MEBUTRA

TRUCK SCALES

the key to safe transport and road

protection

LONGBOARD WITH ONE-WHEEL DRIVE

construction

BUILDING DISASTERS

Analysis of causes and circumstances

And also:

Stability of open steel truss bridges with underpass

AnS

Akademia Nauk Stosowanych
im. Stanisława Staszica w Pile

Foreword

This year, just like in 2023, the University Journal "MEBUTRA" is dedicated generally to students and graduates of the Departments of Mechanical Engineering, Transport, Civil and Electrical Engineering of Stanisław Staszic Academy of Applied Sciences in Piła. The name of the journal is an abbreviation taken from the first letters of the above-mentioned departments, i.e. **ME**chanics, **E**lectrical Engineering, **BU**ilding, *and* **TRA**nsport.

The magazine idea was born about 6 years ago but then we had no courage to implement it. The topics covered are mainly related to technology in a broad sense, especially since many of our students' diploma theses win national competitions, which is very satisfying. An example here is the engineering diploma thesis concerning a test rig for testing belt transmission slip, the authors of which are inż. Ryszard Kucznier and inż. Michał Zabłocki (supervisor: dr inż. Jarosław Mikołajczyk). This thesis received a gold medal and the Belgian Polonia Award at the 17th International Invention and Innovation Show INTARG in Katowice organized between 21-23 May 2024. During the same INTARG Show, the second diploma thesis concerning a lab station for galvanic coating, the authors of which are inż. Mariusz Pigulewski and inż. Tomasz Flakiewicz, won a silver medal (supervisor: dr Małgorzata Kastelik). Following this success, dr inż. Piotr Stanowski joked that all we needed to complete the set were platinum and diamond. The enormous amount of work put into preparing the entire team to go and participate in the above-mentioned INTARG Show was done by dr Marta Chudzicka-Adamczak, Head of the Department of Mechanical Engineering at Stanisław Staszic Academy of Applied Sciences in Piła, to whom we extend our sincere words of thanks.

We have agreed that the journal will be published only in electronic form once a year. The deadline for submitting papers is the end of September each year. The magazine will be posted and made available at our university platform. This issue is the second edition of this journal.

I would like to encourage all students, including Erasmus Programme students and those organized within Student Research Groups, to submit articles.

ON BEHALF OF THE EDITORIAL STAFF

DR INŻ. JAROSŁAW MIKOŁAJCZYK
jmikolajczyk@ans.pila.pl

Spis treści

TRUCK SCALES -
THE KEY TO SAFE TRANSPORT AND ROAD PROTECTION

mgr inż. Jolanta OLECHNOWICZ
e-mail: jolechnowicz@ans.pila.pl
Katedra Transportu, Akademia Nauk Stosowanych im. Stanisława Staszica w Pile
ul. Podchorążych 10, 64-920 Piła

dr inż. Jarosław Robert MIKOŁAJCZYK
e-mail: jmikolajczyk@ans.pila.pl
ORCID No.: 0000-0001-9196-0039
Katedra Inżynierii Mechanicznej, Akademia Nauk Stosowanych im. Stanisława Staszica w Pile
ul. Podchorążych 10, 64-920 Piła

1. Introduction

Road transport is the backbone of cargo transportation. According to data from the Central Statistical Office, only in 2023 it accounted for 87.3%, leaving far behind rail transport - 10.3% and pipeline transport - 2%.

As of 31 December 2023, according to the Central Register of Vehicles, the total number of motor vehicles and truck tractors was 35.9 million, and in 2022 - 34.9 million. Trucks account for 3.8 million, including passenger-truck vehicles, while the number of tractor units is 567.8 thousand. All data are higher compared to 2022, e.g. the number of trucks – an increase of 2.5% and tractor units – 5.7%.

How do these numbers relate to cargo transportation?

In 2023, 1,942.8 million tons of cargo were transported. In 2023, Poland ranked first among the 27 European Union countries in terms of the volume of cargo transported by road, which, expressed in tonne-kilometres, accounted for 20.3% of total transport in the European Union countries.

Trucks deliver goods to points located in various regions of Poland. They are accessible via national, provincial, district and municipal roads.

In 2023 national roads in Poland constituted 4.5% of the road network which amounted to 19.5 thousand km. The condition of roads managed by the General Directorate for National Roads and Motorways at the end of 2023 was – for 58.8% – good, for 25.1% unsatisfactory, and for 15% – was defined as poor technical condition of the surface.

It should be remembered that trucks, while going on their route, also pass through road engineering structures - such as bridges and viaducts - and they also pose a risk to them if they are overloaded.

In 2023, the share of trucks with a load capacity not exceeding 1.5 t amounted to 80.3%, but the largest increase (by 8.4%) compared to 2022 was recorded in the group of vehicles with a load capacity of 20 tons and more, also 5.1% more truck semi-trailers and 2.6% more truck trailers were registered.

The Polish legislator in the Journal of Laws of 19 August 2024, item 1251 – in Art. 61. 1. specified that the load may not cause the permissible total weight or permissible load capacity of the vehicle to be exceeded. The permissible total weights of vehicles and permissible load capacities can be found in the Regulation of the Minister of Infrastructure of 31 December 2002 on the technical conditions of vehicles and the scope of their necessary equipment in §3.

Taking the above into account, the permissible values of vehicle dimensions and weights in Poland are presented in Table 1.

Table 1. Permissible dimensions and weights of vehicles in Poland [2]

	Height [m]	Width [m]	Length of tractor and semi-trailer [m]	Length of vehicle and semi-trailer [m]	Load on driving axle [ton]	GVW*** Vehicle + semi-trailer [ton]	DMC*** Vehicle + semi-trailer [ton]
Value	4	2,55*	16,5	18,76	10**	40	40

*   with a container body 2.6m;
**   depending on the road category;
***   GVW- gross vehicle weight (permissible gross weight)

How to calculate the load capacity of a given means of transport?

This is the difference between the permissible own weight of the unit/vehicle (curb weight) and the permissible gross vehicle weight. In other words, the gross vehicle weight - GVW - results from the vehicle's construction (this is the means of transport without cargo) and the load capacity (this is the maximum weight of cargo that the vehicle can transport).

One should remember that in the Road Traffic Act, the GVW is the total weight of a vehicle or unit, which, in addition to the weight of the load, also includes the weight of the vehicle equipment, the weight of the drivers and fuel [1, 2-3].

2.   So how do you check the weight of a truck/ unit?

Taking into account the common good – the safety of the driver and other road users, the wear and tear of the fixed asset – such as the unit, and the wear and tear of the road surface – the company from Piła met everyone's needs by producing the EB+ system.

A) EB+ System

The EB+ System (Electronic Braking System) is an advanced braking system used in trucks and trailers. Its main task is to electro-pneumatically control the trailer brakes, which provides better control over braking, thus increasing road safety. The system also allows of electronic load detection [4, 5].

Fig. 1. ISO 7638 7-pin (PWR-A) – EBS full function [4, 5]
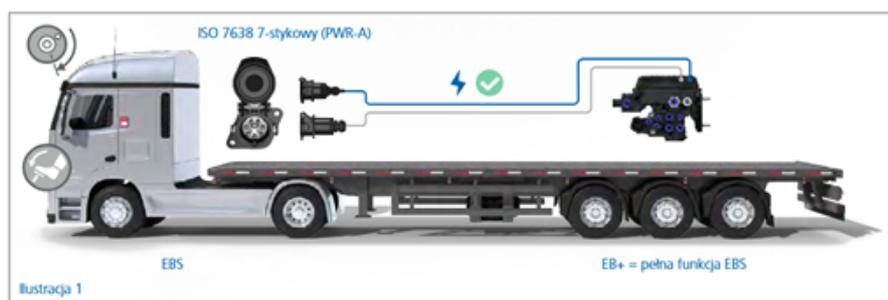
In the trailer installed are 2 or 4 sensors and 2 or 4 modulators. Depending on the model, they have different functions but probably the most convenient is ISO 7638 because it controls the trailer warning device on the driver's console.

Thanks to this solution, the driver can read his current weight, which is 20t (which means that the unit has no load on it):
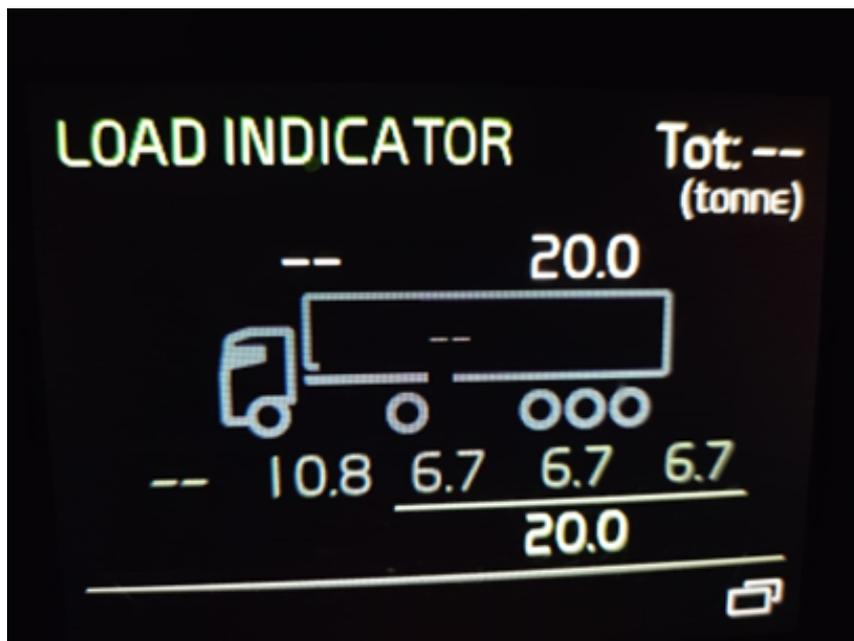
Fig. 2. Vehicle weight measurement record preview

B) „Meteor" scale
This is a portable truck scale for weighing vehicles in motion.

Fig. 3. View of the "METEOR" type road scale used by the Road Transport Inspection
This is an advanced device that allows to accurately measure axle loads and sum the total weight of vehicles.

The "METEOR" scale set (Fig. 1) includes two measuring platforms, connecting cables, a weighing terminal in a transport case with a built-in printer and an RS 323 communication port, and a USB port with a pen-drive for saving data.
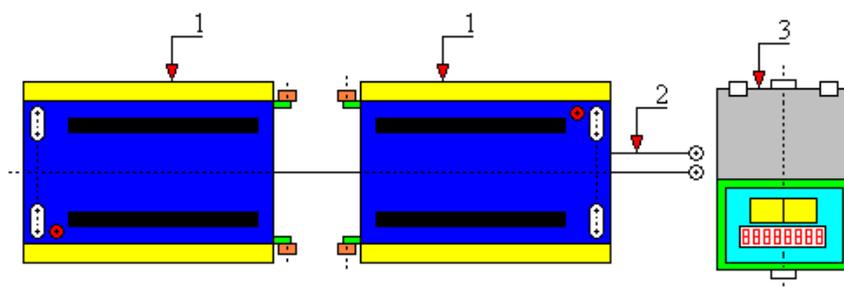
Fig. 4. Construction of the "METEOR" axle scale

1 – measuring platform (2 pieces); 2 – connecting cables (2 pieces); 3 – weighing terminal in a transport case with a built-in printer and RS 323 communication port

The weighing platform itself (Fig. 6) is composed of, inter alia, mini ramps, transport wheels, positioning markings, a built-in spirit level and handles.
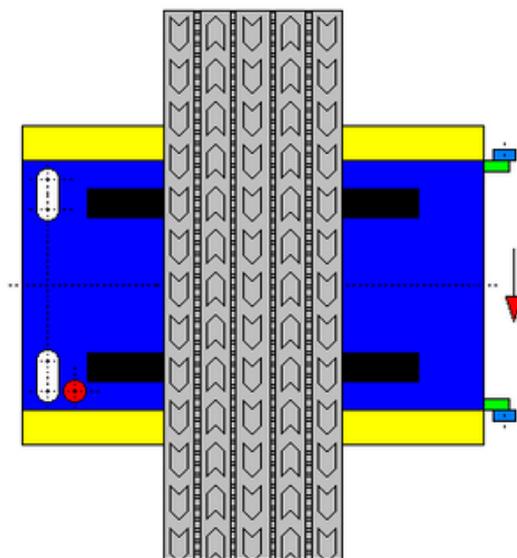
Fig. 5. Construction of the measuring platform 1 – mini ramps; 2 – transport wheel; 3 – positioning markings; 4 – level eye; 5 – handle

The correct wheel positioning on the measuring platform is shown in Fig. 3. The platform spacing can be freely adjusted taking care of the connecting cables. This ensures also the possibility of smaller vehicles.
 Fig. 6. Correct wheel positioning on the measuring platform

Meteor enables weighing of vehicles moving at a speed of 5 km/h. It is most often used by the Road Transport Inspection services.
The measurement provides information on the gross vehicle weight. It includes, among other things, the following data:
• user name (in this case, the Chief Road Transport Inspectorate);
• measurement date;
• measurement time;
• consecutive weighing number;
• weight of the load on individual vehicle axles, e.g. axle 1, axle 2, etc.;
• sum of individual weights on each vehicle axle;
• speed of the vehicle passing through the scale;
• data of the measuring device;
• expiry date of the measuring device legalization.• user name (in this case, the Chief Road Transport Inspectorate);

- measurement date;
- measurement time;
- consecutive weighing number;
- weight of the load on individual vehicle axles, e.g. axle 1, axle 2, etc.;
- sum of individual weight loads on each vehicle axle;
- speed of the vehicle passing through the scale;
- data of the measuring device;
- expiry date of the measuring device legalization.

Fig. 7. vExample printout of a BUS vehicle weight measurement

3. Summary

Scales used both in trucks and on the road are a very good solution that promotes road safety. The awareness of shippers, also freight forwarders (who take several orders for one truck and do not pay attention to kg) and other people responsible for transporting loads should be growing. Of course, we could expand on the subject by writing about rates, whether then the journey of a truck would be profitable, but this is not the main topic.

The main issue is human life, it has the highest value and truck scales play a key role in ensuring road safety because, among other things:

a)   prevent overloads – overloaded vehicles can cause damage to road infrastructure – surface, bridges, etc., which in turn can pose a threat to other road users

b)   ensure vehicle safety – overloading a loaded means of transport may affect vehicle stability, extend braking distances and increase the risk of accidents

c)   have impact on environmental protection – overloaded vehicles consume more fuel and emit more pollutants, which of course has a negative impact on the environment.

Literature:

1.https://stat.gov.pl/files/gfx/portalinformacyjny/en/defaultaktualnosci/3323/6/19/1/transport_-_activity_results_in_2023.pdf

2.http://www.dgslogistic.com/pl/dopuszczalne-wymiary-masy-naciski-osi-dla-pojazdow-w-niektorych-panstwach,aktualnosci,6

3.https://www.timocom.pl/blog/ladownosc-busa-3-5-tony-jak-nie-dopuscic-do-przeladowania-498666

4.https://e-testynaprawojazdy.pl/aktualnosci/najczesciej-popelniane-bledy-kategoria-c

5.Haldex | EB+ Gen3

ELEKTROTECHNIKA

specjalności

- **elektromobilność**
- **odnawialne źródła energii**
- **systemy automatyki i elektroniki**

perspektywy zatrudnienia

- przemysł elektroniczny
- automatyzacja i robotyzacja procesów przemysłowych
- branża odnawialnych źródeł energii
- sektor energetyczny
- przedsiębiorstwa informatyczne pracujące w obszarze elektrotechniki
- utrzymanie ruchu procesów produkcji
- branża elektromobilności

przykładowe przedmioty

- układy elektroniczne
- teoria obwodów
- sterowniki programowalne
- komputerowe projektowanie układów elektrycznych i elektronicznych
- automatyki i regulacja automatyczna
- systemy sterowania układami elektromechanicznymi
- elektroenergetyka
- energoelektronika

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co zyskujesz?

- umiejętność analizy zagadnień teorii obwodów
- znajomości wykonywania pomiarów elektrycznych
- wiedzę z zakresu automatyki i regulacji automatycznej oraz programowania sterowników przemysłowych
- możliwość rozwijania pasji w kole naukowym
- szansę na zdobycie doświadczenia pracując lub odbywając praktyki w instytucjach o zasięgu międzynarodowym
- możliwość studiowania w formie dostosowanej do Twoich potrzeb (oferujemy miejsca w grupach dziennych i wieczorowych)

ciekawostki o kierunku

Absolwenci naszej elektrotechniki, od wielu lat, znajdują się w czołówce ogólnopolskiego badania Ekonomicznych Losów Absolwentów (źródło: *ela.nauka.gov.pl*). To w dużej mierze dzięki STUDIOM DUALNYM podczas których, zyskujesz doświadczenie zawodowe i masz szansę na napisanie pracy inżynierskiej na potrzeby Twojego pracodawcy.
Na kierunku funkcjonuje studenckie koło naukowe, gdzie studenci zajmują się programowaniem mikroprocesorów, sterowników programowalnych, czy robotów przemysłowych.
Często organizujemy wizyty studyjne w firmach z którymi współpracujemy.

APPLICATION OF NEURAL NETWORKS TO PREDICT THE NUMBER OF TRAFFIC ACCIDENTS DEPENDING ON WEATHER CONDITIONS

dr inż. prof. ANS Piotr GORZELAŃCZYK
e-mail: pgorzelanczyk@ans.pila.pl
Katedra Transportu, Akademia Nauk Stosowanych im. Stanisława Staszica w Pile
ul. Podchorążych 10, 64-920 Piła

Abstract: Every year a significant number of people die on the roads. This value is decreasing from year to year, but it is still high. To this end, all measures should be taken to reduce this value.
The purpose of the article is to forecast the number of road accidents in Poland depending on weather conditions. For this purpose, annual data on the number of road accidents in Poland according to the prevailing weather conditions were analyzed. Based on the data from the Police Department, a forecast was made for 2022-2040 depending on the occurrence of the criterion under study. Selected neural network models were used for the forecast. The results of the study indicate that we can still expect a decrease in the number of traffic accidents, and later its stabilization.

Keywords: traffic accident, pandemic, forecasting, neural networks, weather conditions

1. Literature review

A large number of people die in traffic accidents every year. According to WHO, about 1.3 million people die each year as a result of traffic accidents. Road accidents are the leading cause of death for minors and young people between the ages of 5 and 29 (WHO, 2018). The UN General Assembly has set a goal to halve the number of deaths and injuries on the roads by 2030.
We can obtain data on road accidents from a variety of sources. These include data collected by government bodies with the help of relevant government agencies. Data collection is done through police reports, insurance databases or hospital records. Partial information on traffic accidents is then processed for the transportation sector on a larger scale (Gorzelańczyk et al., 2020).
In the literature, one can find various methods used to forecast the number of accidents. Among the most popular of these are time series methods (Helgason, 2016; Lavrenz, 2018) which have the disadvantages of not allowing to assess the quality of the forecast based on outdated forecasts and frequent autocorrelation of the residual component (Forecasting, 2022). In contrast, Procházka et al. (2017) used the multiple seasonality model for forecasting, and Sunny et al. (2018) used the Holt-Winters exponential smoothing method. The disadvantage of this method is that exogenous variables cannot be introduced into the model (Dudek, 2013; Szmuksta-Zawadzka and Zawadzki, 2009).
We can also use vector autoregressive models for forecasting, however, their disadvantage is that they need a large number of observations of variables in order to correctly estimate their parameters (Wojcik, 2014), which is not always achievable, as well as autoregressive models (Monederoa et al., 2021) and regression models with curve fitting (2018). These, in turn, require only simple linear relationships (Mamczur, 2022) and autoregressive order (assuming the series is already stationary) (Pilatowska, 2012).

Chudy-Laskowska and Pisula in their work (2015) used the ANOVA method to forecast the issue at hand. The disadvantage of this method is the adoption of additional assumptions, the violation of which can lead to erroneous conclusions (Traffic Safety, 2022). Neural network models are also used to forecast the number of traffic accidents. The disadvantage of this method is having a working knowledge of the subject (Chudy-Laskowska and Pisula, 2017; Sparrow, 2017). In addition, the prediction result depends on the adoption of the initial conditions of the network, as well as the impossibility of interpretation in the traditional way, since SNF is usually referred to as a black box in which input is given and the model gives the results without knowledge of the analysis. (StatSoft Data Mining Techniques; 2022). The latter is addressed in the article.

