified. And the tools which are generic in application nature and do not demand investment to implement them need to be precipitated for SMEs.

Upadhye et al. have suggested certain set of tools suitable for implementation in SMEs (Table 2). They have presented a case to demonstrate the improvements achieved in an Indian medium size auto component's manufacturing unit after the implementation of Lean manufacturing system (LMS).

Rose et al. (2011) have also suggested a set of tools suitable for SMEs. The proposed practices were based on three categories: least investment, feasible to apply in SME and recommended by researchers. There are seventeen Lean practices which could be considered are feasible and relevant to the MSME characteristics (Table 3).

Table 2. Lean Manufacturing Tools suitable for SME **(**Upadhye et al., 2010)

Sr. No.	Attributes	Lean tools/techniques to Identify, Measure & Eliminate waste
1	**Shop Floor**	
	a. Availability of drawings, Jigs/Fixtures and Measuring instruments.	5S, Shop Layout, House-Keeping
	b. Change over time	Ishikawa diagram, SMED, Standardized parts
	c. Lead time of product, cycle time of the processes	5 Why, Planning and scheduling-, Cells and cellular layout, Continuous Flow, Elimination of Seven Wastes
	d. Quality/rejection level	Six sigma, Quality Tools, Process charts, SPC, SQC Jidoka, Poka Yoke (Mistake Proofing), Elimination of Seven Wastes
	e. Breakdown maintenance	5 Why Preventive Maintenance
	f. Employee involvement	Kaizen, suggestion schemes, Quality circles
2	**Inventory**	
	a. Stores inventory management	ABC Analysis, 5S
	b. WEEP	One-piece flow, shorter lot sizes
	c. Finished goods {Ancillaries only}	Make to order
	d. Returned/Rejected components	Elimination of Seven Wastes
	e. Material Yield	Value analysis
3	**Man Power**	
	a. Poor morale	Empowerment & Training
	b. Incapability, Inefficiency	Training, Problem solving approach
	c. Low reliability	Job satisfaction, Job assurance, and Incentive scheme and merit rating

Matt & Rauch (2013) have deduced a selection of suitable/recommendable methods for small enterprises. Their paper analysis is aimed at small enterprises in Italy. These are following:

1. First-in-first-out (FIFO).
2. 5S (Seiri, Seiton, Seiso, Seiketsu, Shitsuke).
3. Benchmarking.
4. Kaizen - Continuous Improvement meetings.
5. Just in Time delivery.
6. Pull-principle and Kanban.
7. Visual Management in Production.
8. Zero Defect through process-integrated failure control.
9. Idea Management to utilize the worker's Know-How.
10. Setup Time Reduction to reduce waste.
11. Value Stream Mapping.
12. Efficient and ergonomic work stations.
13. Poka Yoke and standardisation in product and process.
14. Cellular Manufacturing and autonomous teams.
15. Job rotation to avoid monotonny.

16. Low Cost Automation ("keep it smart and simple").

Table 3. The list of selected practices for SME Implementation by Rose et al. (2011)

Criteria Practices	Less investment	Feasible to implement	Recommended to SME
Set up time reduction	Y	Y	X
Visual control	Y	Y	X
Cell layout	Y	Y	X
Standard operation	Y	Y	X
Kanban	Y	Y	X
Continuous flow	Y	Y	X
Uniform workload	Y	Y	X
Small lot size	Y	Y	X
TQM/TQC	Y	Y	X
Continuous improvement	Y	Y	X
5S	Y	Y	X
Quality circle	Y	Y	X
Multifunction employee	Y	Y	X
Training	Y	Y	X
Teamwork	Y	Y	X
Supplier management	Y	Y	X
Preventive maintenance	Y	Y	X

Various Lean tools which have been found useful for MSMEs as per the literature review are made a part of the question related to the Lean tools used. These tools are: Value Stream Mapping, Kaizen, Work Standardization, Six Sigma, Error Proofing, Workplace Organisation (5S), Visual Management, Kanban, SMED, Process Mapping and an option is kept open for the respondent to mention any tool vital to implementation according to them. Following is the analysis of the responses.

4. Results and discussion: Utilization of Lean techniques/tools

Following given Figure 2 presents the survey feedback on the various Lean Techniques used during the implementation of Lean.

The figure 2 shows that the percent of responses from Medium, Small or Micro category of industries utilizing various Lean tools.

VSM – 69% of the Medium enterprises, 65% of the Small enterprises and 50 % Micro industries are using VSM as an important Lean Tool.

Kaizen – 88% of the Medium sized enterprises, 100% of the Small enterprises and 100% of the Micro enterprises are using Kaizen tool under Lean Implementation.

Work Standardization - 88% of the Medium sized enterprises, 92% of the Small enterprises and 100% of the Micro enterprises mentioned that they are using Work Standardization.

Six Sigma – Responses on the usage of this Lean tool were 13% by the Medium enterprises, 2% by the Small enterprises and 0% by the Micro industries. This means tools requiring special training on a tool were applied least.

Error Proofing – This tool found acceptance in 88% of Medium enterprises, 95% of Small enterprises and 50 % of Micro enterprises. Work Place Organisation or 5S is being utilized by 88% Medium, 100% Small and 50% Micro industries.

Visual Management – This tool found high acceptance levels among all the three categories of enterprises. 88% of the Medium sized enterprises, 91% of the Small enterprise and 100% of the Micro enterprises mentioned that they are using Visual Management techniques to improve their productivity.

Kanban – The tool to ease out material replenishment was adopted by 56% of Medium-sized enterprises, 39% of Small enterprises and 100% of the Micro enterprises.

SMED – This Lean tool developed by Shigeo Shingo which strives for Single digit Minute Exchange of Die is being used by 69% of Medium enterprises, 93% of Small enterprises and 50 % of Micro enterprises.

Process mapping – Process mapping is used by 69% of Medium enterprises, 56% of Small enterprises and 100 % of Micro enterprises.

Other – 38% of the Medium enterprises, 18% of the Small enterprises and 0% Micro industries mentioned other Lean tool being used in their Lean implementation.

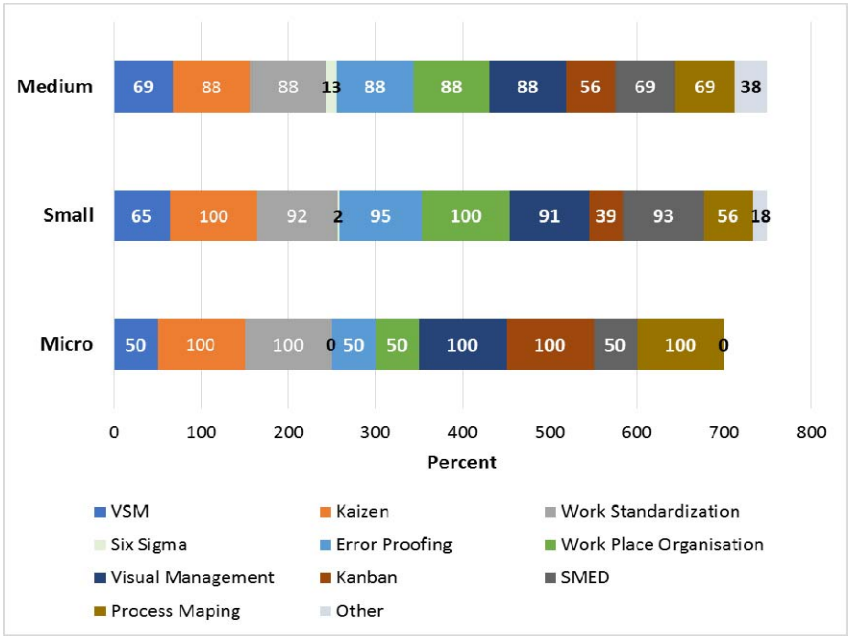

Fig. 2. Lean Tool Utilization in SMEs

Table 3 categorizes the Lean techniques/tools as per their utilization in SMEs. The Lean techniques/tools most popular and being utilized highest has been placed on the top as rank 1. The table also shows the overall utilization of the Lean tools. The Lean tools making deep roots in the Indian

MSMEs are Kaizen (98.7%), Work place organization (98%), Error Proofing (94%), Work Standardization (1.3%), Visual Management (90.6%) and SMED (89.9%). Other techniques doing fairly well are Value Stream Mapping (65.1%) and Process Mapping (57.7%). Kanban fared with 41.6% utilization. Utilization of Six Sigma (3.4%) is a surprising outcome.