2. Materials and methods

There are many road accidents every year. In recent years, the pandemic has reduced the number of road accidents which has significantly affected the forecast value obtained. Despite the pandemic, the number of road accidents is still high. Therefore, all measures should be taken to reduce the number of road accidents depending on the prevailing weather conditions. In addition, we should determine in what weather conditions the highest number of accidents occur (chart 1). The highest number of road accidents occur in good weather conditions.
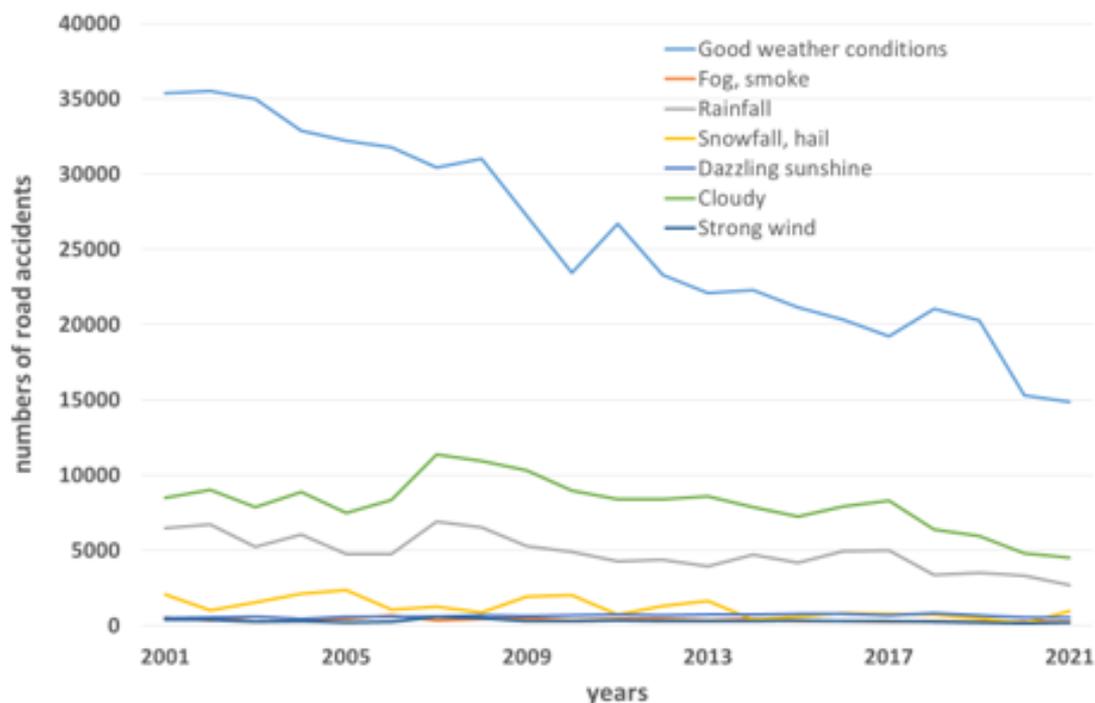
Figure 1: Number of road accidents in Poland according to weather conditions from 2001 to 2021

Selected neural network models have been used to predict the number of road accidents in Poland depending on weather conditions. The advantage of this method is that it mimics the behavior of the human brain. A neural network consists of nodes that have inputs, weights, variances and outputs. During the study, the optimal weights were adjusted by Statistica software. The prediction result of the neural network method depends on the choice of the model and its parameters.

The following forecast errors, determined from equations (1-5), were used to calculate measures of forecast excellence:

- ME – mean error

$$ME = \frac{1}{n}\sum_{i=1}^{n}\left(Y_i - Y_p\right),\tag{1}$$

- MAE – mean absolute error

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|Y_i - Y_p\right|,\tag{2}$$

- MPE – mean percentage error

$$MPE = \frac{1}{n}\sum_{i=1}^{n}\frac{Y_i - Y_p}{Y_i},\tag{3}$$

- MAPE - mean absolute percentage error

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\frac{\left|Y_i - Y_p\right|}{Y_i},\tag{4}$$

- SSE – sum of squares error

$$SSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(Y_i - Y_p\right)^2}\tag{5}$$

where:
n - length of the forecast horizon,
Y - observed value of traffic accidents,
Yp - the forecast value of traffic accidents.

Forecasting the number of traffic accidents depending on weather conditions was done using neural network models for which the average percentage error and average absolute percentage error were the smallest.

3. Results

A statistical test was carried out to compare the fluctuation of the number of traffic accidents depending on weather conditions during the analyzed period. The value of the statistic for the analyzed non-parametric Kruskall-Wallis test is 134.55, with a test probability of $p = 0.0000$. Therefore, it is reasonable to reject the hypothesis of equality of the average level of traffic accidents depending on weather conditions during the analyzed period (Figure 2).
Based on the analysis of the data it can be concluded that the highest number of traffic accidents occurs during good weather conditions, and the lowest during strong winds (Police Statistics, 2022).
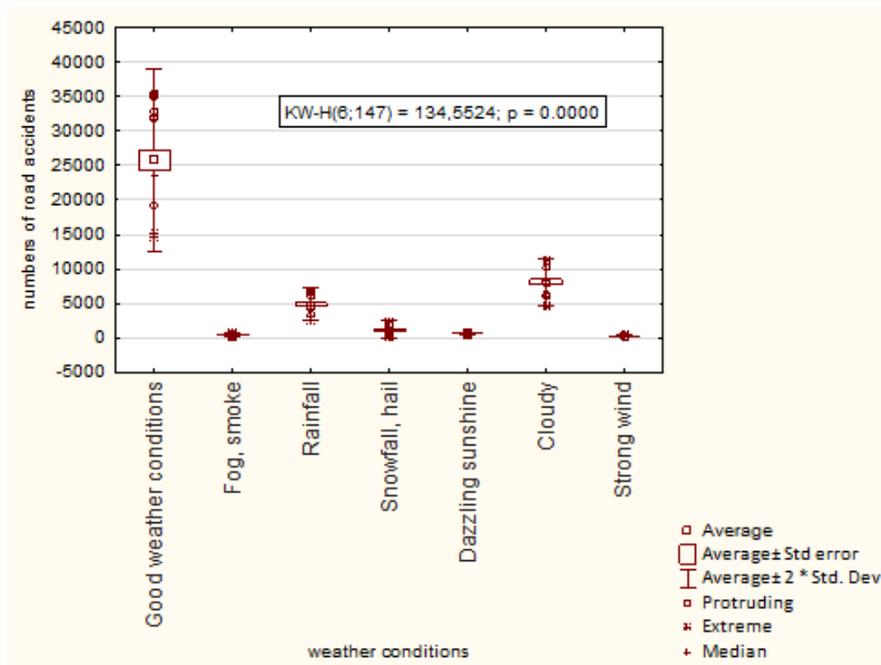
Figure 2. Average number of road accidents by weather conditions from 2001 to 2021

Polish Police data from 2001-2021 (Police Statistics, 2022) was used to predict the number of road accidents in Poland depending on weather conditions. The study was conducted using Statistica software, assuming two random sample sizes:
1.teaching 70%, testing 15% and validation 15%.
2.teaching 80%, testing 10% and validation 10%,
with the following number of teaching networks: 20,40,60,80,100,200, for which the MPE error value was minimal (Tables 1,2).

Table 1 Summary of neural network learning for the case of random sample sizes teaching 70%, testing 15% and validation 15%.

Weather conditions	Network number	Network name	Quality (learning)	Quality (learning)	Quality (validation)	Learning algorithm	Activation (hidden)	Activation (output)	Errors				
									ME	MAE	MPE	MAPE	SSE
Good weather conditions	20	MLP 10-8-1	0,380743	0,557601	0,714863	BFGS 5	Exponential	Linear	82,3645 045	1443,39 9	0,75%	7,87%	1768,684
Fog, smoke	20	MLP 10-2-1	0,699875	0,066032	0,943312	BFGS 4	Exponential	Linear	8,04241 594	41,1419 4	0,21%	12,38%	60,69985
Rainfall	100	MLP 10-4-1	0,568312	0,485220	0,503122	BFGS 10000	Tanh	Exponential	28,2526 725	182,797 9	1,91%	5,46%	361,2715
Snowfall, hail	80	MLP 10-5-1	0,547138	0,838358	0,997171	BFGS 5	Exponential	Logistics	41,6398 707	129,302 1	11,69%	32,39%	172,6225
Dazzling sunshine	100	MLP 10-5-1	0,340422	0,984501	0,958639	BFGS 12	Linear	Tanh	1617,43 %	5553,96 %	3,71%	8,71%	9172,30 %
Cloudy	100	MLP 10-8-1	0,769632	0,695728	0,778379	BFGS 124	Logistics	Logistics	248,761 533	268,338 9	5,29%	5,52%	569,5951
Strong wind	100	MLP 10-3-1	0,897115	0,844408	0,554336	BFGS 58	Tanh	Exponential	0,87115 941	11,7942 2	0,86%	5,23%	25,49601
Average									60,87	304,62	3,49%	11,08%	435,73

Table 2. Summary of neural network learning for the case of random sample sizes teaching 80%, testing 10% and validation 10%.

Weather conditions	Network number	Network name	Quality (learning)	Quality (learning)	Quality (validation)	Learning algorithm	Activation (hidden)	Activation (output)	Errors				
									ME	MAE	MPE	MAPE	SSE
Good weather conditions	200	MLP 10-4-1	0,436088	0,00	0,00	BFGS 5	Logistics	Exponential	354,369174	1419,214	0,38%	7,37%	1861,726
Fog, smoke	40	MLP 10-7-1	0,698835	0,00	0,00	BFGS 7	Tanh	Linear	5,09933563	33,32237	0,17%	10,30%	42,93103
Rainfall	100	MLP 10-6-1	0,573823	0,00	0,00	BFGS 5	Logistics	Linear	129,266956	347,1995	4,53%	8,99%	398,5465
Snowfall, hail	200	MLP 10-7-1	0,574231	0,00	0,00	BFGS 4	Linear	Linear	15,3183242	118,2604	23,06%	35,33%	183,6962
Dazzling sunshine	20	MLP 10-4-1	0,505107	0,00	0,00	BFGS 3	Linear	Logistics	616,41%	6544,21%	1,05%	10,15%	8731,51
Cloudy	60	MLP 10-7-1	0,825527	0,00	0,00	BFGS 20	Linear	Exponential	77,4751804	175,3706	1,84%	3,37%	307,507
Strong wind	80	MLP 10-2-1	0,882740	0,00	0,00	BFGS 27	Linear	Logistics	2,83773863	5,955856	1,68%	2,95%	11,29727
Average									84,36	309,25	4,67%	11,21%	1648,17

Based on the results presented one can conclude that the number of road accidents in Poland, regardless of weather conditions, will decrease from year to year. The results obtained depend on the selection of a random sample size. Increasing the percentage of the learning group relative to the test and validation group maximizes the average percentage error. For a learning group of 70%, a test group of 15% and a validation group of 15% in proportions (70-15-15), the error was 2.28%, while for the second sample (80-10-10) the error was 4.67%.

Based on the obtained data on the projected number of traffic accidents depending on weather conditions, it can be concluded that a reduction in the number of traffic accidents can still be expected in the coming years, followed by stabilization. It should be added that the results obtained were affected by the pandemic.

Fig. 3. Forecasting number of traffic accidents for 2022-2040 for the 70-15-15 test group
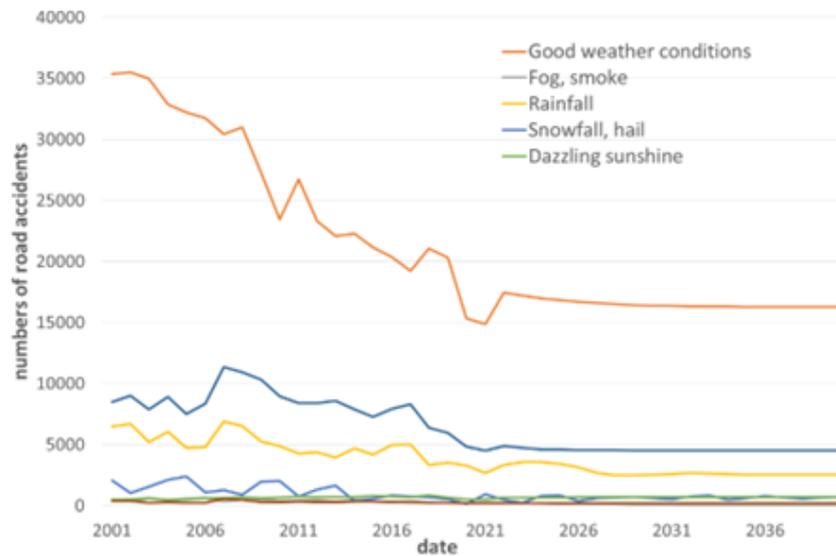
Fig. 4. Forecasting number of traffic accidents for 2022-2040 for the 80-10-10 test group

Based on the results presented one can conclude that the number of road accidents in Poland, regardless of weather conditions, will decrease from year to year. The results obtained depend on the selection of a random sample size. Increasing the percentage of the learning group relative to the test and validation group maximizes the average percentage error. For a learning group of 70%, a test group of 15% and a validation group of 15% in proportions (70-15-15), the error was 2.28%, while for the second sample (80-10-10) the error was 4.67%.

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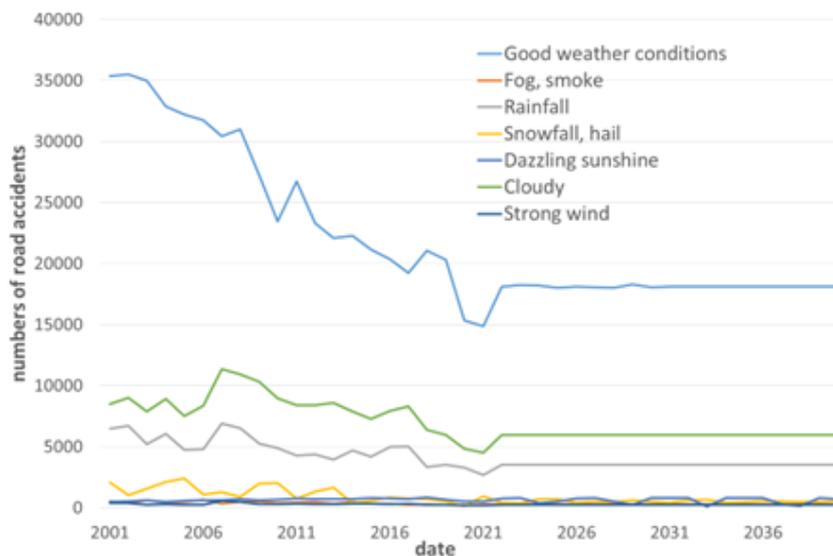
4. Conclusions

Neural networks were used to predict the number of accidents in Poland depending on weather conditions, and the study was conducted in the Statistica environment. The weights used in the study were estimated by the program in such a way as to minimize the mean absolute error and mean absolute percentage error.

Based on the data obtained, it can be concluded that the pandemic has caused a reduction in traffic accidents, and we can expect a further decrease in traffic accidents in the coming years, and stabilization thereafter. However, further pandemic may change the value of the obtained results. The calculated forecast errors prove the accuracy of the models used.

Based on the obtained forecasts, measures should be taken to further minimize the number of traffic accidents. Such measures may include the introduction of higher fines for traffic offenses on Polish roads from January 1, 2022. The pandemic, which drastically changed the number of road accidents, certainly had an impact on the disruption of the obtained research results.

In further studies, the authors plan to take into account more factors affecting accident levels and use various statistical methods to determine the number of traffic accidents. These may include traffic volume, weather conditions or the age of the accident perpetrator, as well as exponential methods for determining the number of traffic accidents.

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studia I stopnia

MECHANIKA I BUDOWA MASZYN

specjalności
- Inżynieria produkcji
- pojazdy i maszyny robocze
- pilotaż bezzałogowych statków powietrznych

perspektywy zatrudnienia

- przedsiębiorstwa produkcyjne przemysłu maszynowego
- firmy projektowe
- przedsiębiorstwa transportowe oraz zajmujące się wytwarzaniem pojazdów i maszyn roboczych
- instytucje użytkujące pojazdy i maszyny robocze
- firmy zaplecza technicznego pojazdów i maszyn,
- przedsiębiorstwa produkcji półfabrykatów, elementów, podzespołów, zespołów, układów, maszyn urządzeń - na wszystkich etapach procesu produkcji

przykładowe przedmioty

- mechanika techniczna
- wytrzymałość materiałów
- mechanika płynów
- podstawy konstrukcji maszyn
- komputerowe wspomaganie projektowania
- inżynieria wytwarzania
- termodynamika techniczna
- elektrotechnika i elektronika
- automatyka i robotyka
- metrologia i systemy pomiarowe

co zyskujesz?

- wysokie kompetencje i umiejętności w zakresie nowoczesnych metod wytwarzania, projektowania i eksploatacji maszyn
- będziesz należał do grona specjalistów z wiedzą, kompetencjami i umiejętnościami dotyczącymi m.in. projektowania, zarządzania systemami eksploatacji maszyn produkcyjnych, pojazdów oraz maszyn roboczych

ciekawostki o kierunku

Na specjalności pilotaż bezzałogowych statków powietrznych, będziesz miał możliwość uzyskania odpowiednich uprawnień w zakresie pilotowania dronów.

Studia na tym kierunku są bardzo praktyczne, czego przykładem są STUDIA DUALNE prowadzone we współpracy z ponad 40. firmami. To gwarancja doświadczenia, poszerzenia wiedzy oraz dobrych zarobków w zawodzie, już w trakcie trwania studiów!

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CONSTRUCTION OF AN ELECTRIC LONGBOARD WITH ONE-WHEEL DRIVE

inż. Łukasz PIOTROWSKI
e-mail: luxiarz1998@gmail.com
Katedra Inżynierii Mechanicznej, Akademia Nauk Stosowanych im. Stanisława Staszica
w Pile
ul. Podchorążych 10, 64-920 Piła

inż. Filip GÓRA,
e-mail: filipgora98@gmail.com
Katedra Inżynierii Mechanicznej, Akademia Nauk Stosowanych im. Stanisława Staszica
w Pile

dr inż. Jarosław Robert MIKOŁAJCZYK
e-mail: jmikolajczyk@ans.pila.pl
ORCID No.: 0000-0001-9196-0039
Katedra Inżynierii Mechanicznej, Akademia Nauk Stosowanych im. Stanisława Staszica
w Pile
ul. Podchorążych 10, 64-920 Piła

Abstract: This article presents an electric skateboard, built in-house, using components available on the market. Because the project was innovative in its nature, it was necessary to appropriately fit individual subassemblies into one unit. This was achieved using elements printed on a 3D printer. The constructed device was tested on an asphalt road at various riding speeds and with various loads. This skateboard design has an electric motor driving the rear right wheel.

Key words: skateboarding, jam, hanger, heelie, jump-ramp, miniramp, McFish, Madonna, sadplant, Puck, AES, bank, baseplate, PLA

1. Introduction

There are many sources where we can find information about the history of a skateboard and its origins. First constructions of a skateboard were made by hand. However, because its popularity has been increasing, industry began to take up its production. Currently, there are many manufacturers on the market offering this type of devices and also additional equipment, such as helmets, knee pads, elbow pads and even footwear. New skateboard solutions are constantly being developed, including electric skateboards. Safety requirements and test methods for skateboards are covered by, inter alia, the standard PN-EN 13613 "Roller sports equipment – Skateboards – Safety requirements and tests methods." The skateboard appears to have originated as a combination of a surfboard and roller skates. And a surfboard probably originated from a small, slender, single-sail boat. Roller skates, on the other hand, are derived from ice skates, and ice skates are derived from runners (sleighs with runners). There is a large time gap between the above-mentioned structures, even several centuries. Currently, commercially produced skateboards are dynamically tested on devices that allow them to reach speeds of up to 18 km/h, ride up curbs three times without any signs of cracking or loosening of mechanisms, and their design allows for, among other things:
- replacement of wheels;
- lubrication of bearings;
- steering adjustments.