Table 3. Ranking of the Lean techniques/tools as per their utilization in SME (Source: Analysis of survey data by Authors)

Factors Enterprise	Micro	Small	Medium	Overall
Kaizen	100	100.0	87.5	**98.7%**
Work Place Organisation	50	100.0	87.5	**98.0%**
Error Proofing	50	95.4	87.5	**94.0%**
Work Standardization	100	91.6	87.5	**91.3%**
Visual Management	100	90.8	87.5	**90.6%**
SMED	50	93.1	68.8	**89.9%**
VSM	50	64.9	68.8	**65.1%**
Process Mapping	100	55.7	68.8	**57.7%**
Kanban	100	38.9	56.3	**41.6%**
Other	0	17.6	37.5	**19.5%**
Six Sigma	0	2.3	12.5	**3.4%**

5. Summary and conclusion

As per the discussion in section 3 the importance of Lean tools and techniques like *Value stream mapping, Kaizen, Work standardization, Error-proofing, Workplace organization (5S), Visual management, and SMED* are same among ***micro, small and medium*** category of industries.

This means that these Lean tools have similar acceptability and utilization among ***micro, small and medium*** category of industries. That is these tools are common to all the MSMEs.

The importance of Lean tools and techniques like *Process mapping*, *Kanban and Other* have significant difference among micro, small and medium category of industries.

The study evolves with a very specific and small set of tools and techniques to implement Lean. These are common to most of the SMEs. The conclusion is very useful towards initiation of Lean in SMEs. The set of these tools and techniques is small and thus does not demand huge investment, hence is very pertinent to convince SMEs to adopt Lean Implementation.

The present study being spread over a large sample and variety of industries, is generic in nature. And so are the results. The future studies may also be done on specific sector of industries to churn out more specific results.

Future studies may also aim at the investment required towards the training and installation of these techniques.

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关于利用中小企业精益技术/工具的研究

關鍵詞
精益技术/工具
精益实施
中小企业（SMEs）

摘要
中小企业（SMEs）是世界上所有主要经济体的支柱。这些行业中的大多数都面临着艰难的生存环境。本研究探讨了中小企业中最常见且易于实施的精益工具/技术。
这是通过对印度中小企业的详细调查实现的。
研究总结了印度中小企业调查人群中实施的九种最常见的精益工具/技术。

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Comparative Analysis of the Level of Satisfaction with the Services Received at the Business Incubators in USA and Poland – pre-incubation and incubation stage

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Abstract
The paper concentrate on the problems of customers satisfaction from services in incubator centres in USA and Poland. The aim of the paper is to analyse the level of satisfaction of Business Incubation Centre on the example of two incubator centres one from USA (Hazelton CAN-Be in Pennsylvania and second in Gliwice Poland). The analysis was conducted in pre-incubation and incubation stage. The analysis was conducted on example of survey analysis in both incubator centres. On the base of achieved results we assessed the priority of customers in each incubator centre.

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JEL: L23, M11

1. Introduction

The world network of the business incubator centers was created for stimulating economic growth in underdeveloped regions. Companies in the business incubator centers receive services which assist in developing successful business ventures. Every new business is entitled to those services. Some of those services are free-of-charge, but a majority of them are offered at below market cost. Assessment of the clients' perspective on the importance of those services as well as clients' satisfaction with those services is needed from the continuous quality improvement perspective.

The aim of the paper is to analyze the level of satisfaction of Business Incubation Centre on the example of two incubator centers one from USA (Hazelton CAN-Be in Pennsylvania and second in Gliwice Poland). The analysis was conducted in pre-incubation and incubation stage.

The concept and practice of business incubation was established in the advanced countries about 50 years ago. The inventor of nowadays innovation concept J. Schumpeter, who first emphasis on the importance of innovation within the economic cycles, considered entrepreneurship with a specific emphasis on innovation. In his view, innovation deals with (Wolniak, 2014; Wolniak, 2017; Wolniak et al., 2018; Wolniak et al., 2014; Wolniak et al., 2017; Olkiewicz et. al., 2017):

- new products,
- new production methods,
- new markets,
- new form of organization.

Successful innovation is a marriage of innovation and commercialization. It requires the cooperation between universities, government and private industry. These three partners work in different reward systems and often have different interests and expectations. Business incubator centers are the common grounds between research economy and commercial economy. The purpose of a business incubator center is to nurture new startup companies by surrounding them with an innovation ecosystem. Every new business is given the opportunity to become associated with a business incubator center. Business incubator centers supply many_critical services to start-up companies. Some of the services are free of charge, but most of them are offered at a discounted rate. Business incubator centers provide new companies with an environment supporting the culture of innovation and celebrating research and creativity (Nadzeya et al., 2018; Dvoulety, 2018; Apa, 2017; Ingram, et al., 2010).

The incubation is a process which tends to be activated whenever there is a strong need to support entrepreneurs in developing their own business (Allahar et al., 2016; Al-Mubaraki et al., 2012; Calza et al., 2014; Dublin et al., 2005; Monsson et al., 2016). The process, or parts of it, is put in place whenever there is a need of nurturing would-be entrepreneurs to think over and further develop the business idea and transforming it into a viable and sustainable activity (Al-Mubaraki et al., 2015; Caiazza, 2014; Lose et al., 2015; Siemieniuk, 2015).

There are three stages of incubation:

- pre-incubation,
- incubation,
- post-incubation.

According to European Commission definition an incubator is a place where the incubation activities are carried out, and where the would-be entrepreneurs can find suitable place, in terms of facilities and expertise, to address their needs and develop business ideas to transform them into sustainable realities (Chiara, 2014; Davies, 2009; Xavier et. al., 2008).

An incubator may still be an incubator even if it doesn't provide physical incubation services, and concentrate on virtual incubation. Virtual incubation in that case applies to "incubators without walls" and to e-platforms of online services deployed by incubators with physical premises (The smat guide, 2010).

Very impotent term in the case of business incubators are innovation-base incubators. In this case the entrepreneur can be seen as the agent of change who's scope is to develop innovation process within the organization. He should create value from an innovative idea in a context of change and uncertainty and the market is the trigger for it to happen. Innovation-based incubators work in the intersection between the sets of innovation and entrepreneurship supporting entrepreneurs to profit from added value of innovative ideas. Innovation-based incubators support innovative business projects which could be either technologically-oriented or non-technologically oriented.

Technology incubators is a variant of more traditional business incubation schemes, assist technology-oriented entrepreneurs in the start-up and early development stage of their firms by providing workspace (on preferential and flexible terms), shared facilities and a range of business support services.

The advantages of the business incubator are wide and wearied. The incubators have big impact on business and local communities. We can use various indicators to measure the functionality and impact of particular incubators. Those indicator can include the following (Grebski, 2018):

- business creation and survival,
- business growth and markets served,
- businesses created by minority or low-income individuals,
- cluster development,
- environmental footprint,
- financial performance,
- markets development for products and services,
- investment in client companies,
- jobs created and safeguarded,
- local economic diversification,
- regional regeneration and social inclusion,
- tax and national insurance contributions.

2. Methodology of Assessment and Data Collection

To determine the level of satisfaction of client companies with services provided to them by the business incubator center, the same survey was conducted at CAN-BE in Hazleton and TECHNOPARK Gliwice. Two identical sets of surveys (and cover letters) were prepared. An English version of the survey was used for clients of CAN-BE in Hazleton. A Polish version of the survey was used for clients of the business incubator center at TECHNOPARK in Gliwice. The surveys were administered between October 15, 2016 and April 15, 2017. There were twelve companies during the incubation stage at both business incubator centers. The return rate was higher in Hazleton with twelve surveys returned compared to six surveys returned at TECHNOPARK. At the same time, surveys were also administered to faculty, students and volunteers providing services to the business incubator centers. The return rate of those surveys was sixteen surveys received from CAN-BE and twelve surveys from TECHNOPARK. After a statistical analysis of the technical data, the results are shown in Tables 1a, 1b, 1c, 1d and 2. During the statistical analysis, the following values were calculated and recorded:

- N-sample size,
- mean value,
- significance (sign): 2-tailed sign,
- T-test for equality of means.