Speed tests of classic skateboards are carried out depending on the skateboard class (Class A and Class B) for 6 minutes or 3 minutes without a break at a nominal speed of 20 km/h ± 0.5 km/h. For this type of test, there should be no seizing of wheel bearings for a mass of 50 kg (for Class A) or 40 kg (for Class B)

The corners and edges of commercially manufactured skateboards should be rounded and should not have any burrs or sharp or protruding edges. The ends of the board should be rounded with a radius R of at least 10 mm (Fig. 1). The main components of the skateboard are shown in Fig. 2. As you can see on the streets and squares, skateboards operate in difficult, mainly dynamic conditions.
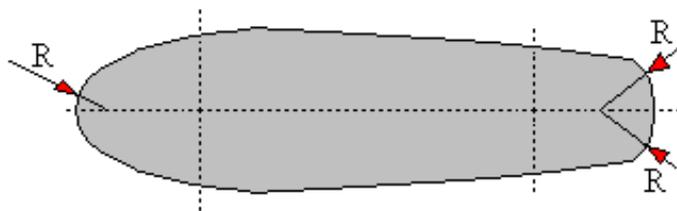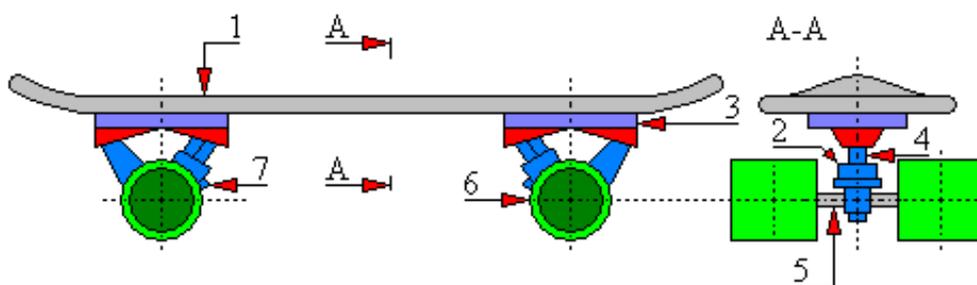

Fig. 1. Rounding radius of the deck edge R ≥ 10mm

Fig. 2. The main components of a skateboard
1 – deck; 2 – rubber band; 3 – truck washer; 4 – adjustment screw; 5 – axle; 6 – wheel; 7 – truck

The process of skateboard construction design has not ended and is still evolving [1, 2, 4]. In view of significant advances in electronics, now there are electric skateboards available on the market. The remote control that controls the speed of the ride is usually held by the skateboard user. The batteries and drive (front-wheel or both front and rear wheels) are most often mounted under the board. Then, the mass of the structure increases. Unfortunately, jumping onto curbs is difficult for these structures [4, 8, 9].
A skateboard is essentially composed of the following parts (Fig. 6):
  • deck;
  • wheels;
  • trucks (axles);
  • rails (plastic strips);
  • tailbone (also known as brake);
  • riserpads (pads) or cell blocks;
  • griptape (lining)

The deck consists of several, e.g. seven, layers of laminated wood. Most boards for riding on ramps have a concave or slightly hollowed shape for your feet to rest firmly on them. The back of the deck, or this part which is behind the rear truck, is raised. Later, the front of the deck, the so-called nose, was also bent upwards, which made it much easier to perform some tricks.
Wheels are made from different materials, such as urethane, and have different hardnesses measured in durometers (referred to by the letter "A"). The higher the A value, the harder the wheels are. Typical street wheels have a hardness of 92A. The most commonly used wheels have a hardness of 85A to 97A. Wheels with a hardness of 90A÷92A are used for riding on asphalt. Wheels with a hardness of 92A÷95A are used for smoother surfaces and on ramps. Wheels with a hardness of 97A are used primarily in pools and for freestyle skating. For street skating, people choose the wheels hardness at their own discretion. Among the most commonly used are wheels with a hardness of 92A÷95A. But many people prefer hard wheels (97A) to make slides easier.

There are two ball bearings in the wheel and a spacer sleeve between them that separates the ball bearings when the nut is tightened onto the axle core. The bearings used must be sealed on both sides to prevent dust, sand or other contaminants from getting inside.

Trucks (axles, or board suspension) are usually made of aluminum. Some trucks (Fig.7) have plastic pads that help reduce pressure on the deck. By moving the nut (so-called "kingpin") upwards one can adjust the skateboard's maneuverability. The maneuverability of a skateboard also depends on the hardness of the rubber bands used. Rubbers of different hardness are used, ranging from soft for slalom skating to hard for freestyle skating.

A hard plastic casing (coper) is often placed underside the axle to protect the entire truck, but also to make it easier to perform certain tricks (e.g. grind).

Rails are plastic strips attached along the length of the deck using wood screws or some type of T-shaped wooden screws. Such strips allow for a better grip of the board while jumping and at the same time protect the lower part of the deck.
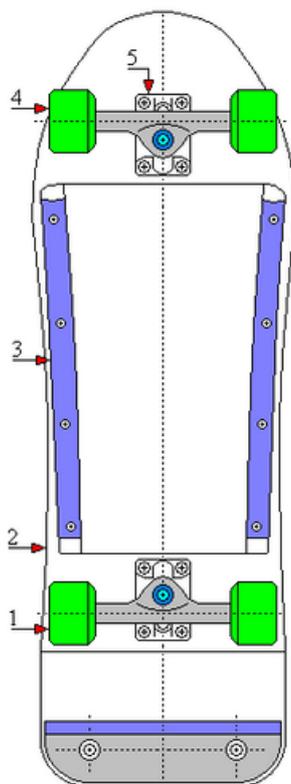
Fig. 6. Bottom view of a typical skateboard [8, 13]
1 – rear wheels; 2 – deck; 3 – stiffener/reinforcement; 4 – front wheels; 5 – front truck mount

A tailbone, or the so-called brake, is screwed on using wood screws or special T-shaped screws.

The brake protects the tail, or back, of the deck.

Riserpads, or cellblocks as they are sometimes called, are plastic plates about 5 mm thick placed between the truck and deck. If they are missing, there is a risk of wheelbite when taking a sharp turn. One should use approximately 5÷10 mm thick pads These pads are usually made of hard plastic.

Fig. 7. Truck components [8, 13]
 1 – coper; 2 – kingpin (nut); 3 – washer; 4 – rubber bands; 5 – nut; 6 – axle; 7 – pivot bushing; 8 – kingpin; 9 – baseplate

Wedge pads or rad pads are wedge-shaped pads which are used in order to give the board better maneuverability when turning.
Griptape is a sandpaper-like lining that is stuck to the top of the deck to give the feet a better grip on the board.
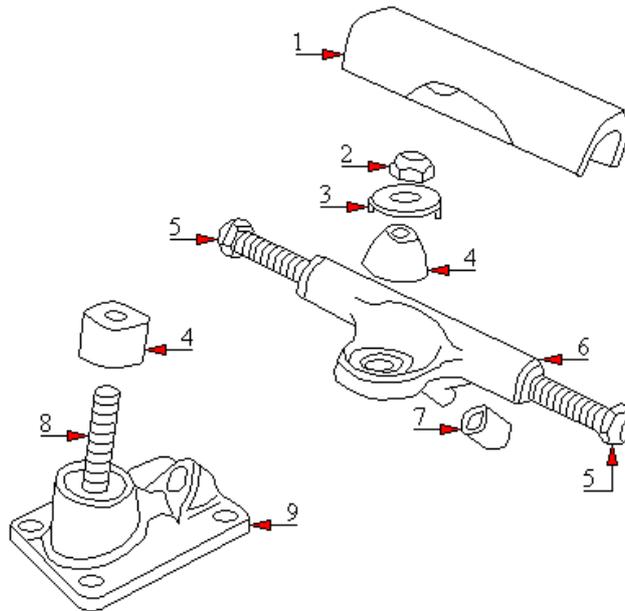Decks used for different skateboarding disciplines have different shapes. Ramp boards are concave and wide. Freestyle boards are narrower and have hard trucks. A slalom board is often pliable and has soft rubbers to make the trucks as flexible as possible.

2. Construction of an electring longboard

There are many models of electric longboards available on the market which are a fast transport alternative, especially in the cities. But there are also users who choose this type of transport to move between the cities as now the distance range of this type of structures currently produced may exceed 20 km. Of course, skateboards are most often used for sports purposes.
To build this structure, a brushless motor of 1820W with dimensions of 80.52x49.52x8mm was used as a drive unit and it was mounted from the underside of the deck (Fig. 8). Brushless motors are characterized by relatively small dimensions compared to their power. They allow for precise control of speed and torque and are quieter during operation than brushed motors.
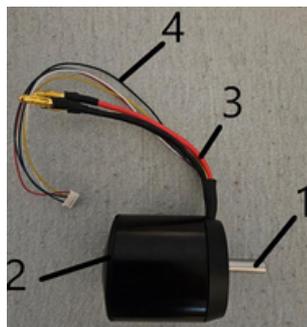

Fig. 8. View of brushless motor 1820 W, dimensions 80.52x49.52x8 mm
1 – motor shaft; 2 – rear part of the motor housing; 3 – three-phase cables; 4 – cables for connecting the Hall sensor

Due to high power of the engine, it was decided to build one battery consisting of twenty individual Sony lithium-ion cells with a capacity of 3100 mAh and nominal voltage of 3.6V. They were connected in parallel cells to increase capacity without changing voltage. A single cell consists of four cells (Fig.9) connected together by a 0.1 mm thick and 7 mm wide nickel-plated tape (Fig.10). All cells were placed in a housing printed on a 3D printer. The nickel-plated tape was connected to the batteries using a spot welder (Fig. 11, Fig. 12).

All details - such as covers, housings, handles, belt pulleys - were designed on our own and printed on an Anycubic Typer 3D printer (Fig. 13).
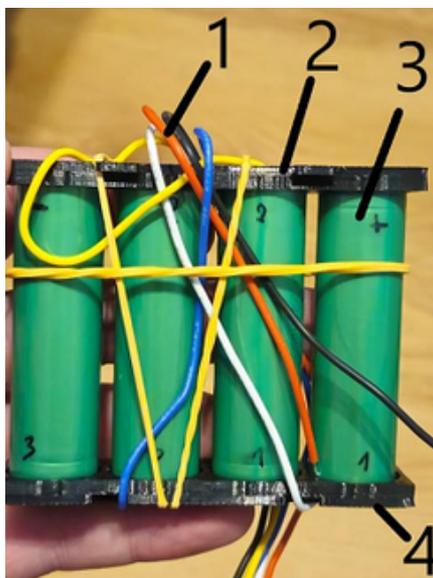
Fig. 9. View of a single battery cell
1 – cables connecting the cells; 2 – upper part of the housing printed on a 3D printer; 3 – single 18650 cell; 4 – lower part of the housing printed on a 3D printer

An element which is responsible for controlling the electric longboard is the transmitter with the FlySky GT3C + GR3E receiver. This device is designed for remote control of RC models. The transmitter has a large LCD display which allows to change settings quickly and efficiently. The transmitter is powered by a battery with capacity of 800 mAh and voltage of 3.7V (Fig. 14).

To control the speed of the electric longboard, a Redox 80 A EVO type controller was used.

The body of the longboard is a commercial deck manufactured by Master Sports Equipment, with dimensions of 1040x240 mm. It consists of eight layers of maple wood, which allows for a load capacity of 180 kg (Fig. 16). The elements responsible for stability, control and proper driving are aluminum seven-inch axles, so-called trucks, from the same manufacturer.
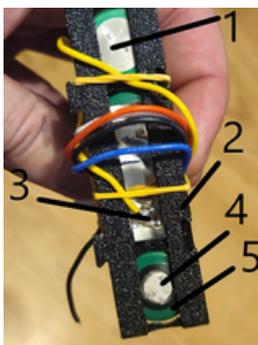
Fig. 10. Places of linking the batteries
1 – the negative of the 18650 cell; 2 – battery cell housing; 3 – place where the wire is welded to the battery; 4 – the positive of the 18650 cell; 5 – protective wrapping of the 18650 cell
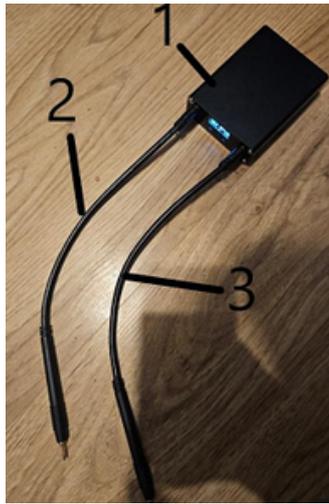
Fig. 11. View of the spot welder
1 – spot welder; 2 – soldering pen negative; 3 – soldering pen positive

Fig. 12. View of the spot welder menu
1 – spot welder display; 2 – control buttons
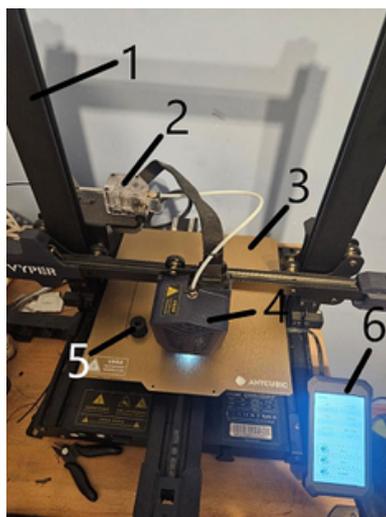
Fig. 13. View of the Anycubic Vyper 3D printer
1 – housing with Z axis screw; 2 – material feeding mechanism; 3 – platform with dimensions 245x245mm; 4 – extruder head; 5 – printed element (active pulley); 6 – touch control panel

Fig. 14. View of FlySky GT 3C transmitter
1 – power button; 2 – potentiometer with a trigger for accelerating or braking the riding speed; 3 – transmitter handle; 4 – transmitter battery

All drive components (driving gear, passive gear, additional adapter for the skateboard driving gear, battery housing, speed controller box housing) were designed in the Fisiom 360 software and printed using an Anycubic Vyper 3D printer (Fig. 15).
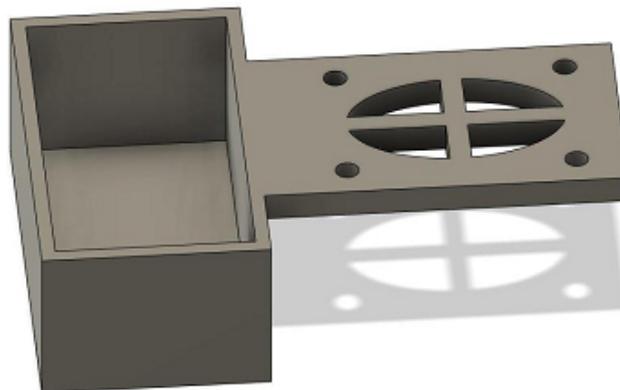
Fig. 15. View of the speed controller box and remote control module
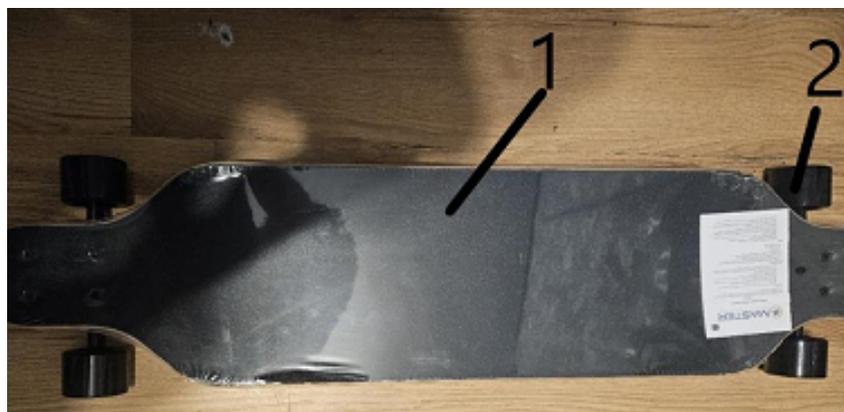
Fig. 16. View of MASTER 41 longboard
1 – longboard wheels; 2 – longboard deck

The drive wheel is connected to the electric motor by means of an Optibelt transmission belt with catalogue number CT 2604736001, and number of teeth z=75, belt thickness g=12mm, belt length l=225mm.

The final assembly began by placing the battery embedded in the box, and speed controllers and remote control module box next to the truck with the electric motor so that the distance between them allowed for their free connection without tensioning the electrical cables. The battery box was screwed to the bottom part of the deck. The speed controller box (housing), drive (rear) truck and front (passive) truck were mounted in a similar manner (Fig. 17, Fig. 20).
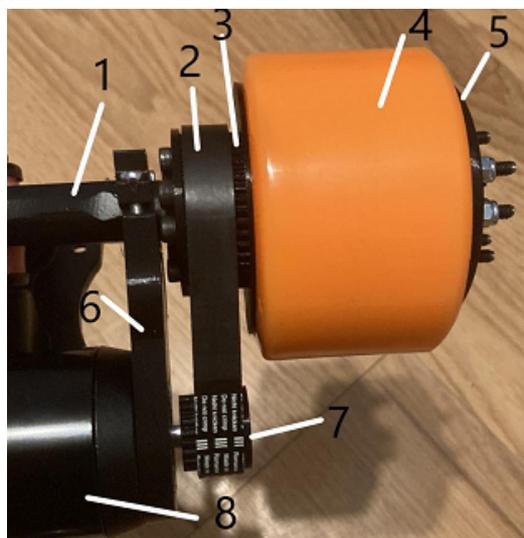
Fig. 17. Transfer of the electric longboard drive from the motor onto the active wheel

1 – rear truck axle; 2 – Optibelt transmission belt with catalog number CT 2604736001; 3 – passive pulley; 4 – longboard wheel (rear right); 5 – wheel mounting adapter; 6 – motor mounting element; 7 – active pulley mounted on the electric motor shaft; 8 – brushless electric motor

Unfortunately, this design solution resulted in that the rear wheel diameters were bigger than those of the front ones. Indeed, they had to be greater because the battery box had to be put under the deck. Subsequently, however, the front wheels were replaced with the same diameter as the rear wheels. This ensures that the surface of the deck is parallel to the ground.

Figures 18 and 19 show the active and passive gears. The gear ratio of the belt transmission is i=2.095. The driving wheel is mounted on the motor shaft, and the idler wheel is attached with six screws to the rear right road wheel of the skateboard. Unfortunately, this results in the skateboard having a single-wheel drive only. If we transport some load in a straight line, then the skateboard deviates from its straight course. However, if it is moved by a competitor or user, then because it is possible to use body balance, he or she can correct the direction of riding. Of course, a much better solution here would be to use the drive on both wheels. For this type of construction, possible are four types of drive:

·one-wheel drive (rear right, rear left, front right, front left);
·two-wheel drive (both rear, both front, or diagonally – rear right + front left and rear left + front right, and one-sided: front right + rear right; front left + rear left);
·three-wheel drive;
·all-wheel drive.

As in cars, all-wheel drive results in higher energy consumption, but the driving dynamics improve.
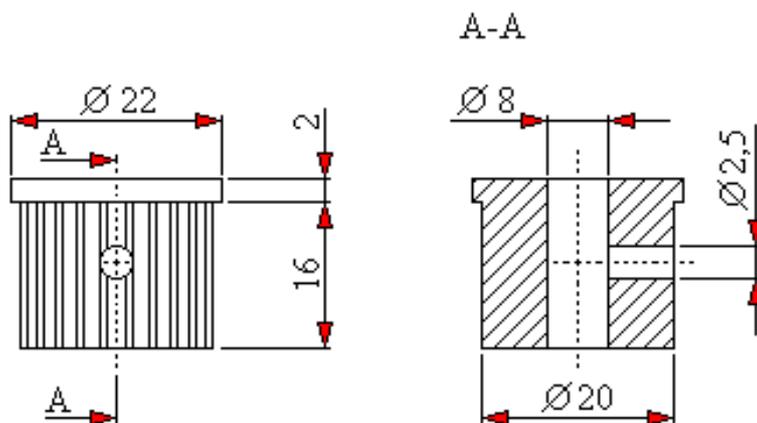
Fig. 18. Driving gear mounted on the motor shaft. Number of teeth z=21. Material: PLA

The electronic system that charges the batteries and protects them against excessive discharge is the HXYP-C47-MA18-4S charging controller. This is a module designed for four lithium-ion cells.
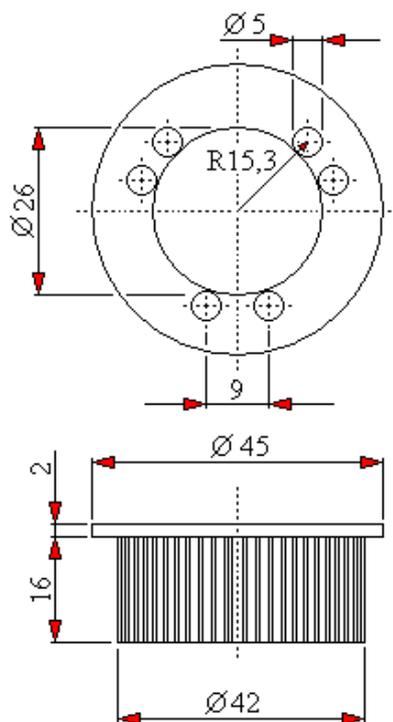
Fig. 19. Idler gear attached to the rear right wheel of a skateboard. Number of teeth z=44. Material: PLA

It is easy to see that the surface of the mounted battery box (Fig.20) relative to the surface of the deck is about one third, maybe one fourth. This makes it possible to install a much larger battery and possibly an additional motor to drive the second rear wheel.