For a majority of the data, the significance was within .05 (chance of error less than 5%). Only one set of data had a significance of .258 (chance of error 25.8%). This was due, however, to the relatively small sample. However, for comparing two business incubator centers, 25.8% error seems to be acceptable.

3. Limitations and problems using QFD method

Table 1 reflects the satisfaction with help received by the company at the beginning (pre-incubation stage). The graphical comparison of the client satisfaction for the pre-incubation stage is shown in Fig. 1.

An assessment of the client satisfaction received at the pre-incubation stage (evaluation of the innovation concept, engineering analysis, etc.) indicates a higher level of satisfaction at CAN-BE (9.0% - 9.5%) than TECHNOPARK (6.5% - 7.15%). It seems that the companies at both business incubator centers are very satisfied with the assistance received at the pre-incubation stage. Both incubators, TECHNOPARK and CAN-BE, have a relatively large number of walk-in clients. (90 clients at CAN-BE and 100 clients at TECHNOPARK). Those walk-in clients receive help in the evaluation of the invention and business idea.

Table 1. Assessment of support received from the business incubator center in the beginning (before incubation) stage

(CAN-BE – upper number; TECHNOPARK – lower number)
Scale 0-10; 1 = No Support; 10 = Exceptional Support

Type of Support	N (Sample Size)	Mean Value	Significance (2-Tailed)	T-Test for Equality of Means
Help in evaluation of innovation concept.	12 6	9.50 7.16	0.159 0.169	2.26 1.59
Help in engineering analysis and designing of the details of the invention.	12 6	9.00 6.50	0.122 0.122	2.43 1.81

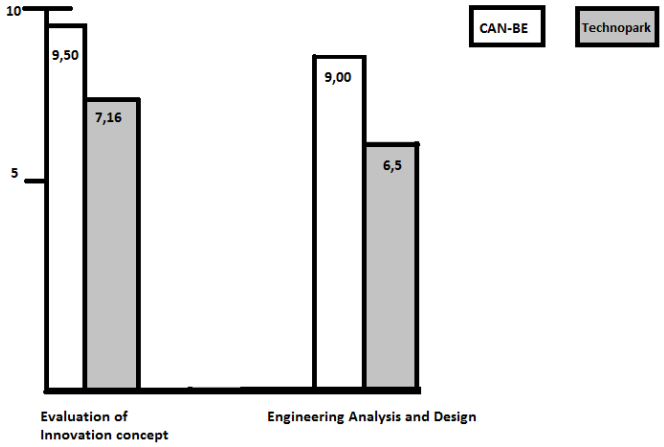

Fig. 1. Assessment of support received from business incubator center in beginning (before incubation) stage

A high percentage of those clients receive further assistance in the development of a business plan or business model as well as introductory engineering analysis and design (50 clients at CAN-BE and 35 clients at TECHNOPARK). TECHNOPARK expects the clients to prepare a draft of the business plan before they start receiving assistance from TECHNOPARK.

This policy of expecting the clients to do extensive "homework" before asking for help is effective and increases the retention rate during the incubation stage. (The retention rate is 66% at CAN-BE and 91.7% at TECHNOPARK.) The clients seem to be very satisfied with the evaluation of the innovation concept. (The level of satisfaction is 95% at CAN-BE compared to 71.6% at TECNOPARK.) The level of satisfaction in introductory engineering analysis and design is also high. (CAN-BE has a 90% level of satisfaction as compared to 65% at TECHNOPARK.) The level of satisfaction at the pre-incubation stage is relatively high at both incubators. (It is slightly higher at CAN-BE.).

Table 2 reflects the satisfaction with help received by the company at the incubation stage.

Table 2. Assessment of support received from business incubator center during incubation stage

(CAN-BE – upper number; TECHNOPARK – lower number)
Scale 0-10; 0 = No Support; 10 = Exceptional Support

Type of Support	N (Sample Size)	Mean Value	Signfi-cance (2-Tailed)	T-Test for Equality of Means
Office space/ secretarial support.	12 6	5.50 6.33	0.158 0.258	1.17 1.08
Manufacturing space/ warehouse.	12 6	5.00 1.66	0.023 0.023	3.35 2.88
Consulting service from volunteers.	12 6	7.50 1.33	0.001 0.001	6.95 6.39
Consulting services from faculty and students.	12 6	9.00 1.66	0.001 0.001	8.35 6.60
Help from students cooperating with the company in the form of capstone design projects.	12 6	8.75 1.66	0.001 0.001	7.89 6.33
Assistance from personal of the business incubator center.	12 6	5.00 3.33	0.159 0.159	1.47 1.37
Legal assistance in protecting intellectual property (patent).	12 6	7.00 0.00	0.000 0.000	8.44 12.12
Assistance in creating internet website for the company.	12 6	8.00 0.00	0.000 0.000	9.87 14.18
Legal assistance in establishing and registering the corporation.	12 6	8.50 0.00	0.000 0.000	15.60 22.40
Legal assistance in accounting and filling income tax.	12 6	8.75 0.00	0.000 0.000	15.55 22.34
Assistance in marketing of the product.	12 6	7.75 2.16	0.008 0.008	4.68 3.80
Legal assistance in securing tax-free status during the incubation stage.	12 6	9.00 2.22	0.002 0.002	7.02 5.45
Assistance in professional development and training.	12 6	6.50 0.00	0.000 0.000	8.79 12.62
Legal help in obtaining financial subsidies for creating new jobs.	12 6	5.00 0.00	0.000 0.000	5.89 8.47

The graphical comparison of the assessment data which represents satisfaction of companies during the incubation stage is shown in Fig. 2. This refers to the services received from the business incubator.

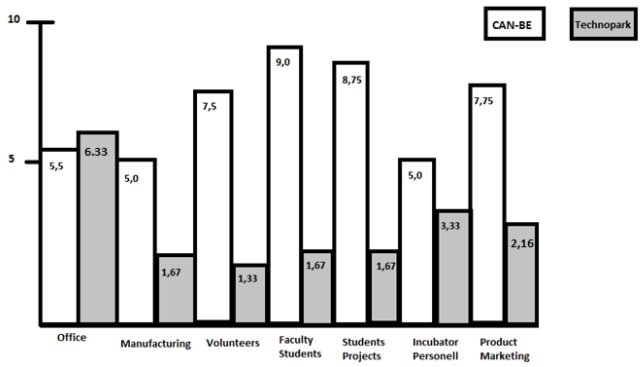

Fig. 2. Assessment of support received from business incubator center during incubation stage

By comparing the level of client satisfaction with the services received during the incubation stage, the discrepancy between CAN-BE and TECHNOPARK is much larger. This is because the business incubator at TECHNOPARK does not provide some of the services available at CAN-BE. The business incubator center at TECHNOPARK does not provide any services in the following areas:

- assistance in creating internet websites for the companies,
- legal assistance in establishing or registering a corporation,
- legal assistance in accounting and filing taxes,
- legal assistance in obtaining financial subsidies for creating new jobs,
- (There is a very limited subsidy for creating new jobs in Poland.)
- legal assistance in securing tax-free status during the incubation stage, and
- (There is no tax-free status for start-up companies during the incubation stage in Poland.)
- legal assistance in protecting intellectual property.

The assessment numbers in those areas would be "0" for TECHNOPARK and no comparison should be made in those specific areas between CAN-BE and TECHNOPARK. The rating of the quality of office space and secretarial support is higher at TECHNOPARK (5.67%) compared to CAN-BE (5.5%). By comparing the quality of manufacturing/warehouse space, there is a discrepancy in favor of CAN-BE, that is CAN-BE (5) and TECHNOPARK (1.67). This discrepancy is due, however, to the nature of the client companies. Most of the companies in TECHNOPARK are not involved in manufacturing yet. Client companies at CAN-BE utilize manufacturing and warehouse space to a greater extent. Consulting services provided by volunteers, faculty and students as well as assistance from students doing capstone design projects for client companies is being rated higher at CAN-BE compared to TECHNOPARK. The main reason is the larger network of volunteers at CAN-BE to provide a wider range of services. The entrepreneurial team building projects involving students from different majors in providing services to the client companies probably makes the biggest impact on the client satisfaction.