Fig. 20. View of the assembled electric longboard of own design
1 – battery; 2 – speed controller with remote control module; 3 – rear truck with electric motor and drive wheel.

Fig. 21 shows the bracket for mounting the electric motor to the truck arm. This bracket was damaged during heavy braking tests. Then, PLA material was used, and the element itself was made using 3D printer. Eventually, the same piece was made from steel, which solved the problem.
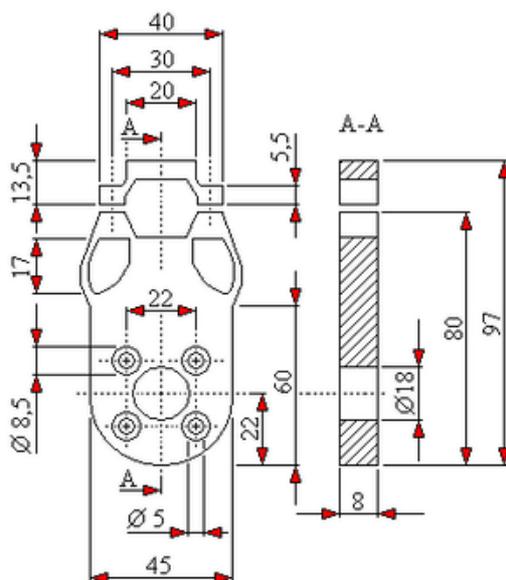
Fig. 21. Motor mounting bracket for truck arm. Material: PLA

 Increasing the total battery capacity and installing an additional motor would allow for an increase in the electric skateboard's range and speed. Theoretically, without load this vehicle could reach a speed of about 100 km/h. Of course, at a much lower speed it would be very dangerous to ride it. This design has neither a software speed limit nor a centrifugal clutch that would disconnect the drive when the set speed limit is exceeded.
 This type of construction can be used for forward, reverse or slalom riding. Jumping onto ramps, going down stairs and similar obstacles would result in the destruction of the device. For this type of riding it would be necessary to protect the drive and control system against all types of impact and vibrations.
Construction plastic material: PLA manufactured by Devil Design. PLA – polylactide, fully biodegradable, thermoplastic aliphatic polyester, made from renewable raw materials (e.g. corn flour, sugar beets), which is why it is relatively cheap. It is most often used in the plastics processing as transparent. It has good organoleptic properties and is suitable for contact with food. It has good rheological properties.

It is often combined with multiple additives to better optimize its characteristics for special applications. The melting point of PLA ranges from 150°C to 180°C (depending on the additives used and the degree of crystallinity of the polymer). PLA can be found in semi-crystalline and amorphous varieties. Amorphous PLA has better processability but worse mechanical properties compared to crystalline PLA. When using this material, there is considerable complexity in setting the optimal parameters for 3D printing. The most important variable is the relative humidity of the filament - this material is hygroscopic. PLA stored in a low-humidity atmosphere can withstand higher tensile forces. The melting point of the polymer causes water particles to boil, water turns into gas bubbles, and this leads to the material's porosity and tendency to crack. The mechanical properties of parts printed using PLA are strongly correlated with the thickness of the printed layer. The use of ultrasonic vibration improves the surface finish of PLA printing. Printing of reinforced PLA, e.g. using fibers, nanomaterials, fillers, graphene, etc., makes it possible to increase the strength of 3D parts. PLA is also characterized by low processing shrinkage, so it does not require heating the base of the 3D printer table. The disadvantages of PLA include a low softening temperature (45°C) [11].

In terms of strength, a better solution would be to have gears (active and passive) made of steel. However, considering this device as a prototype, it was decided to use 3D printing.

Mounting element 6 of the electric motor (Fig. 17) which fixes the motor to the deck was also made on a 3D printer from PLA material. During tests, it was destroyed already after the seventh braking, with a user weighing approximately 100 kg. Finally, it was decided to make an identical element from steel using a laser cutter.

One drawback of this design is the lack of a toothed belt drive tensioner. As the belt lengthens or wears out, when there is greater slack in the structure, etc., power may not be transferred properly to the wheel.

An interesting solution in this type of vehicle would be to use automatically activated direction indicators. The body weight balances, the direction of riding changes, the turn signals activate. Of course, the indicators would be mounted on the side edge of the deck. We have not yet encountered such a design solution on the market.

This design lacks a tachometer and speedometer. It would then be necessary to mount, for example, an encoder on one of the wheels. During the tests, the riding speed was determined as the quotient of the distance travelled to the riding time. It is also possible to determine the speed of the skateboard using a smartphone.

4. Summary

The designed and built electric skateboard allows for a maximum driving speed of 27 km/h on asphalt, with a user weight of 100 kg. The legally permitted maximum riding speed for this type of construction is 22 km/h (in some countries 25 km/h). The emergency braking distance at a speed of 20 km/h, for the same person operating the skateboard, was 6.2 metres on asphalt. Unfortunately, the drive of this skateboard is transferred to one wheel only – onto the rear right wheel of the skateboard. A better solution would be to use drive on both rear wheels of the skateboard [2, 3]. The use of front wheels drive is a bit cumbersome due to their steering functions. In addition, this design uses larger diameter skateboard wheels than standard ones due to the fact that the deck is raised in order to put the battery housing underneath. Such a solution was simply a necessity. Any jumps on the ramp or over obstacles with this type of skateboard would be difficult and might be harmful to its structure because of electronic systems.

The steering of this type of vehicle, like other skateboards, is done by means of the rider's mass balance. Of course, it is possible to achieve much higher riding speeds but the safety of riding is then decreased, unless the skateboard is not operated by a human but by a machine or by itself with a load. Steering is then difficult because the load does not perform the mass balance. Then, the rides would be performed in a straight line.

To sum up, for sports purposes, the electric skateboard is currently inferior to the classic skateboard in terms of resistance to all types of damage. However, the development of this type of construction may in the future lead to the creation of an electric skateboard that allow for, among other things, energy recovery during braking, all-wheel drive, increased impact resistance and increased durability of its mechanisms.

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studia I stopnia

TRANSPORT

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- technologia transportu
- podstawy inżynierii ruchu
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- towaroznawstwo z elementami technologii prac ładunkowych
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STABILITY OF HALF-THROUGH STEEL TRUSS BRIDGES

dr inż. Jarosław KOŁODZIEJ
e-mail: jaroslawkolodziej@ans.pila.pl
ORCID No.: 0000-0001-5808-0523
Department of Civil Engineering, Akademia Nauk Stosowanych im. Stanisława Staszica w Pile
ul. Podchorążych 10, 64-920 Piła

1. Introduction

In the engineering practice there is often a problem of stability of elastically supported structures. A classic example of this type of structure is an open truss bridge with underpass. The stability of the upper compressed chord members of this bridge can be roughly investigated by using a model of a bar resting on elastic supports. The stiffness of elastic supports is determined here by the stiffness of the bridge half-frames versus horizontal displacement. The above-mentioned problem of instability of compressed truss chord members was already noticed at the end of the 19th century following numerous railway bridge disasters at that time, and a rough solution to this problem was given by F. Engesser (1888) and F. Jasiński (1893). The article is an attempt to analyze this problem and compare a design solution, which is still applicable, based on the equivalent model of a bar resting on elastic supports, providing the "exact" solution based on modern numerical analysis.

1.Stability of a bar resting on elastic supports

Given is a bar with constant bending stiffness EI, compressed axially with a force N and resting on linearly elastic supports with stiffness c (Fig. 1a). For sufficiently small distances between elastic supports, the interaction of concentrated elastic supports $c_q = c/a$ replaced by the interaction of a continuous elastic foundation with the value (Fig. 1.b).

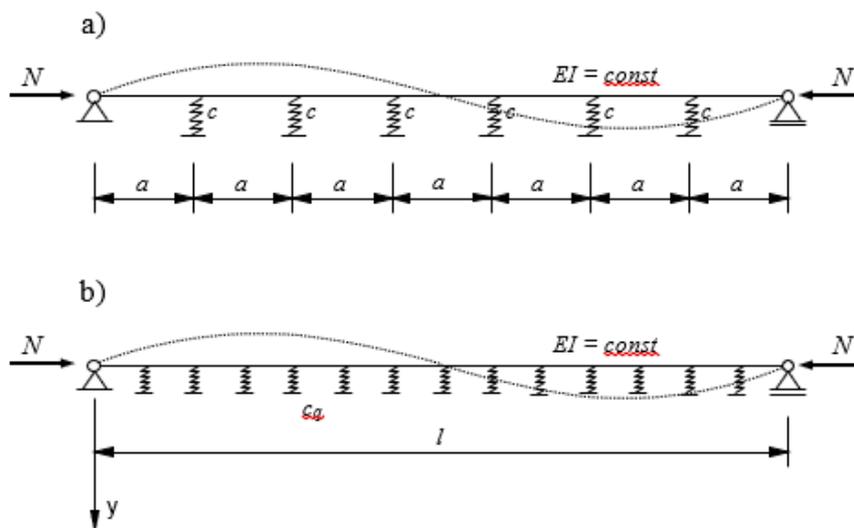

Fig. 1. Example of a bar supported elastically: a) bar on elastic supports, b) bar on elastic foundation

The differential equation for a bar resting on an elastic support has the well-known form:

$$EIy^{IV} + Ny^{II} + c_q y = 0. \tag{1}$$

The buckling form of the bar, i.e. the number of waves and their length, depends on the ratio EI/c_q. For a big value of this ratio the number of buckling waves is small, and for a small value of EI/c_q this number is big.

The solution of equation (1) has the form:

$$y = y_0 \sin \frac{m\pi x}{l}, \qquad (2)$$

where *m* is the number of buckling half-waves.

Further differential equations (2) lead to the following result:

$$y^{II} = -y_0 \left(\frac{m\pi}{l}\right)^2 \sin \frac{m\pi x}{l},$$

$$\qquad (3)$$

$$y^{IV} = y_0 \left(\frac{m\pi}{l}\right)^4 \sin \frac{m\pi x}{l}.$$

After inserting (2) and (3) into (1) we get:

$$EI\left(\frac{m\pi}{l}\right)^4 - N\left(\frac{m\pi}{l}\right)^2 + c_q = 0. \qquad (4)$$

Formula (5) defines the critical force as a function of an unknown argument m of the number of half-waves of the sine curve according to which the bar is bent and is therefore somewhat inconvenient to use. The value N_{cr} may be determined from (5) for instance by trial method, replacing *m* with subsequent natural numbers (*m*=1,2,3,...) and checking for which *m* value obtained is the lowest value of critical force. This solution method is discussed in detail in [9].

Another method of solving equation (5) – discussed in [8] – was given in 1888 by F. Engesser. The number m of buckling half-waves of a bar is determined in this method from the relation:

$$\frac{dN_{kr}}{dm} = 2m\frac{\pi^2}{l^2}EI - 2\frac{l^2}{m^3\pi^2}c_q = 0, \qquad (6)$$

from where

$$m^2 = \frac{l^2}{\pi^2}\sqrt{\frac{c_q}{EI}}. \qquad (7)$$

Putting (7) into (5) we get:

$$N_{cr} = EI\sqrt{\frac{c_q}{EI}} + c_q\sqrt{\frac{EI}{c_q}}, \qquad (8)$$

or after some transformations

$$N_{cr} = 2\sqrt{EIc_q}. \qquad (9)$$

Formula (9) is very simple in practical applications because it allows to determine the value of critical force in a direct way. It follows from formula (9) that the value of this force does not depend on the length of the compressed bar and that the change in the critical force value is influenced to the same extent by the change in the stiffness of bar EI and change in the stiffness ofelastic foundation c_q.

It can be shown that formula (9) usually gives slightly smaller values of the critical force than formula (5). This difference is influenced by the fact that the number of half-waves m calculated from relation (4) is generally not a natural number. From a practical point of view, however, these differences are not significant, especially in the case of a higher value of *m*.

The buckling length of a bar member L_{cr} can be easily calculated by comparing the critical force (9) with the Eulerian critical force, i.e.:

$$2\sqrt{EIc_q} = \frac{\pi^2 EI}{L_{cr}^2} , \qquad (10)$$

from where

$$L_{cr} = \pi \sqrt[4]{\frac{EI}{4c_q}} . \qquad (11)$$

Knowing the value calculated from formula (11) we can easily carry out dimensioning of the bar in accordance with the current standard [10]. However, the buckling length of the bar member determined on the basis of the relation (11) must meet the condition [8]:

$$L_{cr} \geq 1,2a . \qquad (12)$$

Failure to meet condition (12) means that the distances between elastic supports are too large in a given case, and replacing such supports with an "equivalent" elastic foundation would be an oversimplification.

In the case of real elastic supports with stiffness c and spacing a, formula (11) can be presented in the form:

$$l_e = \pi \sqrt[4]{\frac{EIa}{4c}} = \mu \cdot a , \qquad (13)$$

where:

$$\mu = \pi \sqrt[4]{\frac{\alpha}{4}} , \qquad (14)$$

and

$$\alpha = \frac{EI}{ca^3} . \qquad (15)$$

A graphical relationship between the buckling length factor μ and the parameter α is presented in Fig. 2. This relation is valid for the number of spans being at least 4.
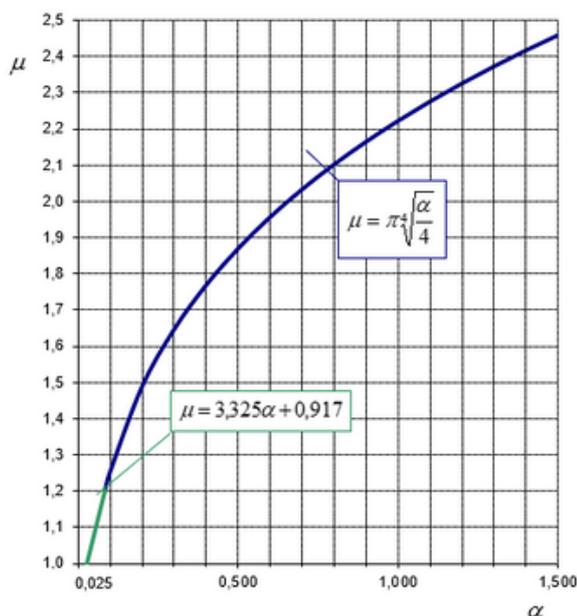

Fig. 2. Relationship between the buckling length factor and parameter value α

As mentioned earlier, the lower limit for the application of formula (14) is generally assumed to be the value of the buckling length coefficient $\mu = 1.2$ $(L_{cr} \geq 1.2a)$. For smaller values μ, the use of formula (14) is burdened with too big an error and then, therefore, one should adopt the real model of the bar member resting on elastic supports. Alternatively, the dependence on the value of the coefficient μ in the considered interval $(\mu < 1.2)$ can be expressed, with a sufficient approximation for practical purposes, by a linear function. Numerical value of the point on axis α, through which a straight line goes can be taken from the limit stiffness condition of flexible supports for which the critical force of the bar resting on elastic supports does not differ from the critical force of the pin joint-supported bar $(\mu = 1$ and $L_{cr} = a)$. This occurs when the stiffness of the flexible supports meets the condition [9]:

$$c \geq \frac{4\pi^2 EI}{a^3} . \tag{16}$$

Using this condition, after simple transformations, we obtain the equation of the sought line in the form (Fig. 2):

$$\mu = 3.325\alpha + 0.917 . \tag{17}$$

3. Stability of compressed chord members of open bridges

According to the recommendations of Eurocode [11], the compressed chords of the main girders of open truss bridges (Fig. 3) should be treated as elastically supported members. In the case of analysis of stability of upper compressed chord member of a girder in elastic buckling out of the truss plane, these codes are generally based on the model of a member resting on elastic supports. The stiffness c of these supports is determined on the basis of the stiffness per unit displacement u of the open bridge half-frames (Fig. 3b).
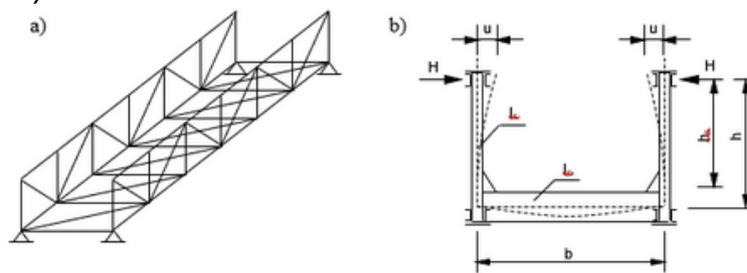
Fig. 3. Example of an open truss bridge: a) view, b) cross-section

This stiffness can be expressed by the formula:

in which:

$$H = c = \frac{E}{\dfrac{h^2 b}{2I_p} + \dfrac{h_s^3}{3I_s}} , \tag{18}$$

h - theoretical height of the truss post,
b - theoretical span of the cross member,
h_s - reduced height of the post measured from the center of gravity of the metal plate stiffening the connection between the post and cross member to the axis of the compressed chord,
I_s - moment of inertia of the post cross-section relative to its axis of gravity parallel to the chord axis,
I_p - moment of inertia of the section of the cross member relative to its horizontal axis.

According to the Eurocode recommendations [11], the compressed chords of open bridge girders are modeled with a bar resting on elastic supports. The stiffness of these supports should be determined based on relationships (18) or (19). The critical force causing buckling of the upper chord of the bridge truss and the buckling length of the chord corresponding to this force can be determined in this case using, for example, an appropriate computer program.
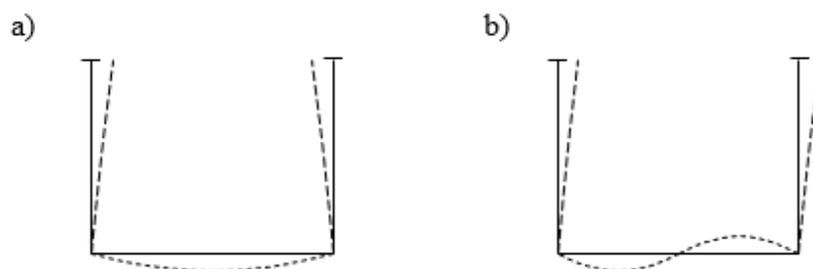
Fig. 5. Forms of stability loss of the bridge cross-section:
a) local stability loss, b) global stabilitby loss (torsional buckling)

The stiffness of the "equivalent" elastic foundation c_q, determined on the basis of relations (18) or (19), allows for easy calculation, e.g. from formulas (9) and (11), of the value of the critical force N_{cr} and the buckling length of the member L_{cr}. One can notice that the standard method [11] discussed here for assessing the safety of compressed truss chords does not depend on the length of these chords (the length of the bridge). Any buckling of the chords is therefore a result of local loss of stability of the bridge cross-section (Fig. 5a). However, for some geometric features affecting the small cross-section value GI_T, EI_z, a global flexural-torsional loss of stability (torsional buckling) of the entire bridge may occur (Fig. 5b), and this type of critical bridge load may be smaller than the previously discussed critical load causing buckling of the compressed truss chords. The possibility of global flexural-torsional loss of bridge stability is not taken into account in Eurocode [11], according to which the compressed chords of open bridge girders are modelled by a single bar separated from the structure and resting on elastic supports.