4. Summary and conclusion

Business incubator centers, CAN-BE in Hazleton, PA (USA) and TECHNOPARK in Gliwice, Poland. Provide a wide variety of services to client companies in the pre-incubation, incubation and post-incubation stages. Clients are generally satisfied with the service that they receive from the business incubators. Some services are not offered at both incubators to the same extent. That created some discrepancy in the assessment results.

Summary of suggestions proposed by client companies related to the improvement of the quality of services provided by the business incubator centers are as follow.

The clients at CAN-BE assigned the highest priority to the following:

- to increase the number of students and faculty providing services to the companies,
- to increase the financial benefits for creating new jobs,
- to increase legal help in protecting intellectual property,
- to increase the number of volunteers and
- to increase engineering assistance.

The client companies at the business incubator center at TECHNOPARK assigned the highest priority to the following:

- to incorporate tax-free status for new companies,
- to increase financial benefits for creating new jobs,
- to increase help in business management and accounting,
- to increase engineering help and
- to improve legal assistance (intellectual property, taxes, etc.).

The clients at the CAN-BE business incubator center already receive extensive help from volunteers as well as Penn State faculty and students. However, the highest priority is still assigned to further increase those services.

The client companies at TECHNOPARK business incubator center receives very limited help from volunteers, faculty and students. At the same time, they assigned a low priority to those resources. The reason for that may be the lack of exposure and lack of understanding of those extremely valuable services. (If you never had something, you do not miss it.)

Companies at TECHNOPARK assigned the highest priority to tax free status as well as financial benefits for creating new jobs. Companies in Pennsylvania like CAN-BE already have that advantage. The engineering and legal assistance in protecting intellectual property is a high priority to companies in Hazleton and Gliwice.

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对美国和波兰企业孵化器收到的服务满意度的比较分析 – 孵化前和孵化阶段

關鍵詞
客户满意度
孵化中心
创新
孵化阶段
每个孵化阶段

摘要
本文重点关注美国和波兰孵化中心服务对客户满意度的问题。
本文的目的是分析企业孵化中心对两个孵化中心（来自宾夕法尼亚州的HazeltonCAN-Be和波兰格利维采的第二个孵化中心）的满意度。 分析在预孵育和孵育阶段进行。该分析是在两个孵化中心的调查分析实例中进行的。在取得成果的基础上，我们评估了每个孵化中心客户的优先级。

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The outline of the expert system for the design of experiment

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RSM

Abstract
The design of experiment (DoE) is a methodology originated from early 1920s when Fisher's papers created the analysis of variance and first known experimental designs: latin squares. It is focused on a construction of empirical models based on measurements obtained from specifically structured and driven experiments. Its development resulted in the constitution of four distinctive branches recognized by the industry: factorials (full or fractional), Taguchi's robust design, Shainin's Red-X® and a response surface methodology (RSM). On one hand, the well-known success stories of this methodology implementations promise great benefits, while on other hand, the mathematical complexity of mathematical and statistical assumptions very often lead to improper use and wrong inferences. The possible solution to avoid such mistakes is the expert system supporting the design of experiments and subsequently the analysis of obtained data. The authors propose the outline of such system and provides the general analysis of the ontology and related inference rules.

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1. Introduction

The methodology known as 'design of experiment' is very efficient tool for discovering new knowledge about technological processes as well as fine tuning them. Unfortunately, this tool set contains many methods which achieve their maximum efficiency for different problems and at different assumptions. In recent decades, software tools (e.g. Statistica, Statgraphics, Minitab, R) have freed engineers and researchers from tedious calculation work. However, it is still the user who is responsible for selection of the right experimental design and appropriate data analysis methods, especially so sophisticated as logistic regression models (Hosmer and Lemeshow, 2000; Hilbe, 2009), a categorical data analysis (Agresti, 2002), a principal component analysis PCA (Jolliffe, 2010), a cluster analysis (Everitt et al., 2011) or – last but not least – a multivariate statistical techniques at all (Izenman, 2008).

The rapid development in a specific field of an artificial intelligence – expert systems (Liebowitz, 1998; Jackson, 1999; Siler and Buckley, 2005) – gives a hope for further relief of users. The advisory expert system appears to be a proper tool to support users in these very difficult and risky decisions. In this paper, authors try to sketch outline of the rules set for such a system.

Another promising area – linguistic summarization (Niewiadomski, 2008) – appears to be desirable tool for a valid results interpretation and automatic creation of condensed, transparent, but not necessarily precise, interpretations of large result datasets, however such problem is beyond a scope of this paper.

In the next chapters, authors make a review of the most popular methods existing under the franchise of 'design of experiment' banner.

2. Review and analysis of popular methods

The authors chose several methods that were considered the most popular among DOE techniques: Latin squares, factorials, Taguchi robust design, Shainin's Red-X® and response surface methodology.

2.1. Latin squares - beginnings

The design of experiments foundations were created in 1918, when R. A. Fisher published his paper (Fisher, 1918) where the analysis of variance (ANOVA) (Gentle and Hardle, 2012) was mentioned first time as a method to split

a combined effect into separated impacts of particular factors. Some years later, in 1925, Fisher found an answer (Fisher, 1925) to the question being a specific "inverse-problem": how to set a scheme of the experiment to make ANOVA maximally effective. The founded scheme is known as a "Latin square" (LS) because of its special construction diagram similar to a "magic square" filled with a Latin letters (Fig.1). This diagram should be interpreted as:

- the column of the diagram is a first factor and the number of the column is its level,
- the row of the diagram is a second factor and the number of the row is its level,
- the Latin letter set at a cross of the column and the row is a level of the third factor.

For the example (Fig.1): the third column, the second row and the letter 'B' – it means that the first factor is set at third level, the second factor – at second level and third factor – at second level (i.e. at letter 'B'). The Latin square constructed for *n* levels is 1/nth of the full experimental design i.e. it is a small fraction from the set of all possible combinations of factors.

A	B	C	D
D	A	B	C
C	D	A	B
B	C	D	A

Fig. 1. The sample latin square for three factors with four levels each

However Latin squares allow to serve any arbitrary number of levels, their impose some limitations:

- only three factors may be analyzed,
- the number of levels must be the same for all factors,
- no interactions between factors are allowed.

Later, in 1935 Fisher published a book (Fisher, 1935) where the term 'design of experiment' was explicitly used even in the title.

2.2. Factorials

The concept of Latin squares were generalized into 'general full factorial' (GFF) experimental design. The GFF is a combination of all levels of considered factor with all levels of all other factors. The GFF has very good statistical properties and a capacity to identify all linear effects and all possible interactions up to the highest possible order however it is the most expensive variant of an experimental research.

In 1935, F. Yates found a way out this impasse. He proposed (Yates, 1935) the recipe how to greatly reduce the number of the required experiments. He reversed the statement "if GFF is used then all effects and interactions are identifiable" into "if higher order interactions are removed from the model then only some combinations of factor treatments should be used". Such subset of GFF is known as the fractional factorial where the term 'fractional' is related to the fragmentary in contrary to the whole experimental design.

He might to make such radical decision about removing of the higher order interactions at a relatively low risk because they are very rarely observed in the real industrial processes, especially in machining. The only exceptions are chemical and termomechanical processes.

Additionally, Yates described the effective algorithm (Montgomery, 2008) to construct the fractional factorial in the specific case where all factors have only two level settings. It is very often met, especially when sensitivity of the technological process is investigated at preliminary research.

The first step is to determine the biggest two-level full factorial which size is still lower than assumed limit determined by the economy or deadline limitations. The founded experimental design is assumed as a core while interactions of sup-ported factors are used to generated the rest of the factors.

The following example describe this procedure for the searching of the smallest fractional factorial supporting only linear effects:

- the process with four factors (A, B, C, D) should be investigated,
- the economy limitations does not allow to make more than 10 experimental tests,
- two-level fractional factorial should be proposed.