4.Analysis of open truss bridge stability

In the considered numerical example, the subject of analysis is the stability of an open truss bridge whose static diagram and the assumed cross-sectional characteristics of members are shown in Fig. 6. For further considerations, additional assumptions were made:
- the chords members are continuous and have a constant cross-section along the length of the bridge,
- the cross members and truss and wind deflection bars are connected to the chords in a rigid (jointless) manner.
-

Values of the critical bridge loads and corresponding forms of the loss of stability of compressed bridge truss chords (in top view) are shown in Fig. 7. The solutions given in this figure take into account three types of cross-sectional characteristics of the bridge elements:
The solution shown in Fig. 7a was obtained by assuming the cross-sections of the bridge elements in accordance with Fig. 6. The critical bridge load $P_{cr} = 694\,\text{kN}$ produces here a maximum critical force in the compressed chord member of the value of $N_{cr} = 19363\,\text{kN}$, which corresponds to the buckling length $L_{cr} = 7,34\,\text{m}\ (\mu = 2,10)$. The form of the loss of bridge stability is related to the symmetrical deformation of the cross-section (Fig. 5a). The stiffness of the elastic supports calculated using formula (19) is in this case $c = 1388\ \text{kN/m}$, and the value of the critical force in the chord member determined using formula (9) is equal to $N_{cr} = 12954\,\text{kN}$, which corresponds to the buckling length $L_{cr} = 8,98\,\text{m}\ (\mu = 2,57)$. The "exact" solution resulted in a critical force in the chord member that was almost 50% higher.

2. The difference in values of both critical forces is effected by two factors. First, formula (19) does not take into account the stiffness of the diagonals, and second, formula (9) was derived assuming a constant compressive force in the member.

2. In the second solution variant, much stiffer cross members (HEB-600 $I_y = 171000 cm^4$) were taken, leaving other data unchanged. The solution results for this case are shown in Fig. 7b.
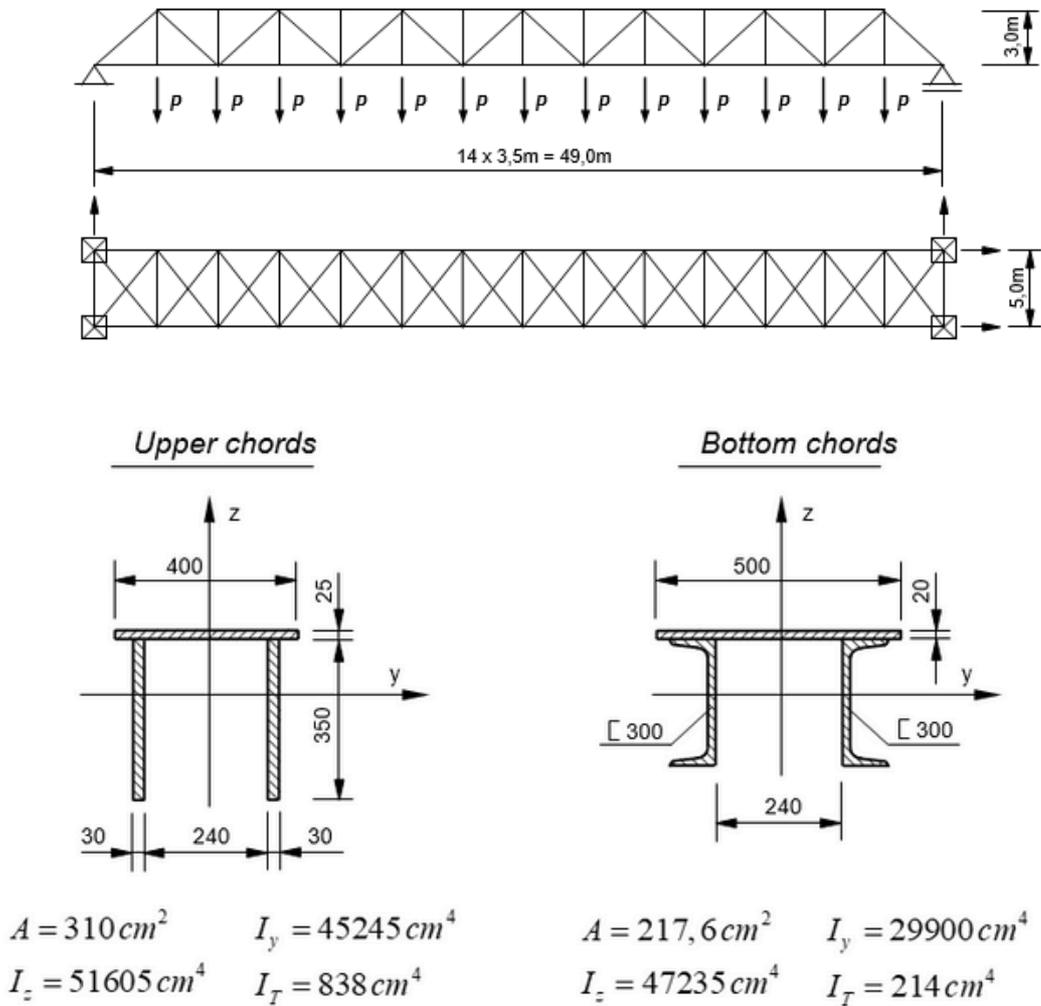
Upper chords

$A = 310 cm^2$ $I_y = 45245 cm^4$
$I_z = 51605 cm^4$ $I_T = 838 cm^4$

Bottom chords

$A = 217,6 cm^2$ $I_y = 29900 cm^4$
$I_z = 47235 cm^4$ $I_T = 214 cm^4$

Posts & diagonals
HEB-240

$A = 106 cm^2$
$I_y = 3920 cm^4$
$I_z = 11260 cm^4$
$I_T = 103 cm^4$

Cross members
IPN-400

$A = 118 cm^2$
$I_y = 29210 cm^4$
$I_z = 1160 cm^4$
$I_T = 183 cm^4$

Wind bar
L 100x100x12

$A = 22,7 cm^2$
$I_y = 328 cm^4$
$I_z = 86,2 cm^4$
$I_T = 10,8 cm^4$

Fig.6. Static diagram of bridge and cross-sectional characteristics of elements
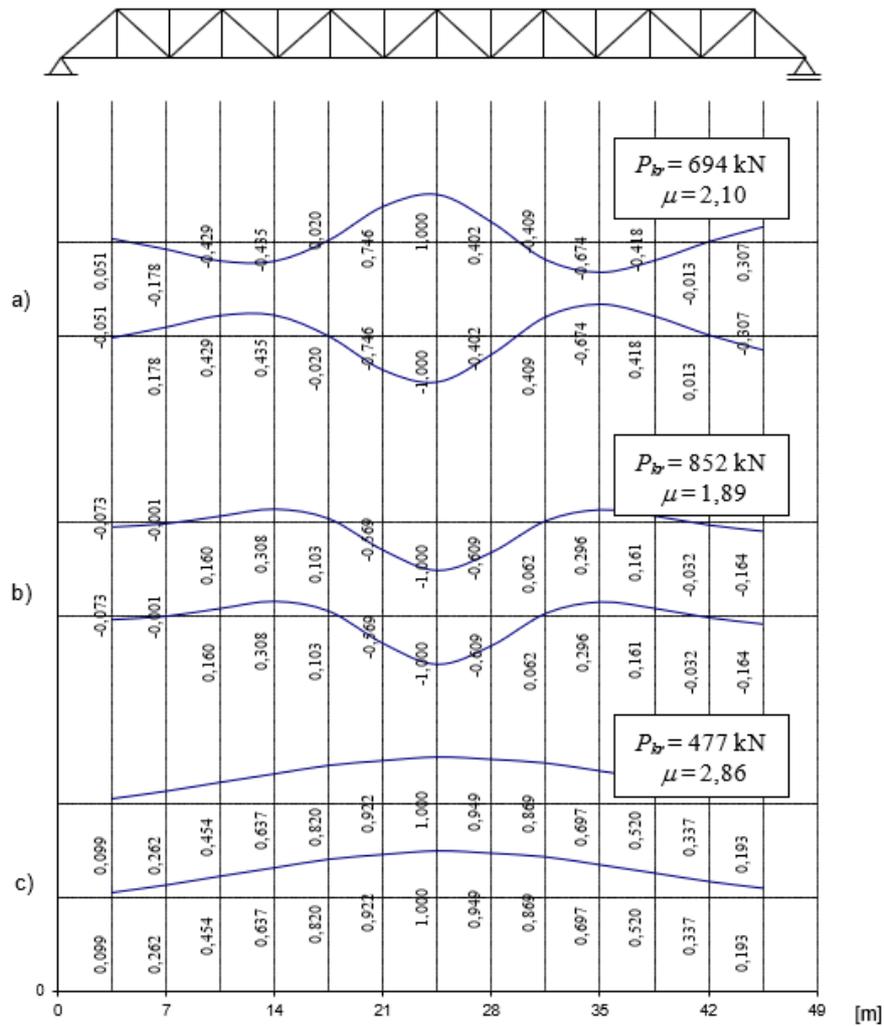
Fig. 7. Buckling modes of compressed truss chords corresponding to the lowest critical bridge loads: a) IPN-400 I-bar bridge cross members, b) HEB-600 I-bar bridge cross bembers, c) HEB-600 I-bar bridge cross bembers and significantly reduced cross-sections of the compressed chords members.

What is worth noting here is the antisymmetric form of the cross-section deformation (Fig. 5b), characteristic of the flexural-torsional loss of stability (torsional buckling) of the entire bridge. In this case – due to high stiffness of the elastic supports – the first thing that occurs is a global loss of stability of the entire bridge. This type of stability loss cannot be examined using formula (9).

3. The third variant of the solution (Fig. 7c) differs from the second one in that it takes into account a very small $(A = 10 \, cm^2)$ cross-section of the compressedchords members (the moment of inertia of the chord cross-section was left unchanged). Here, the buckling of the entire bridge is also a characteristic form of stability loss but this occurs under a much smaller critical load. According to the author, the reduction of critical load is caused by the fact that the moment of inertia I_z of the bridge cross-section decreases. It is also worth noting that in this case using the recommendations of the standard [11] leads to a quite significant error putting safety at risk. The stiffness of elastic supports calculated using formula (19) is $c = 2870 \, kN/m$ which corresponds to the critical force in the chord member equal to $N_{cr} = 18638 \, kN$. The value of this force is 40% greater than the "exact" solution obtained from the analysis of stability of the entire bridge.

4.Summary

The stability analysis of an open truss bridge conducted in this article is more qualitative than quantitative. The critical load of the bridge depends on a very large number of factors which makes it very difficult to draw conclusions or make detailed recommendations useful in each individual case. Therefore, it seems that with the development of more and more effective methods of analyzing structural stability it is necessary to depart from the recommendations of the standard [11] (such a departure is permitted by the standard)
  and base calculations on more accurate methods, which will contribute to more economical design of bridge structures.

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SUSTAINABLE DEVELOPMENT OF CITIES AND COMMUNITIES IN THE EUROPEAN UNION – KEY CHALLENGES

dr Małgorzata Alicja KOZŁOWSKA
e-mail: m.kozlowska@ainw-spatium.pl
ORCID No.: 0000-0003-3300-2419
Instytut Naukowo-Wydawniczy SPATIUM
ul. 25 Czerwca 68/62, 26-600 Radom

Zuzanna Alicja KOZŁOWSKA
e-mail: kozuzia04@gmail.com
ORCID No.: 0009-0003-7714-4870,
Wydział Prawa i Administracji, Uniwersytet Marii Curie-Skłodowskiej w Lublinie
Pl. M. Curie-Skłodowskiej 5, 20-031 Lublin

Abstract: The main goal of this paper is to present Sustainable Development Goal 11. This goal focuses on the development of cities and communities by integrating political, economic, and social activities while maintaining ecological balance and sustainability of fundamental natural processes. The objective is to ensure the ability to meet the basic needs of individual communities for both the present and future generations.

Sustainable development of cities and communities in the European Union - key challenges

Abstract: This paper aims at presenting the 11th Sustainable Development Goal. This goal concerns the development of cities and communities through the integration of political, economic and social activities with the preservation of natural balance and sustainability of basic natural processes in order to guarantee the possibility of meeting the basic needs of individual communities of both the present day and future generations.

1. Introduction

Cities are centres of culture, science, industry and productivity. As hubs of human activity they act as places to live and work. They are a source of new ideas, innovation and progress. In cities, diverse cultures, communities and perspectives intersect, which is conducive to creating an inspiring environment for generating new thoughts. Urban infrastructure, including universities, research laboratories and cultural centres, promotes interaction between people with different points of view. Cities attract thinkers, researchers, artists and entrepreneurs who are looking for opportunities to cooperate and exchange knowledge. It is in such an environment that innovative ideas are born that have the potential to transform society.

However, rapid urbanization, despite the economic benefits, has numerous negative ecological and social effects. The expansion of cities leads to deforestation, disruption of natural ecosystems and loss of valuable green areas, which negatively affects biodiversity and ecological balance. The increase in production, consumption and transport in cities results in the increased use of energy, water and natural resources and waste generation. The increasing number of residents generates problems related to overcrowding, leading to increased social tension, congestion, noise, air pollution and limited access to recreational places.

The main objective of this study is to present indicators monitoring the EU's progress towards Sustainable Development Goal 11, in improving the quality of life in cities and communities, promoting sustainable mobility and improving environmental impact.

2. The place of cities and communities in the concept of sustainable development

Sustainable development is a fundamental element of the debate about the future of our planet. It is a comprehensive approach to growth that integrates social, economic and environmental aspects, trying to meet the needs of both current and future generations. Cities have a decisive role in achieving sustainable goals. On the one hand, they are centres of innovation, economic development and social progress. On the other hand, they face urbanization challenges such as environmental degradation, social inequalities, and difficulties in accessing basic services. Each city has unique advantages, ambitions, potentials and opportunities but at the same time it has to face a variety of problems. Among the challenges faced by cities around the world are climate change, air pollution, exploitation of natural resources, economic crises, unemployment, and recently also the COVID-19 pandemic.

Modern cities strive for intelligent and sustainable development, harmonizing ecological, economic and social aspects. In the course of this dynamic process, existing structures are transformed into more advanced and perfect forms. The prevailing opinion in the literature is that in order to talk about a "sustainable city" it is necessary to meet the needs of all people, both those living within and outside the city limits, and both present and future generations. It is also necessary to reduce the use of certain resources and increase the ability of the environment to absorb and neutralize the negative effects of human activities at the local, regional and global levels. A key element of sustainable urban development is the integration of activities around major challenges, such as quality of life, innovative and low-carbon economy, resource efficiency and adaptation to climate change. Comprehensive planning and design of urban policy, with the participation of all city users, especially in the field of public transport and mobility, efficient management and protection of biodiversity in cities, are becoming crucial.

This document contains 17 Sustainable Development Goals and 169 related activities to be implemented by all stakeholders - national governments, international organizations, non-governmental organizations, the science and business sector, as well as citizens. In line with Goal 11, cities should become safe, stable, sustainable and inclusive. To make this plan a reality, you need to[1]:

1. By 2030, ensure that all people have access to adequate, safe and affordable housing and basic services, as well as improve living conditions in slums.
2. By 2030, ensure that everyone has access to safe, affordable and sustainable transport systems, increasing the level of road safety, especially by developing public transport. Particular attention should be paid to the needs of vulnerable groups, women, children, people with disabilities and the elderly.
3. By 2030, increase the degree of inclusivity, ensure sustainable urbanization and participation in integrated and sustainable planning and management of human settlements in all countries.
4. Strengthen efforts to protect and secure the world's cultural and natural heritage.
5. By 2030, significantly reduce the number of deaths as a result of natural disasters, including floods, and reduce the number of people affected by them; significantly reduce the direct economic losses in relation to global GDP incurred as a result of disasters, focusing on the protection of the poor and vulnerable groups.
6. By 2030, reduce the unfavourable indicator of the negative impact of the city on the environment per capita, paying special attention to air quality and management of municipal waste and other pollutants.
7. By 2030, provide easy and universal access to safe and inclusive green areas and public spaces, especially for women, children, the elderly and people with disabilities.
8. Support economically, socially and environmentally beneficial connections betwee

[1] https://www.gov.pl/web/rozwoj-technologia/cele-zrownowazonego-rozwoju (access: 10/01/2024)

9. By 2020, significantly increase the number of cities and human settlements benefiting from development and implementing integrated policies and plans aimed at increasing inclusivity and efficiency of resource use, mitigation and adaptation to climate change, and resilience to disasters. Comprehensive disaster risk management at all levels should be developed and implemented, in accordance with the Disaster Risk Reduction Framework for 2015–2030[1].
10. Support the least developed countries through financial and technical assistance in building sustainable and resilient buildings, using local materials.

The continuation of global efforts for sustainable urban development, launched in Agenda 2030, was reflected in the adoption of the New Urban Agenda at the UN Habitat III conference in Quito, 21 October 2016. This document directly refers to the 2030 Agenda, while extending its scope to include the vision and priorities of urban development for the next two decades[2].

The New Urban Agenda emphasizes the need to face the current and future challenges facing cities and settlements by promoting sustainable and inclusive economic development. The priority of the document is proper planning and management in cities to ensure high quality of life, health, safety and economic development. The agenda promotes sustainable urban mobility, social participation and the concept of smart city[4].

3.   Sustainable cities and communities in European Union policies

The European Union plays a key role in promoting sustainable development. Over the past four decades it has introduced some of the most stringent environmental standards in the world implementing an ambitious climate policy and supporting the Paris Agreement. The EU is also a model for the rest of the world in achieving the goals set out in the 2030 Agenda[5]. In response to Goal 11, in 2016 the Urban Agenda for the EU was created, initiated by signing the "Amsterdam Pact" by member states. The aim of the Urban Agenda for the EU is to solve the problems of cities by creating partnerships between the European Commission, EU organizations, national governments, local authorities and other entities such as non-governmental organizations. It strives to create better regulations, facilitate access to finance and exchange knowledge on issues relevant to cities[6]. The document identifies priority action areas including air quality, circular economy, adaptation to climate change, digital transformation, energy transformation, housing, social integration of migrants and refugees, innovative and responsible public procurement, jobs and skills in the local economy, sustainable land use and natural resource solutions, urban mobility and the fight against urban poverty.

The Urban Agenda for the EU has been incorporated into the work of the European Commission and is a reference point in many key programming documents. The European Union, while monitoring progress in sustainable urban development, focuses on environmental protection, social and cultural equality and improving the quality of life of residents, mobility and recycling of municipal waste and wastewater. This makes it possible to evaluate, compare and analyse the effectiveness of actions taken at the European level. The main indicators include air pollution, safe mobility, housing conditions and recycling of municipal waste.

[2]Sendai Framework for Disaster Risk Reduction 2015 -2030, https://www.undrr.org/news/sendai-framework-6th-anniversary-if-only-early-warning-had-led-early-action (access: 10/01/2024).
[3]A. Augustyn, Zrównoważony Rozwój Miast w świetle idei Smart City, Wydawnictwo Uniwersytetu w Białymstoku, Białystok 2020, p. 43.
[4]A. Szpak, Nowa Agenda Miejska – wizja rozwoju miast na przyszłe 20 lat, https://obserwatormiedzynarodowy.pl/2016/12/02/nowa-agenda-miejska-wizja-rozwoju-miast-na-przyszle-20-lat/ (access: 20/01/2024).
[5] M. Kozłowska, Efekty ekonomiczne realizacji strategii zrównoważonego rozwoju transportu w Unii Europejskiej, SPATIUM, Radom 2022.
[6] https://commission.europa.eu/eu-regional-and-urban-development/topics/cities-and-urban-development/urban-agenda-eu_pl (access: 21/01/2024).

The Action Plan Towards a "Zero Pollution for Air, Water and Soil" includes the target of reducing the health impacts due to air pollution by 55 % by 2030, compared with 2005. The monitoring framework for the 8th Environment Action Program uses number of premature deaths as a headline indicator with the target to reduce the number of premature deaths due to PM2.5 by 55 % by 2030, compared with 2005[7].

The indicator of monitoring progress in the field of road safety results from the assumptions of Vision Zero - an ambitious initiative aimed at completely eliminating fatal accidents and serious injuries by 2050. Vision Zero emphasizes that every life is priceless and no victim of a road accident is acceptable. Sustainable cities, in which the Vision Zero principles are implemented, become not only more friendly to life, but also safer, which directly translates into improving the health and well-being of their inhabitants.