The test number limitations (i.e. 10) imposes that the biggest two-level full factorial in this limit is 23 i.e. full factorial (Fig.2a) for three factors (acronyms according to well-known Yates's notation).

a)

A	B	C
-	-	-
+	-	-
-	+	-
+	+	-
-	-	+
+	-	+
-	+	+
+	-	+

b)

A	B	C	D
-	-	-	-
+	-	-	+
-	+	-	+
+	+	-	-
-	-	+	+
+	-	+	-
-	+	+	-
+	-	+	-

Fig. 2. Sample two-level full factorial for three factors (a) as a core for the two-level fractional factorial (b) with generator D=ABC

Three factors allows four interactions: three second-order i.e. AB, AC, BC and one third-order i.e. ABC. In the particular sample (Fig.2b) the interactions ABC was used as a generator for the fourth factor D.

Such experimental design may be used to determine the sensitivity of the process onto the investigated factors. The typical graphical tool used to present this sensitivity is well-known Pareto chart.

In 1946, Plackett and Burman showed (Plackett and Burman, 1946) a special kind of two-level experimental designs based on Hadamard matrices with linear complexity instead of a power complexity in Yates's designs.

2.3. Taguchi's robust design

Taguchi robust design (Phadke, 1989) is not only the specific variant of DoE, but also a general idea of a process or product design insensitive to disturbances. His main concept is to introduce two separate experimental design: one, controlling significant factors of the process or product (known as the internal array) and the second, (known as the external array), controlling most significant disturbances or weakly controlled factors (known as noise factors). The aim of the procedure is to find settings of the controlled factors which simultaneously optimize (maximize, minimize or stabilize) the process outcome and maximize a resistance of the process to the influence of noise factors.

The internal array may be a special orthogonal experimental design (prepared by Taguchi) with different number of levels for each of factors, or typical factorial – full or fractional – experimental design.

The external array is usually highly fractionalized two-level fractional factorial, where levels are related to extreme settings of noise factors e.g. the lowest or highest temperature, humidity, vibrations etc.

Both arrays are crossed giving the complete Taguchi robust design (Fig. 3).

			E	-	-	+	+
			D	-	+	-	+
A	B	C					
-	-	+					
+	-	-					
-	+	-					
+	+	+					

Fig. 3. Combinations of two crossed experimental designs in Taguchi robust design: the internal array (A,B,C) and the external array (D,E). The green box is a sample test with controlled factors (A,B,C) set to (+, –, –) and noise factors (D, E) set to (–, +)

Testing of disturbances may be conducted simultaneously with factors or separately. The first case appears when noise factors imposes production process directly e.g. raw materials instability, process drift etc. The second case is conducted when noise factors are shifted over time in relation to the main process e.g. test in a climatic chamber for impact of operating conditions.

Each of the internal array treatment should be replicated for all of the external array treatments. It means that number of the required tests is a multiplication of the internal array treatments and the external array treatments. To avoid relatively high level of cost, the external array is typically selected as highly fractionalized two-level factorial while the internal array is selected as fractional factorial (with more than two levels) or a specific design prepared by Taguchi and known as Taguchi orthogonal arrays (Phadke, 1989).

The analyzed output is not the measurements directly, but their specific transformation SNR (Signal-to-Noise Ratio) made with one of three available functions:

- *lower-the-better* (Eq.1) – where the sum is evaluated for the particular internal treatment *i* over all (1…*k*) external treatments *j*

$$SNR_i = -10\log\left[\frac{1}{n}\sum_{j=1}^{k} y_{i,j}^2\right] \tag{1}$$

- *greater-the-better* (Eq.2) – where the sum is evaluated for the particular internal treatment *i* over all (1…*k*) external treatments *j*

$$SNR_i = -10\log\left[\frac{1}{n}\sum_{j=1}^{k}\frac{1}{y_{i,j}^2}\right] \tag{2}$$

- *nominal-the-best* – where two variants are considered depending on the relation between the main outcome and its variance over disturbance (Eq.3): (a) linear relation (Eq.4) and (b) lack of the relation (Eq.5)

$$s_i^2 = \frac{\sum_{j=1}^{k}\left(y_{i,j} - \overline{y}_i\right)^2}{k-1} \tag{3}$$

$$SNR_i = 10\log\left(\frac{\overline{y}_i^2}{s_i^2}\right) \tag{4}$$

$$SNR_i = -10\log\left(s_i^2\right) \tag{5}$$

Their names describes the goal selected for the original output while the trans-formed SNR is always maximized. One SNR value is calculated for each of the internal array treatment over all of the related external arrays treatments (Phadke, 1989; Montgomery, 1997).

Instead of the classic factorials, the robust design optimizes not the sole out-come at random disturbances, but the outcome at the average existence of the extremely changing disturbances. It may lead to the results that are slightly suboptimal than obtained from factorials experiments, but are significantly more insensitive to the disturbances.

The limitations of the Taguchi's robust design is lack of the any interactions detection. The typical graphical tool used to select optimal settings is the margin-al means plot (Montgomery, 1997).

2.4. Shainin's Red-X®

Shainin's Red-X® methodology (Bhote, 1991) is not a single algorithm but a set of seven recipes what make it very similar to Six-Sigma package. It goal is not to optimize a process outcome itself but to minimize its variability i.e. to make process window narrower. Its basic foundation is the assumption that small number of factors (up to maximum three) are responsible for the main part of disturbance observed in the process.

The approach was originally introduced in Grumman Aircraft Engineering Corporation during construction of Lunar Expedition Module in Apollo mission, where Dorian Shainin was responsible for the production process quality. Later, Shainin moved to General Motors and implemented his procedure in the automotive industry.

The first step in Shainin's Red-X® is to set a measurement system i.e. to gain assurance that measurement procedure has a capacity to really obtain reliable data and not artifacts. In modern advanced factories, it is usually provided by a measurement system analysis (MSA) but it still very often is not met. In such situation, Shainin's system provides a MSA substitute i.e. ISO Plot® where 30 product samples are two times measured and obtained data are paired. The measurement are presented on the 2D plot and the horizontal dispersion is a process dispersions while the dispersion around slope (line 45 degree) is a measurement dispersion and reflects measurement process repeatability.

The optional second step is Multi-Vari® analysis performed with a specific control charts used to detect a location of the process disturbance: (a) raw material or machined part, (b) production site or tool and (c) production site environment.

Next step depends on the character of the analyzed object/process. If the investigated object is a product allowing reversible dismantling i.e. dismantling and reassembly, the ComponentSearch® algorithm is used. If the investigated object does not allow reversible dismantling i.e. the dismantling and the inspection is destructive, the PairedComparison® algorithm is used. At last, if a process (instead of a material object) is investigated then VariableSearch® (structurally very similar to ComponentSearch®) is used.

The result of this step is a set of the main sources of variability: Red-X® (the main source), Pink-X® (the second order source) and Pale Pink-X® (the third order source).

In the next step, FullFactorial®, the possible interactions between these main source are detected and evaluated. If interactions are not significant, the optimum settings are detected for each of factors independently. If any interaction is more significant than a linear effect (single factor), it means that an optimum pair or an optimum triplet should be determined at the same time i.e. their settings depend mutually on each other.

Finally, the B vs. C® algorithm, based on Tukey's range significance test (Siegel and Tukey, 1960), checks if the new optimum settings changes product/process so enough to be detected.

Optional step, based on dispersion plots of the measured process outcome versus Red-X® and Pink-X®, allows to determine reasonable and argued specification of raw materials and source parts.

The specific property of Shainin's Red-X® approach is to almost completely avoid of any explicit use of the statistics. The base tools for this approach are a millimeter paper, a setsquare, a pencil and a four-function calculator. The necessary statistics are hidden beyond "magic" number located explicitly in the some simple formulas. Due to its simplicity and a low cost, Shainin's approach is very popular in the industry.

2.5. Response Surface Methodology

The response surface methodology (RSM) was developed in 1951 by Box and Wilson (Box and Wilson, 1951). In contrary to the factorial approach, it allows to use continuous factors settings i.e. settings described by a numbers, not a labels. Instead of a fixed-effects model (like Latin square, Taguchi or factorials), it introduced a classic mathematical approximation formulas based usually on a second order polynomials. In 1958, Scheffé generalized this approach to a specific situation of mixtures where a sum of factors setting must to be constant (Scheffé, 1958).