Housing deprivation is a measure of poor amenities and is calculated by referring to those households with a leaking roof, no bath/shower and no indoor toilet, or a dwelling considered too dark[8]. Recycling includes material recycling, composting and anaerobic digestion, and reuse[9].

1.Evaluation of the implementation of 11SDG in the EU

About 325 million people, or almost three quarters of the EU population, live in urban areas - cities, towns and suburbs. About 40% of this number lives exclusively in cities. Forecasts suggest that by 2050 the share of the urban population in Europe will increase to over 80%. Therefore, sustainable cities, towns and suburbs are crucial for the well-being and quality of life of citizens. Overall, the EU has made moderate progress in implementing SDG 11 in recent years. The improvement in the quality of life in cities and communities is noticeable, however, trends for some indicators are less clear.

The first of the mentioned indicatorsestimates the number of premature deaths attributable to long-term exposure to concentrations of PM2.5 above 5µg/m3 (the World Health Organization's guideline level). PM2.5 are particulates whose diameter is less than 2.5 micrometres and which can be carried deep into the lungs where they can cause inflammation and exacerbate the condition of people suffering heart and lung diseases[10]. The number of premature deaths, per 100 000 people is shown in Fig. 1 and 2.

Fig. 1 Change in the number of premature deaths per 100,000 inhabitants in the EU between 2005 and 2021
Source: Own study based on:
https://ec.europa.eu/eurostat/databrowser/view/sdg_11_52/default/table?lang=en (access: 14/06/2024)

[7]https://ec.europa.eu/eurostat/cache/metadata/en/sdg_11_52_esmsip2.htm (dostęp: 14/06/2024).
[8]https://ec.europa.eu/eurostat/databrowser/view/sdg_11_60/default/table?lang=en(dostęp: 14/06/2024).
[9]Ibidem.
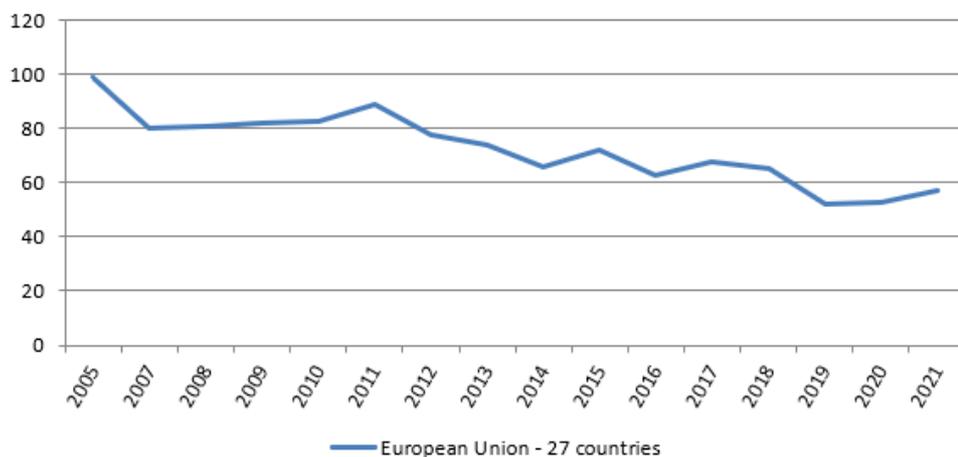[10]https://ec.europa.eu/eurostat/web/products-eurostat-news/w/edn-20231009-1(dostęp: 14/06/2024).
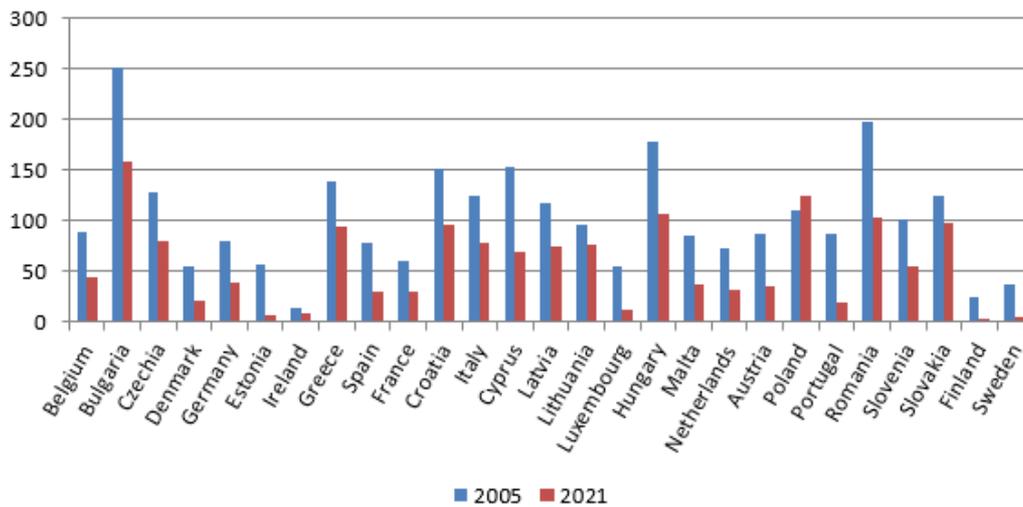
Fig. 2 Change in the number of premature deaths per 100,000 inhabitants in EU countries in 2005 and 2021
Source: Own study based on:
https://ec.europa.eu/eurostat/databrowser/view/sdg_11_52/default/table?lang=en (access: 14/06/2024)

Looking at data published in public statistics one can notice that since 2005 the number of premature deaths caused by air pollution with small solid particles has been gradually decreasing. This indicator, in the analysed period, fell from 99 people in 2005 to 57 people in 2021, i.e. by 42%. Poland is the only country in the EU-27 in which the indicator increased in the analysed period and ranked second to last for mortality caused by particulate emissions in the country. In 2021, this value was 125 people, with the European average - 57 people.

Next indicator measures the number of fatalities caused by road accidents, including drivers and passengers of motorized vehicles and pedal cycles as well as pedestrians. Persons dying on road accidents up to 30 days after the occurrence of the accident are counted as road accident fatalities. After these 30 days, the reason for dying might be declared differently. For Member States not using this definition, corrective factors are applied. The average population of the reference year (calculated as the arithmetic mean of the population on 1st January of two consecutive years) is used as denominator (per 100 000 persons). The change in the road fatality rate is presented in Figures 3 and 4.
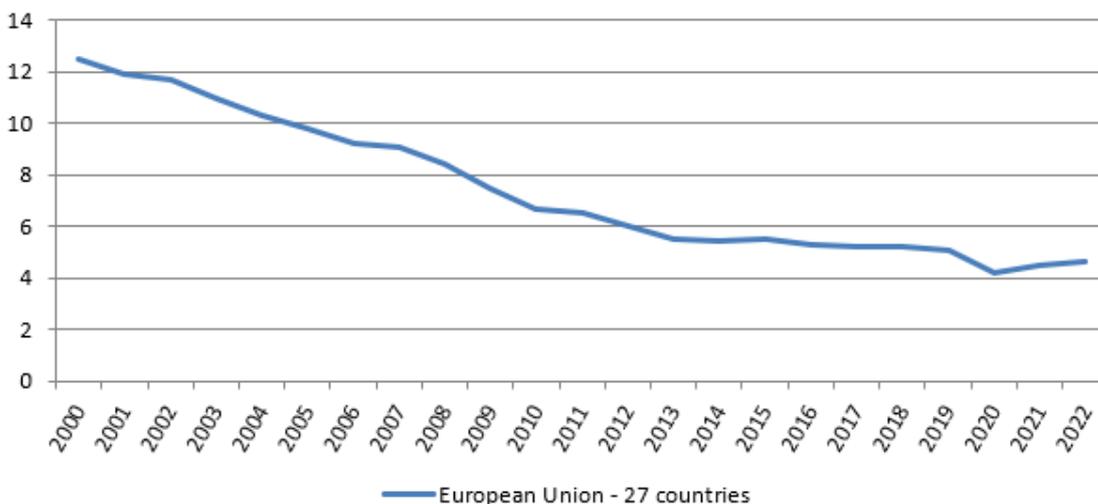

Fig. 3 Change in the number of road fatalities per 100,000 EU population between 2000 and 2022
Source: Own study based on:
https://ec.europa.eu/eurostat/databrowser/view/sdg_11_40/default/table?lang=en (access: 14/06/2024).

Fig. 4 Change in the number of road fatalities per 100,000 EU inhabitants in 2000 and 2022
Source: Own study based on:
https://ec.europa.eu/eurostat/databrowser/view/sdg_11_40/default/table?lang=en (access: 14/06/2024).

From the data presented in Fig. 3 one can conclude that in 2022, about 55 people a day lost their lives on EU roads. This corresponds to just over 19,900 people throughout the year - losses equivalent to the size of an average city. Nevertheless, the EU has made significant progress on this issue compared to 2000 when the number of road fatalities was 12.5 per 100,000 people.

In recent years, the number of road fatalities has undergone some fluctuations, explained in part by significant changes in traffic volumes caused by the COVID-19 pandemic. In the period between 2019 and 2020, there was an unprecedented decrease in the analyzed indicator by as much as 18%. Although in the following years this number increased by 6%, however, the general trend, in relation to the level before the pandemic is still downward. The downward trend is visible in all EU countries, however, the number of fatal road accidents varies significantly between EU countries (cf. 4).

Severe housing deprivation rate is defined as the percentage of population living in the dwelling which is considered as overcrowded, while also exhibiting at least one of the housing deprivation measures.

Fig. 5 Percentage of EU residents experiencing severe housing deprivation in 2010 and 2019
Source: Own study based on:
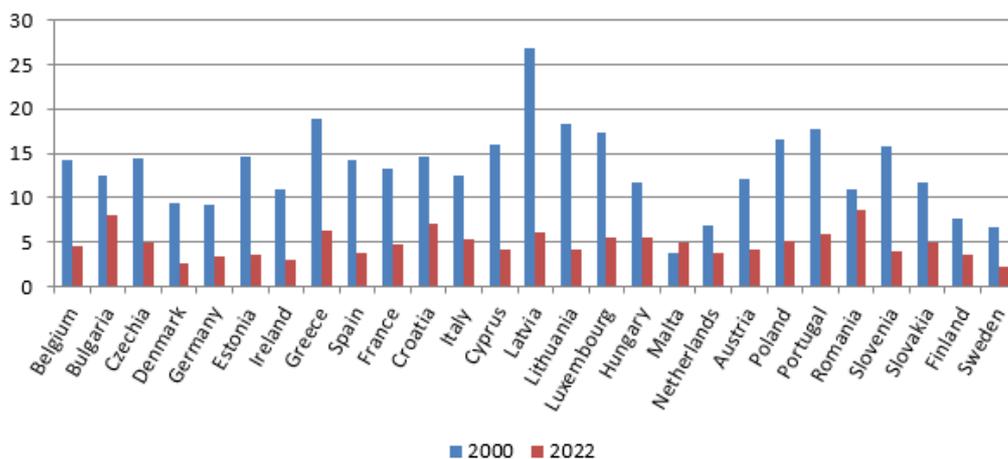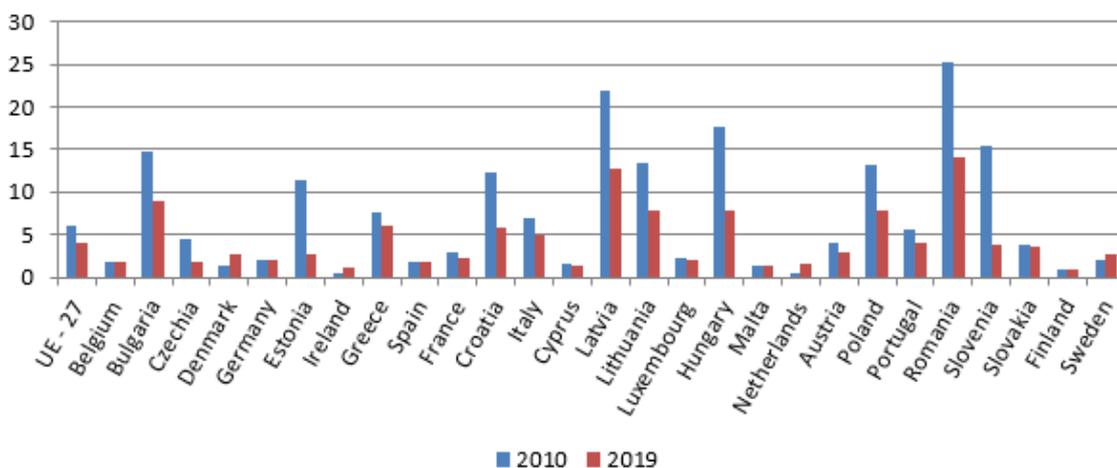https://ec.europa.eu/eurostat/databrowser/view/sdg_11_11/default/table?lang=en (access: 14/06/2024)

In 2019, the highest percentage of the analysed indicator was recorded in Romania (14.2%) and Lithuania (12.7%). Countries in which this indicator deviates significantly from the European average of 4% are also Bulgaria (8.9%), Poland (7.9) and Lithuania and Hungary (7.8%). The lowest degree of housing exclusion remains unchanged in Finland (0.7%) and in Ireland, Malta, Cyprus, the Netherlands, Spain and Belgium (1.2% - 1.9%).

The last analysed indicator measures the tonnage recycled from municipal waste divided by the total municipal waste arising. Recycling includes material recycling, composting and anaerobic digestion, and reuse. Municipal waste consists mostly of waste generated by households but may also include similar waste generated by small businesses and public institutions and collected by the municipality. The waste recycling rate in EU Member States in 2007 and 2020 is presented in Fig. 6
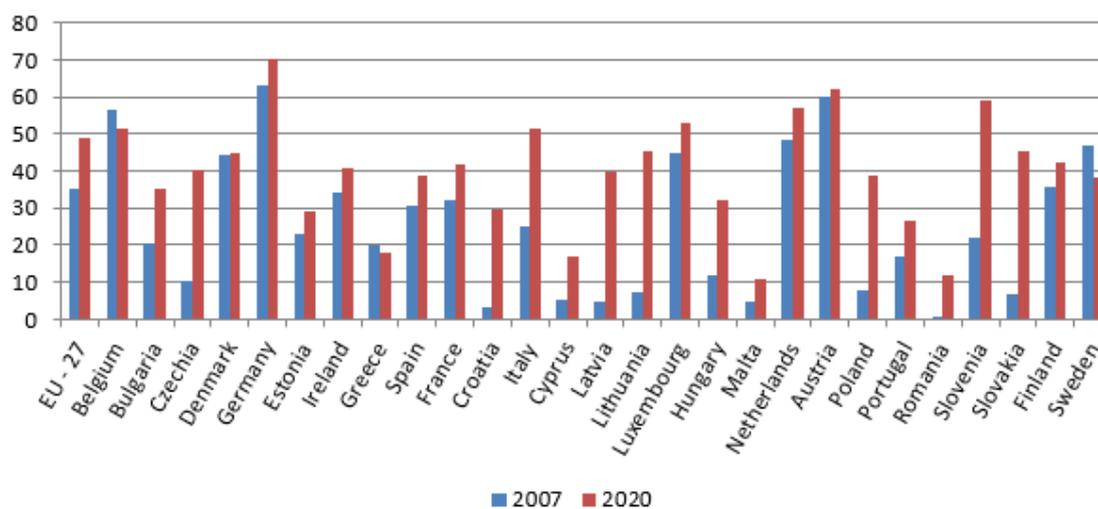
Fig. 6 Percentage of municipal waste recycling in EU cities in 2007 and 2020
Source: Own study based on:
https://ec.europa.eu/eurostat/databrowser/view/sdg_11_60/default/table?lang=en (access: 14/06/2024).

The waste recycling rate in European cities in 2020 was 48.7%, an increase of 13.5 p.p. compared to 2007. (35.2%). The highest level of this indicator was recorded in Germany (70.3%) and Austria (62.3%). Countries where the level of waste recycling was higher than the European average are also: Belgium, Italy, Luxembourg, the Netherlands and Slovenia. At the same time, the largest increase in the waste recycling rate was recorded in Slovakia (38.7 p.p.), Slovakia (37.4 p.p.), Poland (31 p.p.), Lithuania (37.8 p.p.), Latvia (34.7 p.p.) and the Czech Republic 30.4 p.p.). In three countries, there was a decrease in the analysed indicator, i.e. in Sweden by 8.4 p.p. to 38.3%, in Belgium by 5.4 p.p. to 51.4% and in Greece by 1.9 p.p. to 18.1%.

Conclusions

Sustainable cities and communities in the European Union are a key element of a sustainable development strategy, reflecting the desire to harmoniously combine economic, social and environmental development. The EU, as a leader in promoting sustainable development, has adopted many initiatives and documents that emphasize the creation of safe, green, inclusive and climate-resilient urban spaces.
The indicators which monitor progress in this area show positive changes and indicate consistent EU action to create more sustainable and safe cities and improve the quality of life of residents. It should be emphasized, however, that the level of sustainable development of cities and communities in individual EU Member States is not equal. This shows the great role of national governments in shaping local policies and implementing initiatives that support the achievement of sustainable development goals.

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ANALYSIS OF CAUSES AND CIRCUMSTANCES OF BUILDING DISASTERS BASED ON SELECTED EXAMPLES

inż. Izabela MICHALSKA
e-mail: michalska.i@wp.pl
Department of Civil Engineering, Akademia Nauk Stosowanych im. Stanisława Staszica w Pile
ul. Podchorążych 10, 64-920 Piła

dr inż. Mahmoud HSINO
e-mail: mhsino@ans.pila.pl
ORCID No.: 0000-0002-1651-2620
Department of Civil Engineering, Akademia Nauk Stosowanych im. Stanisława Staszica w Pile
ul. Podchorążych 10, 64-920 Piła

1. Introduction

Construction is one of the key pillars of social and economic development; it is an important field of engineering that aims at creating durable and safe structures. Despite technological progress tragic occurrences related to construction disasters still occur. And they have serious social and economic consequences. Therefore, to understand the causes and mechanisms of these disasters is of utmost importance for engineers to effectively design, build and maintain structures, minimizing the risk of their collapse. This paper presents various aspects related to construction disasters; it covers both design and utilization aspects. Real disaster cases were analysed based on available materials, which allowed conclusions to be drawn regarding weaknesses in the design, construction and maintenance of facilities. Modern society, with its dynamic infrastructure development and growing demand for modern construction, is exposed to various challenges related to the safety and stability of structures. One of the most serious aspects that determine the stability of buildings are construction disasters. These dangerous occurrences, which can lead to serious damage to structures or even their complete destruction, pose a threat to human life, the surrounding environment and the economy. Therefore, an important engineering issue is the analysis, understanding and prevention of construction disasters. Construction disasters cover a wide range of occurrences such as the collapse of buildings, bridges or tunnels, structural failures and other situations that lead to potential threats to public safety. The increasing complexity of structures, the materials used and the changing environmental conditions present engineers with greater challenges and, consequently, more stringent regulations and rules. Analysed are some selected examples of construction disasters from Poland and around the world which influenced subsequent construction standards preserved to this day.

According to Article 73 of the Construction Law Act [3]: Construction disaster – an unintentional, violent destruction of a building or its parts, as well as structural elements of scaffolding, formwork elements, sheet pile walls and steening.

Annual reports on construction disasters are available on the website of the General Office of Building Supervision. The register has been kept since 1995, and electronically since 2008. One can read in the report on construction disasters in 2022 [4] that the use of the terms "unintentional" and "violent" by the legislator indicates that these are unplanned, unexpected and quick occurrences. This means that, for example, a gradual destruction of abuilding that has not been renovated on an ongoing basis cannot be considered a construction disaster. An aswer to the question: "what else is not a construction disaster?" is given in the provision of Article 73 (2) of the Construction Law Act. According to this provision damage to a component incorporated into a building object that can be repaired or replaced, damage to or destruction of construction devices attached to buildings and failure of installations do not qualify as a construction disaster. One can notice that the Construction Law specifically indicates what is and what is not a construction disaster, and yet doubts arise in the interpretation of which occurrences can be classified into this category. The answer is obvious.

Terms with similar meaning may be interpreted differently, although they are not identical, such as the term "building failure", which is often confused with the term "construction disaster". Therefore, a clear definition of a given concept and its consistent application are of crucial importance both in everyday understanding and in the context of the existence of similar but separate legal definitions. For example, according to Article 3 (1) points 2 and 3 of the Act on the State of Natural Disaster [1]:

·a natural disaster is understood as an event related to the action of natural forces, in particular atmospheric discharges, seismic shocks, strong winds, heavy atmospheric precipitation, prolonged occurrence of extreme temperatures, landslides, fires, droughts, floods, ice phenomena on rivers and the sea as well as lakes and reservoirs, mass occurrence of pests, plant or animal diseases or infectious diseases of humans, or the action of another element,

·technical failure means sudden, unforeseen damage or destruction of a building, technical device or a system of technical devices causing an interruption in their use or loss of their properties.

Going further in the interpretation of various concepts, attention was also drawn to the term "building object" appearing in the definition of a construction disaster. What is it according to the law? This term is also defined in the Act. Article 3 of the Construction Law [2] states that, in accordance with the provisions of the Construction Law which define the meaning of terms used in the Act, a building object includes a building, structure or small architectural object together with installations enabling its use in accordance with its intended purpose, constructed using construction products. Below is a graphical presentation of this definition.

When it comes to a building, it is an enclosed structure that is permanently attached to the ground, has a roof and foundations. A structure is any object that is not a building or a small architectural object, for example tanks, monuments or wind farms. Small architectural objects include small objects such as garbage sheds, figures or swings. Correct classification of a planned construction project is of great importance - the required procedures and criteria to be met depend on it. For example, the provisions of the regulation of the Minister of Infrastructure regarding the technical conditions that buildings and their location must meet apply only to buildings and selected structures. However, the provision regarding the minimum distance from the plot boundary applies only in the context of buildings. The Act further outlines in detail what exactly is considered as a building object. An important aspect is that in order for something to be considered a building object it must be constructed using construction products. This is also further defined but in the Construction Products Act. In addition, the Act indicates that installations on a structure that enable a proper use of the object as per its intended purpose are an integral part of it and, therefore, they are also defined as a building object. Thus, the knowledge of definitions of similar concepts determine what is and what is not a construction disaster. There is also room for different interpretations of the two most important aspects for something to be classified as a construction disaster. These include a lack of intent to destroy the object, and a rapid course of deterioration. For example, incidents involving gas explosions were under scrutiny. Not all such incidents can be classified as a construction disaster. If experts during the investigation find out that the incident was caused by human action – for example, someone turned on a gas cylinder and used fire – then this event cannot be called a construction disaster. In the book "Building Disasters" author Jacek Szer gives the example of the gas explosion in Gdańsk in 1995. As a result of this situation, 22 people died and 12 were injured. The explosion completely destroyed three floors of the skyscraper, and then a decision was made to blow up the rest of the building – this incident cannot be classified as a construction disaster because its cause, as determined by the prosecutor's office, was a deliberate human action [5]. In the case of the criterion of the incident's rapid course, the case when the building is destroyed but this destruction is spread out over time raises doubts. Obviously this is also a problem in the examination of incidents.

2. Division of construction disasters

Construction disasters can be divided into several categories depending on various factors such as causes, stage of the construction process, type of element failing, entity having control over the facility, type of structure, type of facility or scale of destruction.

a) due to causes:

- construction errors resulting from defects in the building design, such as incorrect structural calculations, errors in the construction geometry or underestimation of loads,
- wrong materials - the use of inappropriate or defective building materials can lead to a loss of structural stability,
- errors during construction, for example, insufficient quality control – the lack of appropriate quality control procedures during the construction process can lead to serious errors in construction; in addition, there may be errors in assembly, i.e. improper assembly of structural elements, for example, too loose connections or improper anchoring may threaten the stability of the building,
- violation of building regulations – ignoring building regulations and standards may lead to a situation in which the building does not meet structural safety requirements,
- utilization errors related to improper use or negligence in the maintenance and upkeep of the building,
- natural factors; earthquake-prone areas may experience building disasters due to improperly designed or constructed buildings; buildings located in flood-prone areas, especially if they are not properly secured, may be destroyed,
- insufficient maintenance and upkeep – lack of regular inspections, as a result of which early signs of damage cannot be detected and repaired; neglect of maintenance – lack of regular maintenance, especially in the case of old structures, can lead to their gradual deterioration,
- human error and project management – inadequate planning and supervision of a construction project can lead to problems such as delays, excessive costs and errors in implementation; inexperienced staff – lack of experience or improper training of staff can lead to errors during construction,
- external factors – sabotage and terrorist attacks; in extreme cases, acts of vandalism, sabotage or terrorist attacks may lead to construction disasters.

In this paper, disasters are divided into two categories – incidents not resulting from and incidents resulting from fortuitous or random causes. The cause of the first ones is mostly the human factor. As for the second case, we are talking mainly about the forces of nature over which we have no control [15].

3. Types of building disasters by type of construction based on the causes of their occurrence

The division of construction disasters by type of structure designs takes into account different types of building objects and their specific risks. Below presented is a division of construction disasters by type of design:

1.Residential buildings:

Structure failure: Wrong design or construction can lead to disaster, especially under conditions of wind, snow or earthquakes.

Gas leaks or fires: Accidents involving gas leaks, explosions or fires in residential buildings can lead to structural destruction or collapse.

2.Public buildings:

Roof collapse: Structures of big public buildings, such as sports halls or shopping centres, may be at risk of roof collapse due to snow, rain or wind loads.

Dangers resulting from human overload: Large crowds in public buildings can lead to crisis situations in the event of evacuations or incidents.

3.Bridges and bridge structures:
Load capacity failure: Design, construction or execution errors can lead to loss of load-bearing capacity of bridges, which may result in their collapse or damage.
Collisions and accidents: Vehicle collisions, explosions or natural disasters (e.g. floods) can lead to catastrophic damage to bridges.
4.Tunnels:
Fires: Fires in tunnels can lead to structural hazards and also make evacuation difficult.
Toxic substance leaks: Leaks of toxic substances in tunnels can pose a threat to structures and human health.
5.Industrial installations:
Explosions and fires: In the chemical, refining or energy industries, disasters can result from explosions, fires or leaks of hazardous substances.
Structural collapse: Neglect in maintenance or improper management of industrial installations can lead to structural failures.
6.Road infrastructure:
Landslides: On slopes or in areas prone to erosion, roads may be damaged by landslides.
Collapse of road bridges: Damage or poor maintenance of road bridges can lead to their collapse.

4. Types of construction disasters divided into causes of their occurrence

a)Building collapse:
It may be the result of faulty design, poor workmanship or improper maintenance. It is often associated with low quality building materials or improper use.
b)Construction accident:
Applies to situations where construction machinery, cranes, scaffolding or other equipment used during construction falls or overturns.
c)Building fire:
Fire can be caused by electrical short circuits, overloaded electrical systems, gas leaks, improper use or deliberate arson.
d)Landslide:
This applies to situations in which the ground beneath a building subsides, leading to the destruction of the building's foundations and structure.
e)Structural damage related to earthquakes:
Earthquakes can cause significant structural damage to buildings, bridges and tunnels.
a)Water related disasters:
Flooding, undermining or erosion can cause foundation damage, weakened structures and other water-related problems.
b)Bridge or tunnel collapse:
It may result from faulty design, over-use, improper maintenance or human activity such as a terrorist attack.
c)Retaining wall collapse:
This applies to structures such as dams or retaining walls that have failed due to improper construction, erosion, or extreme weather conditions.
d)Gas explosions:
They result from gas leakage and subsequent ignition, which leads to structural damage around the explosion site.
e)Terrorist attack:
Sabotage, bombing or other act of terrorism can cause structural disasters leading to significant destruction.

5. Construction disasters in Poland

A building disaster that took place at Katowice International Fair on 28 January 2006 (Photo 1) during the national exhibition of carrier pigeons was a tragic event that shocked not only the inhabitants of Katowice, but also the entire country. This incident resulted in enormous material destruction and loss of human life. The causes of the disaster were multi-faceted. The main factor contributing to the tragedy was a flaw in the design of the exhibition hall roof; the roof failed to withstand the load of snow and ice. It turned out that the direct and main cause was an incorrect executive design of the building, significantly different from the correct construction design. This change was intended to reduce construction costs. In addition, there was some negligence in the regular inspection of the technical condition of the building and deficiencies in its maintenance. As a result of the collapse of the roof of the exhibition hall several dozen people died and dozens were injured. Rescuers immediately began their rescue operation and search trying to find and evacuate the injured from under the rubble as quickly as possible. As a result of the incident, 65 people died and over 170 were injured. Local residents and emergency services from across the country also offered help to the victims. The disaster also had a huge social and political impact. It sparked off a debate on construction safety and the need to comply with rigorous standards in this area. This disaster also led to an acceleration of inspection activities towards other facilities with similar purposes, both in Katowice and throughout Poland. After this tragedy a number of actions were taken to prevent similar accidents in the future. A thorough analysis of the causes of the disaster was carried out and new regulations governing safety standards in construction were introduced. In addition, steps were taken to modernise existing exhibition facilities and increase their resistance to snow loads and other weather factors. The lessons learned from this tragic disaster led to increased public awareness of the need to comply with building safety standards and take actions to improve the condition of the existing exhibition infrastructure. And the memory of the victims of this tragedy remains a lasting reminder of the need to exercise caution and ensure safety in every area of human activity. It is the largest construction disaster of this type in contemporary Poland.

Photo 1. Katowice International Fair after the roof collapse [7]

The gas explosion in Rotunda in Warsaw which took place on 15 February 1979 (Photo 2) was one of the most tragic incidents in the history of post-war Poland. The Rotunda, one of the characteristic landmarks of Warsaw, became the site of this terrible catastrophe. The Rotunda is located in the centre of Warsaw, at Dmowskiego Roundabout. It is a round building designed by architect Jerzy Gieysztoras and was originally intended to serve as an exhibition pavilion during the International Construction Exhibition in 1953. After the exhibition, the Rotunda remained as a representative building that was used for various purposes, including as a venue for conferences and meetings. On 15 February 1979, at approximately 2:30 p.m., there was a gas explosion in the Rotunda basement. The cause of the explosion was gas leaking from one of the gas pipes. The explosion was so powerful that it caused significant damage to the building causing its partial collapse. Glass collapsed onto the sidewalks and street, the storey collapsed all the way to the archives, and even neighbouring buildings were damaged as a result of the incident.

As a result of this explosion 49 people died and over 100 were injured. Rescuers worked for many hours to rescue people trapped under the rubble. It was one of the most tragic incidents of this type in Polish history. What led to this tragic incident was a poor maintenance of the installation and lack of appropriate safety procedures. Interestingly enough, the Rotunda building did not have any gas installation. So how did the explosion happen? The answer to this question was provided by the broadcast of the first episode of the documentary series "Black Series" on 4 September 2000 [14]. The producers of the series managed to find the employee who was probably responsible for the tragedy. When doing maintenance work he put too much force to tighten the orifice screw fastening the gas valve. Due to low temperatures caused by the 'winter of the century' in 1979 what happened was a thermal contraction. The valve orifice which was tightened too hard and the ground movements caused by nearby public transport caused the cracking of valve. A 77 cm crack was formed [13, 14], and snow prevented the gas from reaching the surface.

Due to a coincidence, the gas, deprived of its odour marker, penetrated into the parallel, 12-hole casing of the telecommunications installation cables and from there into the interior of the building [13]. The disaster may have been caused by a short circuit in the electrical system. The gas explosion in Rotunda caused a huge social outcry and grief throughout Poland. It was a time of national mourning, and the tragedy prompted the authorities to take measures to improve safety standards in gas installations and other aspects of building safety. The gas explosion in Rotunda had long-lasting effects on Warsaw and Poland. The repair of buildings lasted many years after the disaster, and the Rotunda building itself was rebuilt and renovated. However, this tragic disaster remains an important point in Warsaw's history and serves as a reminder of the need to take care of building safety and adhere to appropriate standards.

Photo 2. PKO Bank Rotunda in Warsaw after the gas explosion [13]

On 22 March 1966, during construction works on the premises of the Agricultural University in Wrocław, a construction disaster occurred (Photo 3). The causes of this tragedy could have been various - from design errors, through bad weather conditions, to human errors in the construction process. The disaster was the result of rushing and not following the appropriate technological schedule of works. Construction workers were forced to work at a fast pace due to political pressure from the then PZPR activists, for whom the propaganda "growth" of the building was important [9]. The construction management, yielding to this pressure, ordered the construction of subsequent floor elements without simultaneous masonry works, which would ensure the stability of the structure. The lack of parallel masonry work on individual floors meant that the structure was not adequately stiffened. As a result of the wind, which was particularly strong, the structure of the building collapsed. The building under construction, or rather its architectural skeleton, could not withstand the gusts of strong wind, the whole thing swayed and collapsed, turning into a pile of destroyed building materials [6]. As a result of the disaster, the construction supervisor and nine workers died, and many people were injured. This tragic event shows how political pressure and haste can lead to negligence in the construction process, which in turn can have catastrophic consequences. It is also a warning that safety and proper construction procedures should always be a priority to avoid similar tragedies in the future.

Photo 3. Plac Grunwaldzki – the building of the Faculty of Land Reclamation at the Agricultural University in Wrocław collapsed [6]

The tenement house disaster in Świebodzice, which took place on 8 April 2017, was a tragic event (Photo 4) that shocked the local community and all of Poland. The tenement house was located at 27 Kościuszki Street in Świebodzice, a small town in the Lower Silesia Voivodeship. In the morning, the residents of Świebodzice heard a huge bang. A pre-war tenement house in which six families lived collapsed. The rescue operation lasted almost 24 hours. Six people died, including two children, and four people were injured. A special commission led by the construction supervision took steps to investigate the causes of the incident. The initial investigation indicated a gas explosion, which was confirmed by witnesses to the crash. There was a distinct smell of gas, a loud bang, and a flash. The multiple burns on one of the victims also indicate that the cause was a gas explosion. The discovery of a training grenade in the rubble of the building added confusion to the investigation. The hypothesis that explosives stored by one of the residents were the cause of the incident was quickly rebutted. Apart from fragments of the grenade, nothing suspicious was found. The age and technical condition of the building also had an impact. The archaic construction of the tenement house allowed the entire building to collapse as a result of the explosion.

Photo 4. Collapsed tenement house in Świebodzice [18]

The skyscraper disaster in Gdańsk (Photo 5), which took place on 17 April 1995, was one of the most tragic construction accidents in Polish history. The incident involved the residential building "Wieżowiec na Węglowej" in the Wrzeszcz district of Gdańsk. The skyscraper on Węglowa was one of the tallest residential buildings in Poland at that time, with a height of over 90 meters. However, its construction was burdened with numerous controversies and technical problems from the moment the construction began in the 1970s. The construction works were interrupted and resumed many times, which affected the quality of workmanship. On 17 April 1995, during renovation work on one of the floors, a gas explosion occurred. The explosion caused a series of explosions that had catastrophic consequences. As a result of the explosion, part of the building completely collapsed, and the rest was seriously damaged. This tragedy resulted in the death of 22 people, also over 100 people were injured. The cause of the explosion was probably a gas leak from the gas installation in one of the apartments. This leak could have been caused by errors in the installation or improper use of gas appliances. Additionally, the construction controversy surrounding the skyscraper, including shortcomings in the structure and materials used during its construction, could also have contributed to the tragedy. The skyscraper disaster in Gdańsk on 17 April 1995 was a great shock to the local community and the entire country. This tragic story is a reminder of the need to comply with the highest safety standards in construction and regular inspection and maintenance of gas installations to prevent similar disasters in the future.

Photo 5. The skyscraper on Węglowa Street after the explosion [16]

6. Construction Disasters in the World

On the outskirts of Dhaka, the capital of Bangladesh, in Savar there was an eight-story building - Rana Plaza, housing mainly clothing factories, but also retail stores, businesses and banks. On 24 April 2013 the world heard the sad news of one of the most tragic industrial disasters (Photo 6).According to press articles that day Rana Plaza workers refused to start work because of the cracks they had noticed in the walls of the building. The management did not give in to the workers' requests and refused to stop work.

During the day, there was a power outage, and it was nothing unusual because in these areas power cut is quite a common occurrence. In order to avoid any downtime in production it was decided to start generators. Generators cause vibrations during operation. As a result of the vibrations, the structure collapsed, causing one of the greatest construction and industrial disasters in history. And this is considered the direct cause of the disaster. This situation was also influenced by numerous deficiencies in the field of construction safety, overloading the building through repeated and illegal structural modifications. As a result of this terrible event, more than 1,100 people died and more than 2,500 were injured. This event caused a wave of outrage around the world, forcing the international community to reflect on the ethics of the clothing business. The clothing companies whose products were manufactured in Rana Plaza came under fire. This tragedy exposed painful aspects of working conditions in garment factories and sparked a global discussion about ethics in the clothing industry and the responsibility of corporations for the safety of their workers.
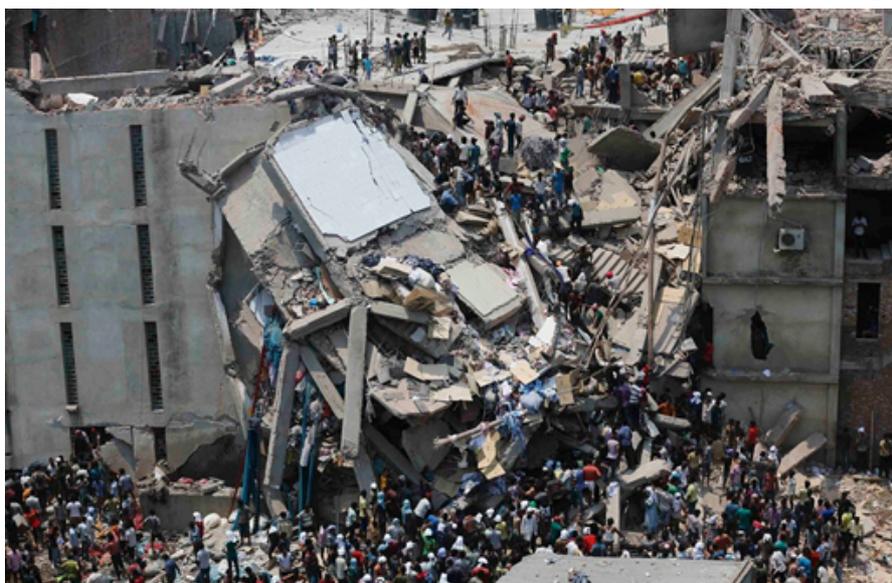

Photo 6. Rana Plaza disaster 24.04.2013 [23]

The Rana Plaza tragedy sparked a global debate about ethics in the garment supply chain. Companies began to raise issues of social responsibility, and consumers demanded higher levels of transparency in the supply chain. NGOs and social movements demanded better working conditions, raising awareness of the toll workers were taking on in garment production. After the tragedy, Bangladeshi governments took steps to tighten building safety and working conditions regulations. Garment companies introduced audit programs and initiatives to improve safety in supplier factories. Still, the problem persists, and certain watchdogs are of an opinion that more remains to be done.

Ponte Morandi was built in the years 1963-67. The designer is the Italian engineer Riccardo Morandi. A huge structure reaching 1182 meters in length with the height of pylons reaching 90 meters. Due to the width, which was only 18 meters, there were only two lanes of traffic in each direction. And so it functioned for over 50 years. The engineer did not foresee such a rapid development in the field of transport. The Ponte Morandi disaster (Photo 7) is a tragic event that took place on 14 August 2018 in Genoa, Italy. It was then that the Morandi motorway bridge, which connected the districts of Sampierdarena and Cornigliano and was part of the A10 motorway, collapsed. The bridge was a key element of the region's communication infrastructure, and its collapse had serious consequences. Ponte Morandi, built in the 1960s, also known as the "Viadotto Polcevera", was a key part of Italy's motorway network. It did not take long between the construction being put into service and the first cracks appearing. The maintenance was only a temporary aid. The only major renovation that was done was the replacement of the suspension cables with new ones [11]. On the day of the disaster, a section of the bridge, approximately 200 meters long, collapsed, causing vehicles to fall and destroying nearby buildings. The causes of the disaster were multiple, but the main role was played by problems related to the construction and maintenance of the bridge.