Typically, a RSM model is identified by a least square method providing a maximum likelihood estimation if the noise term is Gaussian (Montgomery, 2008). This condition may be a priori checked very rarely and this assumption is typically tested a posteriori by a normality test of residuals (John, 1998).

Typical exploration tools are: the analysis of effects, the analysis of variance, the inspection of the pure error, 2D and 3D plots.

The RSM is very popular however authors practically observed many of improper use cases and inference mistakes. The typical error is ignoring a specific statistical assumptions related to a particular experimental design. It very often lead to an erroneous conclusions.

3. Selection rules

The scope of the investigation is theoretically a results of the assumed goal, but in the industrial practice, the most important limitations are economical i.e. available funds and imposed deadlines. They most strongly limit tools and methods which may be used.

The question addressed to the expert system may be formulated in two forms:

1. what are necessary resources (funds, machines, workers, time) for the defined scope of the investigation,
2. what is maximum available scope of the investigation for the defined limits of the resources (funds, machines, workers, time).

In the academy, the first approach is often met when a future research grant is considered. In the industrial practice, especially in production engineering, the second approach is the only allowed one.

3.1. Resource limitations

In the beginning, two basic properties of the single experimental test have to be considered: a cost C_{test} and a duration T_{test}.

In the industrial approach, the budget B_{limit} and deadline T_{limit} are strictly de-fined. The maximum number of tests limited by a budget is defined by an equation:

$$N_{budget} = \frac{B_{limit}}{C_{test}} \tag{6}$$

while the maximum number of tests possible to made on a single experimental unit is defined by a formula:

$$N_{time} = \frac{T_{limit}}{T_{test}} \tag{7}$$

If the N_{budget} is larger than N_{time}, it means that experimental tests may be distributed on many experimental units simultaneously however it requires to introduce a special blocking factor to take into account a systematic error i.e. drift or constant differences between experimental units.

3.2. Selection of the investigation aim

The observed outcome Y should be defined. The DoE investigation should select one of the four possible goals related to this outcome:

1. the identification of the most important factors (screening research),
2. the process stabilization i.e. narrowing of the process window,
3. the process optimization i.e. searching of the process optimum settings,
4. the process mapping i.e. construction of the process prediction model.

The possible rules are:

1. if the goal is screening then possible approaches are factorial (fractional, Plackett-Burman) or Shainin's,
2. if the goal is stabilization then possible approaches are Shainin's, fractional factorial or RSM,
3. if the goal is optimization then possible approaches are factorial, Taguchi or RSM,
4. if the goal is mapping then possible approaches are factorial or RSM.

In the industrial practice, the stabilization should be achieved first even before optimization.

3.3. Selection of investigated factors

It leads to selection of the factors related to the observed outcome. The settings nature of the factors determined the possible methodology:

1. if the factors are continuously set and the constant sum must be met, they should be investigated by mixture otherwise
2. if the factors are continuously set, they should be investigated by RSM, other-wise
3. it should be investigated by factorials, Taguchi's or Shainin's approach.

A special trick, an arbitrary discretization, may be used to transform factors from continuous into not-continuous set.

3.4. Possibility of interactions and the model selection

The n-order interactions is a mathematical term for a phenomenon where observed impact of the particular factor depends on (n–1) other factors settings. Some approaches *a priori* reject the existence of interactions. It means that such approaches should not be used for the investigation of the processes where investigations may be met:

1. if the interactions may be met, then do not use Taguchi, Plackett-Burman, linear factorials or linear RSM otherwise
2. use factorials with non-linear models, Shainin's or RSM with non-linear models.

3.5 Outcome transformations

The observed and measured outcome may related to one of three numbering scales defined by Stevens (Stevens, 1946):

- interval scale, where the value is not limited i.e. may be negative or positive,
- ratio scale, where the value is one-sided bound, typically it means that the value is positive or non-negative,
- absolute scale, where the value is two-sided bound.

In the most popular least squares method, the random noise term describing uncontrolled disturbances is assumed to be Gaussian i.e. normally distributed. It requires unlimited (at least theoretically) outcome, both in negative and positive side. If the outcome is one-side or two-side bound, it requires preliminary transformation:

1. if the outcome is one-side bound, then all values should be shifted into positives and next processed by a special transformation into the whole real numbers space, otherwise
2. if the outcome is two-sided bound, then all values should be shifted and scaled into interval [0, 1] and next processed by a special transformation into the whole real numbers space otherwise
3. the outcome should be left intact.

The typical transformation of the outcome related to the ratio scale is logarithmic transformation. It transforms zero bound into negative infinity, one into zero and larger values into positive values up to positive infinity.

The typical transformations of the outcome related to the absolute scale are logistic (Hosmer and Lemeshow, 2000) or probit transformations (Hosmer and Lemeshow, 2000).

4 Conclusions

The rationale for the construction of the expert system for the design of the experiment was presented. The history roots of DoE and its developing into four main branches was showed. Five groups of selection rules were defined: the resource limitations, the selection of the investigation aim, the selection of the investigated factors, the model selection according to existence of interactions and the outcome preprocessing transformations.

Further efforts will be focused on the testing of the working model in the industrial environment and building rules related to the analysis methods and results interpretations.

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实验设计专家系统概述

關鍵詞
专业系统
实验设计
阶乘
Taguchi坚固的设计
RSM

摘要
实验设计（DoE）是一种起源于20世纪20年代早期的方法，当时Fisher的论文创建了方差分析和第一个已知的实验设计：拉丁方块。它侧重于基于从特定结构和驱动实验获得的测量结果的经验模型的构建。它的发展导致了该行业认可的四个独特分支的构成：阶乘（全部或分数），田口的稳健设计，Shainin的RedX®和响应表面方法（RSM）。一方面，这种方法实现的众所周知的成功案例有很大的好处，而另一方面，数学和统计假设的数学复杂性经常导致不正确的使用和错误的推论。避免此类错误的可能解决方案是支持实验设计的专家系统，并随后对获得的数据进行分析。作者提出了这种系统的概述，并提供了对本体和相关推理规则的一般分析。

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The Response Surface Methodology revisited – comparison of analytical and non-parametric approaches

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Abstract
Since G.E.P. Box introduced central composite designs in early fifties of 20th century, the classic design of experiments (DoE) utilizes response surface models (RSM), however usually limited to the simple form of low-degree polynomials. In the case of small size datasets, the conformity with the normal distribution has very weak reliability and it leads to very uncertain assessment of a parameter statistical significance. The bootstrap approach appears to be better solution than – theoretically proved but only asymptotically equal – *t* distribution based evaluation. The authors presents the comparison of the RSM model evaluated by a classic method and bootstrap approach.

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1. Introduction

In the second half of the twentieth century, industry remained under constant pressure to improve its products. In the last two decades, there has been an additional demand from consumers that these products are new or have completely new functional characteristics. Ignoring these demands leads inevitably to marginalization of the company or pushing it out of the market. On the other hand, conducting research and development is very expensive and involves a high risk of failure. Any tools that increase the effectiveness of these works and reduce the level of risk are highly desirable.

One of the toolset, supporting engineers and researchers, is a design and analysis of experiments (DoE) methodology (Kempthorne and Hinkelmann, 2007; Montgomery, 2008), whose first ideas come from Fisher (Fisher, 1925). It contains many different approaches, optimized to investigate specific objects and processes. They focus mainly on statistical aspects, but also on organizational ones.

The basic feature of the tested object, which differentiates available analytical methods, is the method of setting the value of controlled factors. Setting values can be discrete, stepwise (e.g. type of material, dosage with tablets, supplier, type of part) or continuous (e.g. temperature setting, weight dosing, timing of reaction time). The first group of problems are located in the factorial approach, while the second – in the response surface approach (the well-known acronym: RSM – response surface methodology). The basics of RSM was developed by Box in 1951 (Box and Wilson, 1951), while two duets: Robbins with Monroe (Robbins and Monroe, 1951) and Kiefer with Wolfowitz (Kiefer and Wolfowitz, 1952) created a supporting mathematical formalism.

The general concept of this approach bases on the best identification of the assumed mathematical model while a number of experimental tests is predetermined. This obviously leads to the question: where should the test points be located in the space of controlled factors to achieve the best possible identification of the selected model. These test location schemes are developed by statisticians and known as experimental designs (Montgomery, 2008). From the mathematical point of view, such a problem is almost identically as in the approximation nodes selection e.g. Tschebyshev, Gauss etc. The most popular method of the model identification is least squares method (Gentle and Hardle, 2012), which assume a normal distribution of the random term with a mean equal to zero and an unknown variance. This assumption is very strong and should a posteriori verified. It is usually done by a test of the normality e.g. Kolmogorov-Smirnov (Kolmogorov, 1933; Smirnov, 1948), Anderson-Darling (Anderson and Darling, 1952) or Shapiro-Wilk (Shapiro and Wilk, 1965). If the selected test does not reject, it is good and the predicted response uncertainty may be

estimated by typical asymptotic t distribution. But what to do, if it fails? The possible solution is a non-parametric approach which bases on the resampling scheme introduced by Efron (Efron, 1979).

2. A bootstrap concept – short description

The first idea of the bootstrap was introduced by Efron (Efron, 1979) derived from the jackknife procedure developed by Quenouille (Quenouille, 1949) and expanded by Tukey (Tukey, 1958). The approach treats drawings taken from the raw dataset as a source of true measurements. Resampled datasets are analyzed and functions of interest are evaluated giving the bootstrapped distributions, treated as derived from truly replicated measurements. In a particular case, the model identification procedure may be the evaluated function.

Such approach is iterated many times, typically from thousands to millions, and results are collected. Then, the obtained dataset is analyzed and distributions of selected statistics are numerically identified, especially their means and quasi-empirical confidence intervals.

3. Statistical significance in bootstrapped RSM model

Pietraszek and Wojnar (Pietraszek and Wojnar, 2016) showed how to assessed numerically statistical significance of RSM model parameters without any attempt to typical t distribution based methods.

The classic sequence (raw dataset, statistic evaluation, statistical test, p-value, comparison to alpha) was replaced with (raw dataset, bootstrap, bootstrapped datasets, set of statistics, histogram, alpha/2-tails, check for zero in bounds). It means that bootstrap was a procedure to obtain quasi-empirical confidence interval based truncated on alpha/2 tails. Then, the intervals was checked whether contains zero value inside. If yes – the statistic is insignificant; if not – the statistic is significant. The position of zero relative to the center of the interval gives the well-known p value.

Pietraszek and Wojnar (Pietraszek and Wojnar, 2016) analyzed the dataset obtained from the investigation of the vertebrae strength, however it may easily generalized into any analogous technological problem. The outcome (a strength of vertebrae) was dependent on three observed factors, specific properties of the vertebrae structure: a density of trabecular bone, a number of branches in a trabecular bone and a number of junctions on the branches in trabecular bone. The source dataset was small and it had only 23 records. It was enough to identify a linear prediction model, but it was inadequate to achieve a strong estimation of a uncertainty. They used a specific bootstrap variant described by Shao and Tu (Shao and Tu, 1995):

a) the original dataset is used to identify a predictive model,
b) the model is evaluated on the original data set and residual values are obtained,
c) the residuals dataset is resampled and drawn values are added to model predictions – they create a new dataset of outcome,
d) the new outcome dataset combined with original factors is used to identify a bootstrapped model – obtained bootstrapped parameters are collected.

The steps (c) and (d) are iterated thousands and thousands times, and huge dataset of collected parameters is built. Pietraszek and Wojnar (Pietraszek and Wojnar, 2016) used the approach mentioned above and obtained a complete distributions of the model parameters. Then, their 95% confidence intervals were evaluated. Their basic RSM model was constructed as:

$$R_c = b_{const} + b_{BV/TV} \cdot BVTV + b_{branches} \cdot Branches + \\ + b_{Junctions} \cdot Junctions \quad (1)$$

where:
R_c – observed strength of a vertebrae
b_{const} – constant term,
$b_{BV/TV}$ – coefficient of relative density of a trabecular bone,
$b_{branches}$ – coefficient of a average number of branches in trabecular bone,
$b_{junctions}$ – coefficient of a average number of junctions on the branches in trabecular bone.

The replication of this model based on the data included in the article (Pietraszek and Wojnar, 2016) led to the dataset of bootstrapped parameters of the Eq.1. The data were tested for normality and revealed that data distributions are far from normality. The parameter b_{const} has mean 0.2823 while the classically evaluated is 0.34. Its shape is explicitly non-normal (Fig. 1).

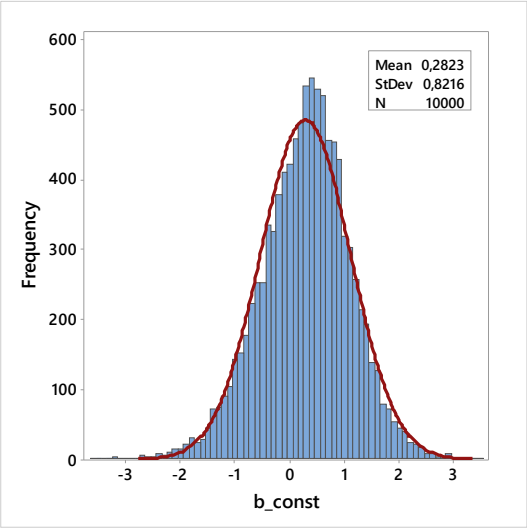

Fig. 1. Histogram of bootstrapped b_{const} parameter

The test of normality shows (Fig. 2) that p-value is less than 0.01 i.e. the normality of the parameter is rejected.