Photo 7. Ponte Morandi motorway bridge before the disaster. The part marked in red collapsed [11]

In particular, corrosion of the supporting structures was identified, as well as improper management and maintenance. In addition, difficult weather conditions prevailed on that day, which could have affected the condition of the structure. As a result of the disaster, 43 people died and many were injured. This event sparked a wide discussion on the state of infrastructure in Italy and the need to review and repair other similar structures. In addition, the Ponte Morandi disaster had an impact on infrastructure policy in Italy, drawing attention to the need to invest in the maintenance and modernization of key elements of the country's infrastructure.
 Did this event actually influence the change of management of the Italian authorities? The bridge was demolished a year after the tragic event. A moment later, the construction of a new infrastructure facility began. It was to be just as colossal as its predecessor. Besides, nothing small could be built in this place, since the route of the bridge leads over the river, railway tracks and apartment blocks [11]. The bridge was built very quickly, to the surprise of all interested parties. The structure was to be prepared for heavy transit traffic. The bridge was to be solid. Doubts were raised by the quick construction, which would not indicate the solidity and durability of the structure at all, and certainly leaves a certain margin of confidence. At the moment, it is known that, like its predecessor, it has two lanes in one direction, which means that during 'rush hours' the bridge will accumulate traffic jams, which in turn will be a significant burden for the structure.
Tacoma Narrows Bridge Disaster (Photo 8) took place on 7 November 1940. The Tacoma Narrows Bridge was a suspension bridge over the Tacoma Narrows in Washington State, USA. The disaster was one of the most spectacular bridge failures in history. The bridge, designed by engineer Leonid P. Moisseiff, had an unusual design for the time with a delicate cross-section, giving it the appearance of an "accordion bridge." It was made in the Art Deco style. However, this construction contributed to the tragedy. This bridge is an example of a structure that was not prepared for the impact of wind. The main span was 840 meters long and 12 meters wide. During construction, workers felt how fragile and light the bridge was. After opening, it became a tourist attraction. The construction of this bridge is a perfect example of a structure that is extremely vulnerable to the impact of wind.

The main span, with a length of 840 m, was only 12 m wide. The light bridge was too wobbly and its structure "caught" the wind. The tall and narrow towers created air turbulence around them. Even during construction, the undulations of the entire structure were a problem for the workers [24]. On the day of the disaster, winds of about 64 km/h hit the bridge, causing it to vibrate in a characteristic way. The structure began to twist with a deflection of up to 8.5 m and a turn of up to 45 degrees. After 30 minutes of such wind, the first elements began to break off, and after an hour the deck collapsed. This shaking caused instability of the structure and led to the disaster. Ultimately, the bridge collapsed and fell into the strait. It is worth noting that there were no fatalities as a result of this disaster, as rescue teams had managed to evacuate the area before the bridge collapsed. However, the disaster was a significant event in the field of engineering, leading to deeper research into the stability of bridges and the effects of wind on such structures.

Photo 8. On 7 November 1940 - Tacoma bridge disaster [24]

 In Italy, the city of Pavia was known as the city of a hundred towers. The Torre Civica, or City Tower, was one of the characteristic features of the city of Pavia in the Middle Ages. Rising close to the cathedral, the monumental structure was a symbol of the city's power and prestige. Originally built in the 11th century from brick and stone, it reached an impressive height of 72 meters. Over the centuries, the tower was expanded, adapting it to changing needs and architectural styles. Its final form, which it took in the 16th century, emphasized its importance as the administrative and social centre of the city.
However, in 1989, an unexpected disaster occurred that demolished the tower (Photo 9). In the morning hours of 18 March bricks suddenly began to fall from the tower, and then the entire structure collapsed. Four people died and 15 were injured in this disaster. The details of this event may vary, but it could have been the result of the weakening of the tower's structure due to the passage of time, errors in maintenance or other external factors, such as an earthquake or storm. This disaster certainly had a profound effect on the inhabitants of Pavia and on the historical and cultural heritage of the city. It was also a turning point in the context of taking action to rebuild or secure other historic buildings in the city and throughout Italy. As it turned out, this disaster motivated the Italian authorities to undertake work to secure the Leaning Tower of Pisa. The monument was slightly straightened and solidly reinforced.

Photo 9. Torre Civica after the disaster [22]

On 4 June 1979, a disaster occurred at the Kemper Arena in Kansas City when a large portion of the roof collapsed (Fig. 10). The arena was empty at the time, which was a fortunate circumstance as potential casualties from this incident were avoided. The cause of the roof collapse was a severe storm that passed through the area. Investigative analysis showed that the roof structure was designed to allow rainwater to drain off the roof slowly and with a delay, in order to avoid overflowing the local sewer system. According to the designers, the temporary ponding of water was to be acceptable. Unfortunately, this project had an unexpected consequence, as the downpour was so heavy that a literal lake formed on the roof. Additionally, the poor quality bolts used in the construction were insufficient to support the water load on the roof during the storm. As it turned out, some of the bolts were incorrectly calculated in the design. This in turn caused a significant portion of the roof structure to collapse, causing massive damage to the arena. As a result of this disaster, the building that is now known as Hy-Vee Arena was closed and then rebuilt a year later. The reconstruction work included improving the roof structure and using more durable materials to prevent similar incidents in the future. This tragic situation had an impact on the design and safety of sports arenas, as well as awareness of the need to properly design and maintain such structures.

Photo 10. Kemper Arena in Kansas City a week after the disaster[21]

In March 2024, an unexpected tragedy occurred in Baltimore (Photo 11). The Singaporean container ship Dali crashed into the structure of the Key Bridge, or more precisely, into a pylon [27]. This caused the structure to collapse immediately. To avoid the tragedy, the ship's crew tried to slow down the speed by throwing out the anchor, but this did not bring the expected results. Unfortunately, this event could not be avoided. Many vehicles fell into the water, but before impact a power failure on board was reported which allowed for a quick reaction - closing the passage for cars. There is a recording of the port dispatcher's conversation in which rescue workers can be heard asking if construction workers were on the Key Bridge when police tried to stop traffic moments before the structure collapsed. "The whole bridge just collapsed," the dispatcher is heard saying a few seconds later.[26] Unfortunately, it turned out that 6 road workers who were repairing the road surface at the time of the accident were missing in the disaster. They are presumed dead at this time. The Key Bridge route was used by about 30,000 people daily, and the blocked port handles the largest import and export of cars and trucks in the United States. This port is the centre of the East Coast economy. Its destruction and the halt of traffic on it will certainly affect the economy and functioning of the region. The disaster has been classified as a "mass disaster." This indicates the scale of the tragedy and how serious its effects can be. Considering the fact that the Port of Baltimore has suspended work indefinitely as a result of the destruction of the bridge, it can be expected that this will have a huge impact on the flow of trade in the USA. The initial list of causes of the container ship hitting the bridge was very long and even included suspicions of a terrorist attack. However, the investigation and evidence collected so far indicate that it was an accident. It turns out that this is not the first accident of this container ship. In July 2016, the same ship, while leaving the terminal, caused an accident in Antwerp, Belgium, hitting a stone quay. No one was hurt. Investigations into the case showed that the cause of the collision was the captain's and pilot's error. The container ship suffered significant damage to its hull. After the accident, the ship was left in the local port, where it was supposed to undergo repairs. A few months later, the repaired Dali ends up in the hands of a Singaporean company. As you can see, the incident in Baltimore should be investigated in many ways. For example, containers are being examined because there is a suspicion that they contain hazardous substances. It is also intriguing that the Key Bridge collapsed so quickly. According to the authorities, the significant aspect is the momentum with which the ship crashed into the structure. The fact that the crew assured that at the time of the disaster the ship had a speed of 8 knots casts doubts. However, the specific design of the bridge is key in this matter. It is a three-span bridge. It is as safe as possible as long as the regulations are complied with and the calculations are carried out well, as well as the design and construction are carried out in accordance with the art of construction. Every bridge is supposed to be resistant to ship impacts to some extent. If we draw this situation, it is clearly visible that when one of the supports is removed, the distribution of forces acting on the bridge changes. However, the theory that it was simply an accident is confirmed.
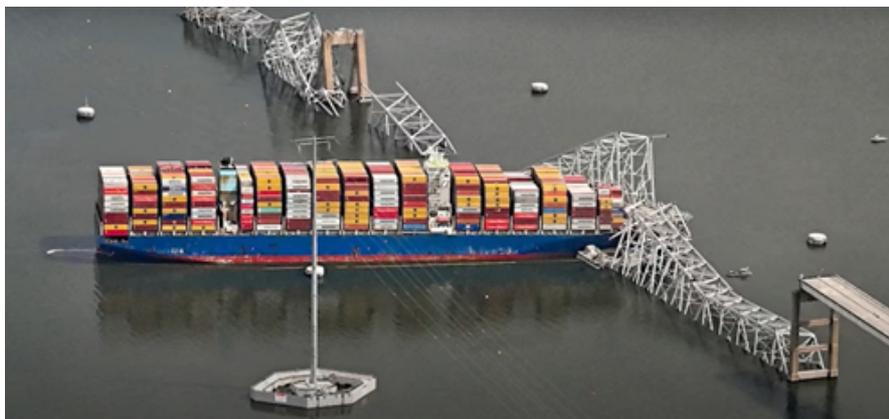

Photo 11. Key Bridge after the disaster [28]

7. Summary

This work on construction disasters presents various types of disasters, including collapses of buildings, bridges, towers and other engineering structures. The most frequently cited causes include design errors, poor quality materials, negligence during construction, inadequate maintenance and those resulting from random causes, i.e. unpredictable natural phenomena such as strong winds or floods. However, the key element of analysis is the human factor, which most often turns out to be the main culprit in construction disasters. This is the most disappointing element. One of the most important elements influencing the safety of structures is the design stage. Design errors may result from various reasons, for example, from the lack of experience of engineers, insufficient knowledge of the latest construction norms and standards, as well as from calculation errors. Also, making mistakes in the selection of materials or not taking into account ground and water conditions. Sometimes, designers may be pressed for time or cost; this leads to missing key analyses and simulations that could prevent disaster. Engineers and architects who do not pay enough attention to detail can create design flaws that can cause disasters and tragedies in the future. The use of low-quality building materials is another factor leading to disasters. These materials may be cheaper, but they do not meet the required strength and durability standards, leading to weakened structures. Sometimes, contractors choose cheaper options to reduce construction costs, which in the long run leads to structural degradation and potential failures. In conditions of limited budgets, developers and contractors opt for cheaper materials to reduce construction costs. These solutions generate higher profits for them, which overshadows safety aspects. Such a compromise, however, often ends in disaster when savings on materials lead to serious structural defects. The economic argument is therefore short-sighted and does not take into account the long-term costs associated with repairs, compensation and, most importantly, potential human losses. During the construction process itself, there may be much negligence that has a direct impact on the overall technical condition of the structure. Negligence during construction can include various aspects, such as improper foundation construction, incorrect concrete reinforcement, lack of proper engineering supervision, and rushing and not adhering to the work schedule, which eventually lead to tragedy. For example, incorrect concrete reinforcement or improper welded joints can result in the structure not being able to withstand the expected loads. Each of these factors can lead to a weakening of the structure and an increased risk of collapse. Some may argue that negligence is inevitable in large construction projects due to their complexity and scale. They point out that human error is an inherent part of any process and that it is impossible to completely eliminate it. However, while errors are inevitable, their number and impact can and should be minimized through proper procedures, training and inspections. This argument is therefore short-sighted and fails to take into account the possibility of implementing effective preventive measures. Construction of any type requires regular maintenance to maintain its structural integrity. Regular inspections, repairs and upgrades are crucial to preventing disasters. Some construction disasters are the result of natural phenomena such as earthquakes, floods or hurricanes. Although these factors are often unpredictable, proper design and construction can significantly reduce the risk of collapse. The use of technologies and materials resistant to extreme weather and seismic conditions is essential in regions exposed to such phenomena.

Analysis of construction disasters indicates that the most important factor leading to such events is the human factor. Design errors, poor quality of materials, negligence during construction and inadequate maintenance are most often the result of human negligence, incompetence or deliberate cost reduction. Some may argue that technology and automation can minimize the impact of human factors on building safety. Modern design software and advanced construction technologies can help eliminate errors that were once inevitable. However, technology alone is not the answer to all problems. It still requires human supervision and interpretation of data, and human errors can occur at any stage. Even entering data so that software can calculate loads is subject to error. The key conclusion is the need to constantly improve the skills and knowledge of engineers, designers and contractors. The introduction of more rigorous educational and certification standards can help minimize design errors. Strengthening construction supervision systems is extremely important. As observed, most disasters occur in facilities managed by an individual. First of all, it is necessary to create a procedure for greater supervision and control over such facilities. Regular and detailed quality checks at every stage of construction can prevent the use of low-quality materials and detect potential negligence. Increasing legal liability for individuals and companies responsible for the design, construction and maintenance of buildings can act as a warning against potential negligence and fraud. Supporting scientific research into new materials and construction technologies that are more durable and resistant to natural phenomena is key to improving the safety of buildings.

To sum up, although construction disasters can have many causes, it is the human factor that most often fails, leading to tragic events. It is necessary to implement strict procedures and standards at all stages of the construction process. Regular training for construction workers, engineers and architects can help improve work quality and risk awareness. It is also a good idea to verify knowledge by introducing periodic exams. Knowledge of current regulations is a very important aspect in every job position. Quality checks should be carried out at every stage of construction, and all irregularities must be corrected immediately. Hiring appropriately qualified staff is also crucial. The problem in this case may be the niche on the labour market when it comes to manual workers. A blind eye is often turned to various omissions, and this has a direct impact on the safety of employees and the whole structure. In addition, the introduction of quality management systems, effective project management and investor supervision are key to ensuring that all stages of construction are carried out in accordance with requirements and standards. Lack of proper supervision, as well as corruption and negligence of officials, can lead to serious consequences. Improving education, supervision, accountability, and investing in modern technologies can significantly reduce the risk of such disasters in the future.

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KOŁA NAUKOWE

NAZWA SKN: ARTEMISIA
OPIEKUN NAUKOWY: **DR HONORATA NAWROCKA-BOGUSZ**
PRZEWODNICZĄCY: HANNA BIEŃKOWSKA
ADRES E-MAIL: HNAWROCKABOGUSZ@ANS.PILA.PL

NAZWA SKN: BUDOWNICTWA CEGIEŁKA
OPIEKUN NAUKOWY: **MGR INŻ. PAWEŁ GRZYBOWSKI**
PRZEWODNICZĄCY: ZUZANNA PIECHOCKA
ADRES E-MAIL: SKN.BUDOWNICTWA2023@GMAIL.COM

NAZWA SKN: DYDAKTYCZNO-TŁUMACZENIOWE
OPIEKUN NAUKOWY: **MGR MARTA KSIĄŻEK-RÓG, DR TOMASZ RÓG**
PRZEWODNICZĄCY: KORNELIA THIEL
ADRES E-MAIL: TROG@ANS.PILA.PL

NAZWA SKN: EKSPLORACJA
OPIEKUN NAUKOWY: **MGR ANDRZEJ GRZESIK**
PRZEWODNICZĄCY: RADOSŁAW MISIAK
ADRES E-MAIL: EKSPLORACJA13@GMAIL.COM

NAZWA SKN: FILAMENT MIBM
OPIEKUN NAUKOWY: **MGR INŻ. MATEUSZ KABAT**
PRZEDWODNICZĄCY: GUSTAW STANOWSKI
ADRES E-MAIL: FILAMENTMIBM@GMAIL.COM

NAZWA SKN: GERMIS
OPIEKUN NAUKOWY: **DR ZOFIA MOROS-PAŁYS**
PRZEWODNICZĄCY: KORNELIA THIEL
ADRES E-MAIL: ZMOROS@ANS.PILA.PL

NAZWA SKN: HEKOSMETER
OPIEKUN NAUKOWY: **MGR JUSTYNA CISZEK**
PRZEWODNICZĄCY: JULIA JAGODZIŃSKA-TROJAK
ADRES E-MAIL: KOSMETOLOGIA@ANS.PILA.PL

NAZWA SKN: ELEKTRONIKÓW
OPIEKUN NAUKOWY: **MGR INŻ. PAWEŁ SZUBERT**
PRZEWODNICZĄCY: ADAM ZIOBRO
ADRES E-MAIL: PSZUBERT@ANS.PILA.PL

NAZWA SKN: ESCULAP
OPIEKUN NAUKOWY: **MGR MILENA PEŁCZYŃSKA**
PRZEWODNICZĄCY: WERONIKA SKIBA
ADRES E-MAIL: LUMIERE@VP.PL

NAZWA SKN: FILOLODZY
OPIEKUN NAUKOWY: **DR MARLENA BIELAK**
PRZEDOWNICZĄCY: ANGELIKA SZAŁOWSKA
ADRES E-MAIL: MBIELAK@ANS.PILA.PL

NAZWA SKN: LOGISTYK
OPIEKUN NAUKOWY: **MGR INŻ. JANUSZ DRZEWIECKI**
PRZEWODNICZĄCY: JAGODA FABISZAK
ADRES E-MAIL: ADRSERVIS@OP.PL

NAZWA SKN: MEDICAL SIMULATIONS IN NURSING
OPIEKUN NAUKOWY: **DR ANNA ŻDANOWICZ MGR MAŁGORZATA KULCZYŃKA-PIECZUL**
PRZEWODNICZĄCY: GRACJAN SZPREJDA
ADRES E-MAIL: **AZDANOWICZ@ANS.PILA.PL MKULCZYNSKA@ANS.PILA.PL**

NAZWA SKN: MŁODYCH EKONOMISTÓW ANS W PILE
OPIEKUN NAUKOWY: **MGR ZOFIA MIECHOWICZ**
PRZEWODNICZĄCY: PATRYCJA KOŹLINKA
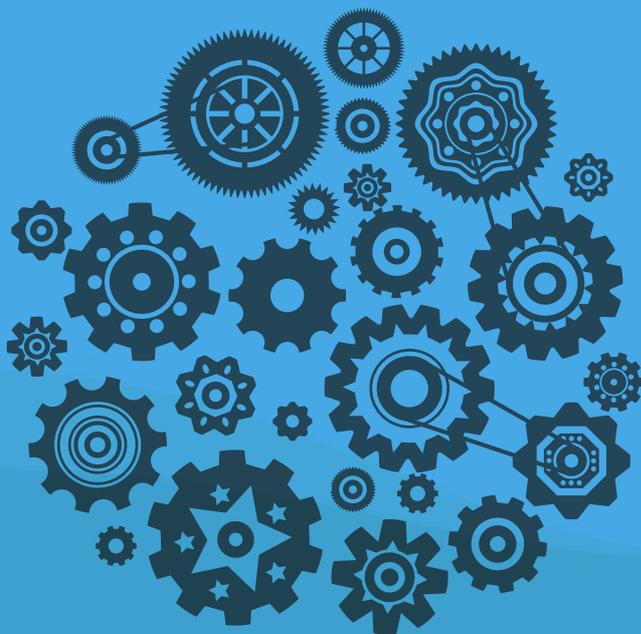ADRES E-MAIL: KOLOEKONOMISTOWANS@GMAIL.COM

NAZWA SKN: NEW LIFE
OPIEKUN NAUKOWY: **DR KAMILA SADAJ-OWCZAREK**
PRZEWODNICZĄCY: BARBARA GRZYBKOWSKA
ADRES E-MAIL: KSADAJ@ANS.PILA.PL

NAZWA SKN: PRZYSŁONA
OPIEKUN NAUKOWY: **MGR PIOTR TRYCHOŃ**
PRZEWODNICZĄCY: ALEKSY MAREK
ADRES E-MAIL: PIOTRTRYCHON@TLEN.PL

NAZWA SKN: MIŁOŚNIKÓW BUDOWNICTWA SOWA
OPIEKUN NAUKOWY: **DR INŻ. MAHMOUD HSINO**
PRZEWODNICZĄCY: OLIWIA BOCHEŃSKA
ADRES E-MAIL: MHSINO@ANS.PILA.PL

NAZWA SKN: VIS PROBANDI
OPIEKUN NAUKOWY: **DR MICHAŁ SZYKUT**
PRZEWODNICZĄCY: DOMINIKA RYBA
ADRES E-MAIL: SKNVISPROBANDI@GMAIL.COM

NAZWA SKN: PODSTAW KONSTRUKCJI MASZYN, TRIBOLOGII I TERMODYNAMIKI
OPIEKUN NAUKOWY: **DR INŻ. JAROSŁAW MIKOŁAJCZYK**
PRZEWODNICZĄCY: KRZYSZTOF BOIŃSKI
ADRES E-MAIL: SKNPKM@EDU.ANS.PILA.PL

wydawnictwo.ans.pila.pl