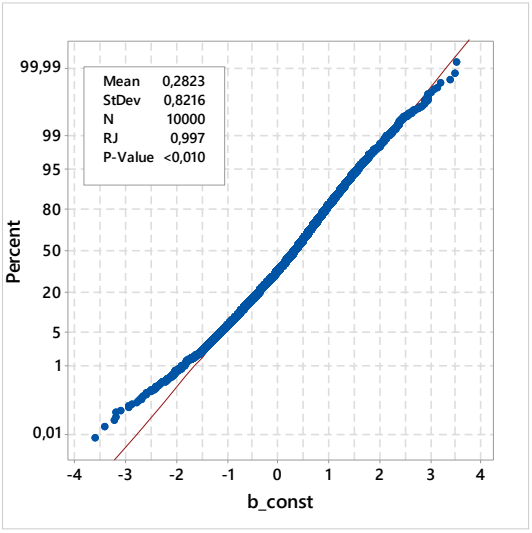

Fig. 2. The probability plot of bootstrapped b_{const} parameter

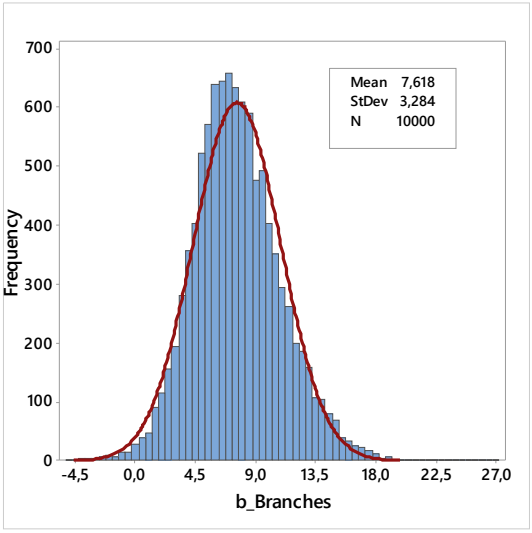

Fig. 5. Histogram of bootstrapped $b_{Branches}$ parameter

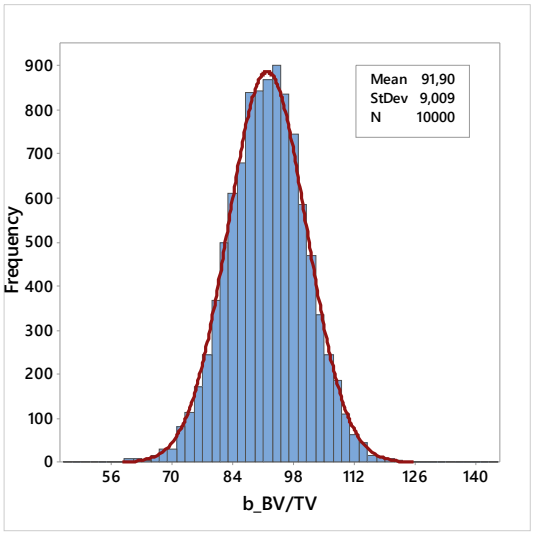

Fig. 3. Histogram of bootstrapped $b_{BV/TV}$ parameter

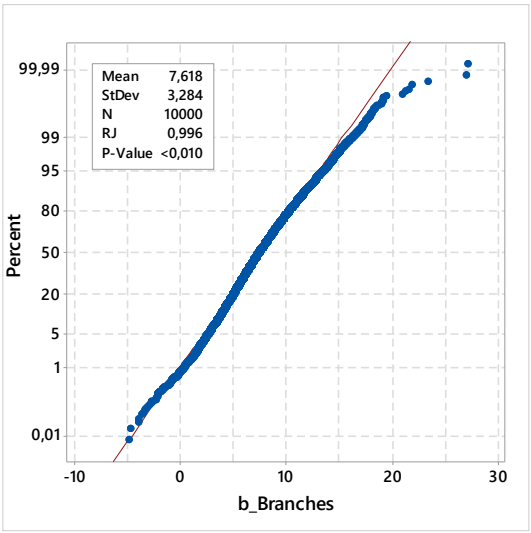

Fig. 6. The probability plot of bootstrapped $b_{Branches}$ parameter

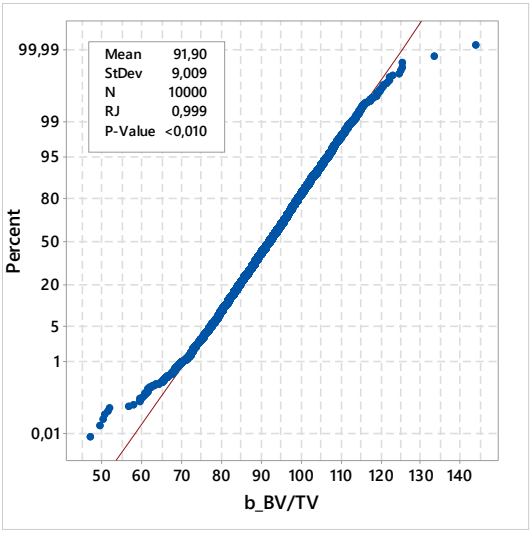

Fig. 4. The probability plot of bootstrapped $b_{BV/TV}$ parameter

The parameter $b_{BV/TV}$ has mean 91.90 while the classically evaluated is 92.61. Its shape is not so explicitly not-normal (Fig. 3) as the previous one, but the test of normality was rejected also (Fig. 4).

The parameter $b_{Branches}$ has mean 7.62 while the classically evaluated is 7.26. Its shape is explicitly not-normal (Fig. 5) and the test of normality was rejected also (Fig. 6).

Finally, the parameter $b_{Junctions}$ has mean -13.74 while the classically evaluated is -13.16. Its shape is explicitly not-normal (Fig. 7) and the test of normality was rejected (Fig. 8).

One can observe that all distributions are not-normal, their means are different than those evaluated classically and, additionally, three distributions (Fig. 1, Fig.5 and Fig. 7) have a distinct skewness. It shows that a classic model, based on assumptions that are not met, leads to not very accurate results. The non-parametric approach using the bootstrap method allows to create the whole-distribution-based statistics, not only *t* distribution based asymptotic one, loosely related to the real data.

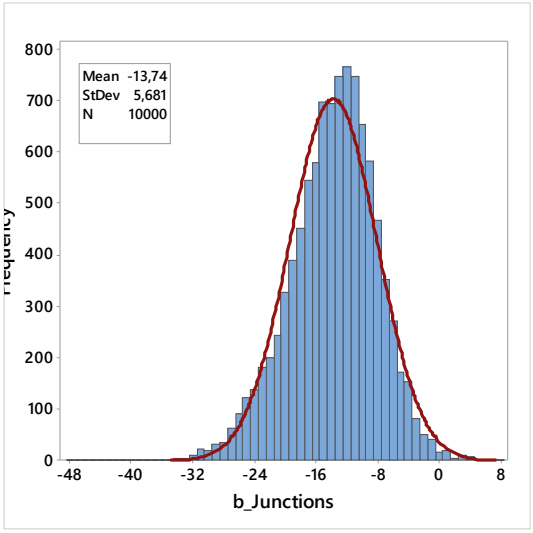

Fig 7. Histogram of bootstrapped $b_{Branches}$ parameter

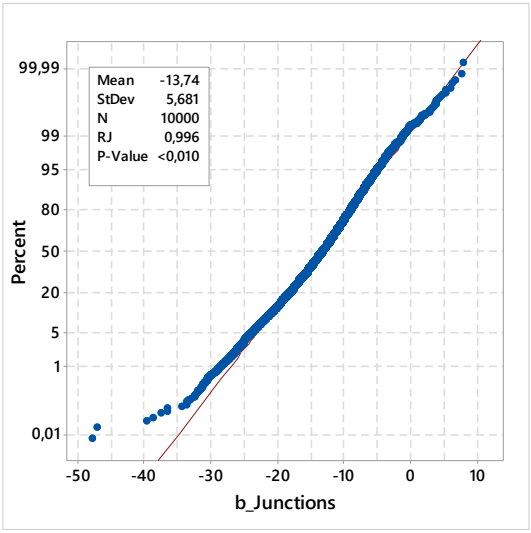

Fig. 8. The probability plot of bootstrapped $b_{Junctions}$ parameter

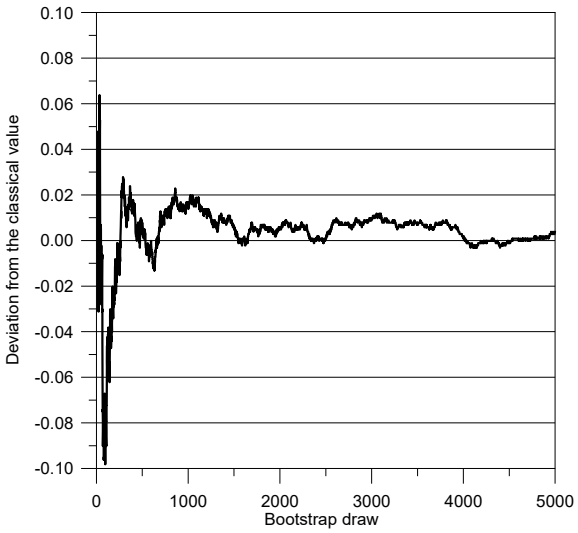

Fig 9. The deviation of a bootstrapped parameter from a perfect value (source: Osocha et. al., 2015)

An interesting question is what should be the number of iterations in the bootstrap method. Such problem was addressed (Osocha et al., 2015) and the stabilization of results appeared only above 4000…5000 iterations.

4. Conclusions

The comparison of the classically evaluated RSM model and the bootstrap based approach was presented. The difference between results obtained from LSQ with normality assumption and – in contrast – the bootstrap based non-parametric approach was showed.

Bootstrap approach appears to be effective computational method to identify parameters of RSM effects model and their statistical properties and – additionally – it does not require to make a priori inconvenient assumptions.

The bootstrap approach appears to be an effective and easy-to-use procedure. However, it should be emphasized that this approach requires careful and continuous watching at residual plot to detect breakdown iterations which stabilizes bootstrap means.

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自动驾驶汽车的不规则操作

關鍵詞
事故重建，自动驾驶汽车，
自驾车
紧急
车辆运动模拟

摘要
今天，随着车辆自主功能的普及，强调了引发事故的责任。自导功能在某些交通情况下起作用，但事故发生，因此，下面的文章提出了对该问题的分析。其目的是表明具有自动驾驶功能的车辆不能提供车辆制造商建议的驾驶员安全水平。在这篇文章中，最近的四个事件和一个分析是否可以避免这些事故是一个人类驱动因素，或者它们是如何发生的，具有适当的自我驱动功能。在每个调查的案例中，涉及具有自驱动功能的车辆。在对事故的评估和评估的基础上，得出结论，当前的自行式车辆是否提供了驾驶员和社会对这些车辆的期望。
在车辆模拟程序的帮助下说明事故过程的重建，特别强调所得到的参数，特别是避免事故。

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